Spatial Misallocation in Housing and Land Markets: Evidence from China

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Abstract

We evaluate the extent of spatial misallocation in China's housing and land markets and examine the consequences for the aggregate and spatial distribution of housing and land prices, net migration flows and welfare. We document the pervasive spatial variations of housing and land market frictions, although larger cities are less distorted. Our dynamic spatial equilibrium framework features endogenous rural-urban migration and developer entry. Our counterfactual analysis using a calibrated model suggests that, in a frictionless economy, housing prices could be much higher and rise faster but with less spatial dispersion. In contrast, land prices could grow moderately more with greater volatility over time and larger dispersion across cities. Overall, housing frictions play a dominant role in driving both prices and dispersions as a result of dynamic amplification in the process of rural-urban migration. While the presence of such frictions may slow down the housing boom in mega cities, it is at the expense of urban welfare loss and lower per-capita real GDP in non-mega cities facing larger frictions, thereby widening tier productivity gaps.

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1 Introduction

Despite the burgeoning literature in macroeconomics and development economics in the last fifteen years on the causes and consequences of factor misallocation associated with capital, labor, and output distortions across different firms, not much has been known about the misallocation across space, especially with regards to housing and land markets. While labor is mobile across space, labor mobility is subject to the costs of migration and living, which depend crucially on immobile housing and land. Location-specific institutions and distortions may affect spatial misallocation, which may further result in non-negligible consequences for the macroeconomy. In this paper, we examine the extent and the consequences of spatial misallocation in China, where the household registration (hukou) system and various housing and land regulatory policies have generated large housing and land market frictions across cities. While such potential distortions make China an interesting case to explore, our model and findings can be generalized to other economies beyond China.

Over the past several decades, the world has witnessed many sizable housing booms over prolonged periods. China —the world's factory— has attracted global attention over the unprecedented rapid growth in its housing market. The disproportionately rapid housing price growth over the past decade or two dwarfs China's urbanization process. Its rural population drops from about three quarters to more than half over the same period. Given this moderate urbanization pace, it is puzzling why China has experienced one of the most noticeable price hikes in the urban housing market. The unprecedented housing booms have triggered the government to implement regulatory measures toward mortgage financing and housing sales to cool off the housing market even shortly after the global financial tsunami.[1] In addition, we have also observed a substantial dispersion of housing and land prices across Chinese cities. The primary purpose of this paper is to investigate how the housing and land market frictions affect the price growth in these markets, as well as the price dispersions across cities.[2] We hypothesize that the large dispersion of housing and land prices are likely

[1] The detailed aspects of China's structural transformation, migration policies, and housing institutions are discussed in Section 4.2 and Appendix A.

[2] Across a set of 287 Chinese prefectural cities, the average housing and land prices in 2013 are 1.58 and 1.53 times their level in 2007, respectively (see summary statistics in Table E.2), with dispersed distributions skewed to the right.

attributable to differences in local government institutions and management practices, which cause market frictions to vary across cities.

We develop a dynamic spatial equilibrium framework that incorporates frictions in both housing and land markets. Our model highlights that land is never simply a derived demand for housing in China. With endogenous rural-urban migration to mimic the rapid structural transformation process undertaken in China, we highlight that the existing frictions in housing and land markets may affect spatial distribution. To further motivate the respective frictions in the housing and land markets, we delineate in Figure E.1 the evolution of the average market share among the top eight housing developers in local residential land markets from 2008 to 2013 by city tiers. On average, the market share of these top buyers across all cities is about 60 percent, suggesting they are likely oligopolies in local housing markets. However, they may not exercise oligopoly power in local land markets when the government essentially controls the land. Nonetheless, such market imperfection can result in price wedges when compared with competitive equilibrium benchmarks. We also find the market shares tend to be lower in larger cities, such as the four tier-1 megacities and those in tier-2(capital and major cities)[3], which implies housing and land markets in larger cities are more competitive. Over time, the market share of top buyers decreased from 82.8% in 2008 to 59.4% in 2013, resulting from urban land- and housing-markets' reforms toward competitiveness.

In our theoretical setup, we consider an economy that is geographically divided into two regions: a rural area that produces agricultural goods and an urban area that produces manufactured goods (inclusive of urban services). Ongoing technological progress drives workers away from the rural agricultural sector to the urban manufacturing sector. New homes are built by real estate developers who purchase land and construction permits from the government. Our framework considers multiple cities categorized into three tiers. This

[3]China's cities are categorized into four tiers, based on the level of economic development. Tier 1 includes only the four mega cities: Beijing, Shanghai, Shenzhen, and Guangzhou. Tier 2 includes most provincial capitals and some very developed prefecture cities, which are typically large, industrialized, and have relatively strong local economies. Tier 3 are those prefecture cities with medium to high levels of income, which are smaller but still large by western standards. Tier 4 cities are further down in economic development and size but still very populous compared to the average western city. See Wu et al. (2016) and Glaeser et al. (2017) for more discussions about the four tiers of cities in China.

allows us to assess the contribution of the spatial differences in frictions to changes in housing price growth rates across city-tiers and across cities within a tier, and provides theoretical guidance to our procedure in estimating city-level housing and land frictions.

The key geographical variations incorporated in our model are city-specific technologies, housing material costs, land supplies and minimum land requirements, developer entry costs, within-the-tier migration lotteries associated with hukou regulations, and housing and land market frictions. The computation of city-specific housing and land market frictions is model-based, depending on developers' optimization problems. Specifically, housing and land market frictions are wedges associated with distorted housing and land prices. This accounting framework extends the factor misallocation literature (cf. Hsieh and Klenow (2009) and Hsieh and Moretti (2019)) to *misallocation in urban housing and land markets across cities* (rather than firms). To ensure the validity of the analysis, city-specific labor wedges and several other city-specific factors are embedded in our quantitative setting. We show housing and land frictions vary substantially across cities, with the dispersion in land frictions being even larger. The spatial spread of housing friction is persistent over the years, while the spread of land frictions drops by more than half. We find housing frictions among tier-1 cities are much smaller than those in tier-2 and tier-3 cities; land frictions are comparable between tier-1 and tier-2 cities but more severe in lower-tier cities. Although both frictions are decreasing with city size, only land frictions exhibit a statistically significant downward trend over time.

A key spatial pattern of housing and land market frictions worth highlighting is: the smaller the city size is, the larger the distortionary wedges are. To understand this, we allow for city-specific developer entry costs and find entry restrictions smaller in larger cities. In other words, the larger cities have lower entry restrictions, which is consistent with more competitive housing markets and lower top-8 developers' market shares, as discussed above.

To disentangle the contributions of housing and land frictions in driving both the price growth and spatial dispersion of prices, we perform various counterfactual exercises in which we either eliminate both frictions or only eliminate one friction at a time. We calibrate the model to mimic the early stages of development in China over the sample period from 2007 to 2013 (constrained by the availability of marketized data), followed by a 50-year projected path through 2063 to mimic the U.S. experience from 1950 to 1990.

The main findings can be summarized as follows. At the national level, the process of structural change can perfectly predict the housing price growth factor from 2007 to 2013 and only moderately over-predict the land price. When both frictions are eliminated in a counterfactual analysis, housing prices will grow more sharply, whereas land price growth increases only moderately. By eliminating one friction at a time, we find that housing friction plays a more critical role in the observed price growth, where the presence of negative housing distortion significantly lowers housing and land price growth. In contrast, land friction is not as crucial as the presence of positive land distortion only causes housing and land prices to grow modestly faster. Because the magnitude of housing distortion is much smaller than land distortion, this implies that housing distortion is amplified to a much larger degree than land distortion in the dynamic process of rural-urban migration.

At the city level and tier level, we find that eliminating housing distortion lowers housing prices but raises land price dispersion dramatically across cities. By contrast, removing land distortion has an overall negligible effect on housing price dispersion and raises land price dispersion only moderately. Thus, the amplification of housing distortion is crucial for driving different housing and land price patterns over time and across cities. Across the three tiers, we find the strong effect of negative housing friction on reducing housing price growth and the relatively weaker effect of positive land friction relatively consistent in all tiers. By contrast, the effects of the two frictions on land price growth are very different across tiers. By analyzing the interactions between frictions and the migration-housing price nexus, we find that, in all tiers of cities, the direct migration flow and cumulative migration stock effects play a dominant role in accelerating housing prices and such housing price responses are not very sensitive to the extent of housing market frictions. While the interaction of positive frictions with a sharp rise in the cost of living leads to a large negative impact of housing prices on migration inflows in tier-1 cities, the interaction of negative frictions with currently affordable prices and expected future price growth induces more migration inflows to tier-3 cities.

While the presence of negative housing friction raises housing price dispersion in all tiers, and the presence of positive land distortions suppresses housing price dispersion only moderately, the effects on land dispersion and relative strengths of these two frictions are quite different across tiers. With the inclusion of urban amenities and disamenities, we find a welfare gain equivalent to 0.25 percent of the baseline economy when all the frictions are eliminated within the urban area, despite an overall welfare loss at the national level mainly led by less rural-urban migration in the frictionless economy. In addition, residents in tier-1 cities suffer a welfare loss in the frictionless economy. The incumbent residents in the tier-2 and tier-3 cities enjoy welfare gain but at the expense of welfare loss among new migrants. In other words, *distortionary policy aiming at cooling down housing prices can be welfare-dampening*, as a result of spatial misallocation across cities and within-the-city misallocation between incumbent urban residents and new migrants. Moreover, such distortionary policy also *lowers per-capita real GDP* in non-mega (tier-2 and 3) cities that face larger frictions, thereby widening tier productivity gaps. In short, such policy is not only harmful to urban welfare but to non-mega cities' output per worker as well.

One may inquire what might happen if the distribution of these frictions in a tier is set to a benchmark distribution. We consider two natural benchmarks, one setting to a more competitive-market benchmark of tier-1 distribution and the other a national benchmark consisting of all cities in all tiers. We find welfare gain in both tier-2 and tier-3 cities under tier-1 benchmarking, and all cities benefit under the national benchmarking with the largest welfare gain in the tier-3 city. Under tier-1 benchmarking with less housing and land distortions, tier-2, tier-3, and overall housing prices all increase more rapidly than the original model economy while tier-1 housing price growth slows down. As a consequence, there is a *dynamic general equilibrium interaction effect* through which the flatter housing price trend influences migration decisions to induce more workers to move to tier-1 cities instead of tier-2 or tier-3. Under national benchmarking with larger housing and land distortions, the hikes in tier-1 and overall housing prices are less steaming whereas changes in the patters of tier-2 and tier-3 are modest because their distributions are closer to the national averages. Similarly, the general equilibrium effect of housing price again encourages more workers to move to tier-1 cities, though the relatively low population weight of tier-1 and modest changes in lower tiers together only result in a small deviation in aggregate migration inflows from the baseline model economy.

The main takeaway of our paper is that spatial misallocation in Chinese housing and land markets is pervasive. It distorts market prices, particularly in non-top-tier cities, where housing and land markets are less competitive, and developers have more substantial market power under more restrictive entry. Overall, housing frictions play a dominant role in driving both prices and dispersions as a result of dynamic amplification in the process of rural-urban migration via dynamic general equilibrium interactions. While such frictions induced by various policies may help slow down the housing boom, especially in mega cities, they are at the expense of urban welfare loss and lower per-capita real GDP in non-mega cities.

Literature Review A growing literature investigates China's housing boom, including research by Chen and Wen (2017), Fang et al. (2016), Jiang et al. (2021), and Wu et al. (2012, 2016). In contrast to this literature, we highlight the structural transformation of the manufacturing sector as a key driver of rural migrants to the cities. While structural transformation also plays a key role in Garriga et al. (2022), they study the causes of aggregate housing price growth in China in a framework with urban income shocks and continual housing demolishing and upgrading with a secular decline in migration costs. In our paper, we examine the extent of housing and land market distortions and the consequences of spatial misallocation across a large set of Chinese cities.

Numerous studies have investigated structural transformation using dynamic general equilibrium models without spatial considerations. For a comprehensive survey, see Herrendorf et al. (2014). Of particular relevance, Hansen and Prescott (2002) and Ngai and Pissarides (2007) emphasize the role of different total factor productivity (TFP) growth rates played in the process of structural change. In our paper, the productivity gap between urban and rural areas is the primary driver of ongoing rural-urban migration.

The literature on dynamic rural-urban migration is much smaller. Lucas (2004) highlights a dynamic driver of such migration, the accumulation of human capital, and hence the ongoing increase in city wages. Bond et al. (2016) show trade liberalization in capital-intensive import-competing sectors prior to China's accession to the WTO has accelerated the migration process and capital accumulation, leading to faster urbanization and economic growth. Liao et al. (2022) find that education-based migration in China plays an equally if not more important role than work-based migration in the process of urbanization. None of these papers study housing markets. A recent paper by Kleinman et al. (2021) provides a systematic analysis of the existence and uniqueness of a series of dynamic spatial general equilibrium. However, the theory can only handle small shocks to an otherwise balanced growth path, while shocks in our paper are much more general and have more dimensions. In addition, we focus on the shocks along the transition path.

Our paper is also related to the factor misallocation literature following Hsieh and Klenow (2009) and Hsieh and Moretti (2019). In particular, Hsieh and Moretti (2019) quantify the role of housing regulation played in factor misallocation in the U.S., while Brandt et al. (2013) study factor misallocation across China's provinces and sectors and find it results in more than 20% TFP losses. Rather than analyzing factor misallocation across firms, our paper examines misallocation in urban housing and land markets across cities.

For a broader literature review, we refer to the review article by Liao and Yip (2018) on the nexus between rural-urban migration and economic development, that by Au and Henderson (2006) on insufficient agglomeration induced productivity losses resulting from rural-urban migration restrictions in China, that by Couture et al. (2019) on growth and spatial sorting, that by Lagakos (2020) on the causes of urban-rural income gaps, that by Ma and Tang (2020) and Tombe and Zhu (2019) on trade and internal migration in China, and that by Han et al. (2018) and Chen (2020) on the connection between internal migration and housing in China.

In our paper, migration increases the demand for residential housing, and thus affects prices. To isolate the contribution of migration flows to housing prices, in the model, housing demand is mainly driven by migrants moving from rural areas to cities (the extensive margin), while the incumbent owners only demand the housing for maintenance purposes. This formalization contrasts with a vast literature using general equilibrium asset pricing frameworks (e.g., Davis and Heathcote (2005)), where prices are determined by a representative individual who adjusts the quantity of housing consumed. From the housing-supply perspective, our model emphasizes the role of government restrictions on the production of housing units. Our model also entertains the scenario in which homebuyers might have limited access to the financial market. Therefore, it connects to a vast literature that explores financial frictions as drivers of housing boom-bust episodes (e.g., see papers cited by Garriga et al. (2019)). In contrast to these housing papers, our paper focuses on the economic-development perspective with the migration decision endogenously determined in the model.

2 The Baseline Framework

The economy consists of two regions: urban and rural. There are J cities in the urban region indexed by $j = 1, 2, ..., J$, categorized into three tiers with $j \in \mathcal{T}_i$ and $\cup_{i\in\{1,2,3\}}\mathcal{T}_i = \{1, 2, ..., J\}$. Time is discrete and infinite. There is a mass one of continuum and infinitely-lived workers who initially lived in the rural area at $t = 0$. Workers are all identical except for the disutility costs of rural-urban migration.

Because the main issue is urbanization-related spatial misallocation associated with urban housing and land markets, we simplify the decision-making in rural areas by assuming in each period the payoff from staying in the rural area is exogenously given as $\underline{U}$, a reservation utility resulting from backyard farming. The value obtained from residing in a farmhouse is normalized to 0.

In the urban area where the main actions occur, a single consumption good is produced. City workers obtain utilities from consumption and housing, and suffer disutility from providing labor. Housing is assumed to be a necessity and satiated good for city workers. Specifically, we follow Berliant et al. (2002), postulating the utility function for city workers takes the following form:

$$U(c, n, h) = \begin{cases} u(c, n) & \text{if} \quad h \geq 1 \\ -\infty & \text{otherwise,} \end{cases} \tag{1}$$

where n denotes the labor supply. The standard properties $u'_c > 0$, $u''_{cc} < 0$ and $u'_n < 0$ apply. Thus, a finite utility level $u(c, n)$ is obtained when a worker is residing in a house; without a house, a city work would be in misery with $U(c, n, h) = -\infty$. Once in a house

($h \geq 1$), a worker does not value additional units of houses. In the equilibrium, each city worker demands exactly one unit of the house. This structure, noted by Berliant et al. (2002), helps reduce the dense set of multiple equilibria and simplifies the analysis dramatically. Nonetheless, the flow utility will be generalized to the inclusion of urban amenities/disamenities in Section 3.2.2 below, to better suit for quantitative analysis when the welfare consequences are under consideration.

Incumbent residents at city j and time t will carry a mortgage debt m from purchasing a house at an earlier time t_m. Let $V_{jt}^{own}(m)$ represent the lifetime value for a worker with an outstanding mortgage balance m. The worker derives current utility $U(c,n,h)$ as specified in (1) above and discounts future payoffs at rate β by choosing between remaining in the city, $V_{j,t+1}^{own}(m')$, and returning to the rural area, $V_{t+1}^{R}(\epsilon)$. Denote w_{jt} as the city-specific wage rate per unit of labor supply. The worker spends his labor income on consumption and mortgage debt repayment under an exogenous mortgage interest rate $r_m > 0$ and an amortization rate $\gamma > 0$. A house owner must incur housing maintenance costs to counter natural depreciation of the purchased unit in order to maintain structural functionality. This unit housing flow cost is denoted by δ_h, so $\delta_h p_t h$ measures the flow housing maintenance cost. At the current period t, the optimization problem for a city-j homeowner who purchased the house in period earlier than t is:

$$V_{jt}^{own}(m) = \max_{c,n,h} U(c,n,h) + \beta \max\{V_{j,t+1}^{own}(m'), V_{t+1}^{R}(\epsilon)\} \tag{2}$$

$$s.t. \qquad c + \delta_h p_{jt} h + (r_m + \gamma)m = (1 - \tau_{n,jt}) w_{jt} n, \tag{3}$$

$$m' = (1-\gamma)m$$

In the above, we have also introduced a city-time-specific labor wedge ($\tau_{j,nt}$), which may distort workers' labor supply decisions and thus labor income.

2.1 Migration Decisions

The J cities in the urban region can be classified into three city tiers due to similar city size and economic scale, which will be matched with contemporary Chinese conditions in the quantitative analysis. A new migrant from a rural to an urban area will endogenously decide which city tier to move. As for which city within the tier the migrant is located, to simplify the analysis we assume there is a hukou lottery such that $\sum_{j\in\mathcal{T}_i}\pi_{ij}=1$, where π_{ij} is the probability for a migrant choosing to move to tier $\mathcal{T}_i$ to end up residing in city $j\in\mathcal{T}_i$. The assumption is also innocuous since even though a small scale of individuals may migrate within the tier and the overall magnitude of inflow into and outflow from a given city are roughly comparable.[4] To ease the notational burden, we shall suppress tier index i whenever it does not cause any confusion.

An individual who migrates into city j at time t must purchase a house at market price p_{jt}. The housing purchase is financed with a long-term mortgage contract that requires a down payment at rate ϕ, and an amortization schedule that decays geometrically at rate γ.

The optimization problem for a migrant who moves to city j in period t and purchases the housing is specified as follows:

$$
\begin{aligned}
V_{jt}^{buy} = \max_{c,n,h,m} U(c,n,h) \quad &+ \quad \beta\max\{V_{j,t+1}^{own}(m), V_{t+1}^{R}(\epsilon)\} && (4)\\
s.t. \qquad c+p_{jt}h \quad &= \quad (1-\tau_{n,jt})w_{jt}n+m && (5)\\
m \quad &\leq \quad (1-\phi)p_{jt}h.
\end{aligned}
$$

While the recursive formulation of the value function resembles that of an incumbent city resident, the budget constraint is modified with a mortgage loan, m, added to the income side and the housing purchase, $p_{jt}h$, to the expenditure side. Moreover, the mortgage contract requires a downpayment at rate ϕ, so the maximum loan-to-value ratio is $1-\phi$.

The expected utility from migrating into city tier i at time t is: $V_{it}^{M}=\sum_{j\in\mathcal{T}_i}\pi_{ij}V_{jt}^{buy}$. We consider a tier-specific scaling factor to migration cost that changes over time, χ_{it}. This is to capture exogenous changes in migration policy or infrastructure and disamenities, which also influences migration decisions. Therefore, the expected payoff from migration at time t for an individual of migration disutility ϵ is: $V_t^M(\epsilon)=\max_{i\in\{1,2,3\}}\{V_{it}^M-\chi_{it}\epsilon\}$, where the individual optimally determines to which tier to migrate. The optimal tier chosen

[4] Based on population census in 2005 and 2010, we calculated net migration flows from Beijing to other cities (including Shanghai) and from Shanghai to other cities (including Beijing) and found them within ±4 percent. Thus, ignoring the city-to-city migration does not seem to be at odds with the evidence.

is thus given by:

$$i^* = \arg\max_i \{V_{it}^M - \chi_{it}\epsilon\}.$$

If the individual stays in the rural at time t, his payoff is current utility $\underline{U}$ plus the discounted future payoff (continuation value), which depends on the decision between remaining in the rural and migrating at time $t+1$: $V_t^R(\epsilon) = \underline{U} + \beta \max\{V_{t+1}^M(\epsilon), V_{t+1}^R(\epsilon)\}$.

Given the expressions for V_t^M, and V_t^R, we can now determine the conditions under which workers with migration cost ϵ will move to city tier i at time t as follows: $V_t^M(\epsilon) \geq V_t^R(\epsilon)$. That is, a rural worker will migrate to a specific city tier if and only if the payoff from migration (i.e., the expected payoff from residing in the specific city tier net of the disutility cost of migration), is greater than staying in the rural area. Thus, there exists an ϵ_t^* that solves the following *locational no-arbitrage condition* and determines the cutoff level of rural workers who migrate to the city in any given period:

$$V_t^M(\epsilon_t^*) = V_t^R(\epsilon_t^*). \tag{6}$$

Proposition 1 *(Migration Decision)*

(i) *(Unique cutoff) In each period t, there exists a unique cutoff migration cost ϵ_t^*, below which workers will choose to migrate to the urban area in t.*

(ii) *(Housing price decelerator effect) While the cutoff migration cost is increasing in the urban wage, it is decreasing in urban housing prices at t.*

Intuitively, everything else being equal, the higher the current urban wage rate, the more attractive it is for rural workers to migrate to urban areas in the current period. Moreover, a higher housing price raises the urban cost of living, thereby discouraging rural-urban migration. This latter channel is crucial for understanding the nexus between rural-urban migration and urban housing, which is conveniently referred to as the *housing price decelerator effect.*

Forward-looing price effect It is worth emphasizing that the intertemporal decision on migration differs drastically from static settings. So long as the down payment requirement is met, migrants would tend to move early and purchase a house before its price rises with greater demand due to a widening gap in urban-rural incomes. This may be referred to as the *forward-looking price effect.* Despite the lack of a closed form solution, we can capture the intertemporal channel of the impact of the urban housing market on migration decisions by expressing migration inflow at time t not only depending on the current but also the future sequence of housing prices:

$$\Delta F(\epsilon_t^*) = m(p_t, \mathbf{P}_t),$$

where $\mathbf{P}_t = \{p_{t'}, t' > t\}$ represents the vector of future housing prices.

Multi-tier urban structure The property of unique cutoff is readily generalized to the multi-tier urban structure. Let the three tiers under consideration feature the following value ordering: $V_{1t}^M > V_{2t}^M > V_{3t}^M$ and the accompanied migration disutility scaling factor satisfy: $\chi_{1t} > \chi_{2t} > \chi_{3t} > 0$. That is, a city in a lower tier provides a higher net payoff after subtracting out higher housing costs; nonetheless, to an individual with a migration cost of given type ϵ, the disutility cost to move to a lower tier is also greater. Thus, only those with lower ϵ find it optimal to migrate to a lower-tier city, and the following conditions subsequently define tier-specific cutoffs:

$$\begin{aligned} &V_{1t}^M - \chi_{1t}\epsilon_{1t}^* = V_{2t}^M - \chi_{2t}\epsilon_{1t}^* \\ &V_{2t}^M - \chi_{2t}\epsilon_{2t}^* = V_{3t}^M - \chi_{3t}\epsilon_{2t}^* \\ &V_{3t}^M - \chi_{3t}\epsilon_{3t}^* = V_{t+1}^M = V_{1,t+1}^M - \chi_{1,t+1}\epsilon_{3t}^*. \end{aligned} \tag{7}$$

Individuals with migration cost belonging to $[\epsilon_{3,t-1}^*, \epsilon_{1t}^*]$ will move to tier-1 cities, and $[\epsilon_{1t}^*, \epsilon_{2t}^*]$ will move to tier-2 cities, and $[\epsilon_{2t}^*, \epsilon_{3t}^*]$ will migrate to tier-3 cities in t. Those with migration cost marginally larger than ϵ_{3t}^* will wait to migrate to tier-1 cities in $t + 1$.

In the case of a multi-tier urban structure, the migration inflow into each tier would depend on the entire distribution of housing prices and wages across all tiers. That is, the migration inflow expression needs to be modified as:

$$\Delta F(\epsilon_{jt}^{*}) = m_j(\{p_{it}, \mathbf{P}_{it}\}_{i=1}^{J}),$$

where $\mathbf{P}_{it} = \{p_{it'}, t' > t\}$ represents the vectors of future housing prices. As a consequence, housing price growth in a specific tier may not necessarily reduce migration inflow if its price hike is at a lesser rate than those in other tiers. It is therefore useful to differentiate between the own-tier and the competing-tier effects, which we shall discuss later after closing the model.

2.2 Production

The market for consumption goods is perfectly competitive. Firms of each city have access to common production technology. We assume trade is costly across cities, so in the equilibrium, each city consumes all the outputs produced within the city. The production takes both capital and labor as inputs: $Y_{jt} = A_{jt}^{m} K_{jt}^{\sigma_j} N_{jt}^{1-\sigma_j}$, where A_{jt} is an exogenous city-specific TFP at t. We assume firms of each city rent capital from a national capital owner outside the model economy. The wage rate is thus determined as $w_{jt} = (1-\sigma_j) A_{jt}^{m} K_{jt}^{\sigma_j} N_{jt}^{-\sigma_j}$.

2.3 Government

We now turn to the supply side of the housing market. In the model economy, the land is owned and supplied by each local city government. At the beginning of each period, the government in city j determines the amount of land available for housing developers, $\ell_{jt} \geq 0$, to maximize land sales revenue net of the land development costs, taking land prices as given: $\max_{\ell_{jt}} q_{jt}\ell_{jt} - \frac{1}{2} B_{jt} \ell_{jt}^{2}$, where B_{jt} governs the coefficient of land development costs, and it mainly measures the difficulty to develop the land based on the city-specific geography. For example, it is more costly to develop land in cities from the mountain area than from the plain area. Solving the local government's profit-maximization problem gives rise to the following first-order condition:

$$\ell_{jt} = q_{jt}/B_{jt}, \tag{8}$$

which yields a linear land supply function resulting from the quadratic cost of land development. Adding ℓ_{jt} to the pre-existing stock of land, $L_{j,t-1}$, the aggregate law of motion for the land is thus given by, $L_{jt} = \ell_{jt} + L_{j,t-1}$.

The local government not only controls the supply of land, but also charges housing developers a housing-development, or permit or leasing, fee, Ψ_{jt}, in units of manufactured goods, which determines the number of permits granted at the beginning of time t: $\Psi_{jt} = \psi_j N_{j,t-1}^{\eta_j}$, where $\psi_j > 0$. We do not impose a strict sign on η_j in the theory, and will calibrate them in the quantitative analysis. Intuitively, $\eta_j > 0$ indicates the government charges a higher development fee in larger cities, which captures public concern about urban congestion and issues associated with urban sprawl. On the contrary, $\eta_j < 0$ suggests the government's intention to utilize agglomeration economies, thus making it cheaper to develop land in larger cities.

2.4 Housing Developers

A housing developer of city j employs construction materials I_{ht} to build houses h_t on land parcels z_t leased from the government. The production function takes a simple Cobb-Douglas form: $h_t = A_{jt}^h (z_t - \underline{z}_{jt})^\gamma I_{ht}^\alpha$, where $\alpha > 0$, $\gamma > 0$, $0 < \alpha + \gamma < 1$, and $A_{jt}^h > 0$ represents city-specific housing construction technology, and $\underline{z}_{jt} > 0$ captures the minimum land requirement for building a house. In equilibrium, $\underline{z}_{jt} = \zeta_{jt} z_t$; that is, the minimum land requirement is a fraction of the equilibrium amount of land purchased by developers. The assumption of minimum land enables us to generate an increasing land share observed in the data with constant power(γ) in the housing production function.[5] The presence of decreasing returns to scale is necessary to allow for a developer to cover the fixed cost incurred from paying for a permit.

To circumvent the complication associated with inventory management for which we do not have good city-level data, we assume each housing developer lives for only one period and is replaced by an identical developer upon constructing and selling the houses built over the

[5] The imputed land cost share measured as the expenditure on land purchase to housing sales revenue can be shown to equal with $\frac{\gamma}{1-\zeta_{jt}}$, which is increasing over time if the minimum land requirement exhibits an upward trend.

time period. Thus, a developer simply decides how much land and construction materials to buy to maximize the operating profit Π^d_{jt}, whose optimization problem is specified as:

$$\Pi^d_{jt} = \max_{z_t, I_{ht}} (1 - \tau_{h,jt})\, p_{jt} A^h_{jt} (z_t - \underline{z}_t)^{\gamma} I^{\alpha}_{ht} - q_{jt} z_t (1 + \tau_{z,jt}) - p_{I,jt} I_{ht}, \tag{9}$$

where p_{jt} represents the selling price of a new housing unit at the end of period t, q_{jt} is the land price that a housing developer must pay to acquire the land parcels from the government, and $p_{I,jt}$ is the unit cost of construction materials, which is exogenously given. Two wedges exist: a housing price wedge $\tau_{h,jt}$ governing housing-market distortions/frictions mainly affects the housing sales revenue, and a land price wedge $\tau_{z,jt}$ capturing land market distortions/frictions mainly influences the marginal product of land. That is, housing and land market frictions are wedges associated with distorted housing and land prices.

