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The Aggregate and Distributional Impacts of Residence Policy Relaxation

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Abstract
Government often designs strict policy to control the conversion rate from temporary to permanent residents. The residence status may directly affect individuals' migration decisions and housing tenure choices. We present a dynamic spatial equilibrium framework to study the aggregate and distributional impacts of residence policy relaxation with a focus on the housing market. The DID approach treating the recent hukou policy reform in China as a shock reveals hukou policy relaxation causes housing prices in the treatment cities to be 4.9% higher than the unaffected cities. The impacts are stronger in cities where obtaining hukou was harder. The model is calibrated to the Chinese economy and predicts that hukou policy relaxation can bring a positive spillover effect to those unaffected cities' welfare. If hukou policy reform were implemented in those super-mega Chinese cities, housing prices would grow by 2.3%, but the welfare gain equivalent to 3.1% of their current levels.

Keywords Housing market · Residence policy · Migration · Multi-city · Welfare · Differential treatment

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1 Introduction

Immigrants in many countries often strive to obtain local permanent residence, because governments often design differential policies that favor permanent over temporary residents. However, there is usually a high threshold to complete the transition. One of the local government's major concerns is that the inflow of migrants may harm the welfare of local natives through influencing the local housing market. Given the dominant role of housing-related expenditure in a representative household's balance sheet, the residence status may directly affect an individual's disposable income and location choice, which in turn affects local housing prices. At the spatial level, whether lowering the requirement to obtain permanent residence in certain cities may exert negative impacts on other cities is also controversial. This paper develops a quantitative spatial general equilibrium framework to examine how the relaxation in the residence policy may affect the local housing market and welfare. In addition, if the residence policy is relaxed only in a subset of the country, we evaluate how the policy will reshape the population distribution and affect an individual's welfare in both the affected and unaffected regions.

China becomes an ideal laboratory for studying these issues, due to its unique household registration system, called "hukou" in Chinese, and ongoing reform in its hukou policies. A "hukou" records each individual's origin. An individual is considered as a migrant if his/her residing city is different from the origin city. Individuals without local hukou may not be able to gain equal access to resources provided by the local government as those natives. As a result, the restriction to obtain local hukou may affect individuals' migration decisions, housing tenure choices, and their financial portfolio. When these decisions are aggregated up to the city-level, they may in turn affect city size, housing prices, and local welfare. Over the past several decades, the Chinese government has gradually relaxed the restriction to obtain local hukou to facilitate the inter-city migration. During the same period, the Chinese economy has witnessed one of the largest population movements in the human history within the country—around 340 million individuals have left their birth places for other cities for a better life. Whether the inflow of migrants has triggered the housing boom in those super-mega cities has been the subject of heated debate in China. In addition, whether the relaxation of hukou policy may cause more regional inequality is controversial. To address these issues, we calibrate the model into the Chinese economy and simulate the outcome from several alternative hukou policies. Hopefully our answers can serve as useful references in hukou policy reform for policy makers.

The dynamic spatial equilibrium framework in the paper is featured with differential policy treatments between permanent and temporary residents, endogenous migration decision, incomplete markets and rich housing market elements. The permanent and temporary residents differ in the following aspects: (1) Temporary residents obtain less publicly-provided private goods than permanent residents. (2) In each period, extra expenses are incurred among the temporary residents on items such as medical care, education, and paperwork to renew their

temporary residence permits. (3) Higher transaction costs are incurred upon housing purchase among temporary residents, due to the lack of local social capital or bargaining power. These differential treatments will certainly result in sharp differences in individuals' consumption and saving decisions, and thus hint at the important role of policies aiming to lower the requirements of obtaining permanent residence.

The model economy is geographically divided into two regions: a "major" region and an "other" region. Our primary focus is on the "major" region, which is further divided into a finite number of cities. Cities are different in production technologies, land supply, and are potentially subjected to different hukou policies. In each period, individuals may choose whether to migrate from the "other" region to the "major" region. Each migrant will start as a temporary resident in the destination city. Permanent residence is obtained either through purchasing a house or by lottery. The relaxation in the residence policy essentially corresponds to increasing the probability of winning the lottery. Other than the ingredients above, the model is a standard life-cycle framework with an incomplete market and rich housing market features. Individuals face idiosyncratic income shocks each period, but borrowing is not allowed. To purchase a house, the individuals may sign a mortgage contract with a specified downpayment and mortgage repayment scheme. Houses differ in their sizes, and individuals may choose to upgrade their houses along the life-cycle.

The relaxation in the residence policy may exert impacts on local housing markets through both extensive and intensive margins. At the intensive margin, it may increase those non-natives' disposable income and thus increase the housing demand; at the extensive margin, it may encourage more migration from the other region to the major region. Therefore, housing demand affects housing prices, which in turn influences individuals' housing tenure and migration decisions in the general equilibrium.

Motivated by a milestone in the national-level hukou reform policy that ook place in 2016 in China, we have also conducted a difference-in-differences(DID) exercise to empirically examine the impacts of hukou policy relaxation on local housing prices. During this reform, all the cities with an urban population size between 1 million and 5 million cannot set conditions such as owning residential property or income-tax-paying records as perquisites to obtain local hukou, and thus they are considered as our treatment group, and those with an urban population size either above 5 million (14 cities) or below 1 million (122 cities) are considered as the control group. Our empirical analysis reveals that housing prices in the treatment cities grow faster than those in the control cities by 4.9% points after the relaxation of hukou restrictions. In addition, we find that the effect of hukou reform on housing prices is stronger in cities where obtaining hukou before the reform was harder.

The empirical exercises cannot provide further evidence on the welfare implications from hukou policy relaxation. It is a quantitative question because equal access to public resources may be beneficial for the migrants; however, the higher housing prices may make housing less affordable and further deter the migration. To quantify the impact of these residence policies, we calibrate the model into the Chinese economy. We classify the major region into three cities: type-1 city refers to those super-mega cities with population size above 5 million, and type-2 city constitutes

a subset of the treatment cities during the 2016 reform but with a relatively higher population size or income level than the remaining treatment cities, which are classified as a type-3 city. The calibrated model successfully captures the observed hump-shaped pattern of the ownership rate, value, and networth along the age cohorts for individuals of different residence status. The model is also able to mimic moments on the population distribution, wealth distribution, and cross-sectional patterns on individuals' expenditure shares for renters and owners.

In the counterfactual exercise, we conduct three policy experiments by gradually relaxing the hukou restriction from only within the type-3 city, to within both the type-2 and type-3 city, and finally to all the three types of cities. When only the hukou restriction in the type-1 city is not relaxed, the model-predicted changes in housing prices are in line with the empirical findings: the type-2 city experiences higher housing price growth than the type-3 city, whereas obtaining hukou in the type-2 city is commonly believed to be harder than obtaining hukou in the type-3 city. Because the current hukou policy reform is only restricted to both the type-2 and type-3 city according to our classification, we also find that if the hukou policy reform were to be further implemented in the type-1 city, its housing price would grow by 2.3% from its current level. In addition, the model predicts that when hukou restrictions in all the cities are uniformly relaxed, housing prices will grow by 4.3%, 3.8% and 3.9% from their levels before the uniform reform in the type-1, type-2, and type-3 city, respectively. We also find a substitution effect between owning a house and owning a local hukou. When obtaining local hukou is easier, migrants can (expect to) enjoy non-discounted access to public goods, which may dampen their desire to own the house, if the motive to own a house before the reform is to use the utility premium of owning a house to compensate for the loss from access to public goods. The substitution effect also explains why the growth in housing prices is only moderate in all the treatment cities.

Nevertheless, all three cities receive welfare gains from the three policy experiments. When the hukou policy is relaxed in both the type-2 and type-3 city, the welfare gain is equivalent to 1.5%, 3.0% and 2.7% of their benchmark levels in the type-1, type-2, and type-3 city, respectively. This finding suggests a positive spillover effect from the treatment city to the unaffected city. The channel is likely to work as follows: relaxation of hukou policy in a subset of the major region will attract a larger population inflow into each city within the major region. The increasing housing demand prompted by a larger population size tends to push up housing price as well as land-sales revenue. The local government is thus able to provide more public goods, which may benefit everyone regardless their residence status. Finally, when the hukou restriction are relaxed in all three cities, the welfare gain is equivalent to 4.7%, 3.1% and 2.8% of their benchmark levels in the type-1, type-2, and type-3 city, respectively. The results are robust in an alternative benchmark economy with differential hukou policy restrictions among the three cities. If the current hukou policy reform were to be further implemented in the type-1 city, it could still collect a welfare gain equivalent to 3.1% of its current welfare.

We have also compared the effectiveness between the hukou policy and the migration policy, which aims to lower the overall migration costs from the "other" region to the major region. When the migration costs are uniformly

reduced, housing prices in all three cities still grow from their benchmark levels, but the magnitudes are smaller than their counterparts in which the hukou restrictions are uniformly relaxed in all the cities. It is also worthwhile to highlight that a uniform reduction in the migration costs leads to less welfare gain in all the cities than an overall relaxing hukou restrictions.

Literature The paper is closely related to several recent papers that focus on the housing market in China. Li et al. (2020) provide a comprehensive overview of housing affordability in 275 Chinese cities. The affordability is also individual's major concern when they make migration and housing tenure decisions in our paper. Chen et al. (2020) develop a quantitative model and argue speculative housing investment is a key channel for a change in loan-to-value(LTV) policy to exert aggregate and distributional impacts on mortgage markets. Kaplan et al. (2020) study the housing boom-bust around the great recession and find the main driver of housing prices and rents was a shift in beliefs. Garriga et al. (2020b) explore the contribution of the structural transformation and urbanization process to China's housing-market boom. Our focus is the aggregate and distributional impacts from hukou policy relaxation. In addition, we emphasize the welfare implications among individuals of different residence statuses in both treatment and unaffected cities. Because we focus on a steady-state equilibria, explaining the driver of the housing boom is not our goal. But given the large scale of migration within China from less to more developed regions, how the hukou policy affects the overall economy is an important issue to study.

Both Chia et al. (2017) and Li and Tang (2018) classify individuals into either natives or immigrants in the housing markets to study the interaction between natives and immigrants in Singapore's housing market. Immigrants are only allowed to purchase private housing, whereas natives can instead purchase heavily subsidized public housing. Whereas natives and immigrants engage in two segmented housing markets in their work, permanent and temporary residents are interacting in the same market in our paper. In addition, housing market features are richer and closer to reality in our model, in which mortgage contracts and housing upgrades are allowed.

The paper is also broadly related to the large literature that examines the determinants of homeownership rates (e.g., Chambers et al., 2009, Halket & Vasudev, 2014). We complement the literature by incorporating individuals of different types by nature, in addition to the idiosyncratic shocks that they face each period. By incorporating limited access to the financial market for housing purchases, our paper is also connected to a large literature that explores financial frictions as drivers of housing boom-bust episodes (e.g., Garriga et al., 2019). Housing price in our paper is also determined via a general equilibrium asset-pricing model (e.g., Davis & Heathcote, 2005), in which prices are determined by equalizing the net housing demand from individuals of different types with newly-built houses.

The paper is also connected to the literature that focuses on hukou policy in China. Cheng and Selden (1994) discuss the origins and social consequences of

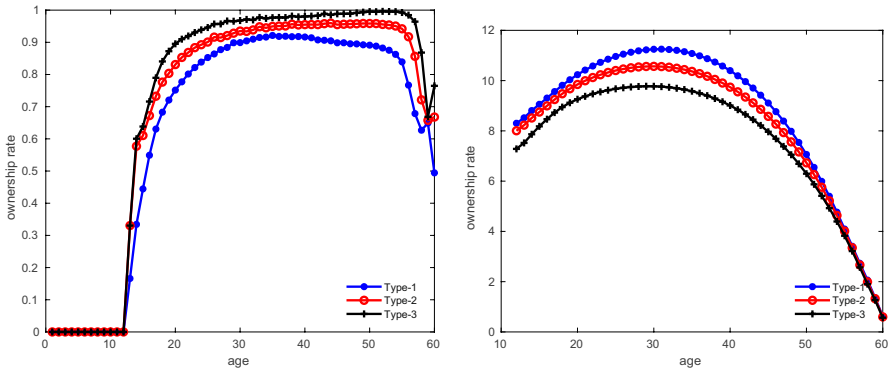
the hukou system. Liu (2005) finds that people who obtained urban hukou late in their lives fared significantly less well than other urban residents, and argue the hukou system is a major contributing factor to rural–urban inequality. Several studies quantify the impacts of the hukou system. An et al. (2020) examine the local labor market effect of relaxing internal migration restriction in the context of China. They find migrants' wages in non megacities relative to those in megacities decline after the policy shock. We echo their findings by also finding a positive spillover effect to the megacities' welfare. Based on a 1% sample from China's 1990 census, Huang (2001) finds hukou status adversely affects the occupational attainment of female migrants in the labor market. Fan (2001) compares the labor market returns received by people of different hukou status in the city of Guangzhou and finds the returns are not only a function of human capital, but are also influenced by hukou status. Chen et al. (2012) argue hukou constraints may explain the high saving rate in China. They show the consumption by migrants without an urban Hukou is 30.7% lower than that by urban residents. Those works are mostly qualitative or empirical, whreas our quantitative frameworks avoid the issue of endogeneity and allow rich counterfactual experiments to evaluate the welfare gain/loss.

Empirical Evidence

China is unique in its household registration system, called "hukou" in Chinese, which officially identifies an individual as a resident of an area. The local government often designs differential policies that favor "hukou" holders in terms of the access to education and medical resources, and the provision of various social benefits. The central government has implemented a series of hukou reform policies during recent decades in the hope of lowering the requirements for migrants to obtain local hukou, so that both natives and migrants can receive equal policy treatment. A milestone in the national-level hukou reform took place in September 2016, when the State Council issued the document of "Notice of Promoting 100 Million Temporary Residents Settling in Cities."[1] The document states that all the cities with an urban population size between 1 million and 5 million cannot set conditions such as owning residential property or income-tax-paying records as perquisites to obtain local hukou. Meanwhile, the hukou restrictions in those mega-cities with an urban population size above 5 million remained unchanged and stayed strict.

To examine how the relaxation of hukou policy affects local housing markets, we treat the 2016 reform as a policy shock and adopt the DID approach using a panel dataset at the city-month-level. Specifically, we define the 114 cities with an urban population size between 1 million and 5 million as the treatment group, and those with an urban population size either above 5 million (14 cities) or below 1 million (122 cities) as the control group. Due to the accessibility of housing price data, our sample period covers the months between Janurary 2015 to April 2019 (i.e., 31

[1] See the official website of the State Council for more details.



(a) Ownerhip rate (b) Average Welfare

Fig. 1 Benchmark results. Notes: We plot the evolution of the ownership rate and value function along age cohorts in each type of city. The average welfare is defined as the population-weighted average of the value function among individuals of different state variables as defined in "Individual's Optimization Problem" section

months after the event), and we define the months after September 2016 as the post period. Therefore, the baseline empirical specification is

$$ln\left(HP_{it}\right) = \beta_0 + \beta_1 * \text{POST}_t * \text{TREAT}_i + \delta_i + \gamma_t + \epsilon_{it}. \tag{1}$$

The dependent variable, $ln\left(HP_{it}\right)$, is the constant-quality housing price index in city i in year-month t(in logarithm term), which is constructed by Wu et al. (2014) using the hedonic method based upon micro-level transaction data. The major independent variable, $\text{POST}_t * \text{TREAT}_i$, is the interaction term between the dummy for the post period (POST_t) and the dummy for the treatment cities (TREAT_i), whose coefficient, β_1, captures the differences in housing prices between the treatment and control groups after the hukou reform relative to the difference during the pre-period. δ_i is the city fixed effects, and γ_t is the year-month fixed effect. ϵ_{it} captures the robust-error term (Fig. 1).

Figure 2 presents the raw trend of housing prices for the treatment and control cities. Before the policy shock, housing prices in the treatment and control cities exhibit similar trends. However, after the relaxation of hukou restrictions, the treatment cities experience faster growth in housing prices, especially since the middle of 2017. The gap in the housing prices between the two groups is enlarged during 2018 and remains large untill the end of our sample period. Such raw trends provide preliminary evidence for the positive impacts of hukou policy relaxation on housing prices.

The regression results are presented in Table 1. As shown in column (1), the coefficient for the DID term is positive and statistically significant at the 1% significance level. Specifically, controlling for other factors, housing prices in the treatment cities are 4.9% higher than those in the control cities after the relaxation of hukou restrictions. These results provide further evidence that the relaxation of hukou restrictions tends to increase housing prices. We further explore how cities with different

Table 1 DID regression results

VARIABLES	ln(HP)	ln(HP)
POST * TREAT	0.0490***	-0.00902
	(0.0137)	(0.0122)
POST * TREAT * INDEX		0.0455**
		(0.0181)
POST * INDEX		0.144***
		(0.00828)
N	25,284	10,885
R-squared	0.380	0.427
Year by Month FE	YES	YES
City FE	YES	YES

Notes: Robust standard errors are used in all the regressions and reported in parentheses

*p < 0.10, **p < 0.05, ***p < 0.01

degrees of hukou restrictions react to the relaxation of hukou policy. To this end, we adopt the hukou registration index constructed by Zhang et al. (2019), which focuses on the period between 2014 and 2016, as the proxy for hukou restrictions before the 2016 reform. A city with a higher index is perceived to have more severe hukou restrictions before the reform. In column (2), we interact INDEX with the DID term, whreas other specifications remain unchanged as in Eq. (1). The coefficient of the triple interaction is positive and significant at the 5% significance level. The result suggests that in cities with higher INDEX, or equivalently, in cities where obtaining hukou before the reform is harder, the effect of hukou reform on housing prices is stronger.

To verify the validity of the DID specification, we have also conducted a parallel-trend test. Figure 3 visualizes the coefficients estimated with dynamic DID specification, with both the coefficients and the 95% confidence intervals reported.[2] The figure shows the treatment and control cities share the common trend before the policy shock. After the policy shock, housing prices in the treatment cities gradually increase and peak around February 2018.

Given the significant impacts of hukou policy relaxation on housing prices, however, the welfare implications of such policy remain unclear. Equal access to public resources may be beneficial for the migrants; on the other hand, the higher housing prices may make housing less affordable and further deter migration. The overall impacts thus become a quantitative question. In addition, we are also curious about the quantitative impacts of further hukou relaxation among those super-mega cities on other cities. In the following section, we present a theoretical framework to guide our quantitative analysis.

[2] We use 12 months before the implementation of the new hukou policy as the baseline period. The empirical specification is.
$ln(HP_{it}) = \beta_0 + \sum \beta_{1,k} * \text{POST}_t * \text{TREAT}_i + \delta_i + \gamma_t + \epsilon_{it}$.

The Model

Time is discrete and infinite. At the beginning of each period, a mass one of finitely-lived individuals are born. Individuals work till retire at age J^{ret}, and die with certainty after age J. These imply that at each given period, an equal mass of individuals from J different age cohorts exists. The economy is geographically divided into two regions: a "major" region and an "other" region. The "major" region contains I different cities. Individuals are initially born into the "other" region, but are allowed to migrate into the "major" region subjected to an idiosyncratic migration disutility. To simplify the analysis, once the individuals move to the "major" region, they are assigned to one of the I cities according to a lottery. They can no longer migrate afterwards.[3] ι_i denotes the probability that they are assigned to city i such that $\sum_{i=1}^{I} \iota_i = 1$.