Upon receiving revenue from selling houses, the developer must pay the fixed development fee to the government. With many identical housing developers operating in each period, *equilibrium entry* (EE) pins down the number of developers, S_{jt}:

$$\Pi^d_{jt} = \Psi_{jt} = \psi_j N^{\eta_j}_{j,t-1}. \tag{10}$$

3 Dynamic Spatial Equilibrium

To sum up, cities differ in the following aspects: (i) the availability of land (exogenously) supplied by the government; (ii) the city-specific housing and land frictions; and (iii) the city-specific production and construction productivity; (iv) initial population size and thus housing stock; (v) the relation between existing housing stock and entry fee. In addition, city selection within each city tier is a lottery. As a result, equilibrium wages, housing supply and demand are city-specific. We formalize the definition of equilibrium:

Definition Given exogenous city-specific time series $\{p_{I,jt}, A_{jt}, A^h_{jt}\}$, tier-specific time series $\{\chi_{it}\}$, initial conditions H_{j0}, a *dynamic spatial equilibrium* consists of a list of prices $\{p_{jt}, q_{jt}, w_{jt}\}$, individual quantities $\{h_{jt}, c_{jt}, n_{jt}\}$, manufacturing firms' investment I^m_{jt}, developer's demand for land and material $\{z_{jt}, I^h_{jt}\}$, government's land supply ℓ_{jt}, an employment vector of workers and developers $\{N_{jt}^m, S_{jt}\}$, migration cutoff $\{\epsilon_{it}^*\}$, and end-of-period population distribution in each city $\{\mu_{jt}^{own}(m), \mu_{jt}^{mig}\}$ that satisfies the following conditions: (i) (Optimization) Workers, manufacturing firms, housing developers, and local governments all optimize; (ii) (Locational Choice) At each period t, there is a tuple of cutoff mobility costs ϵ_{it}^* pinned down by (7), with those having migration costs in $[\epsilon_{3,t-1}^*, \epsilon_{1t}^*]$ moving to tier-1 cities, in $[\epsilon_{1t}^*, \epsilon_{2t}^*]$ to tier-2 cities, and in $[\epsilon_{2t}^*, \epsilon_{3t}^*]$ to tier-3 cities in t and those having migration cost exceeding ϵ_{3t}^* waiting to migrate in a future period; (iii) (Developer Entry) The number of developers is determined by the equilibrium entry condition (10); (iv) (Market Clearing) Housing, land, and labor markets clear:

$$\begin{aligned}
&\text{(Housing)} \quad \mu_{jt}^{mig} + \textstyle\int_m \delta_h \mu_{jt}^{own}(m)dm = Y_h,\\
&\text{(Land)} \quad S_{jt} z_{jt} = \ell_{jt},\\
&\text{(Labor)} \quad \left[\tfrac{(1-\sigma_j)A_{jt}^m}{w_{jt}}\right]^{\frac{1}{\sigma_j}} K_{jt} = \mu_{jt}^{mig} n_{jt}^{mig} + \textstyle\int_m \mu_{jt}^{own}(m) n_{jt}^{own}(m)dm.
\end{aligned}$$

The dynamic spatial equilibrium features an entry game of one-period lived developers replaced by identical developers. Entry is regulated by the government through licensing. Should the entry be more restrictive, the housing market would become less competitive. When we generalize the framework to multiple cities, entry restrictions will be allowed to be city-specific, and housing markets in different cities will have different degrees of competitiveness in their housing markets.

3.1 Housing and Land

In the following, we turn to solve the housing developer's optimization problem, with detailed manipulation relegated to Appendix B. To simplify the notation, we omit the city and time subscript j in this section except in cases where its omission may be misleading.

The first order condition obtained from the housing developer's optimization problem gives rise to the demand for land and construction-material:

$$z = \frac{1}{1-\psi}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_h I^{\alpha}}\right]^{\frac{1}{\gamma-1}}, \tag{11}$$

$$I = \left[\frac{p_I}{\alpha\,(1-\tau_h)\,pA_h\,(z-\underline{z})^{\gamma}}\right]^{\frac{1}{\alpha-1}}. \tag{12}$$

In the above, we have assumed that $\underline{z}_{jt} = \zeta_{jt} z_{jt}$, under which the *land share in housing construction* is simply measured by $\gamma/(1-\zeta_{jt})$. Plugging the two expressions above into the profit function, the free entry condition can thus be expressed as:

$$(1-\tau_h)\, pA_h \left(z - \underline{z}\right)^{\gamma} I^{\alpha} \left[1 - \alpha - \gamma \frac{1}{1-\psi}\right] = \Psi. \tag{13}$$

Housing demand in this economy stems from two sources: the incumbent owners' demand for the purpose of maintenance, and the new migrants' demand for new houses. The housing market clearing condition can be expressed as:

$$N_{-1}\delta_h + \Delta F\left(\epsilon^*\right) = Y_h = SA_h \left(z - \underline{z}\right)^{\gamma} I^{\alpha}. \tag{14}$$

In addition, the land market clearing condition is:

$$Sz = \ell. \tag{15}$$

We now combine equation (11) to (15) to obtain two fundamental relationships governing the housing-distortion-augmented *net housing price*, $(1-\tau_h)\, p$, and the land-distortion-augmented *net land price*, $(1+\tau_z)\, q$:

$$(1-\tau_h)\, p = \Xi_h \left[\frac{N_{-1}\delta_h + \Delta F\left(\epsilon^*\right)}{\ell(1-\zeta)}\right]^{\gamma/(1-\gamma)} \equiv P\left(\overset{+}{\Delta F}(\epsilon^*), \overset{-}{\ell}\right), \tag{16}$$

$$q\,(1+\tau_z) = \gamma \Xi_h \left[\frac{N_{-1}\delta_h + \Delta F\left(\epsilon^*\right)}{\ell(1-\zeta)}\right]^{1/(1-\gamma)} \equiv Q\left(\overset{+}{\Delta F}(\epsilon^*), \overset{-}{\tau_z}, \overset{-}{\ell}\right), \tag{17}$$

where $\Xi_h \equiv \left[\frac{p_I}{\alpha}\right]^{\frac{\alpha}{1-\gamma}} \left[\frac{\Psi}{1-\alpha-\frac{\gamma}{1-\zeta}}\right]^{\frac{(1-\alpha-\gamma)}{1-\gamma}} A_h^{\frac{1}{\gamma-1}}$ is exogenous, depending only on the existing city size N_{-1} via Ψ. We summarize how housing prices are affected in the partial temporal equilibrium in the following proposition.

Proposition 2 *Everything else being equal, housing and land price in each period is*

(i) *increasing in migration inflow, price of construction material, minimum land requirement, and entry fee;*

(ii) *decreasing in land supply and housing construction productivity.*

Migration flow accelerator effect We are now ready to examine the other direction of the nexus between rural-urban migration and urban housing. Specifically, we refer to the positive impacts of migration inflow on housing prices described in the above proposition as the *migration flow accelerator effect*. In addition, an increase in the price of construction materials (p_I) or entry fee (Ψ), a decrease in effective land supplies ($1 - \zeta$), or housing construction technologies (A_h) all serve to enhance the *migration flow accelerator effect*. Recall the *housing price decelerator effect* highlighted in equation (2.1), these two effects work against each other in the temporal equilibrium, which we shall analyze below.

Temporal mechanism The two expressions above together with equation (2.1) are able to jointly pin down the temporal-spatial equilibrium housing, land prices, and migration inflow. We can thus establish the interactions between frictions and the equilibrium outcome in the following proposition.

Proposition 3 *In temporal-spatial equilibrium, treating land supply ℓ_t as exogenously given, an increase in housing friction τ_{ht} or a decrease in the exogenous land supply ℓ_t leads to higher housing prices and lower migration inflow.*

Similarly, we can establish what determines land prices in the following proposition. Note that since the migration function is independent of land prices, and thus changes in land frictions do not exert a direct impact on migration inflow. However, changes in land prices led by changes in land frictions will affect the optimal land supply, which in turn affects housing prices and migration inflow in the general equilibrium.

Proposition 4 *In temporal-spatial equilibrium, treating land supply ℓ_t as exogenously given, a decrease in land friction τ_{zt} or in the exogenous land supply leads to higher land prices and no impacts on migration inflow.*

Proposition 3 and 4 suggest the importance of quantitative analysis to disentangle the role of each friction in housing and land markets. In the general equilibrium, changes in housing friction may affect net migration inflow, which in turn affects land supply and prices. Similarly, changes in land frictions may affect the land supply, which further affects net migration inflow and housing prices.

Intertemporal mechanism Both *the migration flow accelerator effect* and *housing price decelerator effect* prevail in the temporal-spatial equilibrium. When intertemporal dynamics are also taken into consideration, we highlight a *migration stock effect.* The cumulative migration stock affects housing prices via the following two channels: (i) the existing city incumbents need to pay for the housing maintenance costs; ii) the entry fee paid by the potential housing developers depends positively on the city size. Thus, through the two channels, the migration stock effect in intertemporal equilibrium works in the same direction as the migration flow accelerator effect in temporal equilibrium. The migration stock effect also works against the intertemporal *forward-looking price effect* discussed in Section 2.1: while the expected higher housing price encourages earlier migration, the larger existing city size exerts upward pressure on housing prices and discourages further migration.

In addition, we should note that intertemporally, any changes in (τ_{ht}, τ_{zt}) would affect Euler equations and the law of motion equations, thereby feeding back to affect housing and land prices as well as migration. Most importantly, perceived changes in housing/land frictions may affect current migration decisions and housing and land prices. For example, should such changes be expected to raise urban housing prices in the future, it would induce an incentive for migrating earlier and thus increase current housing prices as well. While we are unable to fully characterize these complicated dynamic effects, all of these channels will be captured in the quantitative examination yet to follow.

Mechanism in the multi-tier In the context of multi-tier, we need to differentiate the own-tier effect versus the compeiting-tier effect, because different tiers are locational substitutes. In terms of the impacts of migration on housing prices, the *owner-tier migration stock effect* always works to stimulate housing price growth in its own tier. The *competing-tier migration stock effect* may promote housing price growth in the "own-tier" if migrants switch their destinations from other tiers to the "own-tier." Regarding the migration response to housing prices, the *own-tier forward-looking price effect* tends to push up the current housing price in the own-tier if the prospective migrants do not switch to other tiers, but instead choose to migrate to the "own-tier" earlier. On the contrary, the *competing-tier forward-looking price effect* may also contribute to housing prices in the "own-tier" if the faster price growth in other tiers diverts prospective migrants from other tiers to the "own-tier." Of course, whether these conditions are met would be ultimately a quantitative question that we shall address upon calibrating the model.

We summarize the different working mechanisms between the migration and housing price in both temporal and intertemporal equilibrium, under one-city and multi-tier scenarios, in the following table.

Table 1: Summary of Mechanisms

	Migration ⇒ Prices	Prices ⇒ Migration
Temporal	migration flow accelerator	housing price decelerator
Intertemporal	migration stock	forward-looking price
Multi-tier intertemporal	own/competing tier migration stock	own/competing tier forward-looking price
Elastic labor supply Temporal		own/competing tier atemporal wage-level
Elastic labor supply Intertemporal		own/competing tier future wage-growth

To this end, we would like to acknowledge some model limitations. We have restricted to one unit of housing, abstracting from living space. This simplification is basically innocuous. Quantitatively, we use the floor area of newly built housing units sold to measure housing quantity. Also, we do not consider resales or precautionary/speculative motives by consumers/developers, which allows us to focus on the structural transformation aspect of rural-urban migration and its implications for urban housing markets across space. We note that, with resales, housing demand would depend on the upgrading of current urban residents, which has a positive effect on housing prices that discourages migration. Yet, their previously owned houses are available at lower prices for new migrants, whose migration incentives are strengthened.[6] Moreover, with precautionary/speculative motives, consumers may purchase houses earlier to take advantage of a rising price trend, but developers may also stock inventories for better sales opportunities that would discourage purchases. On balance, it is unclear whether it may induce more or less migration. Thus, we view these limitations as secondary, beyond the primary scope of the paper.

[6]Despite lacking a good resale data moment to target, this resale and upgrading channel is allowed by Garriga et al. (2022) but is found not critical in explaining housing booms in China.

3.2 Generalization

We turn next to generalize the baseline framework by allowing for labor market frictions across cities and urban amenities/disamenities.

3.2.1 Labor Market Frictions

As migration is an integral part of labor decisions while labor market frictions/distortions abound, the first task is to generalize the baseline framework to consider elastic labor supply in frictional labor markets across cities.

Let $\tau_{n,jt}$ represent labor wedge as a result of city-specific labor market frictions, and then $\tilde{w}_{jt} = (1 - \tau_{n,jt})w_{jt}$ measure effective wage. Let $u(c,n)$ take a standard CRRA form (see a comprehensive survey by Keane and Rogerson (2012)): $u(c,n) = \frac{c^{1-\upsilon_c}}{1-\upsilon_c} - \iota_{jt} \cdot \frac{n^{1+\upsilon_n}}{1+\upsilon_n}$, with $\upsilon_c > 0$ and $\upsilon_n > 0$. The budget constraint facing an urban worker is thus given by,

$$c_{jt} = \tilde{w}_{jt} n_{jt} - he_{jt}^{type}, \tag{18}$$

where he_{jt}^{type} is the housing expenditure function that depends on the tenure position of the urban worker (buy or own):

$$he_{jt}^{type} = \begin{cases} \delta_h p_{jt} h_{jt} + (r_m + \gamma) m_{t_m} & \text{if } type = buy \\ \phi p_{jt} h_{jt} & \text{if } type = own \end{cases} .$$

Manipulating the first-order conditions with respect to c_{jt} and n_{jt}, we are arrived at,

$$\tilde{w}_{jt} = \iota_{jt} \cdot n_{jt}^{\upsilon_n} \cdot c_{jt}^{\upsilon_c} = \iota_{jt} \cdot n_{jt}^{\upsilon_n} \cdot \left(\tilde{w}_{jt} n_{jt} - he_{jt}^{type} \right)^{\upsilon_c}, \tag{19}$$

Taking log and totally differentiating, we obtain:

$$\left[1 - \frac{\upsilon_c \tilde{w}_{jt} n_{jt}}{\tilde{w}_{jt} n_{jt} - he_{jt}^{type}} \right] d\ln \tilde{w}_{jt} = \left[\upsilon_n + \frac{\upsilon_c \tilde{w}_{jt} n_{jt}}{\tilde{w}_{jt} n_{jt} - he_{jt}^{type}} \right] d\ln n_{jt} - \frac{\upsilon_c \cdot he_{jt}^{type}}{\tilde{w}_{jt} n_{jt} - he_{jt}^{type}} d\ln \left(he_{jt}^{type} \right),$$

where, under the step function of housing demand, $d\ln \left(he_{jt}^{type} \right) = 0$. This enables us to derive the labor supply elasticity as: $\xi_n = \frac{d\ln n_{jt}}{d\ln \tilde{w}_{jt}} = \left(1 - \frac{\upsilon_c \tilde{w}_{jt} n_{jt}}{\tilde{w}_{jt} n_{jt} - he_{jt}^{type}} \right) \Big/ \left(\upsilon_n + \frac{\upsilon_c \tilde{w}_{jt} n_{jt}}{\tilde{w}_{jt} n_{jt} - he_{jt}^{type}} \right)$.

In equilibrium, housing expenditure is $he_{jt}^{type} = \tilde{w}_{jt} n_{jt} \cdot hs_{jt}^{type}$, where, under binding financing constraint, the housing expenditure share hs_{jt}^{type} is given by,

$$hs_{jt}^{type} = \begin{cases} \frac{\delta_h p_t h_{jt} + (r_m + \gamma) m_{t_m}}{\tilde{w}_{jt} n_{jt} w_{jt} n_{jt}} & \text{if } type = own \\ \frac{\phi p_{jt} h_{jt}}{\tilde{w}_{jt} n_{jt} n_{jt}} & \text{if } type = buy \end{cases}$$

As a result, the labor supply elasticity becomes:

$$\xi_n = \frac{1 - \frac{\upsilon_c}{1 - hs_{jt}^{type}}}{\upsilon_n + \frac{\upsilon_c}{1 - hs_{jt}^{type}}} = \frac{\left(1 - hs_{jt}^{type}\right) - \upsilon_c}{\upsilon_n \cdot \left(1 - hs_{jt}^{type}\right) + \upsilon_c} \tag{20}$$

For welfare comparison in cardinality and for consistency with the micro labor literature, we assume $\upsilon_c < 1 - hs_{jt}^{type}$ that ensures upward-sloping labor supply, on which we shall comment when calibrating the model economy in Section 4.4 below. Under this assumption, the labor supply elasticity is decreasing in the housing expenditure share, hs_{jt}^{type}. That is, should housing take away a major portion of an urban worker's income (high hs_{jt}^{type}), labor supply would become less responsive to effective wage, as one could not afford to work less with a high burden in mortgage payment even if wage falls.

We can further characterize the labor supply function given by (19). By defining $\varpi_{jt}(n_{jt}^{\upsilon_n}, \tilde{w}_{jt}) = n_{jt}^{\upsilon_n} \cdot \left(\tilde{w}_{jt} n_{jt} - he_{jt}^{type}\right)^{\upsilon_c}$ and hence labor supply is captured by,

$$\tilde{w}_{jt} = \iota_{jt} \cdot \varpi_{jt}(n_{jt}, \tilde{w}_{jt}). \tag{21}$$

Straightforward differentiation gives, $\frac{\partial \ln \varpi_{jt}}{\partial \ln n_{jt}} = \upsilon_c + \upsilon_n \left(1 - hs_{jt}^{type}\right) > 0$, $\frac{\partial \ln \varpi_{jt}}{\partial \ln \tilde{w}_{jt}} = \frac{\upsilon_c}{1 - hs_{jt}^{type}} > 0$ and $\frac{\partial \ln \varpi_{jt}}{\partial \ln hs_{jt}^{type}} = -\frac{\upsilon_c \cdot hs_{jt}^{type}}{1 - hs_{jt}^{type}} < 0$. Thus, ϖ_{jt} is monotonically increasing in n_{jt} and $\tilde{w}_{jt}$. Straightforward partial-equilibrium comparative analysis yields the following properties: (i) higher disutility from work (ι_{jt}) reduces work effort; (ii) higher effective wage generates a positive direct effect (the LHS of (21)) and a negative income effect (via the $\varpi_{jt}(n_{jt}^{\upsilon_n}, \tilde{w}_{jt})$ function), thereby requiring the condition described above to ensure labor supply to rise; (3) a larger housing expenditure share tends to induce greater work effort.

In the case of elastic labor supply, the migration decision not only depends on housing prices, but also on endogenously determined wages. We can thus rewrite equation (2.1) as follows:

$$\Delta F(\epsilon_{jt}^{*}) = m_j(\{p_{it}, \mathbf{P}_{it}, w_{it}, \mathbf{W}_{it}\}_{i=1}^{J}),$$

where $\mathbf{W}_{it} = \{w_{it'}, t' > t\}$ represents the vector of future wages.

Additional Channel When labor supply becomes more elastic, the migration inflow tends to lower the current wage level and slows down the growth of wages. A higher level of wages always encourages more migration, which is referred to as the *atemporal wage-level effect*. Similarly, we can name the impact of future wage growth on migration as the *future wage-growth effect*. Intuitively, whether faster wage growth promotes or discourages migration depends critically on two opposing effects – an income effect and an intertemporal substitution effect: If the former dominates, faster wage growth effect would deter early migration; otherwise, early migration would occur.

In the multi-tier structure, the migration pattern is expected to depend on which effects dominate as well as whether prospective migrants choose to switch or stay in the same tier. Should the intertemporal substitution effect dominate and migrants tend to switch, the own (competing)-tier future wage growth effect drives migrants away from (into) the own-tier. Which channels dominate is again a quantitative question that we shall address.

3.2.2 Urban Amenities/Disamenities

In this subsection, we extend the baseline framework by introducing urban amenities/disamenities. We assume each city government spends its land sales revenue on creating local amenities or mitigating disamenities from urban pollution, congestion, and crimes. Such spending in turn improves local residents' welfare. The utility function for city workers becomes the following form:

$$U(c_t, n_t, h_t) = \begin{cases} u(c_t, n_t) + \varepsilon M_t^{\mu} & \text{if} \quad h_t \geq 1 \\ -\infty & \text{otherwise} \end{cases}, \tag{22}$$

where M_t denotes the local amenities financed through land sales profit (i.e., $M_t = q_t \ell_t - \frac{1}{2} B_t \ell_t^2$), ε is the coefficient to govern the relative importance of amenities against private consumption, μ captures the land sales elasticity of amenities. We will refer to εM_t^{μ} as the *net value* of urban amenities upon subtracting out disamenities. It is generally expected that $\varepsilon > 0$ and $\mu > 0$, whose values will be pinned down by data.

3.2.3 Taking Stock

Before turning to quantitative analysis, we would like to highlight the role played by geographical fundamentals. Specifically, from Proposition 2 it is shown that more costly construction materials or entry fee requirements, lower land supplies or housing construction technologies, or higher production technologies or migration lotteries would enhance the *migration flow accelerator effect*. Moreover, from Proposition 3 and Proposition 4, their geographical fundamentals interact with the two distortionary wedges, amplifying the roles such frictions played in housing and land price hikes.

In intertemporal equilibrium, any changes that could lead to higher price of construction materials or construction productivity in the future put upward pressure on future housing prices, and may thus induce early migration due to the *forward-looking price effect*. In the case of multi tiers, if the own-tier experiences the above changes, it may attract more early migrants if prospective migrants do not switch to other tiers; otherwise it may experience population outflow to other tiers. To sum up, the *own/competing-tier forward-looking price effect* always works against each other in reallocating prospective migrants among tiers.

4 Calibration and Estimation

We now turn to quantitative analysis by calibrating the general model with labor wedges and urban amenities to fit the Chinese data. There are four primary tasks to undertake: (i) to estimate and characterize city-specific housing and land distortionary wedges, (ii) to conduct counterfactual analysis to quantify the roles the two distortionary wedges played in determining the paths of housing and land prices, (iii) to benchmark these wedges to more competitive tier-1 or national distributions and (iv) to investigate the macroeconomic implications of the presence of these wedges for real income and welfare.

4.1 Data

To estimate city-specific housing and land distortionary wedges or frictions, we need the following data at the city level: (i) real average prices of newly built housing units, (ii) real average prices of residential land parcels, (iii) floor areas of newly built housing units sold, (iv) investments on housing development excluding land purchase, (v) residential land sales, (vi) real unit construction costs. Due to data availability, we have finally selected a balanced panel of 93 major Chinese cities. The total population and GDP among the 93 cities take up a roughly fraction of 60 and 70 of the entire country. In Figure E.2, we map the selected cities in our sample.[7]

During 2007-2013, the average annual growth rate of housing and land prices among our selected cities are 8.92 and 19.92 percent, respectively. We map the distribution of housing and land price growth rates in Figure E.3. In Figure E.4, we map both housing and land price levels in the year 2013. The unit is RMB per square meter. The top three cities with the highest housing price level are Shenzhen, Beijing, and Shanghai, respectively. They all belong to tier-1 cities in China. Ten cities in our sample have housing prices exceeding 10,000 RMB per square meter in 2013. The top three cities with the most expensive land are Shenzhen, Sanya, and Xiamen, respectively.

4.2 Estimation of Housing and Land Frictions

The computation of city-specific housing and land market frictions is model-based, depending on developers' optimization problems. Similar to the factor misallocation literature, we calibrate these wedges from developers' marginal product conditions. Governed by our model, the *city-level* housing and land market frictions can be computed:

$$1+\tau_{zt}=\frac{\gamma I_{ht}p_{It}}{\alpha q_t(z_t-\underline{z}_t)} \text{ and } 1-\tau_{ht}=\frac{q_t(z_t-\underline{z}_t)\,(1+\tau_{zt})}{\gamma p_t A_t^h(z_t-\underline{z}_t)^\gamma I_{ht}^\alpha}$$

where $I_{ht}p_{It}$ refers to the investment in housing development excluding land-purchase expenses in the data. $q_t z_t$ is land sales revenue and $p_t A_t^h(z_t-\underline{z}_t)^\gamma I_{ht}^\alpha$ is housing sales revenue,

[7] To ease the illustration, we have omitted the islands in the South China Sea from all the maps.

which is computed using data on floor area of newly built housing units sold combined with the relevant price information.

In addition, we need to back out the parameter values for α and γ, which are the construction-material share and land share in housing production. We simply take the log of the housing construction production function, using the equilibrium relationship $\underline{z}_{jt} = \zeta_{it} z_{jt}$ ($j \in \mathcal{T}_i$):

$$\ln(h_{jt}) = \ln(A^h_{jt}) + \gamma \ln(z_{jt}) + \alpha \ln(I_{h,jt}) + \gamma \ln(1 - \zeta_{jt}).$$

In above h_{jt} is the floor area of newly built housing units sold measured in 10,000 sq.m.; ℓ_{jt} is residential land sales measured in 10,000 sq.m.; I_{jt} is construction material, which is computed by dividing the residential investment (excluding land purchase) by the real unit construction cost. These are all "quantity" measures by all developers in each city. The minimum land requirement, ζ_{jt}, is assumed to be tier-specific due to data availability. Tan et al. (2020) have estimated the distribution of regulatory floor-to-area-ratio (FAR) for a selection of 25 major Chinese cities during 2002-2012. Land parcels closer to the city center are usually subjected to a lower FAR ratio. We proxy the minimum land requirement in each city using one divided by the FAR ratio at the 10-percentile of the distribution. The average values of ζ_{jt} are 32% for tier-1 and 24% for tier-2 and tier-3 cities, so the population-weighted average at the national level is 25%. We let cities of the same tier in our sample obey the same minimum land requirement. The empirical specification is thus given by,

$$\log(h_{jt}) = c + \beta_1 \log(\ell_{jt}) + \beta_2 \log(I_{jt}) + \nu_t + \delta_j + \varepsilon_{jt}. \tag{23}$$

Estimating the equation above using OLS might lead to bias because land sales may be endogenously determined by productivity, population, or other factors that also drive housing sales. To alleviate the issue of endogeneity, we introduce outstanding local-government financing vehicle (LGFV) debts as an instrument variable for land sales. The argument is that Chinese local governments have used future land sale revenues as collateral to raise debt financing through LGFVs, and thus to sell more lands when they have a heavier debt burden (Ambrose et al. (2015); Liu and Xiong (2020)). But this tendency should not be relevant to the floor area of housing sales, because the development procedures are mainly controlled by housing developers. Specifically, we use the outstanding short-term loans of LGFVs associated with each city. The regression results are reported in Table E.1.

The results from the first-stage F test of excluded instruments suggest our choice of instruments is sufficiently strong. We have also reported the Cragg-Donald Wald F statistic as a robustness check. The F-stats are both cluster-robust and robust to heteroskedasticity. To alleviate the concern that the drop in the first stage F-statistics among specifications with interaction effects could lead to weak instrument bias, we have also reported the limited information maximum likelihood (LIML) estimates, which have been shown to be less affected by weak instrument bias. Our findings that LIML estimates are fairly close to the 2SLS counterpart provide some reassurance against this concern. The estimation results suggest that $\gamma = 0.20$ and $\alpha = 0.37$. Then, A^h_{jt} is computed as the sum of the city-fixed effects, year-fixed effects, and constant terms. The estimates of γ and ζ_j yield the *effective land share*[8] in housing production at 15% at the national level, and 13.6% for tier-1 and 15.2% for tier-2 and tier-3 cities.

Table 2: Summary Statistics for Estimated Frictions

	Housing Frictions					Land Frictions				
Year	Mean	Sd	P25	Median	P75	Mean	Sd	P25	Median	P75
2007	-1.06	1.10	-1.45	-0.80	-0.40	2.29	2.67	0.60	1.45	2.59
2008	-1.81	1.15	-2.21	-1.58	-1.06	3.51	3.65	1.25	2.32	4.27
2009	-1.15	1.19	-1.57	-0.95	-0.30	1.49	1.92	0.18	1.02	2.35
2010	-1.05	0.97	-1.43	-0.86	-0.32	0.68	1.33	-0.25	0.22	1.22
2011	-1.33	0.86	-1.59	-1.17	-0.74	0.72	1.20	-0.12	0.37	1.07
2012	-1.52	1.25	-1.93	-1.30	-0.80	1.11	1.57	0.10	0.59	1.71
2013	-1.37	0.99	-1.76	-1.19	-0.69	0.83	1.49	-0.15	0.37	1.19
Total	-1.33	1.11	-1.76	-1.13	-0.62	1.52	2.34	0.07	0.90	2.12

Notes: This table reports the summary statistics for estimated frictions among 93 Chinese prefecture-level cities. P10, P25, P75, and P90 refer to the respective percentile within the same year.

The summary statistics for our estimated city-level housing and land market frictions are presented in Table 2. Housing and land frictions vary substantially across cities: the average friction in the housing market is about -1.33, with a standard deviation of 1.11,

[8] defined as $\frac{q\ell(1-\zeta)}{ph}$

while the average friction in the land market is about 1.52, with a standard deviation of 2.34. These imply housing developers are subsidized at an amount equivalent to 133 percent of housing sales revenue but taxed at 152 percent of land purchases, relative to their competitive benchmarks. The dispersion in housing frictions is large: cities at the 75th percentile of the housing frictions across cities are subsidized at about 62 percent of housing sales revenue, and those at the 25th percentile are subsidized at around 176 percent of the housing sales revenue, yielding a 114-percentage-point spread. The dispersion in land frictions is even larger. Cities at the 75th percentile are taxed at a level equivalent to 212 percent of the land sales revenue, while those at the 25th percentile are at 7 percent. There is a 205-percentage-point spread. While the spatial spread of housing friction is persistent over the years, the spread of land frictions drops by more than half.

With these distortionary wedges are computed in a reliable manner by allowing for several locational heterogeneities including city-specific construction TFP, material costs, minimum land requirements and land development costs, we feed them in the model, to interact with other city-specific factors, including city-specific developer entry costs, city-specific production technologies (both TFP and labor shares), and city-specific migration costs and migration lotteries. This enables us to study how these interactions affect housing supply and demand, land demand, developer entry, and housing and land prices, as well as macro aggregates.

Frictions by city-tier In Table F.2, Table F.3, and Table F.4, we have presented the summary statistics within the group of tier-1, tier-2, and tier-3 cities, respectively. The following features stand out: (i) Housing frictions among tier-1 cities are much smaller (subsidized at 17 percent) than those in tier-2 and tier-3 cities (subsidized at 109 and 148 percent, respectively), possibly because of their much better functioning housing markets as well as the more strictly imposed housing-market cooling-down policies; (ii) land frictions are comparable between tier-1 and tier-2 cities but more severe in lower-tier cities, likely due to their less established land auction.[9]

[9]To alleviate the concern that housing production function may vary across cities, we have estimated a tier-specific housing production function and re-estimated housing and land market frictions in Appendix F. The qualitative patterns of frictions across tiers still maintain.

To reconfirm these patterns, we further explore how frictions change with respect to city size, and report the results in Table E.6. The first specification only includes the city size measured by GDP on the right-hand-side, and it shows that larger cities are subsidized less (less negative) in the housing sales revenue and taxed less in the costs of land inputs. Doubling the measured city size reduces housing subsidies by 26.4 percentage points and lowers land taxes by 68.0 percentage points. While the second specification includes both the linear time trend and the interaction between city size and the time trend, the third incorporates both time and city fixed effects. Although the gaps in housing frictions between large and small cities stayed roughly the same over the years, the positive interactive coefficient indicates that the city-size elasticity of land frictions gets closer to zero over time. By including time and city fixed effects in the third specification, both coefficients on city size turn out to be insignificant. This suggests both frictions are probably rooted in city characteristics such as institutional/geographical factors that correlate with city size, but are not alleviated by economic development over time.

Thus, our results reveal the smaller the city size is, the larger the distortionary wedges are. This suggests larger cities have more competitive housing markets, consistent with lower top-8 developers' market shares.

Institutional evidence Institutionally, the positive relation between city size and housing frictions suggests that housing is still heavily subsidized in small cities. Since 2005, the Chinese government has implemented several rounds of strict housing-market intervention policies in major cities (especially the tier-1 and a few tier-2 cities) to curb the housing price surge. The major policies include restrictions on the loan-to-value ratio and interest rates for housing mortgages, higher transaction taxes for housing resales, and perhaps most importantly, restrictions on multiple home purchases for local households or any home purchases for non-resident households since 2010. However, during most periods, these policies did not apply to the smaller tier-3 and tier-4 cities. By contrast, explicit or implicit housing subsidies are still prevalent in these smaller cities, especially during the stimulus period (late 2008 to mid-2010) and the destocking campaign (2015-2016). The types of subsidies vary with the city, mainly including transaction-tax rebates, local hukou awards, lower mortgage interest rates, or even monetary subsidies for home purchases.

Table E.7 further reports the evolution of the frictions over time. Recall from Proposition 4 that a decrease in land distortion increases the land price while controlling net migration flow. Thus, the reduction in land frictions suggests that land inputs become more expensive over time. Table E.7 also shows that there is no clear-cut trend in housing frictions.

The fact that land frictions decrease over time is likely due to the following policy changes. In May 2002, the Ministry of Land and Resources (MLR) required all residential- and commercial-land-parcel leaseholds to be sold via some type of public auction process. This requirement can be considered the starting point for the development of a competitive and transparent urban residential land market. However, for most cities, especially the smaller cities, the subsequent land market development took a relatively long period of almost one decade. Generally, the urban residential land market is more competitive in larger cities than in smaller cities for at least two reasons. First, the rules associated with the urban land market are typically better established in the leading cities. Second, larger cities typically have many more developers, and thus, more potential competing buyers are in the residential land market.

Table 3: Institution and Policy and Spatial Misallocation

	large distortion across cities	**mostly subsidy in housing**	**mostly tax in land**	**less subsidy to housing in larger cities**	**land taxed less in larger cities**	**lower land distortion over time**
housing price controls	x	x				
land price control			x			
zoning restriction	x					
relaxation in land developer restriction	x					
hukou restriction	x					
hukou relaxation				x		
urban amenity improvement				x		
relaxation in zoning restriction					x	x
relaxation in land developer restriction					x	x
land auction establishment					x	x

According to Proposition 3, if housing is subsidized in most cities, housing price tends to be lower than in a frictionless market while controlling for net migration flow. This might be due to the prevalent presale arrangements in the housing-development projects in China. Specifically, a developer can presell the uncompleted units to household buyers during the construction stage. The payment from buyers would then be immediately transferred to the developer and considered a subsidy to housing developers. The housing subsidies can also result from local governments' unexpected investments in urban amenities, which leads to additional returns for the developers. Similarly, based on Proposition 4, the fact that land is taxed in most cities implies land price is also lower than their level in a frictionless market. This is also a result of immature land markets.

In terms of cross-city comparison, we find that housing is less subsidized in larger cities, suggesting a higher housing price in larger cities. This can be partly caused by the cooling measures implemented in the major cities and the stimulus plan in the small cities. The major cooling measures include higher downpayment requirements and mortgage rates for a second home and higher transaction taxes for housing resales. In addition, since April 2010, 46 cities have gradually implemented the Home Purchase Restriction policy, which imposes restrictions on multiple home purchases for residents or any home purchase for non-residents. By contrast, in small cities, subsidies such as transaction-tax rebates, lower mortgage rates, monetary subsidies, and hukou restriction relaxation are prevalent. Similarly, the land is also taxed less in larger cities. This suggests that land prices are higher and closer to frictionless market prices in larger cities, likely because a better-functioning land auction market in larger cities is more competitive, as demonstrated in Figure E.1. We summarize the patterns and the related institutional backgrounds in Table 3.

4.3 Projection of Urban Population

Calculating the path of future prices requires making different assumptions about the length of the structural transformation process. In the baseline case, we assume the path of China's structural transformation will take another 50 years since 2013. Under this assumption, in the year 2063, urban employment in China will become steady. Our algorithm is simply as follows: we assume net migration flow into urban areas will continue to grow until the year 2020, after which, it will steadily decline. The definition of net migration flows from rural to urban areas includes permanent and temporary permits, where many of the latter, mostly renting, are later granted permanent permits. Overall, the time path of the fraction of urban employment is plotted in the left panel of Figure E.7. By 2063, the fraction of urban employment will reach 88 percent.

Note more optimistic projections may exist regarding the progress of structural transformation in China, with a much faster transition for China than the U.S.. The conjecture above is provided as a starting point. As a robustness check, in Appendix C we have considered a more optimistic structural transformation prediction, in which it will take a shorter time till the urban population reaches 88 percent. Although the results have some effects in the very long run, they have only a minor impact on the simulated dynamics of housing prices between 2007 and 2013.

4.4 Calibration

To properly parameterize the model economy, we calibrate the generalized framework with a full account of labor market frictions and urban amenities/disamenities.

The utility function is CRRA as described above. A worker's disutility level from migration is assumed to follow a Pareto distribution defined over interval $[\underline{\epsilon}, \infty)$: $F(\epsilon) = 1 - \left(\frac{\underline{\epsilon}}{\epsilon}\right)^{\lambda}$, where $\lambda > 0$ is the inverse of the tail index.

Each period in the model corresponds to one year. The subjective discount rate, β, is set at 0.95. The rural reservation utility, $\underline{U}$, is normalized to be zero. The annual mortgage rate, r_m, is set at 5 percent. The down payment ratio ϕ, which represents the fraction of the house value that the worker must pay in advance, is set at 0.3. The decay rate for outstanding mortgage balances is $\gamma = 0.033$, which corresponds to a 30-year amortization schedule. All the policy parameters are consistent with the Chinese government policy during 2007-2013. The annual housing depreciation rate is set to be $\delta_h = 0.025$. α and γ in the housing production function were estimated in Section 4.2. λ captures the tail index of the migration cost distribution, and we take the estimation from Liao et al. (2022).

Regarding utility generated from net urban amenities, εM_t^{μ}, the scaling parameter ε is chosen so that the net value of amenity takes about 10% of the average utility in the initial steady-state. Because μ captures the amenity elasticity, it is picked so that the ratio of migration cost scale in the tier-1 to that in tier-3 cities in the final steady-state is kept the same between the baseline economy and the extreme case without amenity in the utility function. Their calibrated values turn out to be $\varepsilon = 30.2$ and $\mu = 0.27$.

The city-specific series include $\{A^m_{jt}, A^h_{jt}, \ell_{jt}, p_{I,jt}, \tau_{h,jt}, \tau_{z,jt}, \Psi_{jt}, \pi_{ijt}\}$, and tier-specific series $\{\chi_{it}\}$. The evolution of the residential land supply and material costs are obtained from Hang Lung Center for Real Estate at Tsinghua University (CRE). We extrapolate each of these series for the remaining periods by assuming they take their average values during 2007-2013, because we do not observe a prominent time trend. Similarly, we directly use the estimates from Section 4.2 for city-specific housing($\tau_{h,jt}$) and land frictions($\tau_{z,jt}$) from 2007 to 2013. For the remaining periods, we again assign the average value of the series during the sample period.

We divide our sample cities into three tiers following the same convention as in Section 4.2. During 2007-2013, the population size among the three city tiers together with the rural population steadily takes up about 81 percent of the total population in China as shown in panel (a) of Figure E.6. Hence, we consider our division represents well the entire Chinese economy, and in the following exercises, we thus define the total population as the sum of these four components. In panel (b) of Figure E.6, we plot the fraction of each component in the total population. The pattern not only reveals a persistently declining rural population share, the population share of each city tier has also steadily grown. This suggests a population outflow from the rural area to each city tier.

The fraction of rural migrants into each city tier is computed as the ratio of the incremental population within each tier to the decline in rural population. Figure E.6 presents the estimation results. Tier-3 cities absorb more than half of the rural population inflow, and about 33 percent of rural migrants move to tier-2 cities. Only slightly more than 10 percent of the migrants move to tier-1 cities. However, taking into account the fact that tier-1 cities only take up less than 1 percent of the total population, the magnitudes of rural inflow are indeed dramatic. The tier-specific scaling factor of migration cost, χ_{it}, is calibrated to match the percentage of rural inflow into each tier over time. The no-arbitrage conditions (7) subsequently determine tier-specific cutoffs $\{\epsilon^*_{it}\}_{i\in\{1,2,3\}}$ in each year.[10]

We now move to the estimation of the city lottery. Due to the limited data availability, we have only estimated city-specific housing and land frictions for 93 cities. Panel (d) of

[10]When no-arbitrage conditions (7) hold, in each period workers with lower migration costs, tend to move to lower-tier cities. This is consistent with the empirical evidence. We have run panel regressions using both the 2005 and 2015 Chinese mini-population census. In both censuses, we observe each individual's current residing city and birth city. The dependent variable is set as the migration flow between all possible pairs of city tiers. Controlling both origin and destination tier fixed effects, the results suggest that individuals with higher education and younger age tend to move to cities of the lower tier. Intuitively, those agents should also suffer lower migration dis-utilities as it is easier for them to adjust to the new working environment and settle down without heavy family obligations.

Figure E.6 presents the percentage of the total population in our sample with 93 cities to the total population of each tier. Our sample contains all the four tier-1 cities, with above 90-percent of tier-2 cities, and about 58 percent of tier-3 cities. In the quantitative exercises, we thus create an “other” city within each city tier to absorb these out-of-sample populations. The payoff from staying in “other” cities is assumed to be the population-weighted average payoff from staying in sample cities of the same tier. The probability of being drawn into a city within our sample is just the city’s population share within its tier.

We assume it is a common belief that every individual considers the structural transformation will continue till the year 2063, by then the urban population share will reach 88 percent. An alternative interpretation is that when individuals make migration decisions, they only take into account the potential changes in all the economic outcomes till 2063, afterwards they consider the economy will reach a final steady-state, in which rural-urban migration no longer takes place and all the economic variables will stay constant.

We consider the year 2007 as the initial steady-state, in which individuals do not foresee the changes in economic outcomes that will take place at the beginning of 2008. We estimate the series of the migration cost scale for each city-tier to match the fraction of rural outflow into each tier presented in Figure E.6. The right panel of Figure E.7 plots our calibrated outcome. The scale of migration cost features a downward trend over time, which suggests relaxing migration policy or improvement in transportation infrastructure.

City-specific Production TFP The wage rate at each city can be expressed as $(1 - \sigma_j)\frac{Y_{jt}}{N_{jt}}$. We first compute city-specific labor share using an annual survey of manufacturing firms in 2007. The labor share is defined as the ratio of the total wage bill to the total production costs, which includes user-cost of capital, expenditure on intermediate inputs, and total wage bill. We compute the labor share for all the 491 1-digit industries in the survey data. The city-specific labor share $(1 - \sigma_j)$ is then an employment-weighted average of the industry-specific labor share. We measure Y_{jt}/N_{jt} as the per-capita GDP of each city. Since $Y_{jt}/N_{jt} = A^m_{jt} K^{\sigma_j}_{jt} N^{-\sigma_j}_{jt}$, we then denote $\tilde{A}_{jt} = A^m_{jt} K^{\sigma_j}_{jt}$. Using data on per-capita GDP and population from China City Statistical yearbooks, we are able to compute $\tilde{A}_{jt}$ during the sample years. We assume K_{jt} grows at a constant rate of 3.1% over time across all the cities, which is to capture the average growth rate of aggregate physical capital during 2007-2013. We are then able to back out the city-specific growth rate of A^m_{jt}. We let A^m_{jt} continue to grow at this constant rate in the out-of-sample periods till the final steady-state is reached. We normalize A^m_{j0} to be 1. We consider this normalization innocuous since the differences in wage levels are then captured by the differences in K_{jt}.

Labor wedge and supply elasticity The macro housing literature highlight a stable housing expenditure share at about 0.25 across many cities over time, i.e., $hs^{type}_{jt} = 0.25$; see the pivotal study by Davis and Heathcote (2005). According to Chetty et al. (2011), the Frisch elasticity is: $\xi^{Frisch}_n = \frac{d \ln n_{jt}}{d \ln \tilde{w}_{jt}}\Big|_{c^{-\upsilon_c}=constant} = 1/\upsilon_n = 0.75$, implying $\upsilon_n = 4/3$. To satisfy the labor supply restriction, we take $\upsilon_c = 0.5$ and then obtain $\xi_n = \frac{(1-0.25)-\upsilon_c}{\upsilon_n \cdot (1-0.25)+\upsilon_c} = 0.167$. Two remarks are in order. First, while the value of the CRRA parameter υ_c is lower than typically considered in the macro literature, it is not uncommon when one tries to match the micro estimates of the Frisch elasticity in a stylistic setting without unemployment or other bolts and nuts. The reader is referred to a sizable literature since the pivotal paper by MaCurdy (1981). Second, having $\upsilon_c < 1$ is handy when one comes to cardinality measures for comparison of average welfare between different tiers of cities, under which all such welfare measures are positive. For the same reason, intertemporal elasticity of substitution exceeding one is required in the expected utility literature and the macroeconomic public finance literature, among others.

From the producer's optimization, the wage rate can be computed according to $(1-\sigma_j)\frac{Y_{jt}}{N_{jt}} = w_{jt}$. Next, form (19), by normalizing the disutility scaling parameter to one for all cities, we have: $(1-\tau_{jt})\, w_{jt} n_{jt} = \left[n^{1+\upsilon_n}_{jt} \cdot \left(1 - hs^{type}_{jt}\right)^{\upsilon_c} \right]^{\frac{1}{1-\upsilon_c}}$. Lacking good city-specific work hour data, we assume $n_{jt} = 0.3$, computed as the average of a workload of 9 hours per day-5.5 days per week for 52 weeks and a workload of 10 hours per day-5.5 days per week for 50 weeks (2-week vacation), as typically observed in developing countries. We can then back out labor wedge: $(1-\tau_{jt}) = \frac{0.3^{11/3} \cdot 0.75}{w_{jt}} = 0.009075/w_{jt}$. Accordingly, from (18), consumption is computed as $c_{jt} = 0.3 \cdot (1-\tau_{jt})\, w_{jt}(1-0.25) = 0.00204$. In Figure E.5, we plot the estimation results for each city. It shows that the four cities that belong to tier-1 cities are all subjected to a relatively smaller labor wedge than other cities, implying a more competitive labor market.

Table 4: Benchmark Parameterizations

Description	Para.	Value	Source/Targets
		External Parameters	
Subject discount factor	β	0.95	Macro literature
Mortgage rate	r_m	0.05	government policy
amortization rate	γ	0.033	government policy
Downpayment	ϕ	0.3	government policy
depreciation rate	δ_h	0.025	standard
Material share	α	0.37	Section 4.2
Land share	γ	0.21	Section 4.2
coefficient in labor supply	ι	4.0	Section 4.4
Rural utility	$\underline{U}$	0	normalization
migration cost tail parameter	λ	2.8	Liao et al. (2022)
Production TFP	$\{A^m_{jt}\}$		Section 4.4
labor share in goods production	σ_j		Section 4.4
Construction TFP	$\{A^h_{jt}\}$		Section 4.2
Housing frictions	$\{\tau_{j,ht}\}$		Section 4.2
Land frictions	$\{\tau_{j,zt}\}$		Section 4.2
Land cost coefficients	$\{B_{j,t}\}$		Land supply from CRE
Material cost	$\{p_{j,It}\}$		CRE
Migration lottery	$\{\pi_{jt}\}$	Figure E.6	Data and own's calculation
Minimum land requirement	ζ_{it}		imputed from Tan et al. (2020)
		Jointly Determined Parameters	
Entry fee coefficient	ψ_j		initial housing price level
Entry fee power	η_j		housing price growth factor
Minimum migration cost	$\underline{\epsilon}$	6.07	initial rural population share
Migration cost scale	$\{\chi_{it}\}$	Figure E.7	Tier-specific population share

Entry fee We next turn to the city-specific entry fee function: $\Psi_{jt} = \psi_j H_{j,t-1}^{\eta_j}$. Again, ψ_j is the entry fee scaling parameter which varies across cities, and we calibrate it to match the initial housing price level at each city; η_j is the entry fee curvature parameter measuring the city-size elasticity of the entry fee. The curvature is calibrated to minimize the distance between model-predicted city-specific housing price growth factors during 2007-2013 and their data counterparts.[11] Our estimation results suggest the curvature parameters are

[11] Specifically, we need to estimate a total of 93 η_j in order to match $6 * 93$ moments on the city-specific annual housing price growth rate. The estimation is accomplished using a nonlinear minimization algorithm. Specifically, the objective function is

$$\min_{\{\eta_j\}} \left[\bar{\mathcal{S}} - \mathcal{S}(\eta)\right] \mathcal{W} \left[\bar{\mathcal{S}} - \mathcal{S}(\eta)\right]'.$$

The identity matrix is used as the weighting matrix $\mathcal{W}$.

smaller in larger cities. This indicates developer entry is less restrictive in larger cities, which lends further support to our claim that larger cities' housing markets are more competitive. Both η_j and ψ_j are city-specific but constant over time.

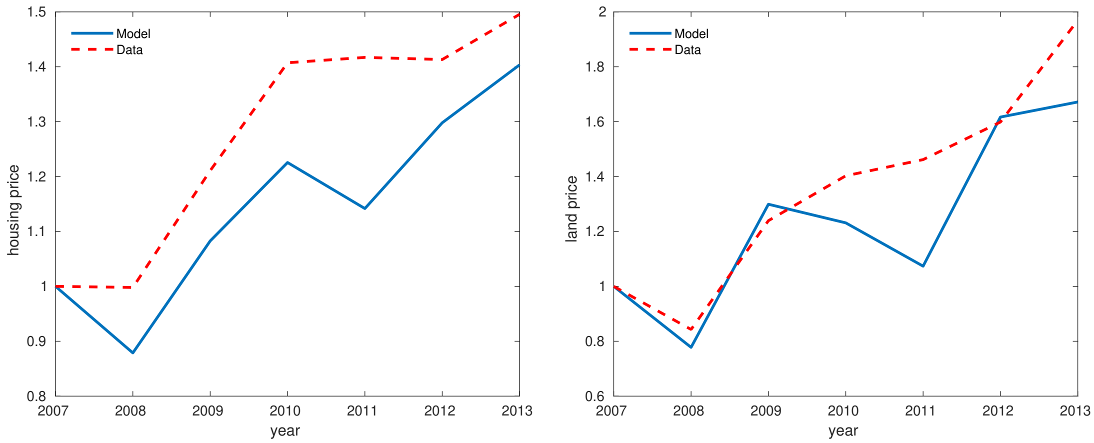
We summarize the parameterization of the calibrated model economy in Table 4. A summary of both the initial level and the growth factor during 2007-2013 for several key statistics at the tier level can also be found in Table E.8.

5 Quantitative Results

In Figure 1, we plot the model-predicted housing and land prices together with the data counterparts from 2007 to 2013. The model has mimicked well the housing price and land price data series over time. Overall, the growth factor of housing prices measured by the price ratio of 2013 to 2007 (which corresponds to geometric average growth) is 1.50 in the data, and 1.27 predicted by the model. While the simple average annual housing price growth rate in the data is 7.27 percent, the model predicts a growth rate of 4.8 percent. These together imply the model can rationalize $1.27/1.50 \approx 84.7$ percent of the housing price growth factor, and $4.8/7.27 \approx 66.0$ percent of the average housing price growth rate. Similarly, the land price growth factor is 1.97 in the data and 1.79 by the model, which explains 90.9 percent of the observed growth trend.

We show in Figure E.8 that the model has good fit for housing price dynamics in all tiers of cities. The model also mimics land price dynamics well in the tier-1 and tier-2 city as shown in Figure E.8. The model does not do as well in predicting land price growth in tier-3 cities, where city-level institutional factors are much larger and divergent, thereby influencing local land sales beyond the fundamentals in our theory and weakening the model prediction. We shall return to looking into the details of counterfactual analysis in tier-3 cities.

We further compare the welfare among individuals of different tenure statuses. With equal weight to all individuals, we can compute the average welfare among all the residents of city j in t is defined as a population-weighted-average between the incumbent owner's



(a) Housing Prices (b) Land Prices

Figure 1: Baseline Results: National

Notes: This figure plots the model-predicted national housing and land price levels against their data counterparts during 2007-2013. We have normalized the price level for all the series to be 1 in 2007.

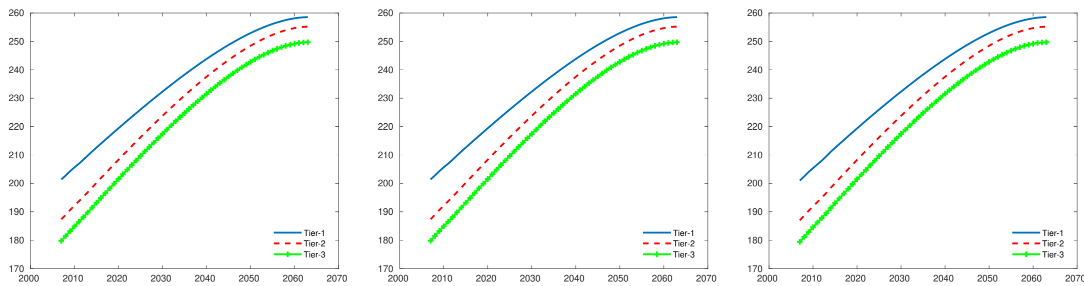
value function and the new migrant's value function:

$$\bar{W}_{jt} = \frac{\left[\sum_m \mu_{jt}^{own}(m) V_{jt}^{own}(m) + V_{jt}^{mig}(\epsilon)\mu_{jt}^{mig}\right]}{\sum_m \mu_{jt}^{own}(m) + \mu_{jt}^{mig}}. \tag{24}$$

The tier-level and aggregate-level average welfare are then population-weighted averages of the city-level average welfare: $W_t^i = \sum_{j \in \mathcal{T}_i} \mu_{jt} \bar{W}_{jt}$ and $W_t = \sum_i \mu_t^i W_t^i$. We present the evolution of the overall average welfare, as well as the average welfare among owners and new migrants in Figure 2. The average welfare is always the largest in tier-1 cities, and smallest in tier-3 cities, which is needed in the calibrated model economy to preserve the sorting property. The welfare is increasing at a decreasing speed over time. The welfare gap between tier-1 and tier-2, and the gap between tier-2 and tier-3 cities appear to shrink over time, while the former seems to shrink faster than the latter one.

5.1 Toward Understanding the Key Drivers

Migration and urban home purchases are connected via intertemporal choice, as specified in Section 2.1. Also as noted in Section 3.1, the dynamic general equilibrium effects of housing and land frictions on net migration inflows and housing and land prices are complicated. In



(a) Urban (b) Owners (c) New migrants

Figure 2: Benchmark Welfare Comparisons

Notes: The average welfare in each city is a population-weighted average of welfare among incumbent city owners and new migrants(buyers). The incumbent owner's welfare varies according to their outstanding mortgage balances. The average welfare at the tier level is a population-weighted average of the average welfare in each city.

this section, we shall quantify such dynamic interactions and consequences. Moreover, as discussed in Section 3.2, migration is an integral part of labor decision, and the role played by endogenous labor supply and labor frictions in migration choice and housing markets are thereby examined.

5.1.1 The Nexus between migration and housing prices

To examine the interaction between rural-urban migration and housing price dynamics, we conduct two counterfactual exercises. First, by restricting rural-urban population inflow to zero by setting the scale of migration cost at a sufficiently large value, one can extract the impact of migration on housing prices. Second, by setting the housing prices of each city constant at their initial levels, one can then isolates the implications of rising housing prices for the incentives to migrate to cities. As to be illustrated below, these exercises suggest strong interactions between migration and housing price dynamics, which are the roots of our study.

From Migration to Housing Price When rural individuals no longer migrate to the urban area, the housing demand in the urban area is purely driven by the maintenance costs incurred among incumbent owners. As shown in Figure E.31, when the channel of migration is shut down, the average housing price at the national level has declined by about

25 percent during the sample period, in which housing prices in tier-1 cities decline the least towards the end of the sample period. This counterfactual exercise verifies the propositions derived in Section 3.1 concerning the positive migration as accelerator and migration stock effects, both amplifying the growth of urban housing prices.

The tier-level effects can be better illustrated in Table 5. The first column records the deduction in housing prices when the migration channel is shut down. The housing prices shrink by 14.9, 21.1, and 14.9 percent from their baseline levels in tier-1, tier-2, and tier-3 cities, respectively. Note that when migration is allowed, the increasing migration inflow pushes up the demand for housing and thus the housing prices – this direct impact is the migration accelerator effect. These interactive direct effects are accompanied by the reinforcing migration stock effect, the opposing forward-looking price effect, as well as their respective competing-tier effects.

Migration accelerator effects are found to be strongest in tier-3 cities, followed by tier-2 and tier-1 city. This ranking is inferred by ranking the ratio of average migration inflow to its initial population size in the baseline economy. As for the cumulative migration stock effect, we expect it to be strongest in the tier-1 cities, followed by tier-2 and tier-3 cities, because initial population size and population elasticity of entry matter more. Combining these two effects may justify the decline in housing prices is highest in tier-2, followed by tier-1 and tier-3 cities as shown in the first column of Table 5.

Table 5: Migration Effects on Prices

	Base v.s. No Migration	Frictionless v.s. No Migration	cDID
Tier-1	0.149	0.112	0.037
Tier-2	0.211	0.209	0.002
Tier-3	0.149	0.134	0.015

Notes: The first column reports the percentage decline in housing prices from baseline to the economy without migration. The second column reports the percentage decline in housing prices from a frictionless economy to one without both frictions and migration. The last column is the difference between the first and the second column, i.e., counterfactual difference-in-difference (cDID, to be discussed in the next subsection).

From Housing Price to Migration When housing prices do not grow, more individuals flow to the urban area as shown in Figure E.30. The urban population size has increased by about 8 percentage points by the year 2013 compared with the baseline level. Based on our model in Section 2 and the theoretical findings in Section 3.1, there are two general-equilibrium price effects: a negative housing price decelerator effect and a positive forward-looking price effect. The counterfactual exercise suggests that the direct decelerator effect dominates, though the intertemporal effect weakens the direct effect.

In Table 6 we compare the surge in population led by rising housing prices in the baseline and stagnent prices at each city tier. The first column shows that when housing prices are kept at their initial levels, population size in the baseline economy becomes 52.9, 62.2, and 63.4 percent of its level in the counterfactual economy in tier-1, tier-2, and tier-3 cities, respectively.[12] Price decelerator effect is certainly strongest in tier-1 city due to its high level of housing prices, followed by tier-2 and tier-3 city.

As discussed before, from the dynamic perspective migration decision is also influenced by speculative early move. Since in the baseline economy, the growth factor of housing prices is highest in tier-3 cities, followed by tier-1 and tier-2 cities, and thus when the motive of speculative early move is shut down by stagnant housing prices, we expect inflow is dampened most in tier-3 cities, with moderate and small effects on tier-1 and tier-2 cities, respectively. As for the competitive-tier effects, since income grows the most in tier-3 city, followed by tier-2 and tier-1 cities, this makes the tier-3 cities more attractive than others when there is no housing price growth in all the cities, and thus we expect larger inflow into tier-3 cities than other cities. Overall, our findings suggest that direct housing price decelerator effects dominate all other effects, hence population size in tier-1 cities is expanded the most.

5.1.2 The role of labor supply and frictions

Turning now to the role played by labor decisions and frictions, one can see from Table E.13 that new migrants (buyers) on average supply more labor than the incumbent owners, among which migrants to tier-3 cities tend to supply more labor than those to tier-1 cities.

Since labor supply is affected by city-specific wages, housing prices, and labor wedges, to

[12]To ensure consistency with our cDID exercises conducted later, we examine the population changes from baseline to the economy without housing price growth.

Table 6: Price Effects on Migration

	Base v.s. No Price Growth	Frictionless v.s. No Price Growth	cDID
Tier-1	0.529	0.793	-0.265
Tier-2	0.622	0.636	-0.014
Tier-3	0.634	0.518	0.116

Notes: The first column reports the decline in population from one baseline economy without price growth to the baseline economy. The second column reports the decline in population from one frictionless economy without price growth to a frictionless economy. The last column is the difference between the first and the second column.

further disentangle the role of labor wedges below, we consider a counterfactual no-labor-wedge economy by setting labor wedges in all the cities to zero during the entire period. As shown in Figure E.21, the evolution of aggregate housing prices more or less tracks with the baseline counterpart with a slightly steeper trend. More specifically, removing labor market frictions tends to induce faster housing price growth in tier-1 and tier-2 cities, while raising the level of housing prices in tier-3 cities without changing the trend. As the former dominates in aggregation, it yields a similar but weakened pattern in the housing growth trend at the national level. To understand the results, we note that, when labor wedges are removed, holding wage constant, the value of $n(1-\tau)$, and hence the disposable income, is increasing. This in turn makes urban more attractive as a whole, as shown in panel (a) of Figure E.23. However, because labor market frictions in tier-1 and tier-2 cities are less severe, their relative attractiveness falls when such frictions are removed, inducing an extensive margin shifting away from tier-1 and tier-2 to tier-3 with overall effect in aggregation more modest due to opposing forces.

Moreover, the changes in the migration pattern, in turn, dampen the migration accelerator effect on housing prices in tier-1 and tier-2 cities. On balance, the net effects are not as strong and hence housing demands do not respond as much. This explains the relatively modest impact of labor friction removal on housing prices. Land prices tend to change in the same direction as the population inflow as demonstrated in Proposition 4. For the same reason as above, such changes in land prices are also moderate, as shown in Figure E.22. Finally, it is not surprising that all the cities experience welfare gain from removing labor wedges. The gain on average is equivalent to 16.7 percent of its baseline level.

5.1.3 The role of dynamics

Finally, we would like to illustrate the importance of employing a dynamic general equilibrium rather than a static framework. This can be done by running a counterfactual exercise with the migration decision made by only comparing the *current payoff* from staying in the rural with that from staying in the urban area. To make it more comparable with the baseline economy, we revise the mortgage payment scheme to be a consol mortgage by setting γ_m to be zero. In this way, the outstanding mortgage balance is no longer a state variable to the incumbent owner. We resolve the baseline economy with the consol mortgage scheme and compare the outcome with the one under the assumption of myopia.

Figure E.32 shows that when individuals become *myopic*, there is no longer rural-urban migration under our baseline parameterization. That is, the static payoff obtained in the period of purchasing the house in the city is insufficient to dominate the reservation utility from staying in the rural area when intertemporal considerations and continuation values are removed. Accordingly, in this counterfactual myopic economy, migration to cities ceases and the housing price dynamics coincide with the no migration case discussed above.

5.1.4 The role of entry fee

Both the entry fee cofficients and population elasticity of entry fee are city-specific in the model. To further explore the role of entry fee, we have also performed two sets of counterfactual exercises with respect to the entry fee by either lowing the entry fee coefficient ψ_i by 10% from their baseline levels, or having a less dispersed distribution of population elasticity of entry fee. The latter is achieved by moving the city-specific η_i to be 10 percent closer to their national mean.[13] Lower entry fee induces more housing supply, and thus housing prices decline while urban population increases as shown in Figure E.33 and Figure E.34. We do not find any systematic change in the migration pattern between the baseline and the counterfactual economies.

Since population elasticity of entry fee is highest in tier-1 city, followed by tier-2 and tier-3 city, and thus less dispersed η_j lowers the value of η_j in tier-1 city and increases those

[13] Specifically, $\hat{\eta}_i = 0.9\eta_i + 0.1\bar{\eta}$, where $\bar{\eta}$ is the national average of η_i in the baseline economy.

in tier-3 city. This tends to dampen (amplify) the reenforicng migration stock effects on housing prices in tier-1 (tier-3) city. As a result, tier-1 city tends to be more attractive than the baseline economy. Our quantitative results shown in Figure E.35 and Figure E.36 suggest that housing prices in both tier-1 and tier-2 city significantly decline from baseline levels by about 41.4 and 11.8 percent, while the housing price in tier-3 city increases by about 29 percent. This leads to an increase in population share by 0.34 and 0.21 percentage points in tier-1 and tier-2 city, respectively.