Residents in each city of the major region can be divided into either permanent or temporary residents. The differences lie in the benefits that they can collect from the local government, which we specify later. All the migrants from the "other" region will start as temporary residents in the first period they move to the city. With certain city-specific probability π_i, the temporary residents in city i can switch to be permanent residents of city i. We simplify the decision-making in the "other" region by assuming a constant and exogenous reservation utility inflow from staying in the "other" region each period, denoted as $\bar{U}$.

Preferences

The utility of a resident in the major region depends on the consumption of non-housing(c), housing services(x), and public goods(g). The expected lifetime utility for an individual of age a assigned to city i can be characterized as[4]:

$$E_a \sum_{\tau=1}^{J-a} \beta^{\tau-1} u\left(c_{i,\tau}, x_{i,\tau}, g_{i,\tau}\right), \tag{2}$$

where $\beta \in (0, 1)$ is the subjective discount factor. The instantaneous utility function takes the following form

$$U(c, x, g) = \frac{\left[\left[\theta c^{\sigma} + (1-\theta) x^{\sigma}\right]^{\frac{1-\phi}{\sigma}} g^{\phi}\right]^{1-\eta}}{1-\eta}, \ \sigma < 1, \eta > 0, \phi \in (0, 1).$$

σ governs the elasticity of substitution between the non-housing(c) and housing services(s). θ and ϕ capture the weight on c, x, and public goods g in preferences, respectively. η reflects the risk-averse attitudes.

[3] We consider this assumption innocuous. Although individuals may still flow within the "major" region in the data, the overall magnitudes of the population inflow and outflow are relatively comparable in the Chinese data.

[4] In what follows, we omit the time subscript except in cases in which its omission may be misleading.

Individual's labor endowment depends on his age a and a stochastic term $\tilde{e}$. $\tilde{e}$ can further be decomposed into a transitory and a persistent shock: $\tilde{e} = zs$. The persistent shock follows an AR(1) process, and the transitory shock is a random draw from a log-normal distribution, which are specified as follows:

$$\begin{aligned} \ln\left(z_{i,a}\right) &= \rho \ln\left(z_{i,a-1}\right) + \epsilon_{i,a}, \epsilon_{i,a} \sim \mathcal{N}\left(0, \sigma_z\right)^2, \\ \ln\left(s_a\right) &\sim N\left(0, \sigma_s^2\right). \end{aligned}$$

The uncertainty dissipates when an individual retires. Instead, he receives a pension equivalent to a fraction ν of the income in the last period of working age.

Individuals can choose to be either renters or owners. Renters pay p_a for an apartment of size h_a, and receive housing services $x = h_a$. If individuals choose to buy a house, they can choose a house of size $h \in H = \{h_1, h_2, \ldots h_N\} > h_a$, pay unit price p_h, and receive housing services $x = \zeta h$. We let $\zeta > 1$ capture the utility premium from owning instead of renting a house.

Interest rates on savings and mortgage debt are both exogenously given and set as r_b and r_m, respectively.[5] Mortgages are long-term contracts subject to a minimum downpayment ratio γ. The minimum mortgage payment in each period follows a constant amortization schedule during the remaining lifetime such that

$$m \geq \frac{r(1+r)^{J+1-j}}{(1+r)^{J+1-j}-1} d,$$

in which d is the outstanding principle and evolves according to $d' = \left(1 + r_m\right)d - m$. Mortgage default is not allowed.

Production

In each city of the major region, there are two production sectors: goods sector and construction sector. Labor is assumed to be perfectly mobile between the two sectors. Non-housing services are produced in the goods sector and only require labor as input. The production function in city i takes form $Y_i = A_i N$, where A_i is the city-specific labor productivity and N is the total supply of efficiency labor. When the market structure is perfect competition, the equilibrium wage rate per unit of efficiency labor in city i is thus $w_i = A_i$.

New houses are produced in the construction sector. The production requires land, non-housing services, and labor as inputs. The production function is a constant return to scale and takes the following form:

$$Y_{ih} = A_{ih} F\left(N_h, M_h, L_h\right). \tag{3}$$

A_{ih} represents the city-specific construction technology. N_h, M_h, and L_h denote the inputs of labor, construction material, and residential land, respectively. Profit maximization then implies:

[5] In China, they are primarily controlled by the government and are thus exogenous.

$$q_i = \frac{F_L(N_h, S_h, L_h)}{F_S(N_h, S_h, L_h)},\ w_i = \frac{F_N(N_h, S_h, L_h)}{F_S(N_h, S_h, L_h)}.$$

We follow Kaplan et al. (2020) by assuming the rental price is determined from the following no-arbitrage condition:

$$p_a = \psi + p - (1 - \delta_h)p,$$

where ψ denotes the operating cost for each unit of housing rented out. The formula above can be micro-founded from the optimization problem of a competitive rental sector that owns housing units and rents them out to households.

Permanent vs. Temporary Residents

The government exogenously supplies L_h units of land for building new houses. The government then collects the land sales revenue as well as income tax, and spends them on pensions, the provision of public goods, and transfers to maintain a balanced budget:

$$G + \mathcal{T} + \Omega = qL_h + \tau Y, \tag{4}$$

where $\mathcal{T}$ denotes the lump-sum transfer to individuals who cannot afford the subsistence consumption, which we specify later. Y is the total taxable labor income and Ω is the amount of pension.

Educational and medical resources, as well as social security and benefits, are provided by the government in most economies in the world. They are considered public goods because they are free of charge. On the other hand, the usage of these resources is not entirely non-rivalry. Their capacities are divided among permanent and temporary residents. As a result, they can be considered as "publicly-provided private goods". In reality, temporary residents usually cannot enjoy the equal access to public schools or medical care as those permanent residents. To capture this situation, we assume temporary residents can only freely enjoy a fraction $\delta \in (0, 1)$ of the public goods. Overall, the total public goods are allocated according to:

$$G = gN_p + \delta gN_t, \tag{5}$$

in which with a slight abuse of notations, we denote N_p and N_t as the number of permanent and temporary residents, respectively.

For those public goods such as social security and employment benefits, the temporary residents can live without having them. However, for items such as children's education and access to medical resources, they have to spend their income on obtaining them. This also justifies in the data that the average non-housing consumption among temporary residents is lower than that of permanent residents with the same education level. Therefore, we further assume temporary residents need to pay an extra ξ from their budgets each period on some expenses only incurred to

temporary residents.[6] We make the following two notes on the assumption of ξ and δ: (1) Even though individuals may purchase those necessary public goods for consumption, we do not assume they will obtain utilities from consuming them, because they are not freely-provided as g in the utility function. (2) We do not impose the assumption that $\xi = (1-\delta)g$. The two values may differ because the necessary public goods may be just a subset of $(1-\delta)g$. In addition, ξ may also include the pecuniary value associated with the cost and the time needed to renovate permits. Nevertheless, the values of ξ and δ are certainly correlated. In our quantitative exercises, they are jointly calibrated to match the key moments on the differences between permanent and temporary residents.

The temporary residents are also directly affected in the housing market. We assume asymmetry in the transaction housing price. The temporary residents need to pay an extra χ percent of housing price upon housing purchase. The justification is that temporary residents have less bargaining power due to their asymmetric market information. In addition, home buyers from distant areas may encounter higher search costs, due to less knowledge about local housing markets.

Individual's Optimization Problem

We characterize the individual's optimization problem in this section. We use subscript 0 or 1 to denote the individual's resident status. In each period, whreas a representative resident of city i needs to make consumption and saving decisions, as well as housing tenure choices, an individual in the "other" region decides whether to migrate to the major region.

If a temporary resident of city i starts age a as a renter, his value function can be specified as:

$$\begin{aligned} V_{i0}^{rent}(a,y,z) = \max_{c,b'} U(c,h_a,\delta g) \quad & +\beta\{\pi_i \max\left\{\mathbb{E}\left[V_{i1}^{buy}(a+1,y',z')\right], \mathbb{E}\left[V_{i1}^{rent}(a+1,y',z')\right]\right\} \\ & +(1-\pi_i)\max\left\{\mathbb{E}\left[V_{i0}^{buy}(a+1,y',z')\right], \mathbb{E}\left[V_{i0}^{rent}(a+1,y',z')\right]\right\}\} \\ \text{s.t.} c \quad & +p_a h_a + b' = y - \xi \\ y' \quad & = (1-\tau)we(a+1,z',s') + b'(1+r_b) + \mathcal{T}. \end{aligned}$$

y and y' denote the individual's income in the current age and next age, respectively. Income includes both labor income and the return from savings. Since temporary residents can only freely obtain δg units of public goods from the government, they have to pay ξ from their own budget to maintain basic consumption of public goods. With probability π_i, the individual may become a permanent resident of city i in the next age. In the beginning of the next age, he chooses whether to remain as a renter or buy a house after the realization of income shocks and residence status.

[6] If the public-provided private goods and non-housing consumption are substitutable, we may expect temporary residents to consume more non-housing consumption than permanent residents of similar characteristics to compensate for the utility loss. However, we do not observe in the data. In the quantitative exercise, we essentially calibrate ξ to match the ratio of average non-housing consumption between permanent and temporary residents.