5.1.5 Taking stock

The above analyses indicate that while the direct migration as accelerator effect plays a dominant role in amplifying housing price growth, the housing price decelerator effect, in general, outweighs the forward-looking price effect reduce migration incentives and slows down migration inflows. With labor-market considerations, the general-equilibrium wage effect of labor supply leads to a negative income effect that lowers housing demand and prices, while eliminating labor frictions induces faster housing price growth in tier-1 and tier-2 cities. Dynamic considerations with forward-looking responses are crucial – without these, rural agents stop migrating to cities.

5.2 Decompose the Role of Housing Market Frictions

Tooled with a better understanding of the key drivers considered in our dynamic general equilibrium framework, we are now prepared to explore how housing and land frictions may affect both housing and land price levels, as well as their growth trends. This is done by performing counterfactual exercises in which we remove both frictions by setting them to zero (frictionless) or remove one of the frictions at the time (housing friction only or land friction only). By comparing the calibrated model economy with land-friction-only results we identify the net effect of housing friction while comparing the calibrated model economy with housing-friction-only yields the net effect of land friction. The joint effect of both frictions is obtained by comparing the calibrated model economy with the frictionless case. The summary of the results in all the counterfactual exercises is presented in Table 7.

In Figure 3 we compare the housing prices in the counterfactual with the calibrated model economy. At the aggregate level, removing both friction or only housing frictions result in higher housing price levels and faster growth than the calibrated model economy counterpart. The growth factor increases from 1.27 in the calibrated model economy to 1.62 when both frictions are removed, and 1.51 when only housing frictions are removed. Different from these two scenarios, when only land frictions are removed, housing prices become lower than the baseline levels, whereas the growth factor is still higher at 1.36.

We have shown in Proposition 3 that in the temporal-spatial equilibrium, higher housing frictions lead to higher housing prices, and housing frictions are mostly negative according to our estimation results in Section 4.2. Therefore, it is not surprising to observe that housing prices become higher than the baseline levels when housing frictions are all set to zero. Land frictions do not exert direct impacts on housing prices in the temporal-spatial equilibrium, but smaller land frictions imply a larger land supply according to Proposition 4. This may explain why housing prices decline as a result of removing land frictions, since when mostly positive land frictions are set to zero, the increasing land supply may trigger lower housing prices and bigger population inflow based upon Proposition 3. Overall, the fact that housing prices increase in the frictionless economy suggests housing frictions dominate in determining housing prices. This finding can be further confirmed by observing the dynamics of housing prices in the calibrated model economy closely tracked with the one without land frictions.

Housing prices in tier-2 and tier-3 cities follow a very similar pattern to the aggregate housing prices. In tier-1 cities housing prices are lower in the frictionless than the calibrated model economy. In addition, when housing frictions are removed, housing prices in tier-1 cities become lower than the baseline level starting from the year 2010. This is driven by the positive housing frictions in tier-1 cities as opposed to negative frictions in other cities.

The evolution of land prices in various economies is also reported in Figure 3. At the aggregate level, when both frictions are removed, land prices become higher than the baseline levels. The growth factor decreases from 1.79 in the calibrated model economy to 1.60. The decline in the land prices become less dramatic during 2007-2008 with the annual growth rate increasing from 0.79 to 0.84. The growth is also more prominent than the calibrated model economy during 2011-2012, with the annual growth rate increasing from 1.52 to 2.05. When mostly positive land frictions are all removed, from Proposition 4 land prices are thus expected to increase as demonstrated in the Figure. Housing frictions also do not directly affect the land market in the temporal-spatial equilibrium, but when mostly negative housing frictions are set to zero, the population inflow may become smaller as shown in Proposition 3. The smaller population inflow in turn leads to lower land prices based on findings in Proposition 4. This trade-off in the temporal-spatial equilibrium prevails in tier-3 cities. However, the aggregate land prices are still higher than the baseline levels in a few years, and this is mainly driven by the forward-looking price effect. This can be confirmed by the population movements in Figure E.10, which will be discussed later. When housing frictions are removed, more individuals prefer to move to tier-2 cities than in the calibrated model economy during the first several periods. This also explains why land prices in the case without housing frictions are higher than in the calibrated economy in the early years. In Table E.14 we have also implemented a simple OLS regression to explore the land supply pattern across regions in both baseline and the frictionless economy. First, we find the Northeastern region on average supplies the most land than other regions, followed by the Middle region. Western and Eastern region supply roughly similar level of land. Second, moving from the baseline to the frictionless economy the rank of land supply remains the same, while the Eastern region supplies less than the Western region compared with the gap in the baseline economy.

Because the migration decision depends not only on current but also on future housing prices, the negative housing price decelerator effect may be mitigated by the positive forward-looking price effect. In Figure E.10, we compare the population distribution in different scenarios. When both frictions or only housing frictions are absent, the urban population share becomes lower than the calibrated model economy by 0.26 and 0.27 percentage points in the year 2013. Larger migration inflows to tier-1 and tier-2 cities during the initial years, but eventually only population share in tier-1 cities are significantly higher than the baseline level by 0.53 and 0.54 percentage points in 2013, respectively. This suggests a disproportionately fraction of migrants flow to tier-1 cities when either housing or both frictions are removed. Even though housing is more expensive in tier-1 cities than in other cities, but from Figure 3 its growth is indeed less dramatic than in the other two tiers of cities. Together with the higher wage offer, these make tier-1 cities more attractive than other cities.[14]

With all the "partial" changes illustrated above, we are now ready to conduct a unified analysis of the interactions between frictions and the migration-housing price nexus. For illustrative purposes, we write the equilibrium housing price function as $g(N, \tau)$, depending crucially on two highlighted drivers, cumulated migration inflows (i.e., the stock of migrants or the location-specific population share) N that summarize both migration stock and current migration inflow, and housing-market frictions τ, among others. Our theory suggests that $g_N > 0$ and $g_\tau > 0$, confirmed by our quantitative analysis. By "counterfactual difference-in-differencces" (cDID) exercises (in a way similar to the pre-/post-DID method in econometrics), we evaluate:

$$cDIDg \equiv \frac{g(N+\Delta N(\tau),\tau) - g(N,\tau)}{g(N,\tau)} - \frac{g(N+\Delta N(0),0) - g(N,0)}{g(N,0)},$$

That is, we compare how the rates of housing price change in response to migration flow, $\Delta N(\tau)$ and $\Delta N(0)$, with and without housing-market frictions, respectively. First-order approximation leads to:

$$cDIDg \approx \frac{g_N(N,\tau)\Delta N(\tau)}{g(N,\tau)} - \frac{g_N(N,0)\Delta N(0)}{g(N,0)} = \varepsilon(N,\tau)\frac{\Delta N(\tau)}{N} - \varepsilon(N,0)\frac{\Delta N(0)}{N}$$

where $\varepsilon(N,\tau)|_{\Delta N(\tau)=0} = \frac{g_N(N,\tau)N}{g(N,\tau)}$ and $\varepsilon(N,0)|_{\Delta N(0)=0} = \frac{g_N(N,0)N}{g(N,0)}$, respectively, are the migration elasticity of housing price with and without frictions.

Similarly, we can express the equilibrium migration inflow as $m(p, \Delta p)$, depending on two highlighted drivers, housing price p and housing price growth Δp (= 1 if no growth), where from our theory the housing-market friction τ does not yield a direct effect on migration – its effect is only through the dynamic general equilibrium price channels. Our quantitative analysis confirms the theoretical results: $m_p < 0$ and $m_{\Delta p} > 0$, where the former is the housing price decelerator effect and the latter the forward-looking price effect. Again, cDID

[14] We have repeated the same decomposition exercises by eliminating housing and land market frictions using tier-specific housing production function in Appendix F Figure F.1. The results remain qualitatively similar.

exercises can be used to compare how the rates of migration flow change in response to housing prices with and without housing-market frictions, respectively:

$$cDIDm \equiv \frac{m(p(\tau), \Delta p(\tau))}{m(p(\tau), 1)} - \frac{m(p(0), \Delta p(0))}{m(p(0), 1)} = \zeta(p(\tau), 1)(\Delta p(\tau) - 1) - \zeta(p(0), 1)(\Delta p(0) - 1)$$

where $\zeta(p(\tau), \Delta p(\tau))|_{\Delta p(\tau)=1} = \frac{m_{\Delta p}(p(\tau),1)}{m(p(\tau),1)}$ and $\zeta(p, 0)|_{\Delta p(0)=1} = \frac{m_{\Delta p}(p(0),1)}{m(p(0),1)}$ are the housing price elasticity of migration inflow with and without frictions, respectively.

The quantitative results are summarized in the last column of Table 5 and Table 6:[15] the former reports the migration effects on housing prices by comparing the frictional with the frictionless economies, whereas the latter repeats the same exercise for the housing price effects on migration inflows.

With regards to the migration effects on housing prices, our cDID results are positive in all three cities implying frictions dampen the migration accelerator effects. The differences is largest in the tier-1 city (0.037), followed by the tier-3 city (0.015), and approximately zero in the tier-2 city (0.002). The negligible migration inflows and the cDID result in tier-2 may suggest population movements may dominate the change from $\varepsilon(N, \tau)$ to $\varepsilon(N, 0)$. Moreover, both migration inflows and the cDID result in tier-1 are doubled compared to tier-3, which further suggests relatively constant $\varepsilon(N, \tau)$ regardless of market frictions. Therefore, in all tiers, our cDID findings are mainly driven by migration as accelerator and migration stock effects on housing prices, and such housing price responses are not very sensitive to whether market frictions are present or not.

With regards to the housing price effects on migration inflows, the cDID results are positive in tier-3, but negative in tier-1 and tier-2, with the magnitude larger in tier-1, compared with tier-2. Recall that housing-market frictions act as taxes in tier-1 but as subsidies in tier-2 and 3. Thus, such frictions tend to amplify the housing price in tier-1 but dampen it in lower tiers. The combination of positive friction with a strong housing price as a decelerator effect leads to a large negative impact of housing prices on migration inflow in tier cities with the frictional housing market. On the contrary, in tier-3 cities, housing

[15] In the second column of Table 6, we repeat the same exercise as in the first column by comparing the effects of price growth in the frictionless economy. In the last column of Table 6, we perform the cDID exercise by substrating results in the second column from those in the first column.

prices are low, to begin with, and developers are subsidized to keep prices low. Yet, with a lower base, housing price growth is high. As a result, the interaction of negative frictions with currently affordable prices and expected future price growth induces more migration inflows.

5.3 Counterfactuals under Benchmark Distribution of Frictions

The estimation results of city-level frictions in Section 4.2 suggest that the features of both housing and land frictions (τ_h, τ_z) vary greatly across different city tiers. One may inquire what might happen if the distribution of these frictions in a tier is set to a benchmark distribution. Such exercises are similar in spirit to counterfactuals conducted by Hsieh and Klenow (2009) where the distribution of capital and output wedges in China and India are set to the U.S. benchmark. In our exercises here, two natural benchmarks are: (i) a more competitive-market benchmark of tier-1 distribution and (ii) a national benchmark of all cities in all tiers.[16]

The first task is to approximate the distribution of the two frictions. Assuming that housing and land frictions within each city tier follow certain independent parameterized distribution, we can then estimate the best-fitting tier-specific distribution of housing and land frictions. Specifically, in each city-tier we fit the two positive wedges, $1 - \tau_h$ or $1 + \tau_z$, with a class of well-known parameterized distributions defined over $(0, \infty)$. We check the fitness using both χ^2 statistics and p-value: the smaller value of χ^2 or a larger p-value implies a better fit and thus more unlikely to reject the null hypothesis of no significant deviation from the true distribution. The results are presented in Table E.10 and E.11, supporting $1 - \tau_h$ to follow a log-logistic distribution and $1 + \tau_z$ to follow a log-normal distribution. The parameters that govern each distribution are presented in Table E.12.

[16] One may view "cities" in our paper as analogous to "firms" and "tiers" to "industries" in the factor misallocation literature. Yet, while industry classification is an international standard, there is no such standardization in city tiers. Thus, for the purpose of this study, within-the-country benchmarking is more appropriate than across countries.

Table 7: Summary of Results: Migration, Welfare and Per-capita GDP

	Baseline	Frictionless			No Labor Wedge	Alt. Bench. Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
Panel (a): Migration							
Urban							
Net migration inflow	1.448	1.396	1.395	1.452	1.433	1.401	1.413
Tier-1							
Net migration inflow	0.186	0.254	0.258	0.187	0.000	0.285	0.237
Tier-2							
Net migration inflow	0.461	0.423	0.425	0.461	0.312	0.397	0.417
Tier-3							
Net migration inflow	0.801	0.719	0.711	0.804	1.121	0.719	0.760
Panel (b): Welfare							
Urban							
Welfare change	0.000	0.250	0.172	0.010	16.363	0.167	0.227
Tier-1							
Welfare change	0.000	-0.015	-0.016	0.002	12.236	-0.011	0.074
Tier-2							
Welfare change	0.000	0.109	0.104	0.015	17.572	0.109	0.174
Tier-3							
Welfare change	0.000	0.147	0.134	0.015	18.225	0.150	0.214
Panel (c): Per-capita GDP							
Urban							
Per-capita GDP change	0.000	0.832	1.034	-0.075	-8.185	-1.198	-57.085
Tier-1							
Per-capita GDP change	0.000	-3.364	-3.694	-0.186	9.917	-4.434	-68.671
Tier-2							
Per-capita GDP change	0.000	0.711	0.749	0.048	6.420	-0.307	-61.380
Tier-3							
Per-capita GDP change	0.000	2.535	3.106	-0.146	-19.798	-0.731	-46.830

Notes: "Net flow" is the simple average of the difference in urban population size in percentage points during 2007-2013. "Wel change" is the simple average of the welfare gain/loss in the counterfactual economy to that in the benchmark economy in percentage terms during 2007-2013. A similar definition applies to "per-capita GDP change"."Urban" welfare excludes rural areas and is the population-weighted average welfare of each city in the urban area. GDP in the urban area is measured as the sum of the value of the composite goods and houses.

5.3.1 Tier-1 Benchmarking

We first consider benchmarking with the tier-1 distribution of the frictions. To begin, we discretize the distribution of housing and land frictions in tier-1 cities each into a vector of seven grids.[17] The corresponding probability that housing(land) frictions take the value at each grid point mimics the distribution of each friction. These give rise to a 7×7 matrix (Θ): with probability Θ_{ij} housing and land friction in a given tier-2 or tier-3 city take the i_{th} and j_{th} grid of each vector. It is realistic to assume that rural workers do not observe the actual value of frictions in each city when they make migration decisions. Therefore, with each possible combination of housing and land friction, we may compute the expected housing price in each city. The migration decision is then based upon the expected housing price of each city.

In Figure E.13, we compare the evolution of housing prices with their original baseline counterpart. Since housing frictions are mostly negative in tier-2 and tier-3 cities, housing prices are expected to rise when those subsidies are switched to taxes prevalent in tier-1 cities. The aggregate housing prices on average becomes 1.27 times their baseline counterpart during the sample period. The ratio is 1.64 and 1.82 in tier-2 and tier-3 cities, respectively. Due to lower net migration inflows, housing prices in tier-1 cities are only slightly higher than their baseline levels, and their growth are also slower than the other two cities with a growth factor of 1.42. This is mostly driven by the increasing population inflow as shown below, which lowers the wage, and housing demands and prices.

When cities draw their land frictions from the same distribution over time, we essentially shut down the downward trend of land frictions. When land frictions in both tier-2 and tier-3 cities follow the distribution in tier-1 cities, our results in Figure E.14 suggest that land prices become more volatile in tier-2 cities and decline more dramatically in tier-3 cities during the sample period. Land prices in tier-2 experience a sharp decline during 2008-2009 when their frictions follow the distribution in tier-1 cities. This seems to suggest proper policies only implemented in tier-2 cities may prevent the collapse of land prices during the outbreak of the global financial crisis. The growth factor of land price in tier-3 cities is 0.67

[17] The median grid corresponds to the mean value of each friction. The remaining 6 grids are either one or two times the standard deviation of each friction below or above the mean value.

compared with 1.07 in the calibrated model economy. As argued before, land price tends to be higher when the friction is closer to zero. When upward pressure on land prices is removed, land prices are thus expected to decline more dramatically in tier-3 cities.

There is a competing-tier effect leading to tier-1 cities becoming more attractive than in the model economy because of more expensive housing prices in other cities. Therefore, there are 0.31 percentage points more population living in tier-1 cities by the year 2013 as shown in Figure E.15. By contrast, the population share in tier-2 and tier-3 cities fall by 0.12 and 0.36 percentage points from their baseline level in 2013.

When all the frictions are set to following the distribution in tier-1 cities, we find a moderate welfare gain as shown in Figure E.16. On average, the welfare gain among the urban area is equivalent to 0.55 percent of the baseline level. Tier-3 cities enjoy the largest gain equivalent to 0.71 percent of the baseline level, followed by tier-2 and tier-1 cities at 0.64 and 0.50 percent, respectively.

5.3.2 National Benchmarking

We next turn to benchmark the national distribution of the frictions. We repeat similar exercises by letting both housing and land frictions follow the national overall distribution as estimated in Table E.12. Thus, housing frictions in tier-1 cities under national benchmarking cities rise and housing prices decline as shown in Figure E.17. Housing prices in the other two cities do not deviate much from their baseline levels since their own distribution of housing frictions only deviate modestly from the national benchmarks. Nevertheless, housing prices become less volatile over time in these two cities.

Figure E.18 shows that land prices in tier-3 cities follow a very similar pattern to their baseline counterpart with a larger decline towards the end of the sample period. The movements of land prices in tier-2 cities differ sharply from their baseline counterparts with an initial higher and eventually lower price level. In tier-1 cities, land prices follow a similar trend as in the calibrated model economy during 2007-2011 with a sudden rise during 2012-2013. Eventually, land prices in 2013 become 1.29 and 1.53 times their baseline levels at the aggregate level and in tier-1 cities, respectively.

The population distribution exhibits mean reversion: more population flow to tier-1 cities while less migrates to tier-2 and tier-3 cities. The overall urban population share does not deviate much from their baseline levels as shown in Figure E.19. There is also a welfare gain on average equivalent to 0.75 percent of the baseline level during 2007-2013 as shown in Figure E.20. The welfare gain is about 0.60, 0.74, and 0.80 percent in tier-1, tier-2, and tier-3 cities, respectively, differing only modestly again because of the mean reversion property of national benchmarking.

5.4 On Migration Policy

The calibrated scale of the migration costs in each year follows a descending order with the incurred migration disutility being the highest in the tier-1 city and lowest in the tier-3 city. This is to mimic a more strict hukou policy in larger Chinese cities. The Chinese government has gradually relaxed the requirement to obtain local hukou in recent years.[18] To better understand the effects of such policy change, we investigate a counterfactual economy where the migration cost scale becomes uniform across all the cities by setting them equal to the national average level while maintaining the overall decreasing trend. That is, the tighter hukou control (especially in tier-1 cities, captured by χ_{1t}) is eased with a gradual relaxation of hukou control. Figure E.28 reports the population distribution as a result of this policy experiment. The overall urban population share becomes higher than the baseline counterpart, mainly driven by the large population inflow into the tier-1 city due to reduced migration costs. In contrast, there is negligible net migration inflow into the tier-3 cities once the migration cost advantages are eliminated.

With this drastic population reallocation, both housing and land prices are affected as shown in Figure E.26 and Figure E.27, respectively. Among others, two primary impacts of changes in migration are on housing demand and labor supply. When more population is reallocated to tier-1 cities in the counterfactual economy, the migration accelerator effect raises housing demand and housing and land prices, but the rising labor supply induces a negative general-equilibrium wage effect and results in lower housing demand and housing and land prices. This negative general-equilibrium effect is more harmful in tier-1 cities

[18]For a comprehensive survey on the recent hukou policy reform in China, please refer to Zhang et al. (2018).

with already pricey housing, thus lowering housing and land prices. On the contrary, in tier-3 cities where housing is cheaper, the direct effect dominates, so reduced population net inflow leads to lower housing demand and housing and land prices. Thus, while the population is reallocated from tier-3 to tier-1 cities, housing and land prices in both tiers turn out to be lower.

5.5 Welfare Decomposition

While the previous experiment provides a general guideline about the consequences of housing and land market frictions for urban welfare by tiers, one may wonder about their impacts on rural welfare, as well as the welfare of incumbent urban residents (homeowners) versus new migrants into cities (home buyers). Our analysis may shed light on who the winners and the losers are from various institutions and policies.

To begin, we report in Table 8 the consequences of removing both frictions during different time periods. Although both urban and rural residents experience welfare gain from removing both frictions, the average welfare of the nation declines (to be explained below)! Nevertheless, our major focus is the welfare changes in the urban area since the reservation utility in the rural area is exogenous in our model setting. Within the urban area, the overall welfare gain is equivalent to 0.25 percent of the baseline level when frictions are eliminated. Both incumbent residents and new migrants experience welfare gain, with the gain among new migrants substantially large (0.222% vs. 0.852%). During the entire sample period, removing frictions benefits incumbent residents whereas worsens the welfare of new migrants in both tier-2 and tier-3 cities. The welfare gain among incumbent residents is about 0.113 and 0.147 percent, and the loss among new migrants is about 0.019 and 0.021 percent of baseline level in tier-2 and tier-3 cities, respectively. This suggests that the existing frictions favor the new migrants at the cost of incumbent residents. When we look into the two sub-periods, in the global financial crisis (2008-09), removing frictions worsens the welfare of both incumbent owners and migrants in tier-1 cities (-0.037% and -0.032%) suggesting the existing policies in tier-1 cities are likely welfare-enhancing. During the normal economic phase (2012-13), removing frictions benefits incumbent residents whereas worsens the welfare of new migrants in all three city tiers with a welfare gain within the urban area equivalent to 0.305 percent of the baseline level. Thus, policies causing frictions in tier-1 cities aimed at cooling down the housing market need not be effective because they are potentially harmful to incumbent residents. Similarly, policies often implemented in the tier-2 and tier-3 cities that are designed to encourage migration and thus balance the regional development may also be undesirable from the perspective of the incumbent residents.[19]

Table 8: Average welfare change among the different subgroups of individuals

Variable	2007-2013	2008-2009	2012-2013
National	-0.072	-0.090	-0.228
Rural	0.002	0.025	0.030
Urban all	0.250	0.255	0.305
Urban owner	0.222	0.242	0.248
Urban buyer	0.852	0.663	1.612
Tier-1 all	-0.015	-0.039	0.006
Tier-1 owner	-0.012	-0.037	0.012
Tier-1 buyer	-0.015	-0.032	-0.004
Tier-2 all	0.109	0.103	0.122
Tier-2 owner	0.113	0.105	0.126
Tier-2 buyer	-0.019	-0.037	-0.009
Tier-3 all	0.147	0.141	0.162
Tier-3 owner	0.155	0.151	0.167
Tier-3 buyer	-0.021	-0.037	-0.011

Notes: We report the percentage change in welfare from benchmark levels when we remove both frictions for different groups of individuals. We focus on the changes in the average welfare both during the entire sample period, and during the two sub-periods: 2008-2009 and 2012-2013. The numbers in the table are in the unit of the percentage points.

To explain the welfare loss at the national level, the average welfare among a subgroup of individuals can be generally expressed as: $W_t = \frac{W_t^1 \mu_t^1 + W_t^2 \mu_t^2}{\mu_t^1 + \mu_t^2}$, where the subgroup index 1 and 2 may represent urban and rural, respectively, or incumbent residents and new migrants, respectively. The ratio of the average welfare in the counterfactual (label with "Tilda") to that in the benchmark economy can be expressed as: $\frac{\tilde{W}_t}{W_t} = \frac{s_t^1 \tilde{W}_t^1 + s_t^2 \tilde{W}_t^2}{s_t^1 W_t^1 + s_t^2 W_t^2}$, where $s_t^i = \frac{\mu_t^i}{\mu_t^1 + \mu_t^2}$ is the population share of type i individuals in the subgroup. The above expression can be further arranged into: $\frac{\tilde{W}_t}{W_t} = \frac{\tilde{W}_t^1}{W_t^1} \frac{\tilde{s}_t^1}{s_t^1} \Omega_t + \frac{\tilde{W}_t^2}{W_t^2} \frac{\tilde{s}_t^2}{s_t^2} (1 - \Omega_t)$, in which $\Omega_t = \frac{s_t^1 W_t^1}{s_t^1 W_t^1 + s_t^2 W_t^2}$. By

[19]The same exercise as in Table 8 is conducted in Appendix F Table F.5 using housing and land market frictions estimated from tier-specific housing production function. The results remain qualitatively similar.

using "hat" notation, $\hat{W}_t = \frac{\tilde{W}_t}{W_t} - 1$ represents the percentage change from the benchmark economy and the above expression becomes:

$$\hat{W}_t = \underbrace{\hat{s}_t^1 \Omega_t}_{\text{type 1 extensive margin}} + \underbrace{\hat{W}_t^1 \Omega_t}_{\text{type 1 intensive margin}} + \underbrace{\hat{s}_t^2 (1 - \Omega_t)}_{\text{type 2 extensive margin}} + \underbrace{\hat{W}_t^2 (1 - \Omega_t)}_{\text{type 2 intensive margin}} + \underbrace{\hat{W}_t^1 \hat{s}_t^1 \Omega_t + \hat{W}_t^2 \hat{s}_t^2 (1 - \Omega_t)}_{\text{residual}}. \tag{25}$$

Specifically, equation (25) suggests that changes in both the population composition and the welfare level of each type of individual affect the welfare gain/loss. In addition to the interactive term, there are (i) an *extensive margin effect* due to population composition changes, and (ii) an *intensive margin welfare level effect* measured by the change in the welfare of each subgroup. When the welfare among both urban and rural residents rises, the sum of the two intensive margin effects is positive but the extensive margin effect can be negative. This thus explains why the average welfare at the national level declines as in a frictionless economy – in this case, more individuals stay in the rural area while the welfare level among rural individuals is on average lower than those in the urban area. In Table E.15 we conduct a decomposition analysis to quantify the contribution to the observed welfare change at the national level, and a brief summary can be found in Table 9 below. Overall, rural-urban population shifts as a consequence of migration are solely responsible for the average welfare reduction, whereas direct welfare changes holding population share constant (resulting from the two intensive margin effects) contribute to mitigating the welfare reduction by 119%. That is, eliminating distortions generates a positive direct welfare effect but a larger negative spatial labor reallocation effect.

For similar reasons explained above, the average welfare among all migrants increases despite the reduction in the average welfare among migrants in each city tier. This is because more migrants are settling down in tier-1 cities in the counterfactual economy, while the welfare in tier-1 cities is the highest among the three city tiers. Within urban areas, incumbent residents' welfare changes account for about 90% of welfare enhancement, thus reconfirming the policy effectiveness arguments discussed above. Within the urban area, incumbent residents' welfare changes are the major driver, enhancing average welfare,

Table 9: Welfare decomposition

	Extensive	Intensive	Total
Urban	-187.1	119.0	-68.1
Urban owner	17.4	89.0	106.5
Urban buyer	-17.3	11.2	-6.1
Rural	37.8	9.3	47.1

Notes: "Extensive margin" refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. "Intensive margin" refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25. Each number in the table is a simple average of the value during 2007-2013.

while the changes in the migrants' welfare also play a non-negligible role. In Table E.16-E.18, we have also reported the decomposition results within each city tier. Incumbent residents' welfare changes take the lion's share again, leading to welfare reduction, while the contribution of the two extensive margins tends to offset each other.

Following the convention in the misallocation literature, we also need a measure of productivity and aggregate efficiency. However, note that we cannot use TFPR/TFPQ measures in Hsieh and Klenow (2009)—doing so gives housing productivity measures rather than composite goods productivity that is more relevant to the macroeconomy.[20] Therefore, it is more appropriate to measure labor productivity and aggregate performance of the macroeconomy by per-capita GDP. Specifically, GDP in the urban area is measured as the sum of the value of the composite goods and houses; one may then back out the rural GDP using consumption equivalence units by assuming zero value of houses there. We have also performed a similar decomposition exercise with respect to per-capita GDP at both the national and urban-level. The results are reported in Table E.19 and E.20. The improvement of per-capita GDP in the urban area serves as the major driver of the changes in the per-capita-GDP at the national level contributing to more than 95%, and changes in the rural population share (4.5%) slightly offset the negative contribution (-24.5%) on changes in per-capita GDP exerted by changes in the urban population share. Within the urban area, expanding population size in the tier-1 city greatly contributes (226.9%) to the changes in the per-capita GDP in the urban area. While changes in both extensive and

[20]The accounting exercise of our benchmark economy also suggests the value of the composite goods takes up about 94% percent of the GDP.

intensive margins in tier-2 (tier-3) cities negatively (positively) contribute to the overall changes in the per-capita GDP in the urban area.

5.6 On Cross-City Variations

To examine the distributional impacts of frictions, we report the coefficient of variation (CV) of housing and land prices in the calibrated model economy as well as under each counterfactual experiment in Table in Table E.21 and E.22. As shown in Table E.21, in the calibrated model economy, the CV of housing prices is, on average, 0.70, whereas that of land prices is 2.11. That is, land prices under our baseline setting are much more dispersed across cities compared to housing prices. In the data, the CVs of housing and land prices are 0.64 and 1.76, respectively. Thus, our model can predict almost perfectly spatial variations in housing prices and over-predict the dispersion in land prices by only about 25 percent. While our model fits well with the data, the moderate over-prediction for land price dispersion is not surprising, because many city-level institutional factors involved in pinning down local land sales in practice may not meet the fundamentals of the local economy. To understand how the spatial variations are connected to the two frictions, we source to counterfactual analysis.

When both frictions are eliminated, about one-third of the dispersion of housing prices is removed in comparison with the baseline scenario. The counterfactual analysis by eliminating each friction one by one indicates that the mitigation of housing price dispersion is almost all due to the removal of housing frictions–the spatial difference of housing frictions is largely the sole driver of housing price dispersion. Because housing frictions are not as large, housing price dispersion is more moderate. Because housing frictions do not change much over time, housing price dispersion is more persistent. By contrast, the elimination of either friction widens the dispersion of land prices, which together induce a much larger deviation between the frictionless economy and the calibrated model economy.

Our analysis suggests eliminating housing distortion lowers housing prices but raises land price dispersion dramatically across cities. On the contrary, eliminating land distortion has an overall negligible effect on housing price dispersion and raises land price dispersion only moderately. Comparing the baseline with the only-land column reveals that the presence of negative housing distortion is crucial for higher housing price dispersion and lower land price dispersion. On the contrary, comparing baseline with only-housing column indicates that the presence of positive land distortion is moderately relevant only for suppressing land price dispersion. This reconfirms the amplification of housing distortion in influencing the dispersion of housing and land prices in dynamic spatial equilibrium.

Finally, the last two columns of Table E.21 and E.22 show that when the frictions follow either tier-1's or the overall distribution, housing prices become less dispersed than the baseline level. The reduction is almost equivalent to the magnitude in the frictionless economy. In contrast, when frictions follow the overall distribution, land prices become more dispersed in most years(except in the year 2010). As for the dispersion of both welfare and per-capita GDP, the results in Table E.23 and E.24 show that frictions exert little effect on both.

Table 10: City-level Results

	Baseline	Frictionless			No Labor Wedge	Alt. Benchmarking Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
Housing prices	0.70	0.45	0.47	0.70	0.75	0.47	0.45
Land Prices	2.11	2.48	2.24	2.36	2.02	2.14	2.45
Welfare	0.06	0.06	0.06	0.06	0.04	0.06	0.06
Per-capita GDP	0.33	0.33	0.33	0.33	0.38	0.33	0.36

Notes: We measure the dispersion of each variable across cities using the coefficient of variation and report the value in each experiment.

6 Concluding Remarks

This paper has examined how housing and land market frictions affect the growth of housing and land prices and the spatial distribution of both prices. We have estimated the city-specific housing and land frictions among a set of national and prefectural Chinese cities. We have shown that both frictions vary systematically across cities. The counterfactual results suggest that if all the frictions are removed, housing prices would be higher, land prices do not deviate much, and average national welfare would be higher.

A natural extension is to conduct a normative analysis to assess efficiency losses attributed to the spatial misallocation along the lines explored by Hsieh and Klenow (2009). We would like to warn the reader that performing such a task is non-trivial. Because of dynamic responses of migration to changes in the wedges, an efficient allocation may not be obtained by merely eliminating the dispersion in marginal revenue products in a static setting, as typically done in the misallocation literature. Moreover, due to the government's household mobility restrictions, our study has been focused on the interplay between labor markets and housing markets across space. One may inquire whether capital markets may also play a role because they are likely to function better in larger cities. Yet, this would require the collection of location-specific bank loans and credit market data over the sample period and is beyond the scope of the current study.

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Appendix

(For Online Publication)

A Institutional Background

For a typical private housing project in China, the development process includes the following steps. In most cases, the development process starts with the transfer of land use rights (LURs) of a residential land parcel from the local government to the developer in the residential land market. Although local governments in China still retain ultimate ownership of all urban lands on behalf of the State, enterprises (e.g., housing developers) have been allowed to purchase 70-year LURs for residential land parcels since the Constitutional Amendment in 1988. In the transfer of LURs associated with a land parcel from the local government to the developer, the developer makes an initial lump-sum payment, including the present values of the land parcel's future rental payments. This lump-sum payment is commonly viewed as the transaction price of the land parcel. Theoretically, the transaction price is determined in a public auction/bidding process with free competition between different developers. The buyer (developer) also needs to pay the deed tax equal to 3% of the total price of the land parcel, and the tax rate does not vary with city or time during our sample period. After purchasing a residential land parcel, the developer will hire professional contractors to plan, design, and build residential housing units on the parcel, which typically takes two to three years, and then sell the completed dwelling units to household buyers. The transaction prices of dwelling units are determined by local housing market conditions.

Because land is the key input of housing production, frictions that affect the housing market will undoubtedly affect the land market. General housing and land market frictions include the government's intervention policies such as strict housing-market cooling measures in major cities with the purpose of curbing housing price surges. By contrast, explicit subsidies to housing developers are prevalent in small cities, especially during the stimulus period (late 2008 to mid-2010) and the "destocking" campaign (2015-2016), such as the relaxation of hukou restriction in those tier-3 or tier-4 cities. Besides the government's intervention policies, during recent decades, almost all the Chinese cities have been experiencing continuous urban amenity improvement. The effects of all the expected urban amenity improvements during the development process, which typically takes two or three years, should be considered and reflected in housing and land prices.

Several frictions only affect the land market, for example, the establishment of the public land auction/bidding process since 2002. This new arrangement substantially enhanced the competition in the urban residential land market. Besides the legal factors, corruption in the land markets can also be considered as frictions. Some developers can illegally benefit from bribing corrupted local chiefs. Most such briberies are aimed at lowering the acquisition costs of land purchases (Chen and Kung(2018)).

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B Solving Housing Developer's Optimization Problem

Housing developer's maximization problem is:

$$\max_{z,I} \ (1-\tau_h)\, pA_h\, (z-\underline{z})^{\gamma}\, I^{\alpha} - (1+\tau_z)\, qz - p_I I.$$

F.O.C wrt z gives:

$$\gamma\,(1-\tau_h)\, pA_h\, (z-\underline{z})^{\gamma-1}\, I^{\alpha} = (1+\tau_z)\, q. \tag{26}$$

FOC wrt I gives:

$$\alpha\,(1-\tau_h)\, pA_h\, (z-\underline{z})^{\gamma}\, I^{\alpha-1} = p_I. \tag{27}$$

From equation (26), we can solve

$$z-\underline{z} = \left[\frac{(1+\tau_z)\, q}{\gamma\,(1-\tau_h)\, pA_h I^{\alpha}}\right]^{\frac{1}{\gamma-1}}.$$

If $\underline{z} = \zeta z$, then

$$z = \frac{1}{1-\zeta}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_h I^\alpha}\right]^{\frac{1}{\gamma-1}}. \tag{28}$$

From equation (27), we can solve

$$I = \left[\frac{p_I}{\alpha\,(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma}\right]^{\frac{1}{\alpha-1}}. \tag{29}$$

The profit can thus be expressed as:

$$\begin{aligned}
& (1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha - (1+\tau_z)\,qz - p_I I, \\
= \; & (1-\alpha)\,(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha - (1+\tau_z)\,qz, \\
= \; & (1-\alpha)\,(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha - (1+\tau_z)\,q\,(z-\underline{z})\,\frac{z}{z-\underline{z}}, \\
= \; & (1-\alpha)\,(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha - \gamma\,(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha\frac{z}{z-\underline{z}}, \\
= \; & (1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha\left[1-\alpha-\gamma\frac{z}{z-\underline{z}}\right], \\
= \; & (1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right].
\end{aligned}$$

Free entry condition thus implies:

$$(1-\tau_h)\,pA_h\,(z-\underline{z})^\gamma\,I^\alpha\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right] = \Psi. \tag{30}$$

In addition, we have land market clearing condition:

$$sz = \ell \tag{31}$$

Housing market clearing condition:

$$sA_h\,(z-\underline{z})^\gamma\,I^\alpha = \Delta\epsilon + N_{-1}\delta_h \tag{32}$$

Taking the ratio of equation (30) and equation (32) gives:

$$\frac{(1-\tau_h)\,p\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}{s}=\frac{\Psi}{\Delta\epsilon+N_{-1}\delta_h}. \tag{33}$$

Taking the ratio of equation (31) and equation (32) gives:

$$\begin{aligned}\frac{A_h\left(z-\underline{z}\right)^{\gamma}I^{\alpha}}{z} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\ A_h\left(1-\zeta\right)^{\gamma}z^{\gamma-1}I^{\alpha} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell}.\end{aligned}$$

Substitute equation (29) and equation (28) into above:

$$\begin{aligned}A_h\left(1-\zeta\right)^{\gamma}\left[\frac{1}{1-\zeta}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_hI^{\alpha}}\right]^{\frac{1}{\gamma-1}}\right]^{\gamma-1}\left[\frac{p_I}{\alpha\,(1-\tau_h)\,pA_h\left(z-\underline{z}\right)^{\gamma}}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\ A_h\left(1-\zeta\right)\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_hI^{\alpha}}\right]\left[\frac{p_I}{\alpha\,(1-\tau_h)\,pA_h\left[z\left(1-\zeta\right)\right]^{\gamma}}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\ A_h\left(1-\zeta\right)\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_hI^{\alpha}}\right]\left[\frac{p_I}{\alpha\,(1-\tau_h)\,pA_h\left[\frac{(1+\tau_z)q}{\gamma(1-\tau_h)pA_hI^{\alpha}}\right]^{\frac{\gamma}{\gamma-1}}}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\ A_h\left(1-\zeta\right)\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_hI^{\alpha}}\right]^{1-\frac{\gamma}{\gamma-1}\frac{\alpha}{\alpha-1}}p^{\frac{\alpha}{1-\alpha}}\left[\frac{p_I}{\alpha\,(1-\tau_h)\,A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell}.\end{aligned}$$

In addition, substitute equation 28 into the land market clearing condition(equation 31):

$$\frac{s}{1-\zeta}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_hI^{\alpha}}\right]^{\frac{1}{\gamma-1}}=\ell. \tag{34}$$

Combining the previous two equations gives:

$$\begin{aligned}
A_h(1-\zeta)\left[\frac{\ell(1-\zeta)}{s}\right]^{\left(1-\frac{\gamma}{\gamma-1}\frac{\alpha}{\alpha-1}\right)(\gamma-1)} p^{\frac{\alpha}{1-\alpha}}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)\left[\frac{\ell(1-\zeta)}{s}\right]^{\left(\gamma-1-\gamma\frac{\alpha}{\alpha-1}\right)} p^{\frac{\alpha}{1-\alpha}}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)\left[\frac{\ell(1-\zeta)}{s}\right]^{\left(\frac{\gamma}{1-\alpha}-1\right)} p^{\frac{\alpha}{1-\alpha}}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)\left[\frac{\ell(1-\zeta)p}{s}\right]^{\left(\frac{\gamma}{1-\alpha}-1\right)} p^{\left(1-\frac{\gamma}{1-\alpha}\right)}p^{\frac{\alpha}{1-\alpha}}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)\left[\frac{\ell(1-\zeta)p}{s}\right]^{\left(\frac{\gamma}{1-\alpha}-1\right)} p^{\left(1-\frac{\gamma}{1-\alpha}+\frac{\alpha}{1-\alpha}\right)}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)\left[\ell(1-\zeta)\right]^{\left(\frac{\gamma}{1-\alpha}-1\right)}\left(\frac{p}{s}\right)^{\left(\frac{\gamma}{1-\alpha}-1\right)} p^{\left(1-\frac{\gamma}{1-\alpha}+\frac{\alpha}{1-\alpha}\right)}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell}.
\end{aligned}$$

Together with equation (34) we have:

$$\begin{aligned}
A_h(1-\zeta)\left[\ell(1-\zeta)\right]^{\left(\frac{\gamma}{1-\alpha}-1\right)}\Theta p^{\left(1-\frac{\gamma}{1-\alpha}+\frac{\alpha}{1-\alpha}\right)}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell},\\
A_h(1-\zeta)^{\frac{\gamma}{1-\alpha}}\Theta p^{\frac{1-\gamma}{1-\alpha}}\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{\alpha-1}} &= \frac{\Delta\epsilon+N_{-1}\delta_h}{\ell}.
\end{aligned}$$

In above, we denote

$$\Theta=\left(\frac{\Psi}{\Delta\epsilon+N_{-1}\delta_h}\frac{1}{(1-\tau_h)\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}\right)^{\left(\frac{\gamma}{1-\alpha}-1\right)}.$$

Therefore,

$$\begin{aligned}
A_h^{\frac{1-\alpha}{\gamma-1}}(1-\zeta)^{\frac{\gamma}{\gamma-1}}\Theta\left[\frac{p_I}{\alpha(1-\tau_h)A_h}\right]^{\frac{\alpha}{1-\gamma}}\left(\frac{\ell}{\Delta\epsilon+N_{-1}\delta_h}\right)^{\frac{1-\alpha}{\gamma-1}} &= p\\
A_h^{\frac{1-\alpha}{\gamma-1}}(1-\zeta)^{\frac{\gamma}{\gamma-1}}\left(\frac{\Psi}{\Delta\epsilon+N_{-1}\delta_h}\frac{\ell}{\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}\right)^{\frac{\gamma-1+\alpha}{\gamma-1}}\left[\frac{p_I}{\alpha A_h}\right]^{\frac{\alpha}{1-\gamma}}\left(\frac{\ell}{\Delta\epsilon+N_{-1}\delta_h}\right)^{\frac{1-\alpha}{\gamma-1}} &= p(1-\tau_h)
\end{aligned}$$

Finally, q can then be solved by combining the land market clearing condition(equation 31 with the free entry condition(equation 30):

$$
\begin{aligned}
pA_h I^{\alpha} &= \frac{\Psi}{(1-\tau_h)\,(z-\underline{z})^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}, \\
&= \frac{\Psi}{(1-\tau_h)\,(z\,(1-\zeta))^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}, \\
&= \frac{\Psi}{(1-\tau_h)\left(\frac{\ell}{s}\,(1-\zeta)\right)^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}.
\end{aligned}
$$

Plugging above into equation (34):

$$
\frac{s}{1-\zeta}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)\,pA_h I^{\alpha}}\right]^{\frac{1}{\gamma-1}} = \ell,
$$

$$
\frac{s}{1-\zeta}\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)}\right]^{\frac{1}{\gamma-1}}\left[\frac{\Psi}{(1-\tau_h)\left(\frac{\ell}{s}\,(1-\zeta)\right)^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}\right]^{\frac{1}{1-\gamma}} = \ell,
$$

$$
\left[\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)}\right] = \left[\ell\frac{1-\zeta}{s}\right]^{\gamma-1}\left[\frac{(1-\tau_h)\left(\frac{\ell}{s}\,(1-\zeta)\right)^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}{\Psi}\right]^{-1},
$$

$$
\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)} = [\ell\,(1-\zeta)]^{\gamma-1}\left[\frac{(1-\tau_h)\,(\ell\,(1-\zeta))^{\gamma}\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}{\Psi}\right]^{-1} s
$$

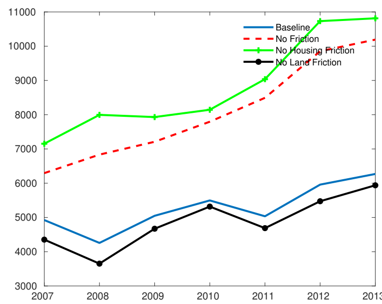
Finally, plugging equation (33) to replace s in above:

$$
\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)} = [\ell\,(1-\zeta)]^{-1}\left[\frac{(1-\tau_h)\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]}{\Psi}\right]^{-1}(1-\tau_h)\,p\left[1-\alpha-\gamma\frac{1}{1-\zeta}\right]\frac{\Delta\epsilon+N_{-1}\delta_h}{\Psi},
$$

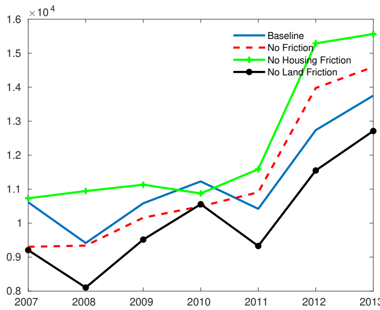
$$
\frac{(1+\tau_z)\,q}{\gamma\,(1-\tau_h)} = [\ell\,(1-\zeta)]^{-1}\,p(N_{-1}\delta_h+\Delta\epsilon).
$$

Housing-land price ratio is thus:

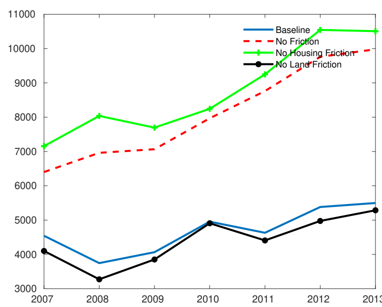
$$
\frac{(1+\tau_z)\,q}{(1-\tau_h)\,p} = \frac{\gamma(\Delta\epsilon+N_{-1}\delta_h)}{\ell\,(1-\zeta)}
$$



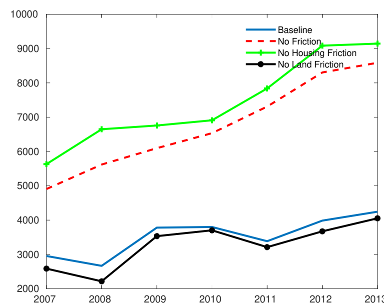
(a) Aggregate housing price



(b) Tier-1 housing price

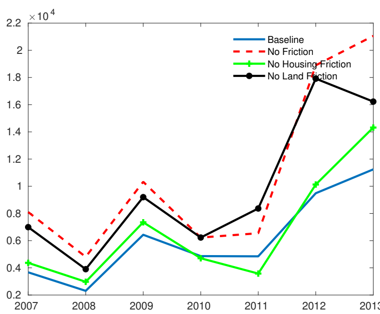


(c) Tier-2 housing price

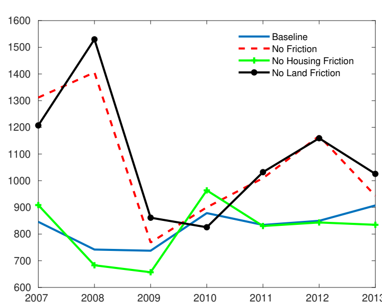


(d) Tier-3 housing price

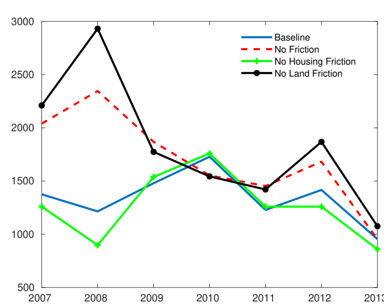
(e) Aggregate land price



(f) Tier-1 land price



(g) Tier-2 land price



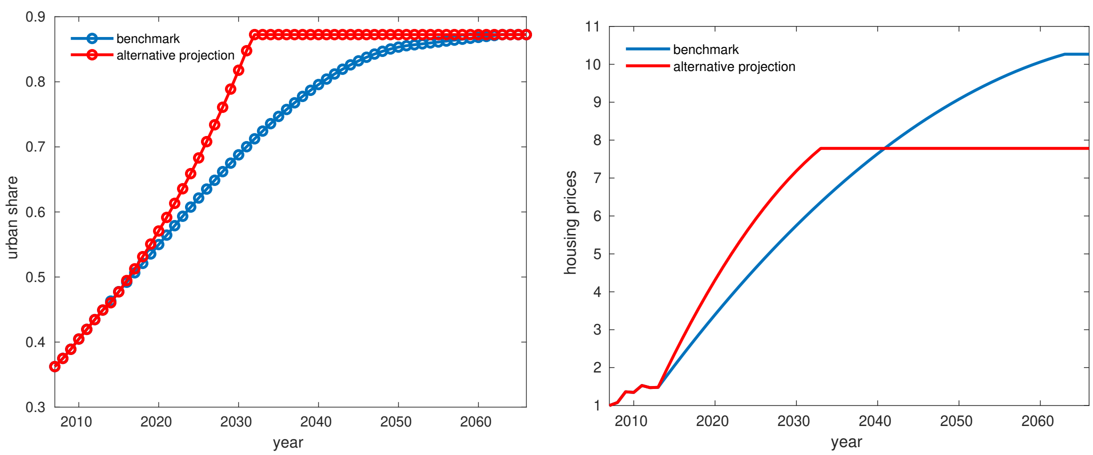
(h) Tier-3 land price

Figure 3: Eliminate either or both frictions: Housing and Land Prices

Notes: We eliminate either one or both types of frictions and report housing prices at the tier-level. The prices at the tier-level is a population-weighted average of the prices in each city.

C Alternative Population Projection

The baseline economy assumes structural transformation will be complete in the year 2063, and the urban population share shall reach 88 percent by then. In this section, we undertake a much more optimistic population projection by assuming that the urban population share will reach 88 percent by the year 2033. The evolution of the urban population under both projections is depicted in the left panel of Figure C.1. In the right panel, we plot the evolution of housing prices under both projections. The results suggest that housing price dynamics during 2007-2013 do not differ much from each other, nevertheless, the baseline housing price in the final steady-state is about 1.3 times of that under the alternative population projection.



(a) Population

(b) Housing Prices

Figure C.1: Housing Price Evolution under Alternative Population Projection

D Computation Algorithm

- Take the year 2006 as the initial steady-state, in which the incumbent residents of each city only spend on housing depreciation, and there are no outstanding mortgage balances. We calibrate $\underline{\epsilon}$ to match the initial urban population share. Normalize the initial migration scale in the tier-1 city to be 1, and calibrate χ_{21} and χ_{31} to match the population distribution among the three tiers.

- Assume the year 2063 is the last year migration will take place. Starting from the year 2064, there are no time-varying parameters, and the migration scale parameters will be set to be a sufficiently large number so that no one will migrate from the rural area. Therefore, the year 2064 can be considered as the final steady-state.

- Along the transition path, workers are assumed to be perfectly foresighted. We calibrate the path of migration scale $\{\chi_{1t}, \chi_{2t}, \chi_{3t}\}$ to match the population distribution between rural and urban, as well as within the urban area. Note that in order to preserve the property that each period workers with the least migration dis-utility flow to the tier-1 city and the highest migration dis-utility flow to tier-3 city, $V_{1t}^M > V_{2t}^M > V_{3t}^M$ needs to be preserved. (This actually imposes some restrictions on our projection of A_{jt}^m...).

- In all the counterfactual analyses, we no longer impose the condition $V_{1t}^M > V_{2t}^M > V_{3t}^M$. Given all the exogenous time series, we proceed as follows:

  step 1 Guess the path of land supply and wage rates of each city.

  step 2 Guess a path of housing prices $\{p_{jt}\}$ across cities over time. Given the series of housing prices, we solve for the value function among incumbent owners, new migrants, and rural workers of each city in a backward fashion.

  step 3 Given the value function, we solve for worker's migration decision from the initial period forward. Specifically, we simulate a large number of individuals(99991) with different migration dis-utility over the interval $[\underline{\epsilon}, \bar{\epsilon}]$. For each ϵ, we record the individual's optimal location and labor supply based upon the value function computed in step 2.

step 4 We then summarize the housing demand of each city based on the population distribution obtained from step 3. We can then update the housing price.

step 5 Repeat from step 2 to step 4 if the updated housing prices are not sufficiently close to the initial guess of housing prices, by changing the guess into a convex combination between the guess and new housing price.

step 6 Aggregate the labor supply computed from step 3, and update the wage rate using a convex combination between the guess and labor supply implied wage rate.

step 7 Repeat from step 2 to step 6 till wage converges.

step 8 Update the land supply using the housing-to-land price ratio and the government's foc. Repeat from step 2 to step 7 if the updated land supply is not sufficiently close to the initial guess of land supply, by changing the guess into a convex combination between the guess and new land supply.

E Tables and Figures

Table E.1: The Estimation of Land Share and Construction-material Share

LHS = log(housingsales)	(OLS)	(2SLS IV)	(LIML IV)
log(landsales)	0.042**	0.201**	0.217**
	(0.018)	(0.05)	(0.05)
log(structure)	0.417***	0.369***	0.356***
	(0.052)	(0.09)	(0.08)
N	651	558	558
R-squared	0.952	0.952	0.931
First stage F-stat		23.3	23.3
Cragg-Donald Wald F-stat		22.1	22.1
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes

Notes: Standard errors clustered at the city level are reported in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table E.2: Summary Statistics for Housing and Land Prices

(a) Housing Prices

year	Mean	Sd	P10	P25	Median	P75	P90
2007	3540	2228	1683	2011	2827	3879	6022
2008	3655	2208	1833	2173	3058	4085	5780
2009	4338	2764	2248	2636	3542	4709	7182
2010	5065	3480	2394	2881	3928	5552	9227
2011	5251	3198	2751	3247	4194	6181	9116
2012	5293	3028	2884	3380	4330	5940	9882
2013	5584	3261	3144	3634	4417	6239	9965
Total	4675	3006	2173	2836	3754	5288	8412

(b) Land Prices

year	Mean	Sd	P10	P25	Median	P75	P90
2007	891	995	210	319	512	1074	1867
2008	860	1119	208	297	458	906	1801
2009	1002	1151	180	343	582	1032	2701
2010	1180	1377	287	453	673	1240	3196
2011	1074	1080	335	468	694	1233	2428
2012	1035	972	340	495	688	1196	1924
2013	1367	1718	356	510	778	1464	2964
Total	1058	1232	261	381	648	1158	2520

Source: Hang Lung Center for Real Estate at Tsinghua University. The unit is in yuan per square meter of floor area.

Table E.3: Frictions in Tier-1 Cities

(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	-0.00	0.18	-0.14	-0.05	0.13
2008	-0.39	0.13	-0.48	-0.39	-0.30
2009	0.25	0.18	0.13	0.29	0.37
2010	-0.08	0.02	-0.09	-0.08	-0.07
2011	-0.45	0.39	-0.69	-0.61	-0.21
2012	-0.32	0.19	-0.48	-0.32	-0.16
2013	-0.17	0.09	-0.22	-0.16	-0.11
Total	-0.17	0.29	-0.39	-0.15	-0.03

(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	1.77	1.37	0.89	1.38	2.66
2008	2.21	2.41	0.68	1.50	3.74
2009	0.43	0.65	-0.07	0.47	0.92
2010	0.46	0.97	-0.17	0.23	1.10
2011	1.11	1.78	-0.07	0.46	2.28
2012	1.03	0.93	0.24	0.99	1.83
2013	0.30	0.60	-0.18	0.16	0.77
Total	1.04	1.40	0.12	0.65	1.62

Notes: This table reports the summary statistics for the estimated frictions among the four tier-1 Chinese cities. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.

Table E.4: Frictions in Tier-2 Cities

(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	-0.78	0.79	-1.46	-0.54	-0.25
2008	-1.66	0.98	-2.34	-1.55	-0.82
2009	-0.90	1.09	-1.32	-0.63	-0.17
2010	-0.85	1.01	-1.28	-0.70	-0.32
2011	-1.15	0.59	-1.33	-1.00	-0.76
2012	-1.16	0.83	-1.40	-1.07	-0.67
2013	-1.13	0.83	-1.38	-0.97	-0.62
Total	-1.09	0.91	-1.43	-0.94	-0.47

(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	2.00	2.62	0.27	1.39	2.13
2008	2.46	2.29	0.90	1.66	3.06
2009	0.91	1.38	-0.15	0.67	1.67
2010	0.39	1.11	-0.32	-0.07	1.08
2011	0.76	1.55	-0.19	-0.01	1.09
2012	0.84	0.80	0.29	0.59	1.25
2013	0.54	1.04	-0.19	0.13	1.12
Total	1.13	1.79	-0.07	0.69	1.66

Notes: This table reports the summary statistics for the estimated frictions among the 25 tier-2 Chinese cities in our sample. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.

Table E.5: Frictions in Tier-3 Cities

(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	-1.22	1.17	-1.47	-0.92	-0.57
2008	-1.95	1.17	-2.21	-1.66	-1.16
2009	-1.32	1.20	-1.80	-1.08	-0.55
2010	-1.18	0.95	-1.56	-0.97	-0.46
2011	-1.44	0.93	-1.82	-1.29	-0.78
2012	-1.71	1.35	-2.03	-1.38	-0.90
2013	-1.53	1.01	-1.95	-1.34	-0.88
Total	-1.48	1.14	-1.89	-1.24	-0.78

(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	2.43	2.75	0.72	1.55	2.76
2008	3.96	4.01	1.44	2.42	5.75
2009	1.76	2.08	0.32	1.25	2.67
2010	0.79	1.42	-0.23	0.45	1.32
2011	0.68	1.04	-0.08	0.44	1.07
2012	1.21	1.79	-0.01	0.55	1.74
2013	0.96	1.64	-0.07	0.48	1.56
Total	1.68	2.53	0.11	0.98	2.30

Notes: This table reports the summary statistics for the estimated frictions among the 73 tier-3 Chinese cities in our sample. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.

Table E.6: City size and estimated frictions

	Housing Frictions)			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(GDP)	0.264***	-4.070	0.753	-0.680***	-243.205**	0.832
	(0.078)	(49.032)	(0.483)	(0.140)	(96.670)	(1.109)
Year		-0.082			-1.185***	
		(0.195)			(0.370)	
Ln(GDP) * Year		0.002			0.121**	
		(0.024)			(0.048)	
N	651	651	651	651	651	651
R-squared	0.049	0.059	0.610	0.073	0.133	0.368
Year FE	No	No	Yes	No	No	Yes
City FE	No	No	Yes	No	No	Yes

Notes: The standard errors clustered at the city level are reported in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table E.7: The estimated frictions over time

LHS = Frictions	Housing Frictions			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	-0.019			-0.357***		
	(0.020)			(0.042)		
Year=2008		-0.753***	-0.753***		1.220***	1.220***
		(0.099)	(0.099)		(0.428)	(0.428)
Year=2009		-0.095	-0.095		-0.802***	-0.802***
		(0.077)	(0.077)		(0.302)	(0.302)
Year=2010		0.008	0.008		-1.617***	-1.617***
		(0.087)	(0.087)		(0.256)	(0.256)
Year=2011		-0.272**	-0.272**		-1.579***	-1.579***
		(0.105)	(0.105)		(0.266)	(0.266)
Year=2012		-0.458***	-0.458***		-1.185***	-1.185***
		(0.125)	(0.125)		(0.292)	(0.292)
Year=2013		-0.314***	-0.314***		-1.469***	-1.469***
		(0.107)	(0.107)		(0.279)	(0.279)
N	651	651	651	651	651	651
R-squared	-0.000	0.044	0.609	0.092	0.164	0.370
Year FE	No	Yes	Yes	No	Yes	Yes
City FE	No	No	Yes	No	No	Yes

Notes: The standard errors clustered at the city level are reported in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. The table reports regressions of city-level frictions against a linear time trend or year dummies. The unit of observation is city-year. The frictions are based on the estimation procedure outlined in Section 4.2.

Table E.8: Tier-level Characteristics

Tier	A_m	Entry fee	Amenity	Labor wedge	Mig cost scale	Minimum land
			Initial level			
Tier-1	1802.3	3625.9	10.4	0.57	50.0	0.32
Tier-2	794.1	3565.3	8.2	0.76	49.6	0.24
Tier-3	407.2	915.2	5.9	0.82	49.5	0.23
			Growth factor			
Tier-1	1.8	1.5	1.5	1.0	1.0	1.0
Tier-2	2.3	1.7	1.4	1.1	1.0	1.0
Tier-3	2.5	2.1	1.5	1.0	1.0	1.0

Notes: We report both the initial level and the growth factor during 2007-2013 for production TFP, entry fee, amenity, labor wedge, the scale of migration cost and the minimum land ratio at the tier-level. The tier-level statistics are population-weighted average city-level statistics.

Table E.9: Summary of Results: Housing and Land Prices

	Baseline	Frictionless			No Labor Wedge	Alt. Bench. Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
Panel (a): Housing Prices							
Aggregate							
Ave ratio to bench	1.000	1.528	1.672	0.919	0.987	1.464	1.503
Ave annual growth rate	0.048	0.084	0.074	0.065	0.066	0.073	0.086
Growth factor	1.273	1.619	1.512	1.364	1.398	1.520	1.630
Tier-1							
Ave ratio to bench	1.000	0.996	1.091	0.899	0.850	1.236	1.321
Ave annual growth rate	0.050	0.082	0.069	0.064	0.107	0.089	0.091
Growth factor	1.296	1.569	1.450	1.381	1.784	1.621	1.629
Tier-2							
Ave ratio to bench	1.000	1.733	1.878	0.936	1.024	1.645	1.132
Ave annual growth rate	0.041	0.078	0.068	0.056	0.073	0.078	0.078
Growth factor	1.210	1.559	1.468	1.289	1.436	1.560	1.557
Tier-3							
Ave ratio to bench	1.000	1.909	2.108	0.920	1.098	1.819	1.255
Ave annual growth rate	0.076	0.098	0.087	0.102	0.066	0.095	0.098
Growth factor	1.210	1.559	1.468	1.289	1.436	1.560	1.557
Panel (b): Land Prices							
Aggregate							
Ave ratio to bench	1.000	1.509	0.989	1.518	1.223	1.070	1.188
Ave annual growth rate	0.147	0.149	0.204	0.103	0.054	0.132	0.171
Growth factor	1.786	1.602	1.935	1.430	1.067	1.689	1.631
Tier-1							
Ave ratio to bench	1.000	1.770	1.095	1.624	0.619	1.113	1.354
Ave annual growth rate	0.385	0.400	0.466	0.330	0.403	0.386	0.450
Growth factor	3.064	2.599	3.279	2.320	3.458	3.882	2.692
Tier-2							
Ave ratio to bench	1.000	1.305	0.984	1.333	0.821	1.005	1.004
Ave annual growth rate	0.016	-0.021	0.008	0.008	0.129	-0.015	-0.005
Growth factor	1.073	0.719	0.919	0.850	1.769	0.701	0.712
Tier-3							
Ave ratio to bench	1.000	1.278	0.932	1.388	1.467	1.028	1.030
Ave annual growth rate	-0.032	-0.094	-0.005	-0.065	-0.112	-0.111	-0.100
Growth factor	1.073	0.719	0.919	0.850	1.769	0.701	0.712

Notes: "Ave ratio to bench" denotes the average price ratio of price levels in the counterfactual economy to that in the benchmark economy during 2007-2013. "Ave annual growth rate" is the simple average of annual growth rate of prices in various economies. "Growth factor" is the ratio of the price levels in 2013 to that in 2007.