For a permanent resident of city i who is a renter at age a, the uncertainty in the future age only stems from the income shocks. He thus solves:

$$\begin{aligned} V_{i1}^{rent}(a,y,z) = \max_{c,b'} U(c,h_a,g) \ &+\beta \max\left\{\mathbb{E}\left[V_{i1}^{rent}(a+1,y',z')\right], \mathbb{E}\left[V_{i1}^{buy}(a+1,y',z')\right]\right\} \\ \text{s.t.} c \ &+p_a h_a + b' = y \\ y' \ &= we(a+1,z',s') + b'(1+r_b) + \mathcal{T}. \end{aligned}$$

If a temporary resident of city i chooses to purchase a house at the beginning of age a, in addition to the consumption and saving decisions, he also needs to decide the housing size and the mortgage debt. In addition, he will become a permanent resident in the next period due to the ownership of a local house. Specifically, he solves the following optimization problem:

$$\begin{aligned} V_{i0}^{buy}(a,y,z) \ &= \max_{c,b',h} U(c,h,\delta g) + \beta \max\{\mathbb{E}[V_{i1}^{rent}(a+1,y'_{rent},z')], \mathbb{E}[V_{i1}^{own}(a+1,y'_{own},h,d,z')]\} \\ \text{s.t.} c \ &+(1+\tau_b+\chi)ph + b' = y - \xi + d \\ d \ &\leq (1-\gamma)ph \\ y'_{rent} \ &= (1-\tau)we(a+1,z',s') + b'(1+r_b) + (1-\tau_s)p'h - d(1+r_m) + \mathcal{T} \\ y'_{own} \ &= (1-\tau)we(j+1,z',s') + b'(1+r_b). \end{aligned}$$

χph is the extra costs incurred among temporary residents upon purchasing the house. This is to capture the information friction or lack of bargaining power in the housing market. These extra expenses cannot be paid over the mortgage contract. Instead, individuals must directly pay from their current budget, which induces an extra burden among those temporary residents. d denotes the mortgage debt that he borrows, which cannot exceed a fraction $1-\gamma$ of the housing value. τ_b is the transaction tax when purchasing the house. In the next age, the individual needs to choose between being an owner and a renter. If he chooses to be a renter, he needs to clear all the outstanding mortgage debt. His future income thus includes housing sales revenue net of debt repayment. τ_s denotes the transaction tax when selling the house.

Similarly, if a permanent resident of city i chooses to purchase a house, he solves:

$$\begin{aligned} V_{i1}^{buy}(a,y,z) &= \max_{c,b',h} U(c,h,g) + \beta \max\{\mathbb{E}[V_{i1}^{rent}(a+1,y'_{rent},z')], \mathbb{E}[V_{i1}^{own}(a+1,y'_{own},h,d,z')]\} \\ \text{s.t.} c \ &+ph + b' = y + d \\ d \ &\leq (1-\gamma_k)ph \\ y'_{rent} &= (1-\tau)we(a+1,z',s') + b'(1+r_b) + (1-\tau_s)p'h - d(1+r_m) + \mathcal{T} \\ y'_{own} &= (1-\tau)we(a+1,z',s') + b'(1+r_b). \end{aligned}$$

For an owner of city i, his value function can be expressed as:

$$\begin{aligned} V_{i1}^{own}(a,y,h,d,z) \ &= \max_{c,b',m} U(c,h,g) + \beta \max\{\mathbb{E}[V_{i1}^{r}(a+1,y'_{rent},z')], \mathbb{E}[V_{i1}^{own}(a+1,y'_{own},h,d',z')]\} \\ \text{s.t.} c \ &+m + ph\delta_h + b' = y \\ m \ &\geq \frac{r_m(1+r_m)^{j+1-a}}{(1+r)^{j+1-a}-1} d \\ d' \ &= d(1+r_m) - m \\ y'_{rent} \ &= (1-\tau)we(a+1,z',s') + b'(1+r_b) + p'h(1-\tau_s) - d'(1+r_m) + \mathcal{T} \\ y'_{own} \ &= (1-\tau)we(a+1,z',s') + b'(1+r_b). \end{aligned}$$

In addition to the consumption and saving decision, the individual owner needs to decide the amount of mortgage debt repayment m, which needs to exceed the

minimum requirement specified by the constant amortization rule. As an owner, the individual also needs to pay for the housing depreciation to maintain a constant housing size. Again, in the next age, the individual faces the choice between remaining an owner and becoming a renter.

We finally turn to the value function and migration decision for an individual from the "other" region. Instead of equalizing wage as in a standard Rosen-Roback migration framework, an individual compares the payoff from staying in the "other" region with moving to the major region net of the migration cost. An individual staying in the "other" region at age a receives reservation utility $\underline{U}$. If he moves to the major region, a migration dis-utility ϵ is incurred. He will then start as a renter without an initial income and permanent residence. The expected payoff conditional on migration before the realization of z is thus $\sum_{i=1}^{I} \iota_i \mathbb{E}_z\left[V_{i0}^{rent}(a+1,0,z)\right]$. The value function for an individual in the "other" region can be expressed as:

$$V^o(a,\epsilon) = \underline{U} + \beta \max\left\{ V^o(a+1,\epsilon), \sum_{i=1}^{I} \pi_i \mathbb{E}_z\left[V_{i0}^{r}(a+1,0,z)\right] - \epsilon \right\}.$$

It is straightforward to show, all else being equal, individuals with lower migration dis-utility are more likely to migrate. In addition, factors leading to a higher payoff from staying in the major region will attract more individuals from the "other" region.

Equilibrium

We denote $\omega^{own} = (y,h,d,z)$ and $\omega^{rent} = (y,z)$ as the idiosyncratic state vectors for homeowners and renters, respectively. We also let $\{\mu_i^{own}(a), \mu_i^{rent}(a)\}$ be the mass of urban individuals of age a and resident status i, such that $\sum_{i\in\{0,1\}} \left[\mu_i^{own}(a) + \mu_i^{rent}(a)\right] = 1 - \mu^o(a)$, where the mass of individuals of age a in the "other" region is denoted as $\mu^o(a)$.

A recursive competitive equilibrium consists of value functions $\{V_0^{rent}(a,\omega^{rent}), V_1^{rent}(a,\omega^{rent}), V_0^{buy}(j,\omega^{rent}), V_1^{buy}(a,\omega^{rent}), V_1^{own}(a,\omega^{own}), V^o(a,\epsilon)\}$, the distribution of each type of individuals μ, individuals' decision rules, rent p_a, house prices p_h, wages w, and factor inputs N, N_h, and S_h such that:

1. Individuals optimize with value functions and associated decision rules.
2. Firms in the construction sector maximize profits by determining $\{p_a, N_h, S_h\}$.
3. The labor market clears in each city.
4. The housing market clears:

$$\sum_{a=1}^{J} \sum_{s\in\{1,2\}} \int h_s d\mu_1^{own}(a) + \sum_{a=1}^{J} \sum_{i\in\{0,1\}} \int h_a d\mu_i^{rent}(a) = H_-\left(1-\delta_h\right) + Y_h, \tag{6}$$

where H_- is the housing stock in the previous period and Y_h is the new construction.

5. The government maintains a balanced budget as shown in Eq. (4).

Calibration

We calibrate the model into the Chinese economy in this section. We focus on a steady-state equilibrium, in which all the parameters and economic outcomes stay constant over time. The permanent residents refer to those with local hukou, and temporary residents are those without.[7] The major region includes all 112 prefecture cities affected by the hukou relaxation policy announced in 2016, and the 14 cities of population size over 5 million. All the remaining prefecture cities belong to the "other" region. To reduce the computational load, we classified those cities in the major regions into three types. Type-1 city is a population-weighted average of the 14 super populous cities. Sixteen of the remaining 112 cities belong to the so-called tier-2 cities conventionally defined in the literature and media according to their population size and economic development level[8]and thus, we group them into the type-2 city. The remaining 96 cities are classified into the type-3 city in the major region.[9]The dataset we mainly rely on is the China Household Finance Survey(CHFS) 2013, 2015 and 2017, 1-percent population census conducted in 2015, the National Bureau Statistical Yearbook(NBS), and city-level yearbooks in 2013–2017.

The production function for building new houses is specified as

$$Y_h = A_h L_h^{\alpha_L} \left[S_h^{(1-\alpha_N)} N_h^{\alpha_N} \right]^{1-\alpha_L}.$$

Land share α_L is set to be 0.33 according to Deng et al. (2020) to capture the average housing-to-land-value ratio during 2007–2013. Labor share α_N is set as 0.7 according to Favilukis et al. (2017). The city-specific housing productivity A_{ih} is calibrated to reflect the ratios of housing prices in the type-2 and type-3 cities to that in the type-1 city. The housing price in the type-1 city is normalized to 0.1.

The city-specific productivity in the production sector is constructed following Garriga et al. (2020a), in which it is defined as the real non-manufacturing output divided by the urban population. The migration lottery is computed according to the 1-percent population census conducted in 2015, in which for each respondent, we observe both the current residing city and the hukou city as his/her birth place. We can thus compute the population inflow rate in each city within the major region, defined as the fraction of the population holding hukou from the "other" region in the total residents. The inflow rate into each type of city is then the population-weighted average of the inflow rate over the cities within each type. Finally, the migration lottery $\{\iota_i\}$ is a re-normalization of the type-specific

[7] In the remainder of the paper, we use "permanent resident" and "hukou holder," and "temporary resident" and "non-hukou holder" interchangeably.

[8] See Wu et al. (2016) and Glaeser et al. (2017) for more discussions about the tiers of cities in China.

[9] Please refer to Appendix 3 for a complete list of cities belonging to each type.

inflow rate such that they sum to 1. Our estimation results suggest 19.3%, 12.6% and 66.1% of migrants from the "other" region flow to the type-1, type-2, and type-3 city, respectively. The operating cost ψ is assumed to be city-specific, and we calibrate them to match the city-specific housing-price-to-rent ratio. According to CHFS, the population-weighted average housing-price-to-rent ratio in the type-1, type-2 and type-3 city is about 43, 28 and 20, respectively.