Table E.10: The Distribution of Housing Frictions

Distribution	p-value	χ stats
	Whole sample	
Gamma	0.00	33.54
loglogistic	0.55	6.86
nakagami	0.00	76.09
rician	0.00	114.67
weibull	0.00	93.73
lognormal	0.09	15.12
	Tier-1	
Gamma	-	1.73
loglogistic	0.23	1.44
nakagami	0.10	4.67
rician	0.07	3.18
weibull	-	3.03
lognormal	-	1.58
	Tier-2	
Gamma	0.03	8.71
loglogistic	0.30	3.63
nakagami	0.00	16.45
rician	0.00	26.96
weibull	0.00	24.70
lognormal	0.18	4.94
	Tier-3	
Gamma	0.00	28.27
loglogistic	0.30	4.85
nakagami	0.00	53.59
rician	0.00	81.23
weibull	0.00	66.40
lognormal	0.01	11.91

Notes: We fit the distribution of housing frictions with a class of well-known parameterized distributions and report both chi-square statistics and p-value to evaluate the fitness of each distribution.

Table E.11: The Distribution of Land Frictions

Distribution	p-value	χ stats
	Whole sample	
Gamma	0.00	36.36
loglogistic	0.57	4.78
nakagami	0.00	84.55
rician	0.00	386.75
weibull	0.00	39.16
lognormal	0.70	4.64
	Tier-1	
Gamma	0.49	0.48
loglogistic	0.39	0.75
nakagami	0.32	0.99
rician	-	1.84
weibull	-	0.28
lognormal	0.54	0.38
	Tier-2	
Gamma	0.25	2.77
loglogistic	0.85	0.34
nakagami	0.01	9.78
rician	0.00	41.19
weibull	0.13	4.01
lognormal	0.87	0.28
	Tier-3	
Gamma	0.00	21.38
loglogistic	0.49	2.43
nakagami	0.00	45.67
rician	0.00	179.32
weibull	0.00	19.01
lognormal	0.50	2.35

Notes: We fit the distribution of land frictions with a class of well-known parameterized distributions and report both chi-square statistics and p-value to evaluate the fitness of each distribution.

Table E.12: The Distribution of Housing and Land Frictions

	Housing Frictions		Land Frictions	
Sample	μ	σ	μ	σ
National	0.746	0.238	0.708	0.780
Tier-1	0.144	0.104	0.623	0.613
Tier-2	0.662	0.230	0.586	0.727
Tier-3	0.809	0.225	0.756	0.809

Notes: The density function for log-logistic distribution follows $f(x|\mu,\sigma) = \frac{1}{\sigma}\frac{1}{x}\frac{e^z}{(1+e^z)^2}$, where $z = \frac{log(x)-\mu}{\sigma}$. The density function for log-normal distribution follows $f(x|\mu,\sigma) = \frac{1}{x\sigma(2\pi)^{1/2}} exp\{\frac{-(\log x-\mu)^2}{2\sigma^2}\}$.

Table E.13: Labor Supply Comparison

Type	Bench	No Friction	No Wedge
Urban buyer	0.348	0.388	0.308
Urban owner	0.300	0.304	0.296
Tier-1 buyer	0.347	0.351	0.000
Tier-1 owner	0.300	0.300	0.297
Tier-2 buyer	0.345	0.386	0.305
Tier-2 owner	0.300	0.303	0.296
Tier-3 buyer	0.350	0.405	0.308
Tier-3 owner	0.300	0.306	0.297

Notes: We report the population-weighted average labor supply among different groups of individuals in both baseline and frictionless economies.

Table E.14: Land supply across regions

	Baseline	Frictionless
Initial population	165.20***	175.05***
	(48.33)	(40.72)
Eastern	-0.00	-0.20
	(0.22)	(0.21)
Middle	0.22	0.13
	(0.17)	(0.18)
Western	0.00	0.00
	(.)	(.)
Northeastern	0.56**	0.58***
	(0.25)	(0.20)
N	93	93
R-squared	0.287	0.331

Notes: We divide China into four regions: Eastern, Middle, Western and Northeastern. In the first column, we regress the average land supply during 2007-2013 against regional dummies while controlling the initial population size in the year 2006. In the second column, we change the dependent variable to the average land supply in the frictionless economy. We choose the western region as the base region. The robust standard error is reported in parentheses. *p<0.10, ** p<0.05, *** p<0.01.

Table E.15: National- and Urban-level Welfare decomposition

National							
Year	Urban(%)			Rural(%)			Residual(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2008	-197.6	-149.3	-346.9	41.0	12.9	53.8	-0.6
2008	-171.8	174.6	2.7	35.2	1.9	37.1	-0.6
2009	-356.7	548.7	192.0	72.4	37.1	109.5	-1.1
2010	-168.0	-292.9	-460.9	33.8	13.4	47.2	-0.5
2011	-117.7	252.6	134.9	23.5	-7.2	16.3	-0.3
2012	-157.7	203.3	45.5	31.2	3.9	35.0	-0.6
2013	-140.1	95.8	-44.3	27.4	3.4	30.8	-0.6
Mean	-187.1	119.0	-68.1	37.8	9.3	47.1	-0.6
Urban							
Year	Owner(%)			Buyer(%)			Residual(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2008	-125.0	61.1	-64.0	123.8	37.9	161.7	2.3
2008	192.1	75.9	267.9	-190.3	25.7	-164.6	-3.4
2009	-47.7	112.4	64.6	47.3	-11.4	35.8	-0.5
2010	-116.9	100.0	-16.9	115.9	1.3	117.1	-0.3
2011	103.4	109.0	212.4	-102.6	-10.8	-113.4	1.0
2012	39.0	80.8	119.7	-38.7	19.4	-19.2	-0.5
2013	77.3	84.2	161.4	-76.7	16.3	-60.4	-1.0
Mean	17.4	89.0	106.5	-17.3	11.2	-6.1	-0.3

Notes: "Extensive margin" refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. "Intensive margin" refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.16: Welfare decomposition: Tier-1

Year	Owner(%)			Buyer(%)			Residual(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2008	136.1	100.0	236.0	-135.8	1.4	-134.4	-1.7
2008	39.5	96.5	135.9	-39.4	3.4	-36.0	0.0
2009	-10.4	97.1	86.6	10.4	2.7	13.2	0.2
2010	-9.8	97.9	88.1	9.8	1.8	11.6	0.2
2011	-835.1	107.4	-727.7	834.1	21.8	855.8	-28.2
2012	-191.8	112.5	-79.2	191.5	-2.8	188.7	-9.5
2013	-343.6	105.2	-238.5	343.2	0.7	343.9	-5.4
Mean	-173.6	100.3	-73.3	173.4	6.2	179.6	-6.3

Notes: "Extensive margin" refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. "Intensive margin" refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.17: Welfare decomposition: Tier-2

Year	Owner(%)			Buyer(%)			Interaction term(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2008	-63.7	101.3	37.6	63.6	-0.5	63.1	-0.7
2008	93.0	100.1	193.1	-92.9	-1.7	-94.5	1.4
2009	119.0	99.3	218.2	-118.8	-1.0	-119.8	1.6
2010	-109.6	101.8	-7.8	109.4	-0.3	109.1	-1.3
2011	-18.8	101.0	82.2	18.8	-0.7	18.1	-0.3
2012	11.0	100.3	111.3	-11.0	-0.5	-11.5	0.2
2013	83.3	98.9	182.2	-83.2	-0.1	-83.3	1.1
Mean	16.3	100.4	116.7	-16.3	-0.7	-17.0	0.3

Notes: "Extensive margin" refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. "Intensive margin" refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.18: Welfare decomposition: Tier-3

Year	Owner(%)			Buyer(%)			Residual(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2008	57.8	98.3	156.1	-57.8	-0.4	-58.2	2.1
2008	62.2	98.4	160.6	-62.2	-0.9	-63.1	2.5
2009	-57.9	102.6	44.7	57.9	-0.4	57.4	-2.2
2010	-1.3	100.2	98.9	1.3	-0.2	1.1	-0.0
2011	-2.1	100.4	98.3	2.1	-0.3	1.7	-0.1
2012	41.2	98.7	139.9	-41.2	-0.3	-41.5	1.6
2013	31.3	98.9	130.2	-31.4	-0.0	-31.4	1.2
Mean	18.8	99.6	118.4	-18.8	-0.4	-19.1	0.7

Notes: “Extensive margin” refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. “Intensive margin” refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.19: Per-capita GDP decomposition: National

Year	Urban(%)			Rural(%)			Residual(%)
	Extensive	Intensive	Total	Extensive	Intensive	Total	
2007	59.3	60.0	119.4	-19.6	0.0	-19.6	0.2
2008	-61.0	143.9	82.9	17.6	0.0	17.6	-0.5
2009	-32.4	123.9	91.5	8.8	0.0	8.8	-0.2
2010	26.2	79.8	106.1	-6.2	0.0	-6.2	0.1
2011	-21.6	117.3	95.7	4.5	0.0	4.5	-0.2
2012	-40.4	133.0	92.6	7.8	0.0	7.8	-0.4
2013	-101.9	184.5	82.6	18.5	0.0	18.5	-1.1
Mean	-24.5	120.3	95.8	4.5	0.0	4.5	-0.3

Notes: per-capita GDP is a population-weighted average of the per-capita GDP in urban and rural areas. GDP in the urban area is measured as the sum of the value of the composite goods and houses. GDP in the rural area is backed out using consumption equivalence units assuming zero value of rural houses. “Extensive margin” refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. “Intensive margin” refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.20: Per-capita GDP decomposition: Urban

Year	Tier-1(%)		Tier-2(%)		Tier-3(%)		Interaction term(%)
	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive	
2007	306.1	30.2	-240.5	-172.1	6.4	182.9	-12.9
2008	239.3	1.3	-177.7	-131.6	30.1	156.9	-18.3
2009	222.9	-73.0	-103.2	-137.3	73.1	132.5	-15.1
2010	278.5	-45.5	-177.3	-181.4	68.7	175.1	-18.1
2011	141.9	-4.9	-112.6	-92.8	41.6	134.5	-7.7
2012	182.4	-3.4	-150.4	-99.2	37.5	147.0	-13.9
2013	217.3	-29.5	-154.5	-116.6	52.2	153.3	-22.2
Mean	226.9	-17.8	-159.5	-133.0	44.2	154.6	-15.5

Notes: GDP in the urban area is measured as the sum of the value of the composite goods and houses. "Extensive margin" refers to the percentage change in the population share of each respective group from benchmark to the frictionless economy. "Intensive margin" refers to the percentage change in the average welfare of each respective group from benchmark to the frictionless economy. More details can be found in Equation 25.

Table E.21: City-level Results: Housing Prices

	Baseline	Frictionless			No Labor Wedge	Alt. Benchmarking Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
2007	0.65	0.47	0.49	0.66	0.56	0.47	0.47
2008	0.65	0.45	0.47	0.65	0.65	0.46	0.45
2009	0.73	0.46	0.50	0.77	0.82	0.48	0.46
2010	0.70	0.45	0.48	0.70	0.73	0.46	0.45
2011	0.73	0.42	0.44	0.69	0.81	0.49	0.43
2012	0.73	0.45	0.46	0.72	0.85	0.48	0.46
2013	0.71	0.46	0.47	0.71	0.82	0.47	0.46
Mean	0.70	0.45	0.47	0.70	0.75	0.47	0.45

Notes: We measure the dispersion of housing prices across cities using the coefficient of variation and report the value in each experiment.

Table E.22: City-level Results: Land Prices

	Baseline	Frictionless			No Labor Wedge	Alt. Benchmarking Dist	
	Baseline	Both	Only Housing	Only Land	No Wedge	Tier-1	National
2007	1.79	1.97	1.94	1.83	1.73	1.49	1.94
2008	1.41	1.66	1.45	1.68	1.68	1.69	1.66
2009	2.45	2.58	2.58	2.45	2.46	2.14	2.26
2010	2.00	1.60	1.96	1.63	2.49	1.48	1.55
2011	1.57	1.84	1.44	2.11	1.55	1.60	1.75
2012	2.60	3.53	2.80	3.32	2.08	2.96	3.77
2013	2.93	4.18	3.49	3.51	2.15	3.65	4.21
Mean	2.11	2.48	2.24	2.36	2.02	2.14	2.45

Notes: We measure the dispersion of land prices across cities using the coefficient of variation and report the value in each experiment.

Table E.23: City-level Results: Welfare

	Baseline	Frictionless			No Labor Wedge	Alt. Benchmarking Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
2007	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2008	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2009	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2010	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2011	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2012	0.06	0.06	0.06	0.06	0.04	0.06	0.06
2013	0.06	0.06	0.06	0.05	0.04	0.06	0.05
Mean	0.06	0.06	0.06	0.06	0.04	0.06	0.06

Notes: We measure the dispersion of housing prices across cities using the coefficient of variation and report the value in each experiment.

Table E.24: City-level Results: Per-capita GDP

	Baseline	Frictionless			No Labor Wedge	Alt. Benchmarking Dist	
	Baseline	Both	No Housing	No Land	No Wedge	Tier-1	National
2007	0.35	0.35	0.35	0.35	0.38	0.35	0.38
2008	0.34	0.34	0.34	0.34	0.39	0.34	0.36
2009	0.33	0.33	0.33	0.33	0.39	0.33	0.38
2010	0.33	0.33	0.32	0.33	0.39	0.33	0.36
2011	0.33	0.33	0.33	0.33	0.37	0.33	0.37
2012	0.32	0.32	0.32	0.32	0.36	0.32	0.36
2013	0.31	0.31	0.31	0.31	0.36	0.31	0.36
Mean	0.33	0.33	0.33	0.33	0.38	0.33	0.36

Notes: We measure the dispersion of housing prices across cities using the coefficient of variation and report the value in each experiment.

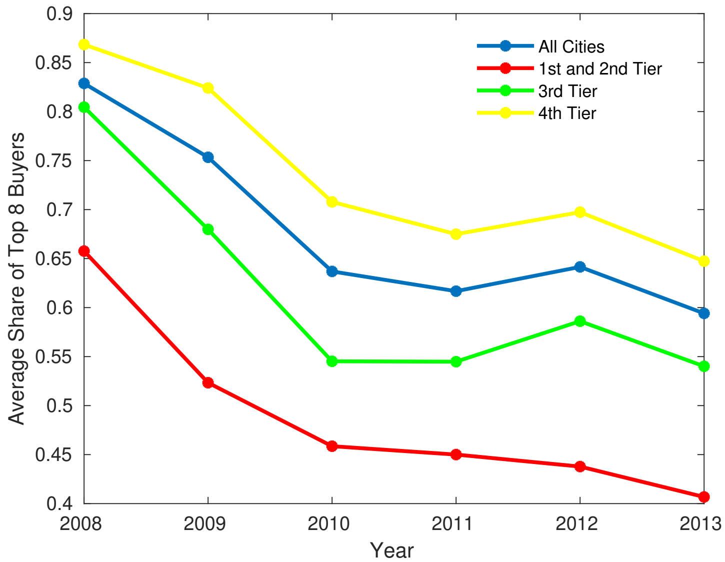


Figure E.1: Average Share of Top 8 Buyers in Local Residential Land Markets

Source: Calculated based on data released by MLR, China

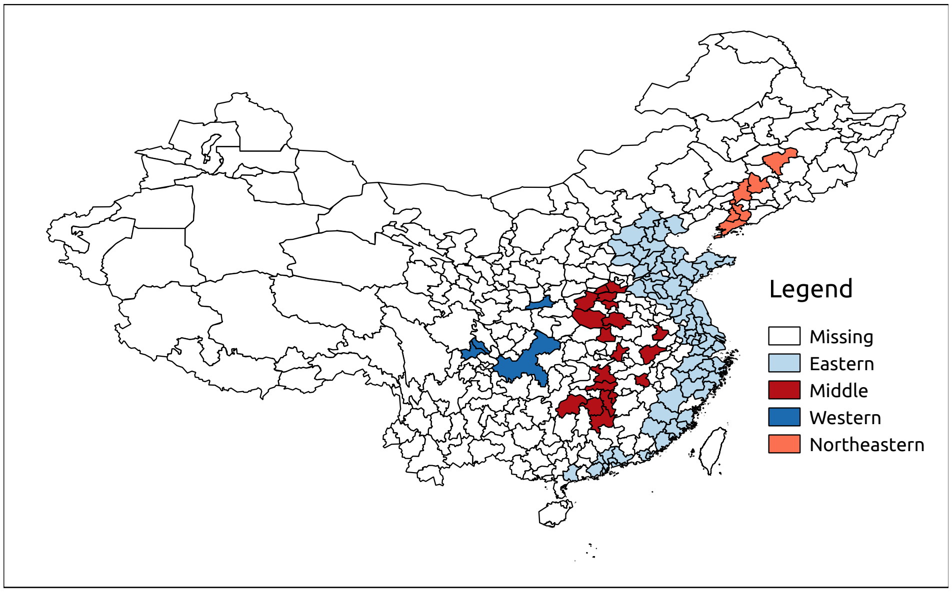
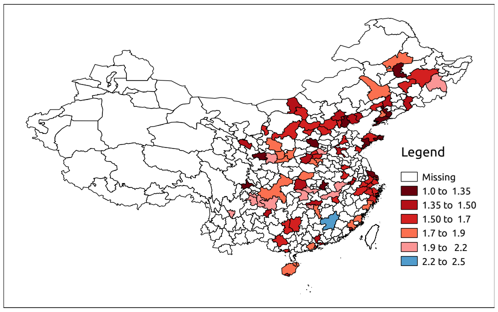
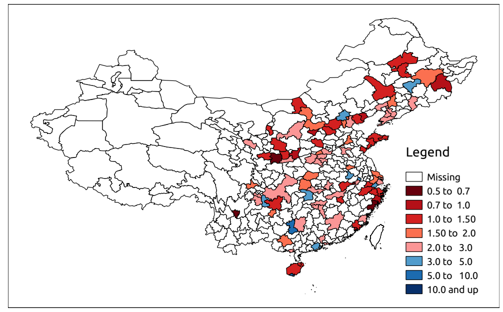


Figure E.2: Selected Sample

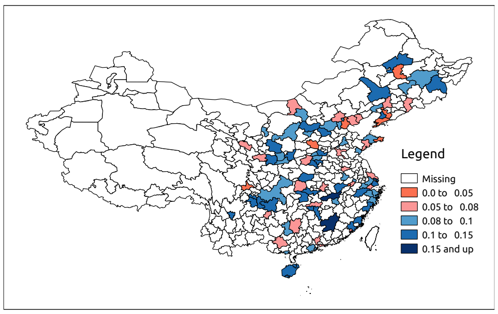
Notes: This graph plots the 93 prefecture-level cities in our sample. All the cities that are included contain the following data information during 2007-2013: (i) Real average price of newly built housing units; (ii) real average price of residential land parcels; (iii) floor area of newly built housing units sold; (iv) investment on housing development (exclude land purchase); (v) residential land sales; and (vi) real unit construction cost.



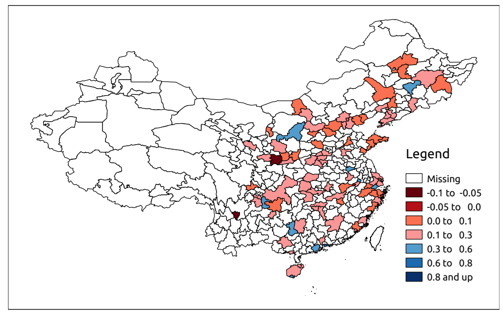
(a) Housing Price Growth Factor



(b) Land Price Growth Factor



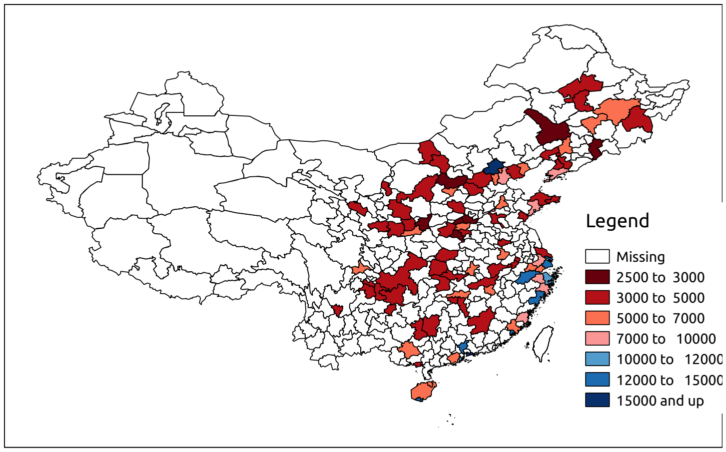
(c) Housing Price Growth Rate



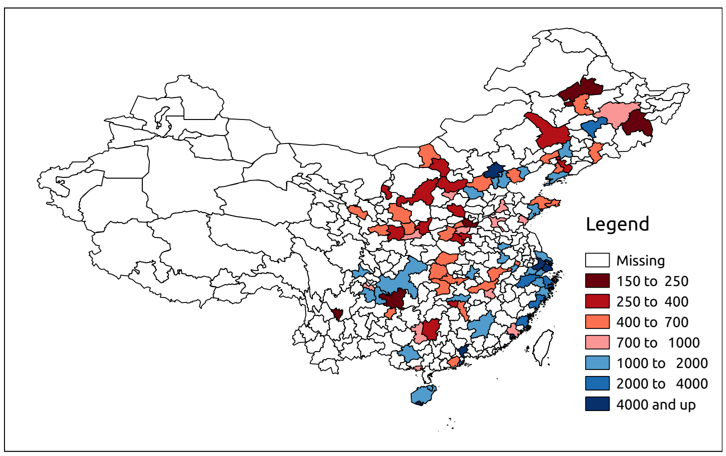
(d) Land Price Growth Rate

Figure E.3: City-level Data

Notes: This table maps some selected statistics on housing and land price growth during 2007-2013 in the data for our selected sample. The growth factor denotes the ratio of price levels from 2013 to 2007. The growth rate is the average annual growth rate during 2007-2013.



(a) Housing Prices



(b) Land Prices

Figure E.4: Price Level in 2013 Data

Notes: This table maps the housing and price levels in 2013 data for our sample. The unit of RMB per square meter was measured at the 2010 price level.

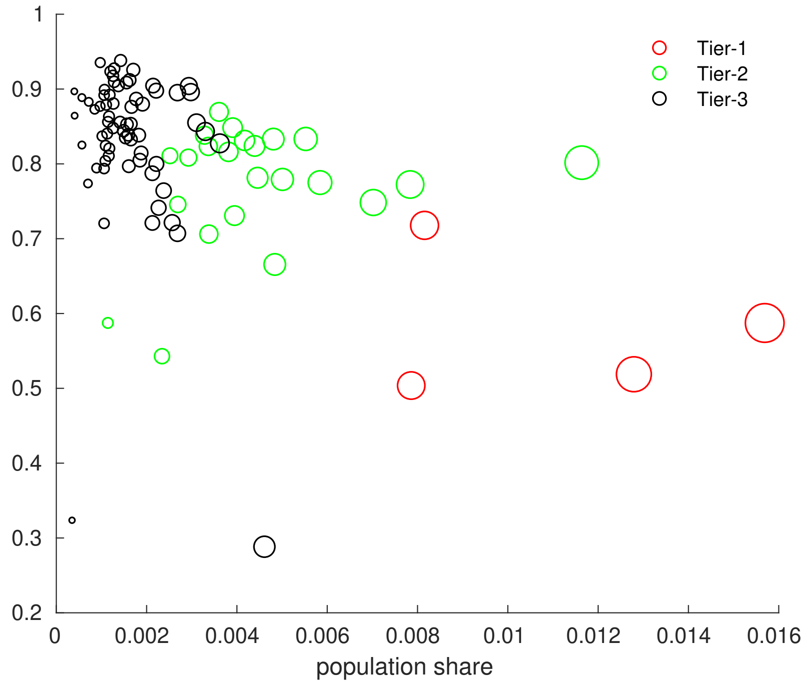


Figure E.5: Estimated Labor Wedge

Notes: We report the average labor wedge for each city during 2007-2013. The x-axis indicates the population share of each city. The size of the bubble reflects the city size.

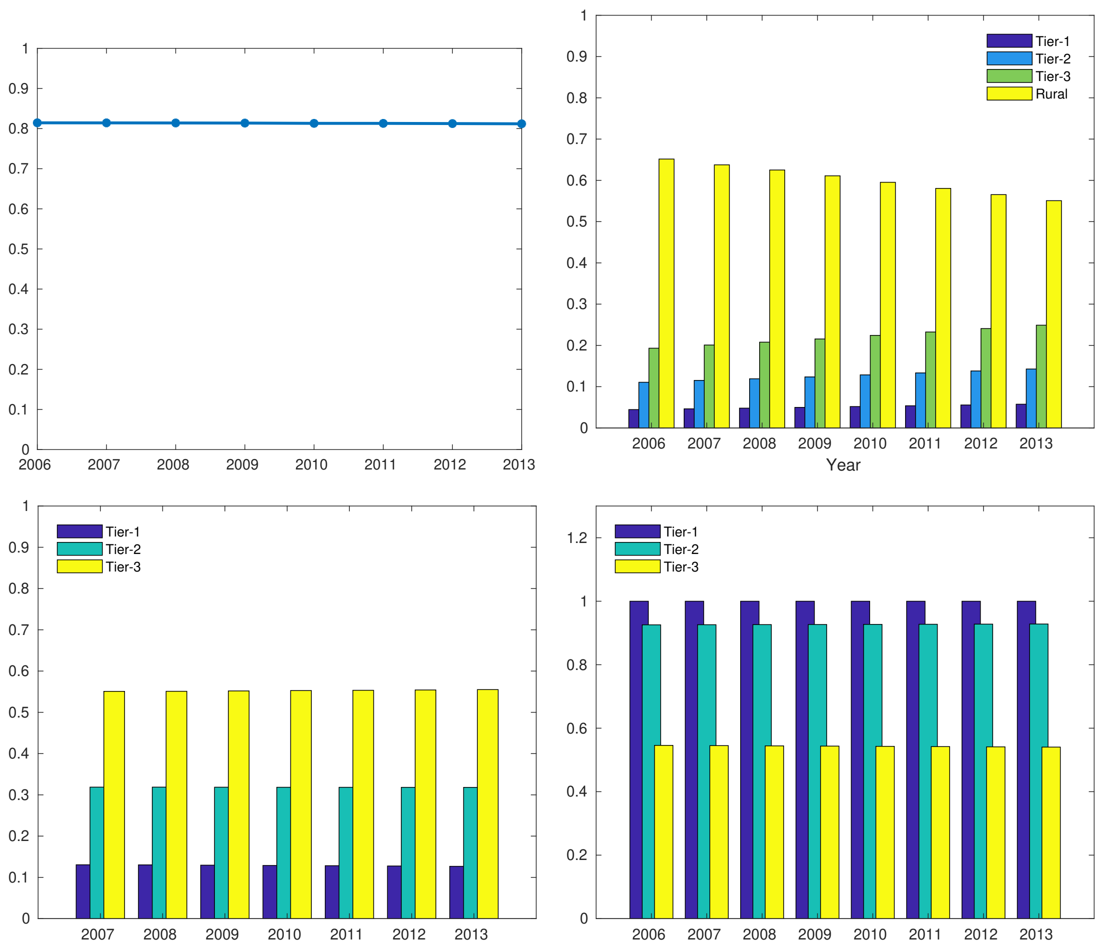
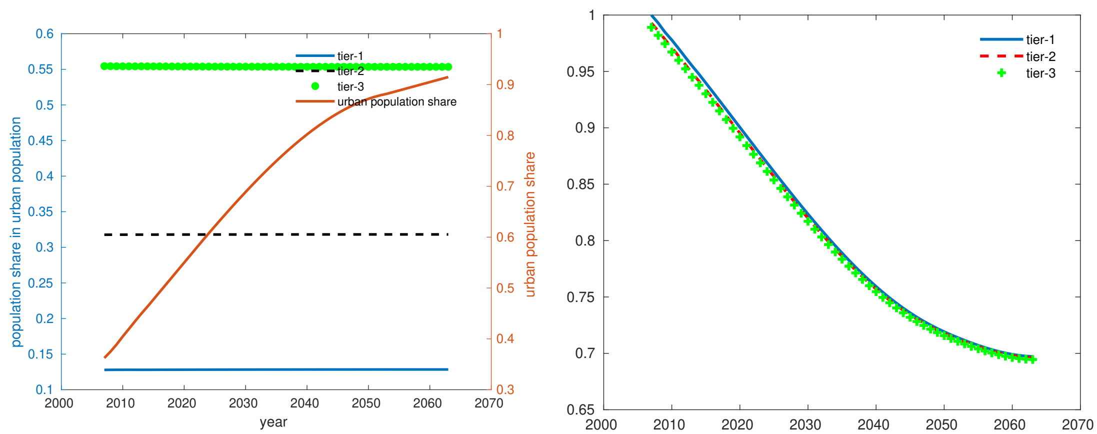


Figure E.6: Population Distribution in the Data

Notes: In panel (a), we sum up the total population in tier-1, tier-2, and tier-3 cities, and report the ratio of the sum to the total population in China during the sample period. In panel (b), we define the total population as the sum of the population over tier-1, tier-2, tier-3 cities, and the rural population, and present the population share of each component in the total population. In panel (c), we define the urban population as the sum of the population over tier-1, tier-2, and tier-3 cities, and present the population share of each city tier in the urban population. Panel (d) plots the population share of our sample cities to the total population of the same tier.

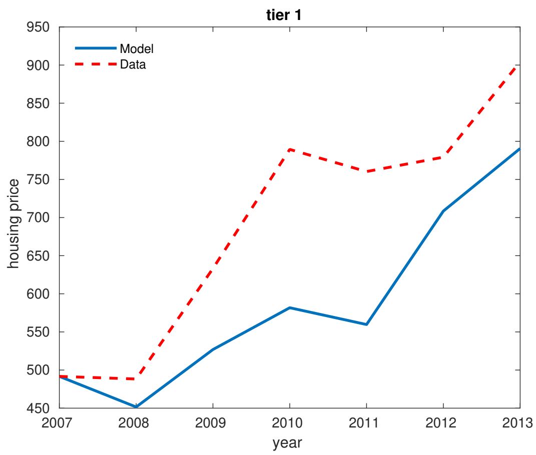


(a) Population Target

(b) Migration cost scale

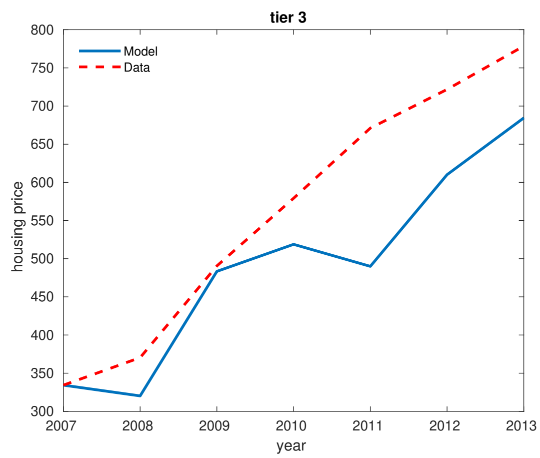
Figure E.7: Population Targets and Calibrated Scale of Migration Costs

Notes: The left panel plots the evolution of urban population share, and the fraction of tier-specific population in the total urban population. They serve as the calibration targets to pin down the tier-specific migration cost scale, which is shown in the right panel.



(a) Tier-1

(b) Tier-2

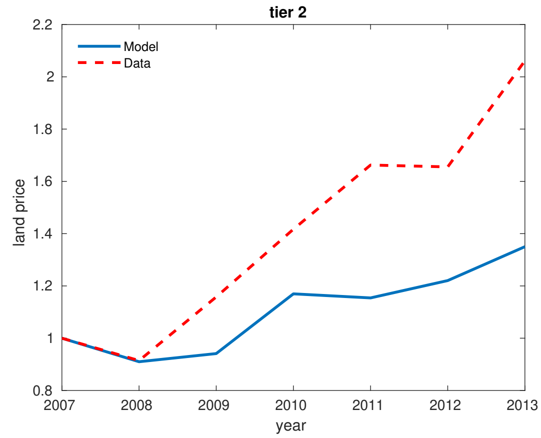


(c) Tier-3

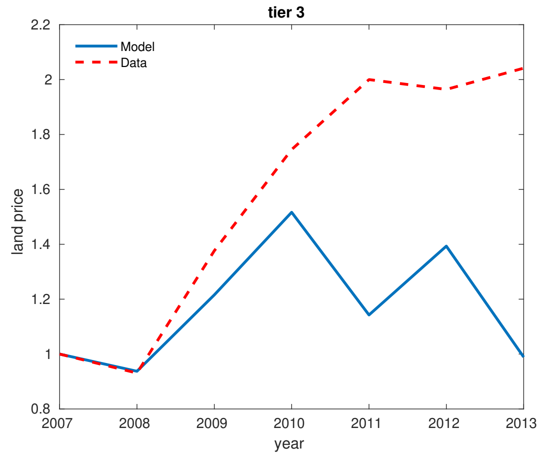
Figure E.8: Baseline Housing Prices: tier-level

Notes: This figure plots the model-predicted housing price levels against their data counterparts in all three city tiers during 2007-2013. The prices at the tier level are the population-weighted average of the prices in each city. The initial housing price level matches the calibration design.

(a) Tier-1



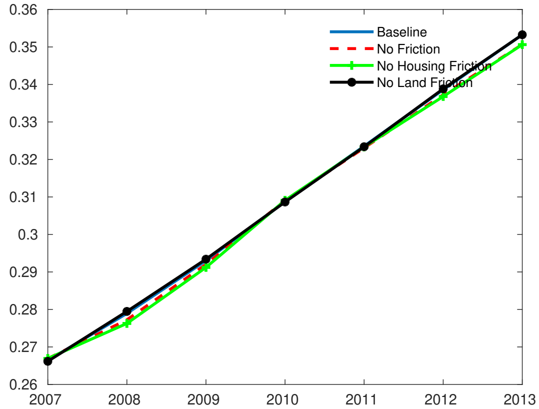
(b) Tier-2



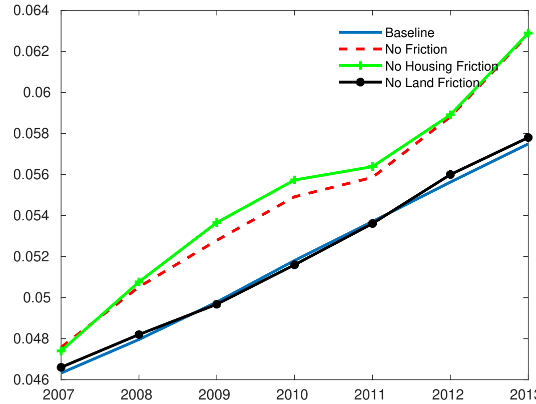
(c) Tier-3

Figure E.9: Baseline Land Prices: tier-level

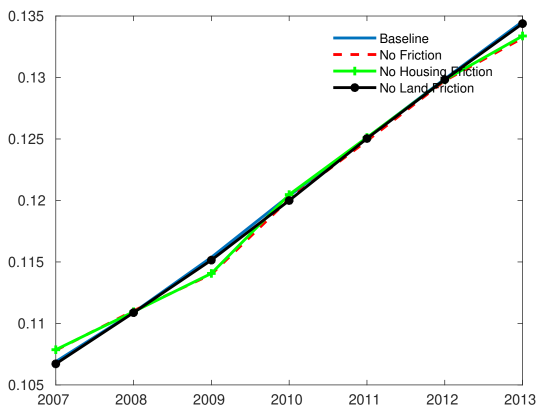
Notes: This figure plots the model-predicted land price levels against their data counterparts in all three city tiers during 2007-2013. The prices at the tier level are the population-weighted average of the prices in each city.



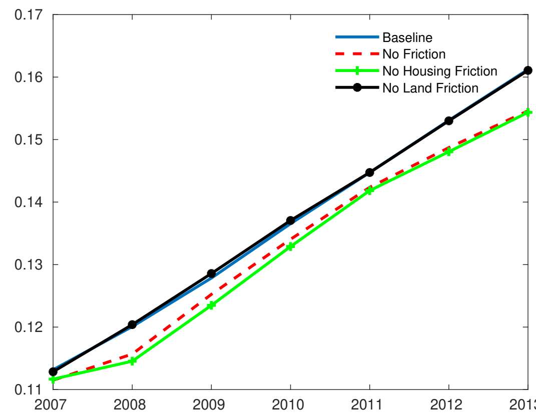
(a) Aggregate



(b) Tier-1



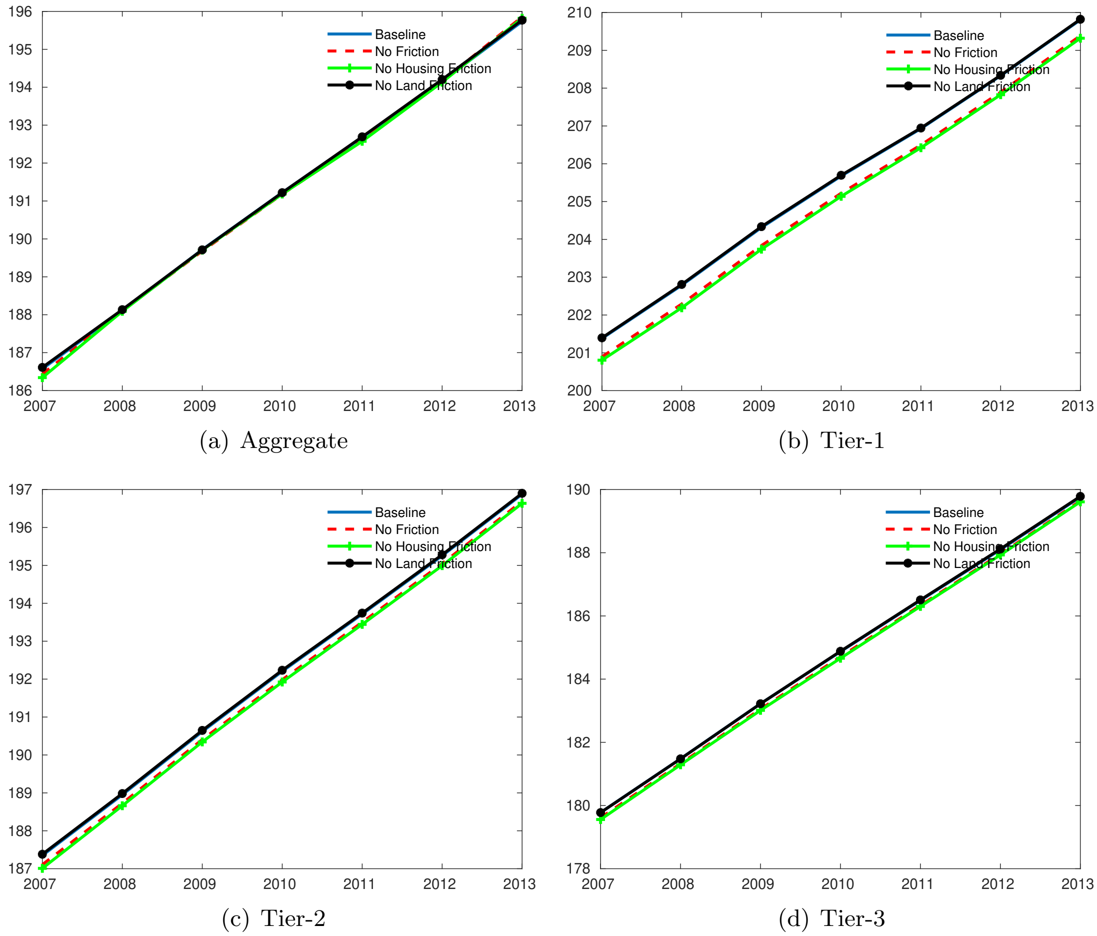
(c) Tier-2



(d) Tier-3

Figure E.10: Eliminate either or both frictions: Population

Notes: We eliminate either one or both types of frictions and report the population at the tier level.

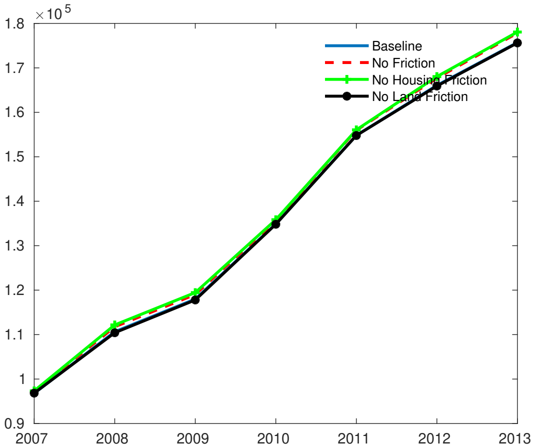


(a) Aggregate (b) Tier-1

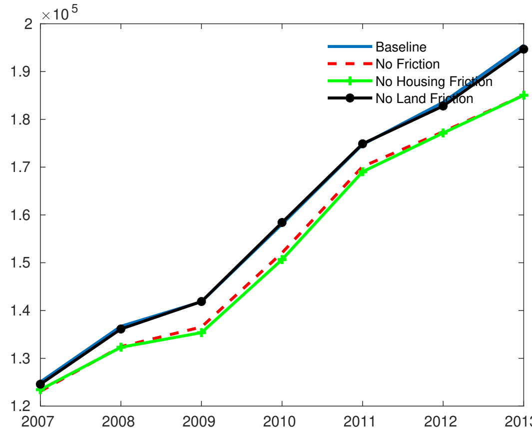
(c) Tier-2 (d) Tier-3

Figure E.11: Eliminate either or both frictions: Welfare

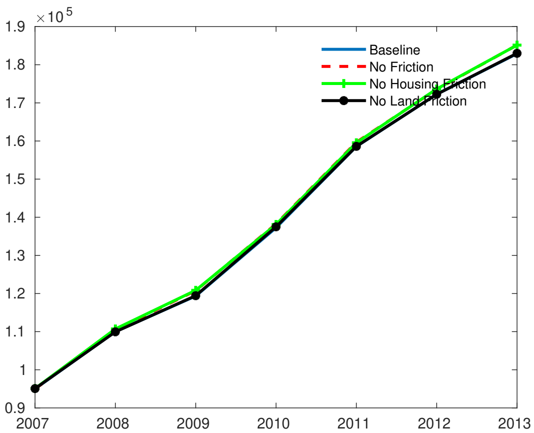
Notes: We eliminate either one or both types of frictions and report the average welfare at the tier level, which is a population-weighted average of the average welfare in each city. Please refer to Equation 24 for the calculation of the average welfare within each city.



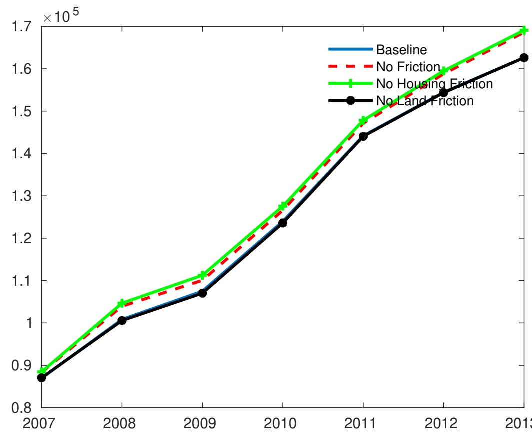
(a) Aggregate



(b) Tier-1



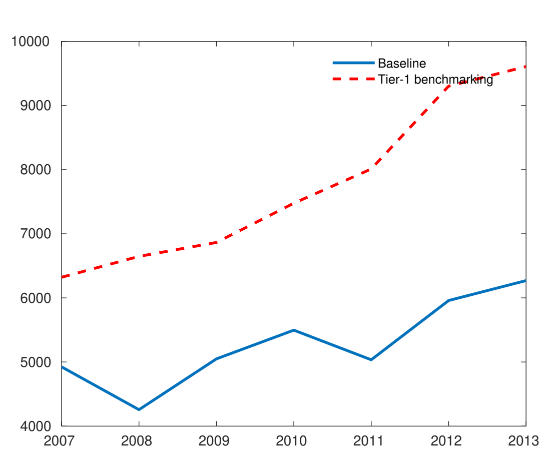
(c) Tier-2



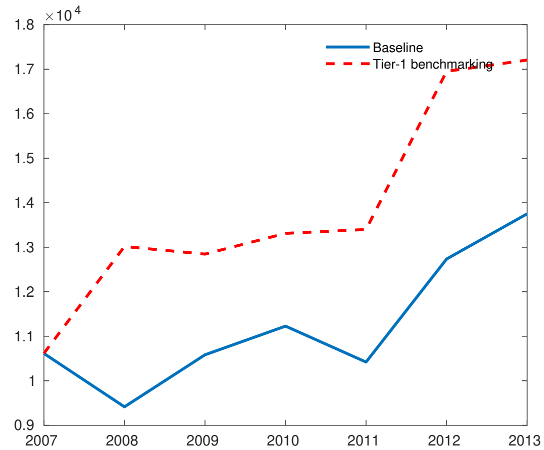
(d) Tier-3

Figure E.12: Eliminate either or both frictions: Per-capita GDP

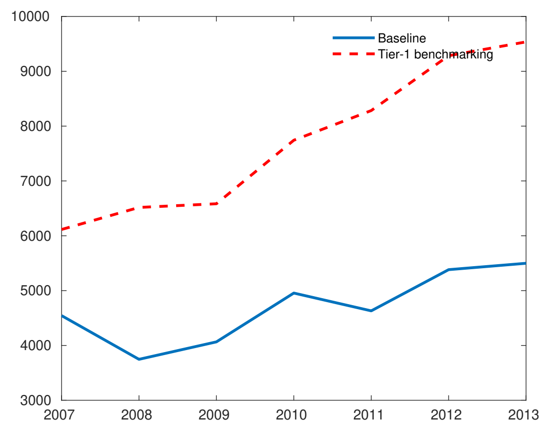
Notes: We eliminate either one or both types of frictions and report the average welfare at the tier level, which is a population-weighted average of the average per-capita GDP in each city. GDP in the urban area is measured as the sum of the value of the composite goods and houses.



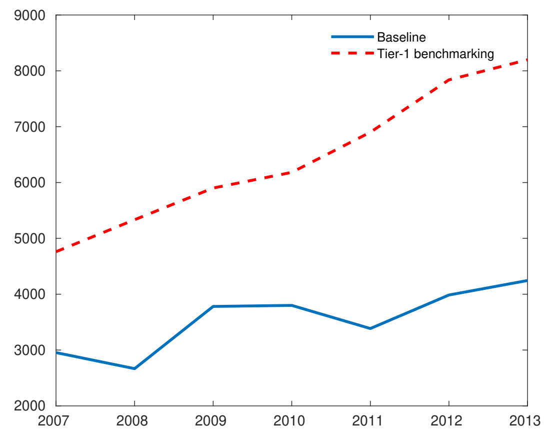
(a) Aggregate



(b) Tier-1



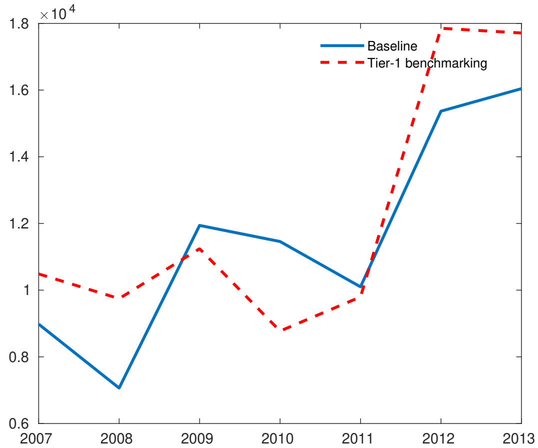
(c) Tier-2



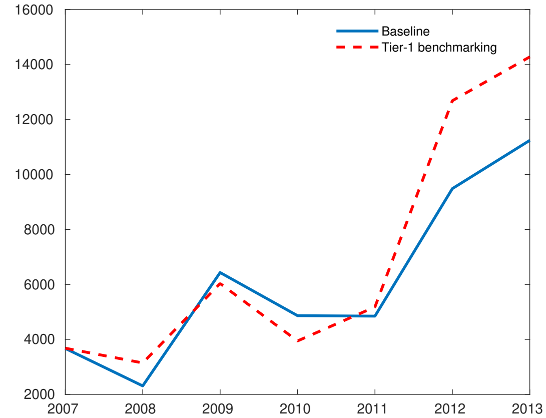
(d) Tier-3

Figure E.13: Set to Tier-1 Benchmarking Distribution: Housing Prices

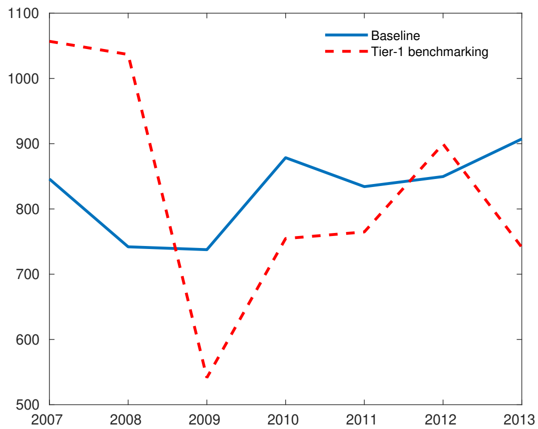
Notes: We let the distribution of housing and land frictions in all the cities follow their distributions in the tier-1 city, and report the aggregate and tier-level housing prices.



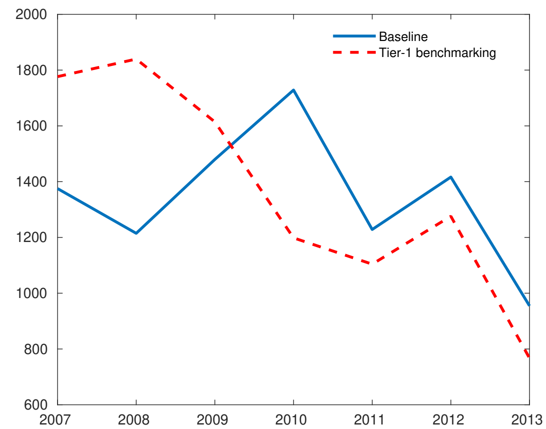
(a) Aggregate



(b) Tier-1



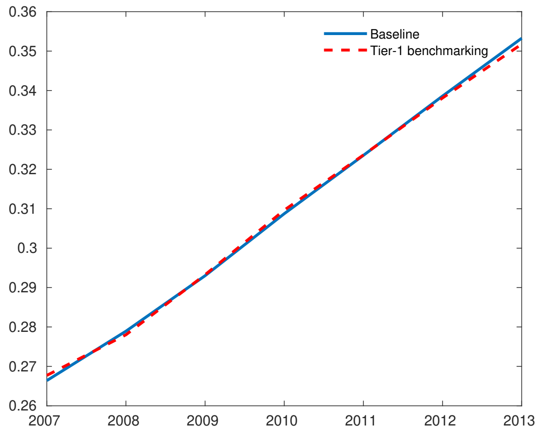
(c) Tier-2



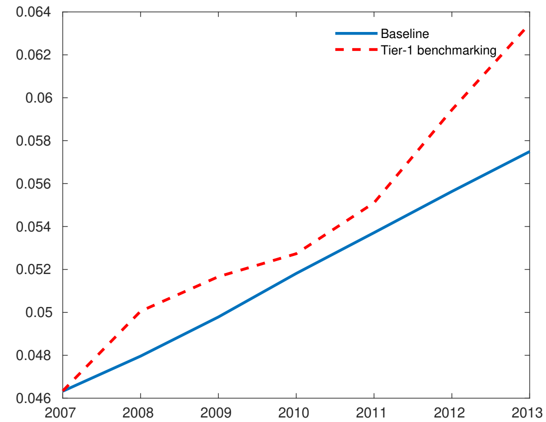
(d) Tier-3

Figure E.14: Set to Tier-1 Benchmarking Distribution: Land Prices

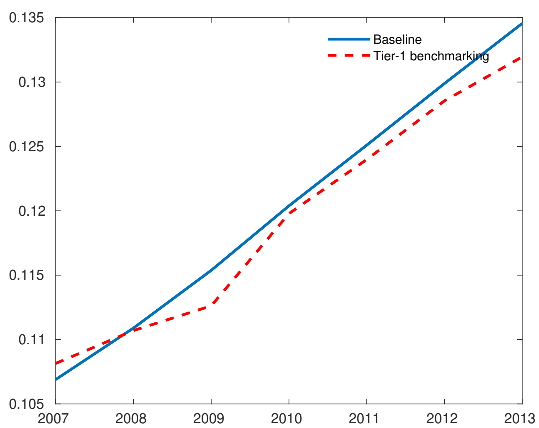
Notes: We let the distribution of housing and land frictions in all the cities follow their distributions in the tier-1 city, and report the aggregate and tier-level land prices.



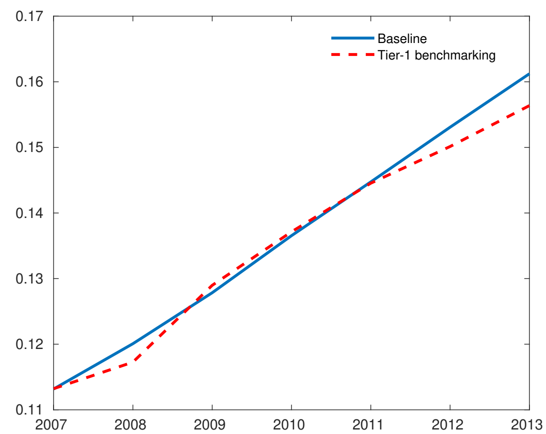
(a) Aggregate



(b) Tier-1



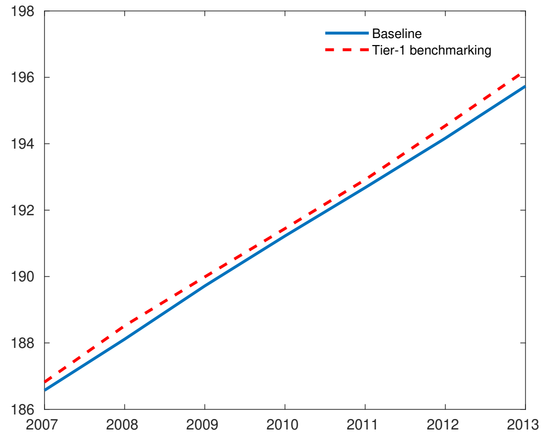
(c) Tier-2



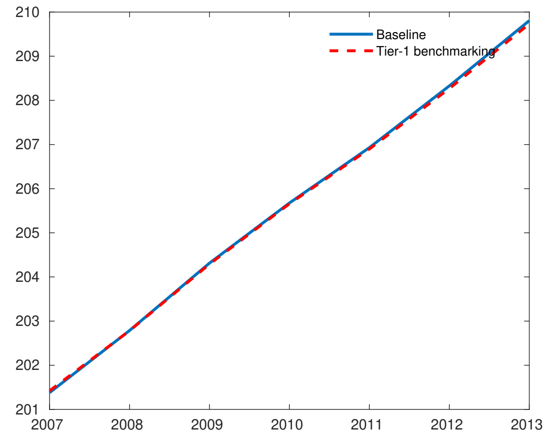
(d) Tier-3

Figure E.15: Set to Tier-1 Benchmarking Distribution: Population

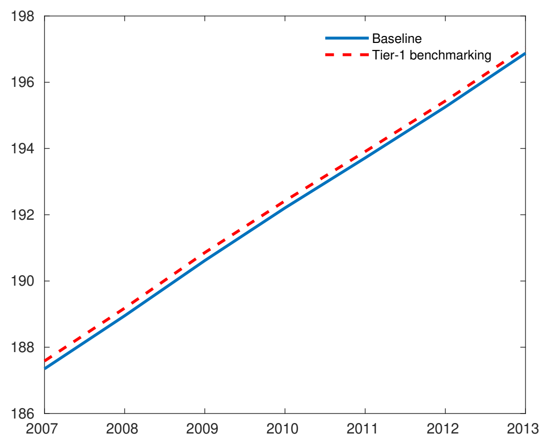
Notes: We let the distribution of housing and land frictions in all the cities follow their distributions in the tier-1 city, and report the aggregate and tier-level population.



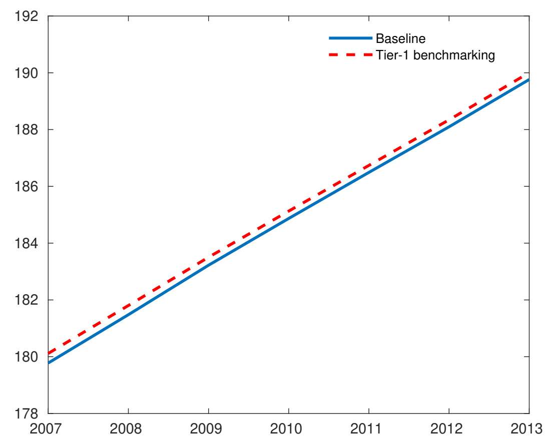
(a) Aggregate



(b) Tier-1



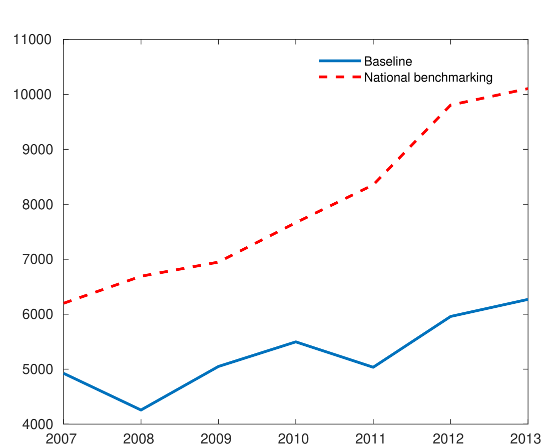
(c) Tier-2



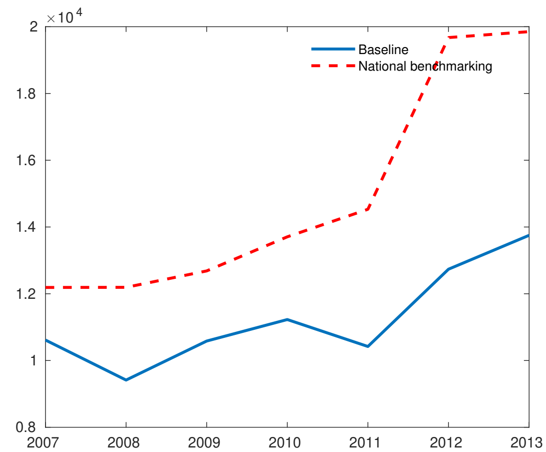
(d) Tier-3

Figure E.16: Set to Tier-1 Benchmarking Distribution: Welfare

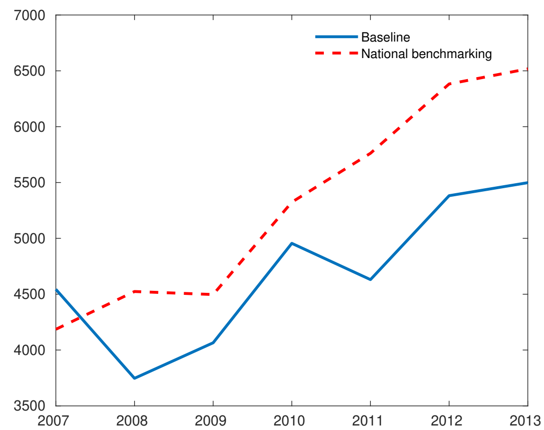
Notes: We let the distribution of housing and land frictions in all the cities follow their distributions in the tier-1 city, and report the aggregate and tier-level average welfare. Please refer to Equation 24 for the calculation of the average welfare at the city level.



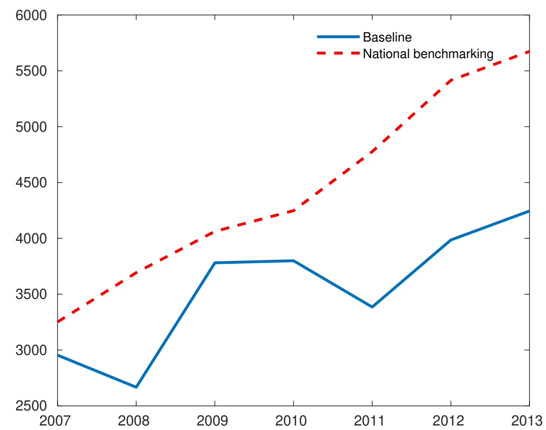
(a) Aggregate



(b) Tier-1



(c) Tier-2



(d) Tier-3

Figure E.17: Set to National Benchmarking Distribution: Housing Prices

Notes: We let the distribution of housing and land frictions in all the cities follow the national average distribution, and report the aggregate and tier-level housing prices.