The migration dis-utility is assumed to follow a Pareto distribution: $F(\epsilon) = 1 - \left(\frac{\epsilon}{\bar{\epsilon}}\right)^{\kappa}$. We follow Liao et al. (2020) to set the tail parameter κ equal to 2.8. The minimum value of the migration cost $\bar{\epsilon}$ is calibrated to match the fact that population in the major region accounts for about 52% of the total population, which we obtain from the 2015 China City-level Statistical Yearbook.

The annual depreciation rates of both owner-occupied and rental houses are set to a standard value of 2.5%. The apartment house size h_a is chosen such that the expenditure share on rental houses is about 30% of the renter's labor income. We assume two types of owner housing of different sizes. The size of the regular house and villa are set such that $h_1/h_a = 1.31$ and $h_2/h_1 = 4.45$, respectively, to be consistent with quality-adjusted dwellings data from the Hang Lung Center for Real Estate at Tsinghua University (CRE). The transaction tax τ_b is set to be 0.005 according to Garriga and Hedlund (2020). It is set to be $\tau_s = 0.12$ among sellers. This includes fees, moving costs, and liquidity discounts, as discussed in Piazzesi & Schneider (2016).

The length of the life cycle is set to be 60 years and the retirement age is 41. This is to mimic the fact that individuals enter the labor force at age 21 and retire at age 60. Since each period corresponds to one year in the data, we choose the subjective discount factor β to be 0.95, which is within the reasonable range in the literature. The risk-aversion coefficient η is set to be 0.5, which is standard in the literature. The elasticity of substitution between non-housing and housing services is σ based on Li et al. (2016). The coefficient on consumption θ is chosen to match an average consumption-to-GDP ratio at 35% according to NBS 2013–2017. The preference weight on public goods φ is set as 0.33. This is from Wu & You (2020), in which they calibrate ϕ to match the expenditure share on local public goods using China Urban Household Survey 2005. The utility premium of owning a house ζ is calibrated to match an ownership rate of 88.0%.

The average income profile across age cohorts is computed from CHFS. We restrict it to be the before-tax labor income, which contains the rewards to all types of labor including entrepreneurial labor. The persistent and transitory shock of labor endowment are governed by parameters $(\rho, \sigma_z, \sigma_s)$. We follow Fan et al. (2010) to estimate the income process. Finally, the persistent shock z is discretized into a seven-state Markov process with transition matrix $\pi_{zz'}$. The minimum down-payment requirement γ is set to be 0.3, which is consistent with the government policy since 2001. The risk-free rate of return r_b is chosen to be 0.08, which is slightly smaller than the 10% used in Hsieh & Klenow (2009) due to the absence of physical capital and other high-return assets in the model. The mortgage rate r_m is set to be 0.06.

χ is the additional transaction costs paid by non-hukou holders. It is to capture the fact that a home buyer with more social capital is able to secure a housing at a more favorable transaction price. It is chosen to match a 66% ownership rate among non-hukou holders according to CHFS. Tu et al. (2017) estimate that local social capital helps home buyers purchase their housing units at an average price that is 7% lower than the prices paid by those with less local social capital. We thus let χ be 0.07 in the benchmark economy. The additional expense incurred among non-hukou holders is calibrated to match the stylized fact that the expenditure share of migrants on private consumption without an urban Hukou is 30.7% lower than that of urban residents, which is estimated in Chen et al. (2012) using Chinese Household Income Project Survey(CHIPS) 2002 dataset. Finally, δ captures the discounted access to public goods, and is chosen to match the ownership rate among non-hukou holders.

In the benchmark economy, we let the probability of obtaining hukou be uniform across all the cities in the major region. π_i is set to be 0.1, which is equivalent to the probability of obtaining hukou within five years is 41%. In addition, the other way to obtain hukou is to purchase a house. The probability is uniform across all the cities. In the counterfactual exercise, we gradually relax the hukou restriction in each city by increasing the probability of obtaining hukou.

The government sends lump-sum transfers to individuals to ensure they can afford an apartment h_a, extra expenditure τ for temporary residents, and a subsistence consumption level denoted as c. Specifically,

$$\mathcal{T}(j,z) = \max\{0, \bar{p}_a h_a + \psi \mathcal{I}_{hukou} - (1-\tau) we(j,z)\},$$

where $\mathcal{I}$ is a indicator function of resident status. We assign a very small number to c so that the value from receiving a transfer is extremely small, which implies individuals will not intentionally choose to receive government transfers. Table 2 provides a summary of our model parameters.

Table 3 compares the model-predicted moments with their data counterparts. The model perfectly matches the population distribution both between the major and the "other" region, and within the major region. The model not only successfully matches the ownership rate among those of different residence status, but also represents the ownership rate within each five-year age group fairly well as shown in Table 4. The model underpredicts the ownership rate in the first few age groups due to the assumption that every individual is born in the "other" region. But the ownership rate catches up and closely mimics the data counterpart among individuals older than age 45. In terms of cross-sectional moments in the wealth distribution, the model-predicted wealth-to-income ratio at different percentiles, and the $90-10$ networth ratio are fairly close to their data counterparts. The housing-wealth-to-income ratio is underestimated relative to the data, likely because the current model does not allow individuals to own multiple houses. As for spending, the model predicts an approximately 27.5% expenditure share on rent among renters. The distribution of expenditure share on rent among renters is also close to their data counterparts. Among owners, we compare the distribution of outstanding mortgage to labor income with data. To sum up, our model predicts, reasonably well, the ownership

Table 2 Summary of model parameters

Description	Parameter	Value	Explanation
Technology			
Owner-housing productivity	A_{ih}	{8.0,5.2,4.9}	housing prices
Production productivity	A_i	{1.0,0.82,0.68}	Garriga et al. (2020a)
Operation cost	ψ_i	{0.018,0.022,0.025}	price-to-rent ratio
Land share	α_L	0.33	Deng et al. (2020)
Labor share	α_N	0.7	Deng et al. (2020)
Housing			
Number of cities	I	3	
Housing depreciation	δ_h	0.025	standard
Rental apartment size	h_a	0.6	expenditure share on rental
Small owner-occupied house size	h_1	0.79	CRE
Large owner-occupied house size	h_2	3.50	CRE
Buyer transaction cost	τ_b	0.005	Garriga & Hedlund (2020)
Seller transaction cost	τ_s	0.12	Guren et al. (2020)
Preferences			
Length of life	J	60	age 20–79
Retirement age	J^R	41	age 60
Risk aversion	η	0.5	standard
Discount factor	β	0.95	standard
Intratemporal substitution	σ	0.487	Li et al. (2016)
Weight on c	θ	0.035	consumption-to-GDP
Weight on g	ϕ	0.33	Wu & You (2020)
Homeownership premium	ζ	1.3	overall ownership rate
Tail index of migration cost dist.	κ	2.8	Liao et al. (2020)
Minimum migration disutility	ϵ	18.8	population share of the major region
Reservation utility in the "other" region	$\underline{U}$	0	normalization
Hukou Policy			
Probability of obtaining hukou	π_i	{0.1,0.1,0.1}	
Migration lottery	ι_i	{0.193,0.126,0.661}	
Public goods expenses	ξ	0.726	cons. expen. share among temp. residents
Housing information cost	χ	0.075	Tu et al. (2017)
Discounted access to public goods	δ	0.73	ownership rate among non-hukou holders
Urban Income Process			
Auto-correlation of persistent shock	ρ	0.844	Fan et al. (2010)
Variance of persistent shock	σ_e^2	0.134	Fan et al. (2010)
Variance of transitory shock	σ_e^2	0.329	Fan et al. (2010)

Table 2 (continued)

Description	Parameter	Value	Explanation
Government Policy			
Income tax	τ	0.2	government policy
Minimum consumption	c	0.001	
Minimum down payment ratio	$\bar{\gamma}$	0.3	government policy
Interest Rates			
Savings interest rate	r_b	0.08	Government policy
Mortgage interest rate	r_m	0.06	Government policy

Table 3 Targeted and Un-targeted moments in the calibration

Moments	Model	Data
Targeted		
population share of the major region	0.52	0.52
overall ownership rate	0.88	0.88
ownership rate among hukou	0.952	0.95
ownership rate among non-hukou	0.607	0.60
expenditure share on rent	0.275	0.28
Wealth		
housing wealth to labor income	6.31	7.20
90 – 10 networth ratio	33.67	33.50
Gini coefficient	0.56	0.60
networth to labor income	10.82	10.55
networth to labor income (median)	13.10	12.9
networth to labor income(10th percentile)	1.95	2.12
networth to labor income(90th percentile)	18.99	19.30
Spending		
rent to labor income(median)	0.331	0.32
rent to labor income(10th percentile)	0.032	0.04
rent to labor income(90th percentile)	0.972	0.96
outstanding mortgage to labor income(median)	3.05	2.88
outstanding mortgage to labor income(10th percentile)	1.21	1.13
outstanding mortgage to labor income(90th percentile)	6.33	6.02

rate, the life-cycle profile of wealth, and the cross-sectional distributions of wealth, expenditure share on rent, and mortgage payment.

In Fig. 1, we plot the evolution of the ownership rate and the average welfare against age cohorts in each city. The ownership rate exhibits an inverse-U pattern: it steadily increases with age during younger ages and declines towards the end of the life cycle. The ownership rate in the type-3(type-1) city appears to be the highest(lowest) among the three cities in all the age cohorts. In addition, the ownership rate in the type-1 city reaches its peak level at the earliest age, followed by the

Table 4 Cross-sectional ownership rate: data vs. model

Ages	Model	Data
30–34	0.532	0.596
35–39	0.562	0.657
40–44	0.648	0.713
45–49	0.821	0.830
50–54	0.907	0.905
55–59	0.947	0.944
60–64	0.962	0.963
65–69	0.966	0.968
70–74	0.961	0.971
≥ 75	0.948	0.970

Notes: We compare the model-predicted ownership rate with the data counterpart within each 5-year age interval starting from age 30. The data source is CHFS 2012

type-2 and the type-3 city. The average welfare is defined as the population-weighted average of value functions among individuals of different state variables as defined in "Individual's Optimization Problem" section. An inverse-U shape between the average welfare and age also prevails in all three cities. The peak level is reached at around age 30. The welfare gap among the three cities is amplified during the younger ages, but shrinks toward the end of the life cycle.

Quantitative Results

In this section, we gradually relax the restrictions to obtaining hukou in different cities, and evaluate the impacts at the aggregate-level, city-level and individual-level, respectively. The aggregate-level results are summarized in Table 5.

When the probability of receiving hukou in the type-3 city is doubled to 0.2, which implies that the probability of obtaining hukou within five years since migration is 67.2%, the population share of the major region increases by about 0.3% points. This finding is not surprising, because the major region now becomes more attractive than that in the benchmark economy, and thus, more individuals from the "other" region prefer to migrate. The increasing housing demand led by a larger population inflow has also triggered the growth in housing prices in all the three cities. Housing prices in the counterfactual economy become 1.35%, 1.07% and 1.89% higher than their level in the benchmark economy in the type-1, type-2 and type-3 city, respectively. This finding is consistent with the empirical evidence that treatment cities (type-3 city) experience faster growth in housing prices than other cities. When obtaining hukou is easier in the type-3 city, housing may become more affordable because individuals are able to purchase at a lower transaction price once they obtain hukou. On the other hand, the benefits associated with local hukou may overcome the need to own a house for the utility premium from owning. In addition, the higher housing price in the general

Table 5 Policy comparison

Moments	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
Aggregate				
Population share	0.520	0.523	0.527	0.529
Ownership rate	0.876	0.873	0.870	0.868
House prices				
Type-1	0.1000	0.1014	0.1020	0.1043
Type-2	0.0549	0.0555	0.0568	0.0570
Type-3	0.0364	0.0371	0.0375	0.0379
Ownership rate				
Type-1	0.803	0.800	0.799	0.792
Type-2	0.873	0.868	0.86	0.859
Type-3	0.916	0.905	0.903	0.903
Hukou population				
Type-1	0.880	0.880	0.880	0.928
Type-2	0.947	0.918	0.942	0.941
Type-3	0.954	0.956	0.959	0.959
Average welfare				
Type-1	9.052	9.163	9.191	9.477
Type-2	8.395	8.480	8.645	8.654
Type-3	7.735	7.915	7.941	7.949

Notes: We relax the hukou restriction by doubling the probability of obtaining hukou in three different scenarios. We report the population share of the major region and the overall ownership rate. At the city-level, we report housing prices, ownership rate, fraction of hukou population, and the average welfare in each city

equilibrium may also tend to discourage the demand for housing. Overall, housing price thus appears to grow only less than 2% in the type-3 city. The slightly higher housing price also explains the slightly lower overall ownership rate than the benchmark levels. The lower ownership rate also explains the decline in the size of the hukou population in the type-1 and type-2 city. However, it increases in the type-3 city because the chance to win hukou from the lottery is higher despite fewer owners. Nevertheless, relaxing the hukou constraint still leads to welfare gain in all the three cities, equivalent to 1.23%, 1.01% and 2.32% of its benchmark level in the type-1, type-2 and type-3 city, respectively. The positive spillover to residents in the type-1 and type-2 city is likely due to the increasing land sales revenue led by higher housing prices. The government in the counterfactual economy is able to spend more on providing public goods, which may benefit all the residents. Our findings shed light on the policy implications that relaxing hukou restrictions in one city may exert positive benefits on other cities despite the potentially higher housing prices.

When the hukou restrictions in both the type-2 and type-3 city are relaxed, housing prices in the type-1, type-2 and type-3 city grow by 2.0%, 3.5% and 2.9% from their benchmark levels, respectively. The magnitudes are all greater than

those when hukou restrictions are only relaxed in the type-3 city. This finding is partially due to the larger population flow from the other region. The population share of the major region is 0.74% points higher than that in the benchmark economy. Different from the previous experiment, housing prices in the type-2 city grow more than in the type-1 city, due to the relaxation of its hukou policy. The ownership rate in all the cities declines further from its benchmark levels. Individuals in the type-1 city continue to receive positive spillover effects from hukou relaxation in the other cities. The welfare gain is equivalent to 1.53%, 2.98% and 2.66% of its benchmark level in the type-1, type-2 and type-3 city, respectively.

Because the hukou policy reform in 2016 is restricted to the type-2 and type-3 city, in the last experiment, we explore the situation if the hukou restriction were also relaxed in the type-1 city. Our results show that housing prices again grow the most in the type-1 city at 4.3% of its benchmark level, followed by the type-3 city at 3.92%. The growth rate is the smallest in the type-2 city at 3.84%. All these findings suggest a widening gap in the price level between the type-1 city and other cities, but a shrinking gap between the type-2 and the type-3 city from their benchmark counterparts. If we view the situation when hukou restrictions are only relaxed in the type-2 and type-3 city as the current situation, our results suggest that if hukou policy reform were to be implemented in the type-1 city, the growth of housing prices in the type-1 city would be equivalent to 2.3% of their current levels. The fact that housing prices in the type-2 city grow less dramatically than in the type-3 city may still be explained by the substitution effect discussed before, which dominates in the tier-2 city given its higher housing price level than the type-3 city. Residents in the type-1 city collect the largest welfare gain among the three cities, equivalent to 4.69% of its benchmark level, followed by the type-2 and type-3 city with welfare gains equivalent to 3.09% and 2.76% of their benchmark levels. The findings seem to suggest that those initially richer and more populous cities tend to benefit the most from a uniform relaxation in the hukou restrictions despite the sharp rise in their housing prices. Compared with the current situation, the type-1 city is still able to collect a welfare gain equivalent to 3.1% of their current levels given the 2.3% growth in housing prices.

We further explore the cross-sectional impacts from the hukou relaxation policy in each city. In Tables 8, 9 and 10, we report the five-year-average of ownership rates among different policy experiments in each city. The ownership rate among individuals of ages 30–34 increases from the benchmark level in all the counterfactual scenarios and cities. This finding suggests individuals tend to buy houses at a younger age when the hukou restrictions are relaxed. It is natural to expect that when the hukou restriction in a given city is relaxed, its residents tend to purchase houses earlier due to cheaper transaction prices and non-discounted access to public goods. The fact that residents from other cities also purchase houses at a younger age is likely due to the larger public good provision from the government led by higher land sales revenue. Given a certain degree of substitution between private consumption and public goods, individuals can thus sacrifice more consumption goods for saving, and therefore afford a house at a younger age. In the type-1 city, the ownership rate among the younger cohorts (30–49) is the largest when the hukou restrictions are relaxed in the type-2 and the type-3 city. This is driven by both the

substitution between owning hukou and house, and the substitution between private and public goods consumption. The ownership rate may fluctuate during the first few age groups in some cities. This fluctuation is driven by technical reasons because these years are the ones at which individuals from the other region flow into the major region, which expands the population size of the major region, and thus, the changes in the ownership rate are less clear. We also plot the comparison in Fig. 5 for better visualization.

In Tables 11, 12, and 13, we also report the four-year-average of welfare among different policy scenarios and cities. The welfare steadily increases when hukou restrictions are relaxed in more cities. This pattern is robust among all the age groups in the three cities. But the gain seems to decrease with ages. In addition, the welfare gain of each age group seems to be more prominent in the type-1 city than the other two cities in all the scenarios. The peak of the welfare is reached during ages 48-51 among all the scenarios in all three cities. The comparison is also presented in Fig. 4.

Robustness Checks

We have also repeated a similar set of counterfactual policy experiments based upon an alternative benchmark economy, in which the probability of obtaining hukou is no longer the same across all the cities. Instead, we assume the only way to obtain hukou in the type-1 city is through purchasing a house, which corresponds to $\pi_1 = 0$. The probability of obtaining hukou in the type-2 and type-3 city is set to 0.05 and 0.1, respectively, to reflect gradually easing hukou restrictions down the city types. We have re-calibrated the model to match the same set of stylized facts illustrated in "Calibration" section. In the counterfactual policy experiments, we double the probability of obtaining hukou either only in the type-2 and type-3 city or in all three cities evaluate the aggregate and distributional impacts. [10]

The results are shown in Table 6. When the hukou restrictions are relaxed in both the type-2 and type-3 city, the population share of the major region increases by 0.8% points. The housing prices grow by 5.1%, 6.2% and 5.5% from their benchmark levels in the type-1, type-2 and type-3 city, respectively. This finding is consistent with our previous findings: housing prices grow faster in the type-2 than in the type-3 city, whreas obtaining hukou is harder in the type-2 than in the type-3 city in the benchmark economy. All three cities still enjoy welfare gains from the relaxation in the hukou restrictions, with the gain equivalent to 1.66%, 2.05% and 1.87% of the benchmark level in the type-1, type-2, and type-3 city, respectively.

When the hukou restrictions in all the cities are relaxed, the population share of the major region increases by 2.6% points from its benchmark level. Housing prices grow by 11.1%, 9.1% and 9.0% from their benchmark levels in the type-1, type-2, and type-3 city, respectively. Despite housing prices growing the most in the type-1

[10] The changes in both the population distribution and housing prices seem to be negligible when hukou restrictions are only relaxed in the type-3 city, so we instead focus on the aforementioned two experiments.

Table 6 Robustness checks

Moments	Bench	Relax Type-2 + 3	Relax all
Aggregate			
Population share	0.520	0.528	0.546
Ownership rate	0.876	0.890	0.883
House prices			
Type-1	0.1000	0.1051	0.1111
Type-2	0.0549	0.0583	0.0599
Type-3	0.0364	0.0384	0.0397
Ownership rate			
Type-1	0.802	0.802	0.778
Type-2	0.873	0.87	0.859
Type-3	0.916	0.915	0.913
Hukou population			
Type-1	0.881	0.880	0.966
Type-2	0.950	0.959	0.970
Type-3	0.964	0.964	0.973
Average welfare			
Type-1	9.207	9.36	9.807
Type-2	8.674	8.851	8.923
Type-3	8.023	8.173	8.245

Notes: We relax the hukou restriction by increasing the probability of obtaining hukou to 0.2. We relax hukou restrictions either in the type-2 and type-3 city or in all three cities. We report the population share of the major region and the overall ownership rate. At the city-level, we report housing prices, ownership rate, fraction of hukou population, and the average welfare in each city

city, residents in the type-1 city still enjoy the largest welfare gain, equivalent to 6.52% of its benchmark level, followed by the type-2 and the type-3 city at 2.87 and 2.77%, respectively.

In the previous exercise, given the uniform relaxation of hukou policy in all the cities (the probability of obtaining hukou increases from 0.1 to 0.2 in all the cities), housing prices in the type-3 city grow more than in the type-2 city. In the current setting, when the hukou policy in the type-2 city is relaxed disproportionately more than the type-3 city (the probability of obtaining hukou increases from 0.05 to 0.2 in the type-2 city, and from 0.1 to 0.2 in the type-3 city), the pattern is reversed. This finding seems to suggest both the substitution effect and the magnitude of hukou policy relaxation contribute to the growth of housing prices.

Relaxing Hukou Policy vs. Lower Migration Costs

Either lowering the overall migration costs or relaxing the hukou restrictions tends to induce the migration from the "other" region. The natural question concerns the

Table 7 Relaxing hukou policy vs. lower migration costs

Moments	Bench	Relax all	Lower migration costs
Aggregate			
Population share	0.520	0.529	0.526
Ownership rate	0.876	0.868	0.875
House prices			
Type-1	0.1000	0.1043	0.1023
Type-2	0.0549	0.0570	0.0557
Type-3	0.0364	0.0379	0.0370
Ownership rate			
Type-1	0.803	0.792	0.799
Type-2	0.873	0.859	0.864
Type-3	0.916	0.903	0.894
Hukou population			
Type-1	0.880	0.928	0.880
Type-2	0.947	0.941	0.914
Type-3	0.964	0.949	0.926
Average welfare			
Type-1	8.733	9.477	9.112
Type-2	8.286	8.654	8.418
Type-3	7.715	7.949	7.733

Notes: We either uniformly reduce the migration costs or relax the hukou restrictions in all the cities so that the population share of the major region is identical in both experiments. We report the population share of the major region and the overall ownership rate. At the city-level, we report housing prices, ownership rate, fraction of hukou population, and the average welfare in each city

effectiveness between these two policies. In the following, we first introduce a scale to the migration cost(ξ), so that the expected payoff from migration for an individual of age a becomes $\sum_{i=1}^{I} \iota_i \mathbb{E}_z \left[V_{i0}^{rent}(a+1,0,z) \right] - \xi\epsilon$. In the benchmark economy, ξ is normalized to 1. In this subsection, we adjust the value of ξ such that the population share of the major region becomes identical to the previous exercise with relaxing hukou restrictions in all the cities. Table 7 compares the aggregate results of both economies.

When the migration costs are uniformly reduced, housing prices in all three cities still grow from their benchmark levels, but the magnitudes are smaller than their counterparts in which the hukou restrictions are uniformly relaxed in all the cities. In addition, a uniform reduction in the migration costs leads to higher ownership rates in both the type-1 and type-2 city, but a lower ownership rate in the type-3 city than under uniform hukou relaxation. These together lead to a higher overall ownership rate. It is natural to expect the size of the hukou population in all the cities to be

smaller than in the economy with relaxed hukou restrictions. It is also worthwhile to highlight that a uniform reduction in the migration costs leads to less welfare gain in all the cities than a uniform relaxation of hukou restrictions. Specifically, the average welfare is only about 96.2%, 97.3% and 97.3% of the level in the economy with relaxed hukou restrictions in the type-1, type-2, and type-3 city, respectively. This is likely because higher housing prices led by the increasing housing demand can provide more public goods, which can benefit more individuals when hukou restrictions are relaxed.

Conclusions

In this paper, we present a dynamic spatial general equilibrium model to evaluate the impacts of residence policy relaxation at the individual-level, city-level and aggregate-level, respectively. Temporary residents are assumed to receive discounted access to public goods provided by the local government than the permanent residents. Therefore, when obtain permanent residence is easier for them, their location choice, housing tenure decisions and financial portfolio may change dramatically. Our DID analysis using the 2016 hukou policy reform in China as a shock reveals the positive and significant impact on local housing prices among the treatment cities. The calibrated model is able to capture the key moments on both population and wealth distribution in China, and mimic the hump-shaped pattern of ownership rates and networth along the age cohorts. Our quantitative exercise suggests a positive spillover effect from the treatment to the unaffected cities' local welfare. The channel is through increasing population inflow, land sales revenue, and public goods provision. The labor allocation within the major region is decided by a lottery in the current setting for the sake of simplicity. A framework with completely endogenous migration decisions may be worth pursuing. In addition, a multi-sector framework that takes into account the ongoing structure change in China from the agricultural to the non-agricultural sector may also be meaningful. We relegate these research directions to future work.

Appendix 1

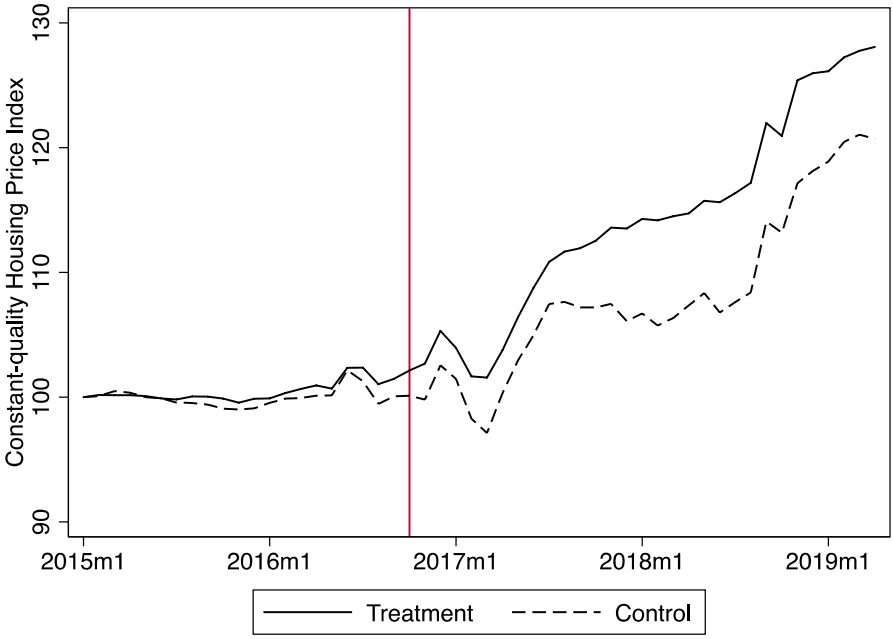


Fig. 2 Raw trend of housing price. Notes: The figure plots the raw trend of the constant-quality housing price index for treatment and control cities. The sample period covers all months between January 2015 and April 2019. The solid line denotes the average housing price index of the treatment group cities, including 114 cities with an urban population of 1 million to 5 million. The dashed line denotes the average housing price index of the control group cities, including 136 cities with an urban population either above 5 million or below 1 million. The vertical line denotes the implementation of the new hukou policy

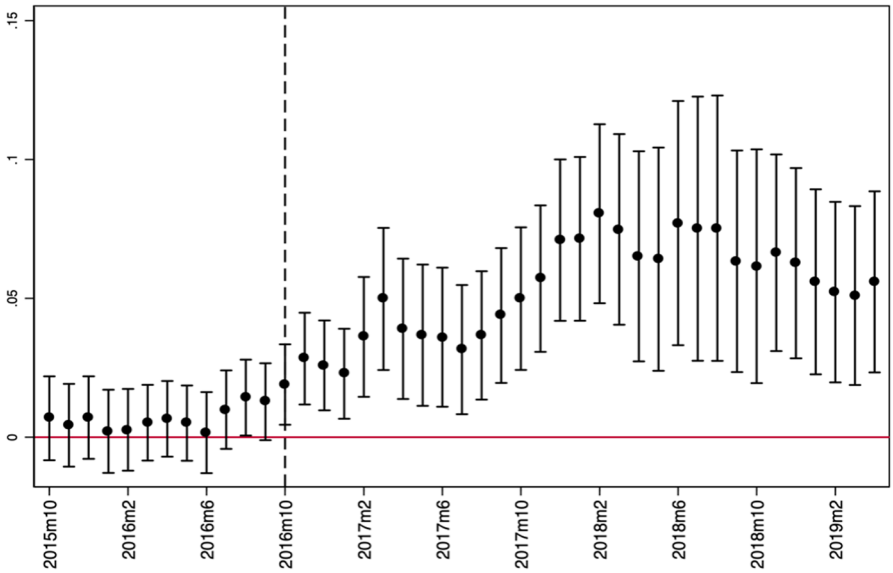
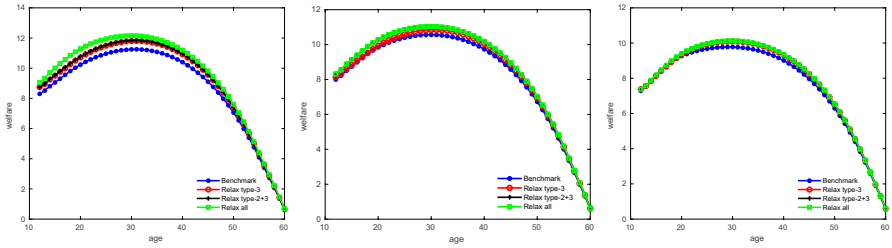
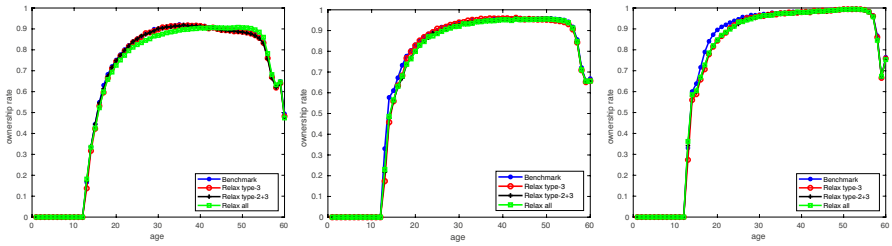


Fig. 3 Parallel trend test. Notes: The figure visualizes the coefficients estimated with the dynamic DID specification, with both the coefficients and 95% confidence intervals reported. The sample period covers all months between January 2015 and April 2019. The treatment group includes 114 cities with an urban population of 1 million to 5 million, whereas the cities with an urban population either above 5 million (14 cities) or below 1 million (122 cities) serve as the control group. The pre-trend period includes 12 months. The vertical line denotes the implementation of the hukou reform



(a) Type 1 (b) Type 2 (c) Type 3

Fig. 4 Welfare comparison. Notes: We plot the evolution of the average welfare along age cohorts in different policy scenarios in each city. In the benchmark economy, the probability of obtaining hukou is increasing with the type of the city



(a) Type 1 (b) Type 2 (c) Type 3

Fig. 5 Ownership Rate Comparison. Notes: We plot the evolution of the ownership rate along age cohorts in different policy scenarios in each city. In the benchmark economy, the probability of obtaining hukou is increasing with the type of the city

Table 8 Ownership rate comparison in the type-1 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
30–34	0.189	0.175	0.191	0.188
35–39	0.667	0.649	0.660	0.640
40–44	0.818	0.814	0.816	0.792
45–49	0.885	0.882	0.883	0.853
50–54	0.913	0.911	0.910	0.885
55–59	0.918	0.915	0.915	0.900
60–64	0.906	0.903	0.902	0.905
65–69	0.895	0.890	0.889	0.906
70–74	0.869	0.864	0.862	0.890
≥ 75	0.643	0.634	0.631	0.644

Note: We compare the ownership rate within each 5-year age interval starting from age 30 in the type-1 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level

Table 9 Ownership rate comparison in the type-2 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
30–34	0.304	0.238	0.251	0.256
35–39	0.763	0.742	0.721	0.723
40–44	0.880	0.880	0.863	0.861
45–49	0.923	0.925	0.913	0.911
50–54	0.943	0.949	0.939	0.937
55–59	0.953	0.957	0.950	0.949
60–64	0.957	0.957	0.953	0.953
65–69	0.957	0.954	0.955	0.954
70–74	0.952	0.943	0.949	0.949
≥ 75	0.764	0.753	0.757	0.756

Notes: We compare the ownership rate within each 5-year age interval starting from age 30 in the type-2 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level

Table 10 Ownership rate comparison in the type-3 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
30–34	0.314	0.284	0.304	0.310
35–39	0.823	0.760	0.768	0.770
40–44	0.929	0.900	0.897	0.899
45–49	0.963	0.952	0.949	0.948
50–54	0.974	0.969	0.968	0.968
55–59	0.979	0.977	0.977	0.977
60–64	0.985	0.984	0.983	0.983
65–69	0.992	0.990	0.989	0.990
70–74	0.995	0.993	0.993	0.993
≥ 75	0.850	0.845	0.843	0.842

Notes: We compare the ownership rate within each 5-year age interval starting from age 30 in the type-3 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level

Table 11 Welfare comparison in the type-1 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
32–35	8.92	9.37	9.40	9.84
36–39	9.91	10.37	10.42	10.95
40–43	10.64	11.15	11.20	11.67
44–47	11.08	11.62	11.66	12.04
48–51	11.24	11.79	11.83	12.14
52–55	11.11	11.66	11.69	11.97
56–59	10.65	11.18	11.21	11.47
60–63	9.82	10.31	10.34	10.58
64–67	8.56	8.99	9.01	9.23
68–71	6.78	7.12	7.14	7.31
72–75	4.42	4.64	4.64	4.75
≥ 75	1.69	1.78	1.78	1.83

Notes: We compare the average welfare within each 4-year age interval starting from age 32 in the type-1 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level.

Table 12 Welfare comparison in the type-2 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
32–35	8.62	8.70	8.99	9.00
36–39	9.56	9.62	9.97	9.98
40–43	10.17	10.31	10.61	10.62
44–47	10.48	10.71	10.94	10.95
48–51	10.55	10.84	11.01	11.03
52–55	10.39	10.70	10.85	10.86
56–59	9.97	10.27	10.40	10.41
60–63	9.22	9.50	9.62	9.63
64–67	8.09	8.34	8.44	8.45
68–71	6.48	6.68	6.76	6.77
72–75	4.30	4.43	4.49	4.49
≥ 75	1.64	1.69	1.72	1.72

Notes: We compare the average welfare within each 4-year age interval starting from age 32 in the type-2 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level

Table 13 Welfare comparison in the type-3 city

Ages	Bench	Relax Type-3	Relax Type-2 + 3	Relax all
32–35	8.01	7.98	8.02	8.03
36–39	9.01	9.02	9.07	9.09
40–43	9.50	9.69	9.73	9.74
44–47	9.72	10.01	10.04	10.05
48–51	9.76	10.08	10.11	10.12
52–55	9.60	9.93	9.96	9.97
56–59	9.21	9.53	9.56	9.57
60–63	8.54	8.83	8.86	8.87
64–67	7.52	7.78	7.80	7.81
68–71	6.07	6.28	6.30	6.30
72–75	4.09	4.23	4.24	4.24
≥ 75	1.57	1.63	1.63	1.63

Notes: We compare the average welfare within each 4-year age interval starting from age 32 in the type-3 city among three different scenarios. We relax hukou policy restrictions by doubling the probability of obtaining hukou from its benchmark level

Appendix 2 Computation Algorithm

The household value and policy functions are solved by backward induction starting from the final period of life. We discretize the idiosyncratic state by fixing grids on liquid assets B (150 points), mortgages M (11 points), house sizes H (2 points), and income Y (100 points), persistent income shocks (7 points), transitory income shocks (7 points). Households choose liquid assets and house sizes on the grids of B and H respectively. We follow Kaplan et al. (2020) and Chen et al. (2020) by restricting household mortgage choice when purchasing a house to be only on M. However, when computing the next period mortgage balance after the current mortgage is repaid, it can either be exactly M, or follow the amortization schedule, which is computed via linear interpolation between grid points. The following algorithm is used to compute the steady-state equilibrium: (1) Make an initial guess of the market clearing house price and the provision of public goods G. (2) Given the initial guess, solve backward for the individuals' value and policy functions. Given individuals' choices, solve forward for the distribution of households over individual states. (3) Calculate the aggregate housing demand, housing supply, and net government expenditure on public goods in the stationary equilibria. (4) Compare the updated housing price with the initial guess. If not the same, replace the initial guess by a weighted average between the two, and return to step 2. (5) Compare the updated government expenditure on public goods with the initial guess. If not the same, replace the initial guess by a weighted average between the two, and return to step 2.

Appendix 3 The List of Cities Within Each City Type

- Type-1 city: Chengdu, Nanjing, Guangzhou, Shantou, Hangzhou, Shanghai, Tianjin, Shenzhen, Beijing, Zhengzhou, Chongqing, Xi'an, Shenyang, Wuhan.
- Type-2 city: Shijiazhuang, Dalian, Changchun, Harbin, Suzhou, Ningbo, Hefei, Fuzhou, Xiamen, Nanchang, Ji'nan, Qingdao, Changsha, Nanning, Haikou, Kunming.
- Type-3 city: Tangshan, Handan, Baoding, Taiyuan, Datong, Jincheng, Hohhot, Baotou, Chifeng, Anshan, Jilin city, Qiqihar, Daqing, Yichun, Xuzhou, Changzhou, Nantong, Lianyungang, Yangzhou, Zhenjiang, Taizhou, Wenzhou, Huzhou, Shaoxing, Taizhou, Wuhu, Bengbu, Huainan, Fuyang, Suzhou, Liuan, Bozhou, Putian, Quanzhou, Ganzhou,Fuzhou, Zibo, Yantai, Weifang, Jining, Weihai, Rizhao, Linyi, Dezhou, Liaocheng, Luoyang, Pingdingshan, Anyang, Xinxiang, Luohe, Nanyang, Xinyang, Yichang, Xiangfan, Jingzhou, Zhuzhou, Hengyang, Changde, Yiyang, Yongzhou, Zhuhai, Foshan, Jiangmen, Zhanjiang, Huizhou, Qingyuan, Dongguan, Zhongshan, Chaozhou, Liuzhou, Qinzhou, Guigang, Yulin, Hezhou, Laibin, Zigong, Luzhou, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Dazhou, Bazhong, Ziyang, Guiyang, Zunyi, Baoji, Ankang, Lanzhou, Tianshui, Wuwei, Xining, Yinchuan, Urumqi.

Declarations

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