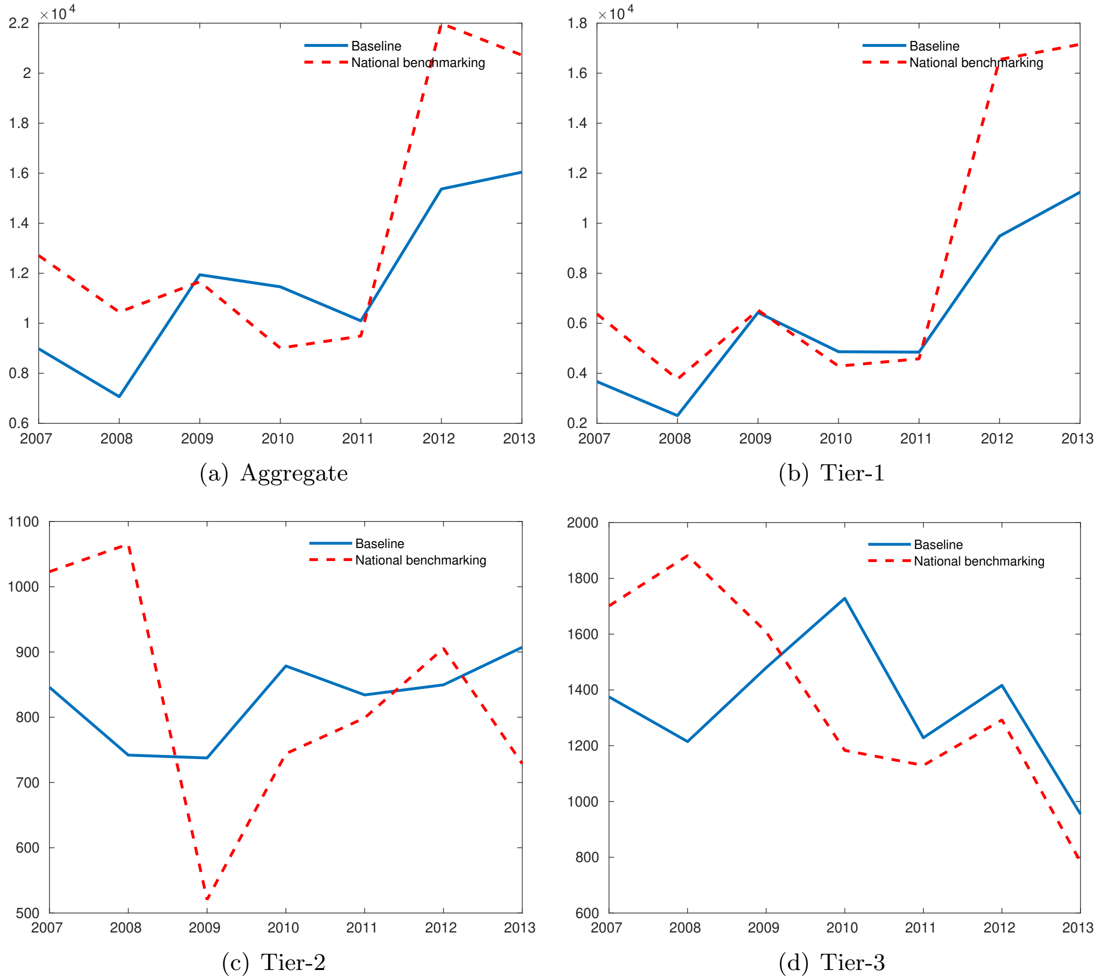
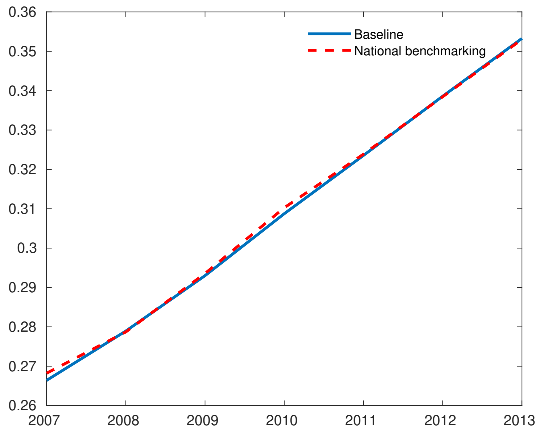
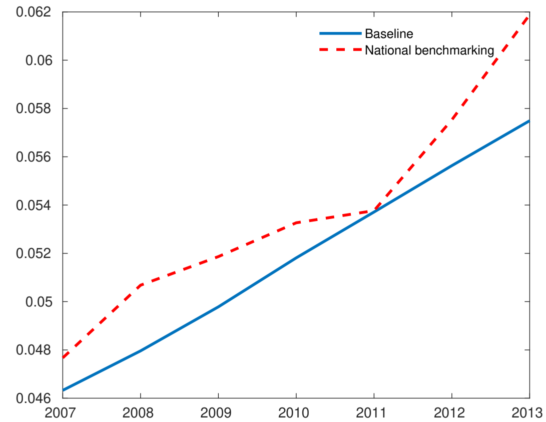


Figure E.18: Set to National Benchmarking Distribution: Land Prices

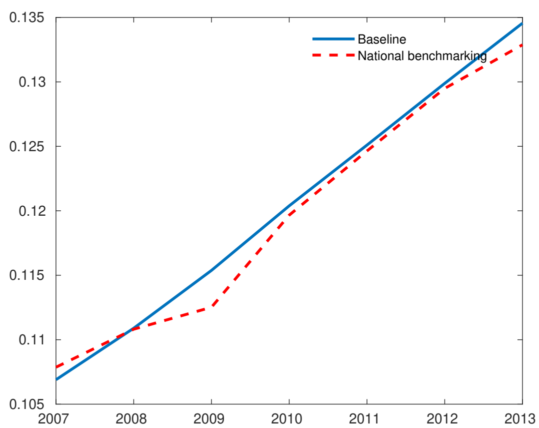
Notes: We let the distribution of housing and land frictions in all the cities follow the national average distribution, and report the aggregate and tier-level land prices.



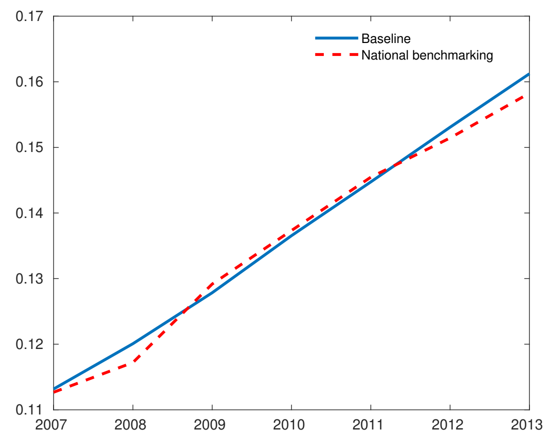
(a) Aggregate



(b) Tier-1



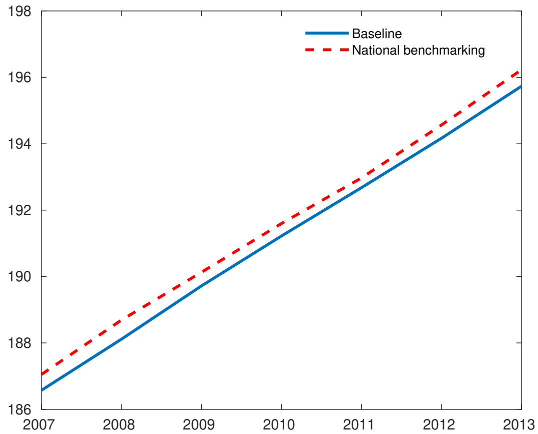
(c) Tier-2



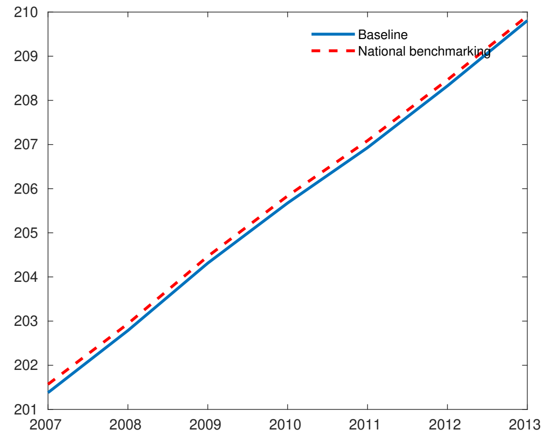
(d) Tier-3

Figure E.19: Set to National Benchmarking Distribution: Population

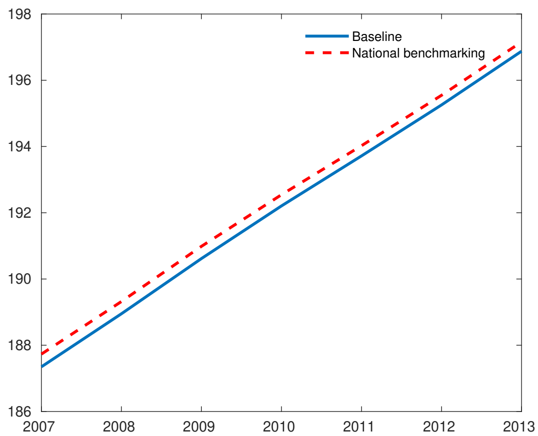
Notes: We let the distribution of housing and land frictions in all the cities follow the national average distribution, and report the aggregate and tier-level population.



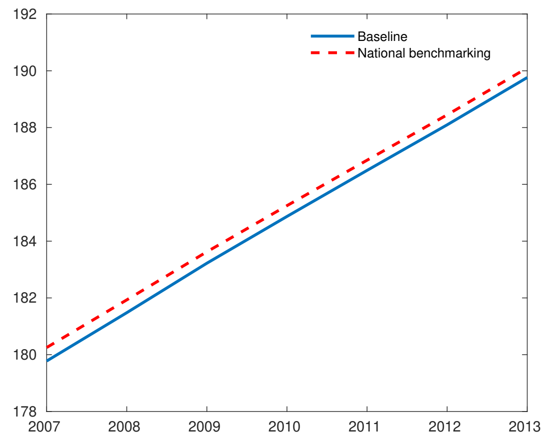
(a) Aggregate



(b) Tier-1



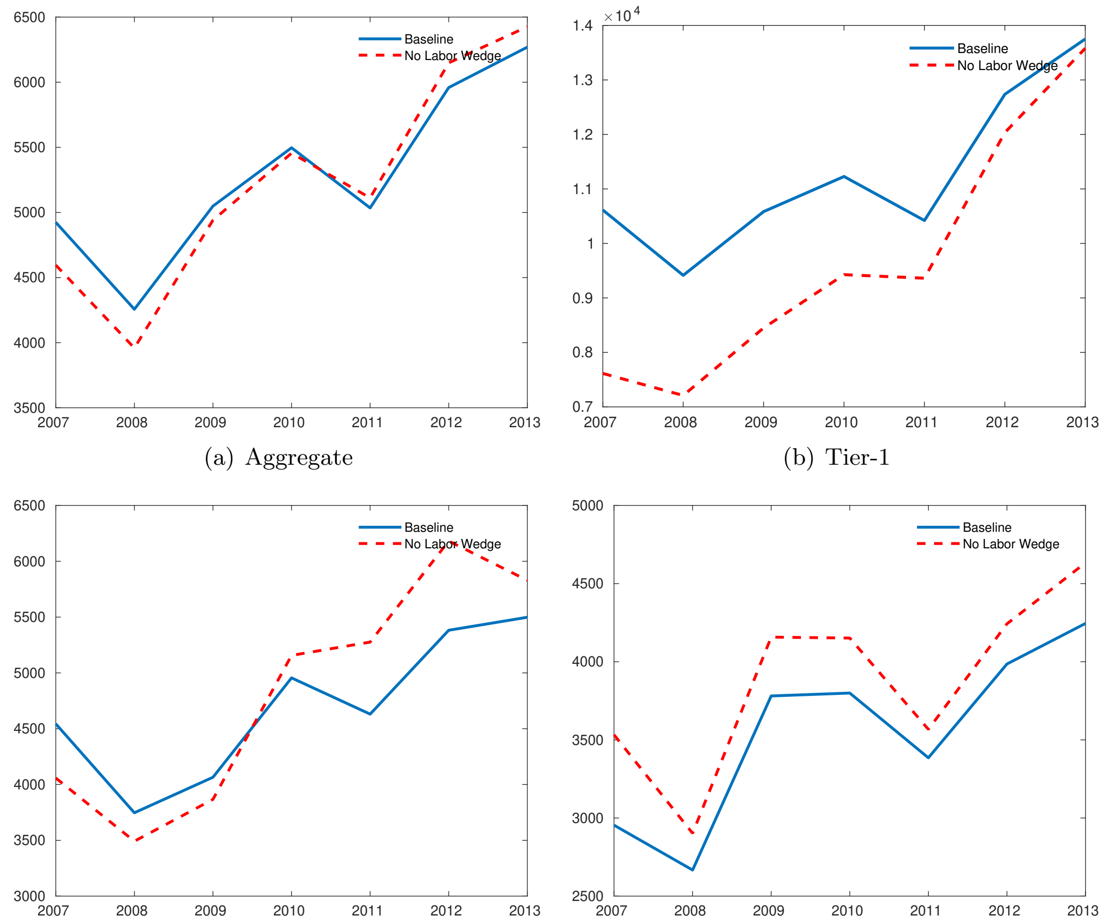
(c) Tier-2



(d) Tier-3

Figure E.20: Set to National Benchmarking Distribution: Welfare

Notes: We let the distribution of housing and land frictions in all the cities follow the national average distribution, and report the aggregate and tier-level average welfare. Please refer to Equation 24 for the calculation of the average welfare at the city level.



(a) Aggregate (b) Tier-1 (c) Tier-2 (d) Tier-3

Figure E.21: No Labor Wedge: Housing Prices

Notes: We eliminate the labor wedges by setting them to zero and report the aggregate and tier-level housing prices.

(a) Aggregate

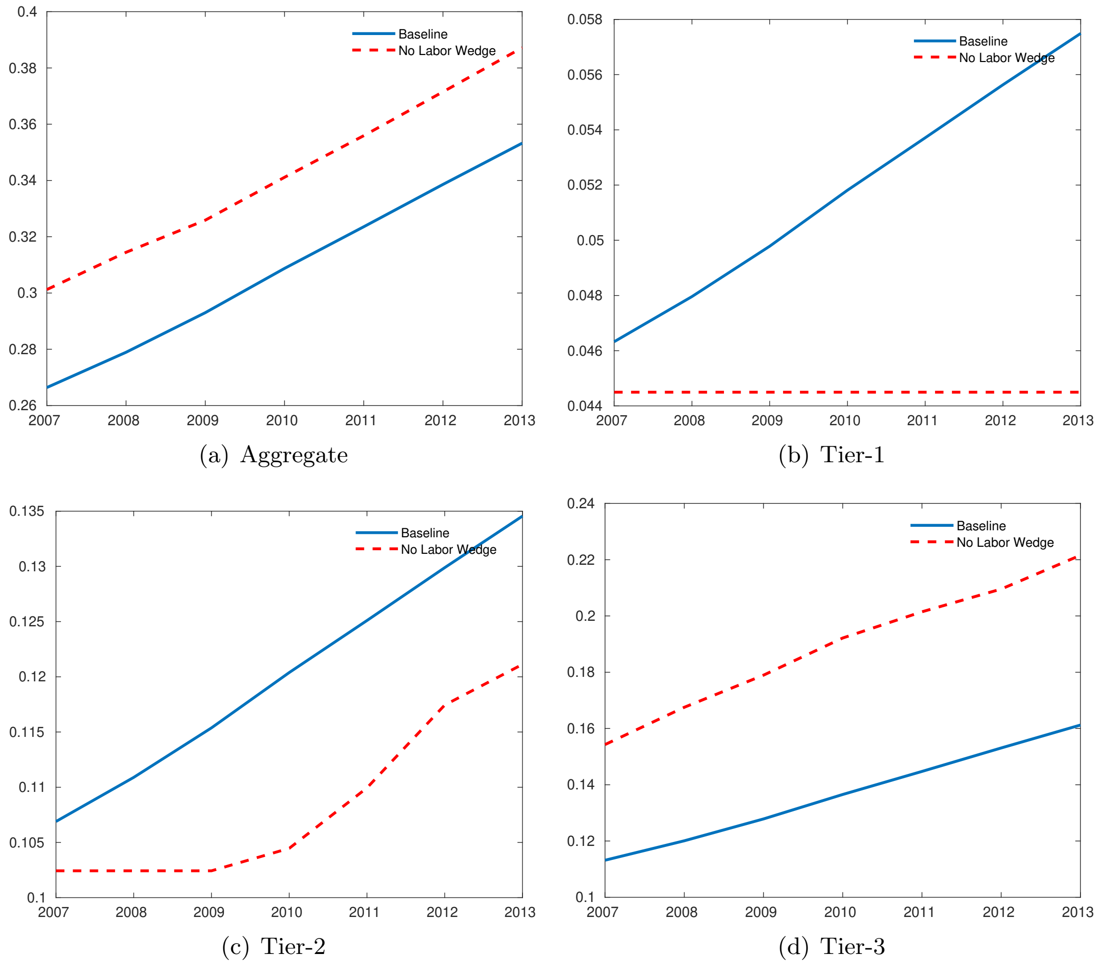
(b) Tier-1

(c) Tier-2

(d) Tier-3

Figure E.22: No Labor Wedge: Land Prices

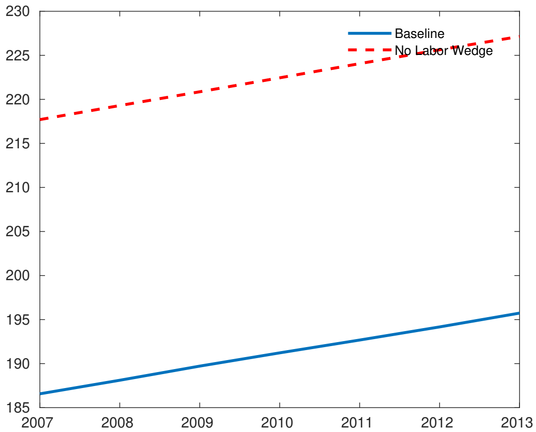
Notes: We eliminate the labor wedges by setting them to zero and report the aggregate and tier-level land prices.



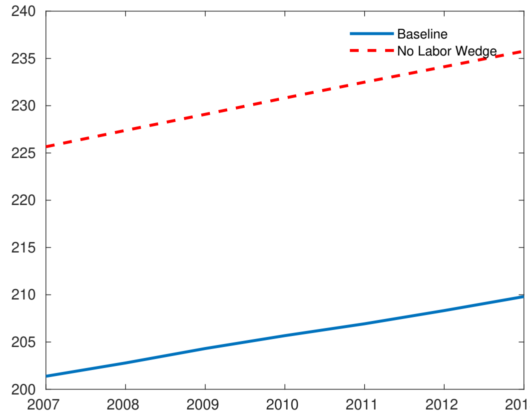
(a) Aggregate (b) Tier-1 (c) Tier-2 (d) Tier-3

Figure E.23: No Labor Wedge: Population

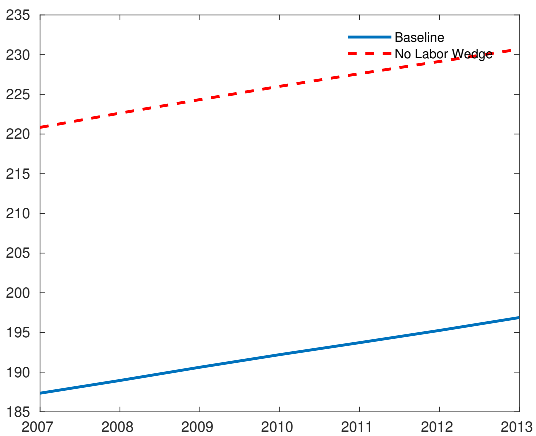
Notes: We eliminate the labor wedges by setting them to zero and report the aggregate and tier-level population.



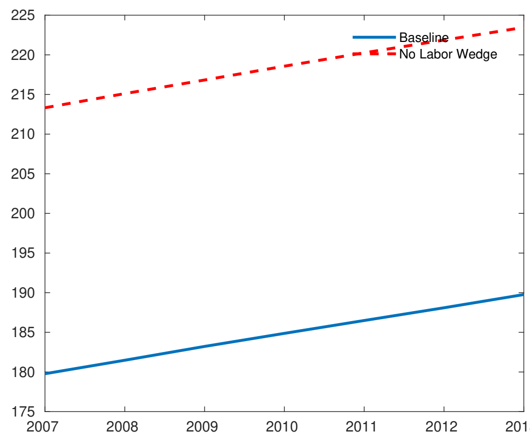
(a) Aggregate



(b) Tier-1



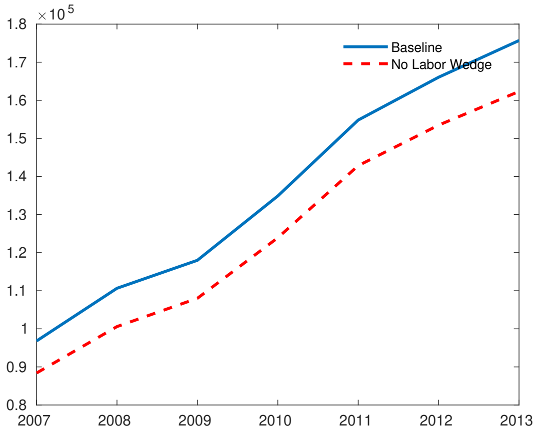
(c) Tier-2



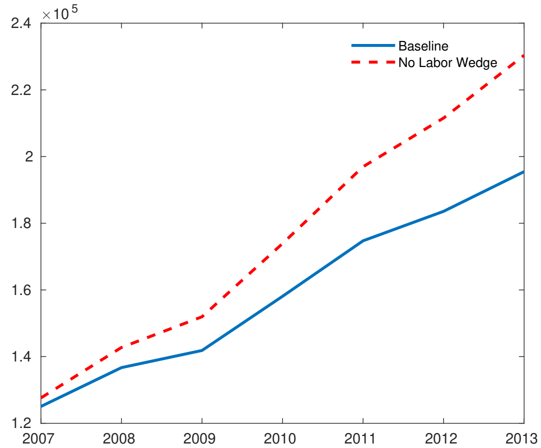
(d) Tier-3

Figure E.24: No Labor Wedge: Welfare

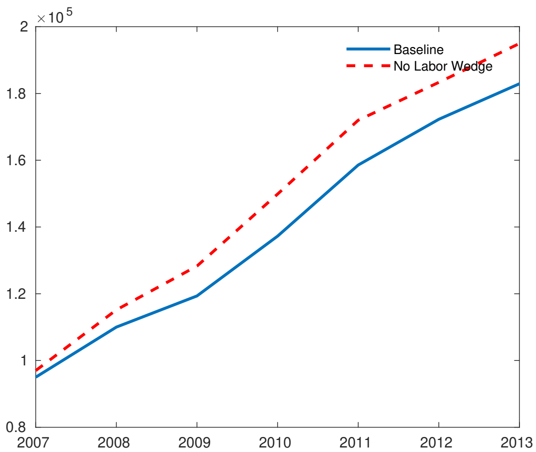
Notes: We eliminate the labor wedges by setting them to zero and report the aggregate and tier-level average welfare. Please refer to Equation 24 for the calculation of the average welfare at the city level.



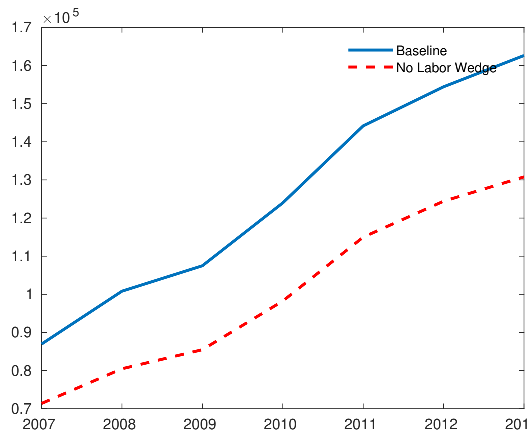
(a) Aggregate



(b) Tier-1



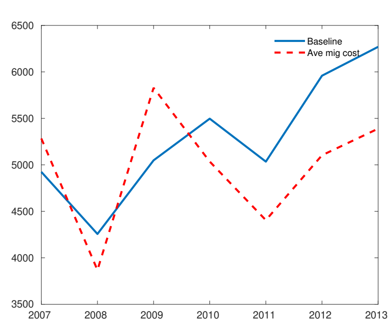
(c) Tier-2



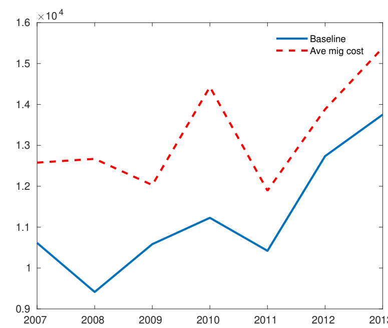
(d) Tier-3

Figure E.25: No Labor Wedge: Per-capita GDP

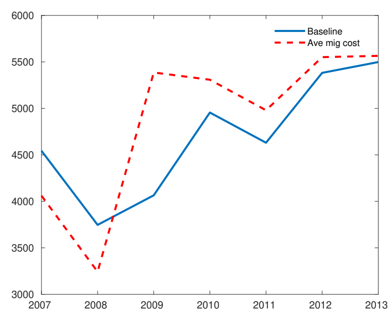
Notes: We eliminate the labor wedges by setting them to zero and report the aggregate and tier-level average per-capita GDP. GDP in the urban area is measured as the sum of the value of the composite goods and houses.



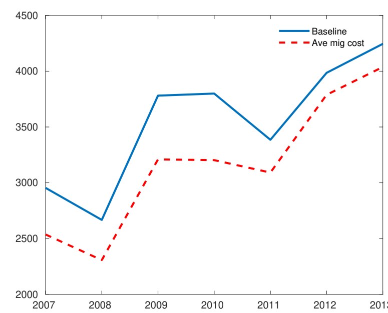
(a) Aggregate



(b) Tier-1



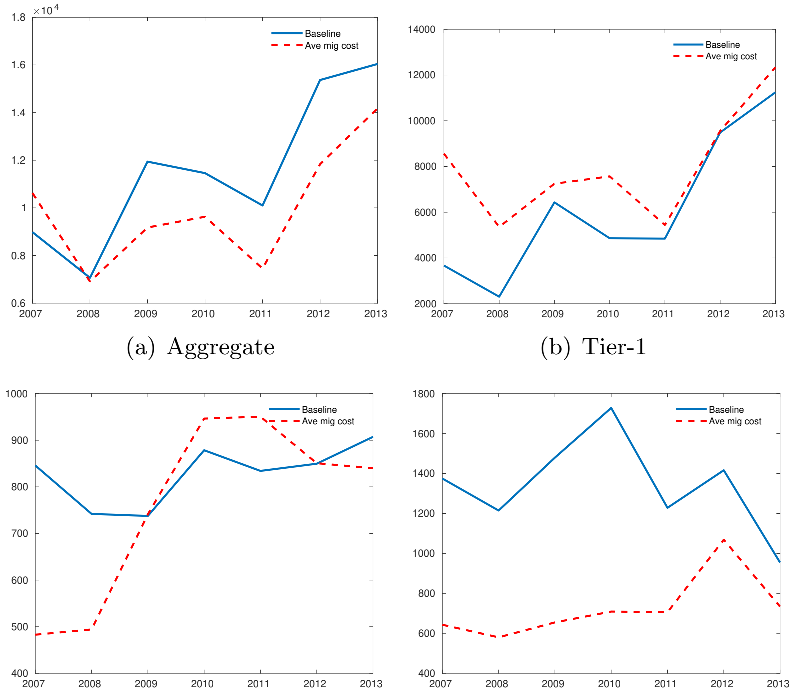
(c) Tier-2



(d) Tier-3

Figure E.26: Benchmark v.s. Uniform Migration Costs: Housing Prices

Notes: We set the scale of migration cost to be the national average level across all three city tiers and report the housing prices.

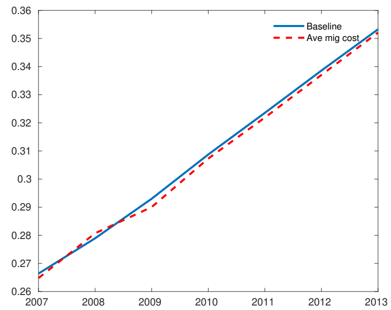


(a) Aggregate (b) Tier-1

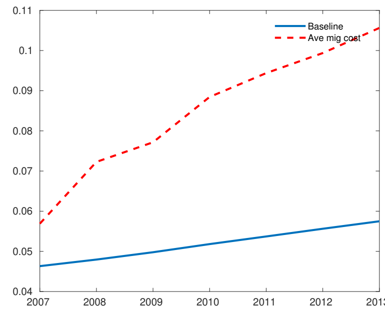
(c) Tier-2 (d) Tier-3

Figure E.27: Benchmark v.s. Uniform Migration Costs: Land Prices

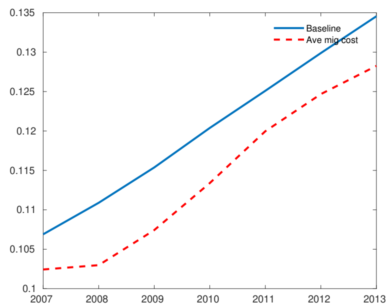
Notes: We set the scale of migration cost to be the national average level across all three city tiers and report the land prices.



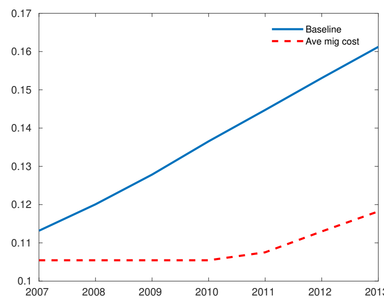
(a) Aggregate



(b) Tier-1



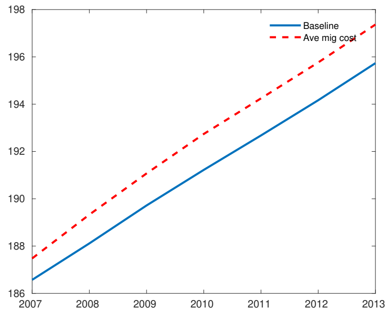
(c) Tier-2



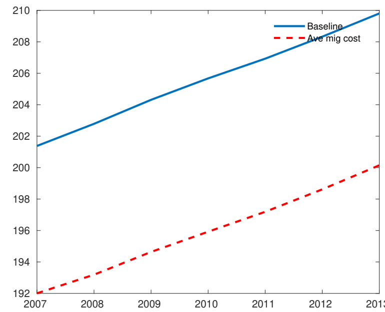
(d) Tier-3

Figure E.28: Benchmark v.s. Uniform Migration Costs: Population

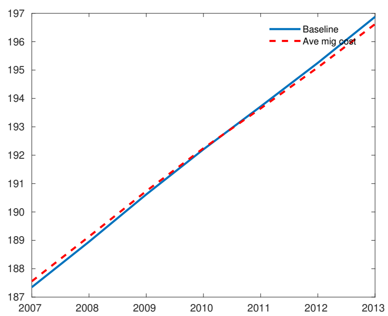
Notes: We set the scale of migration cost to be the national average level across all three city tiers and report the population.



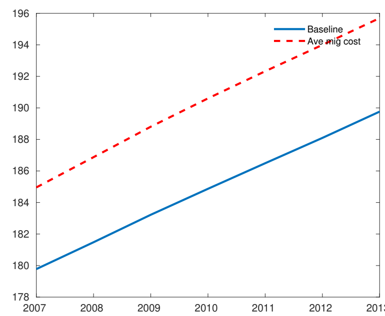
(a) Aggregate



(b) Tier-1



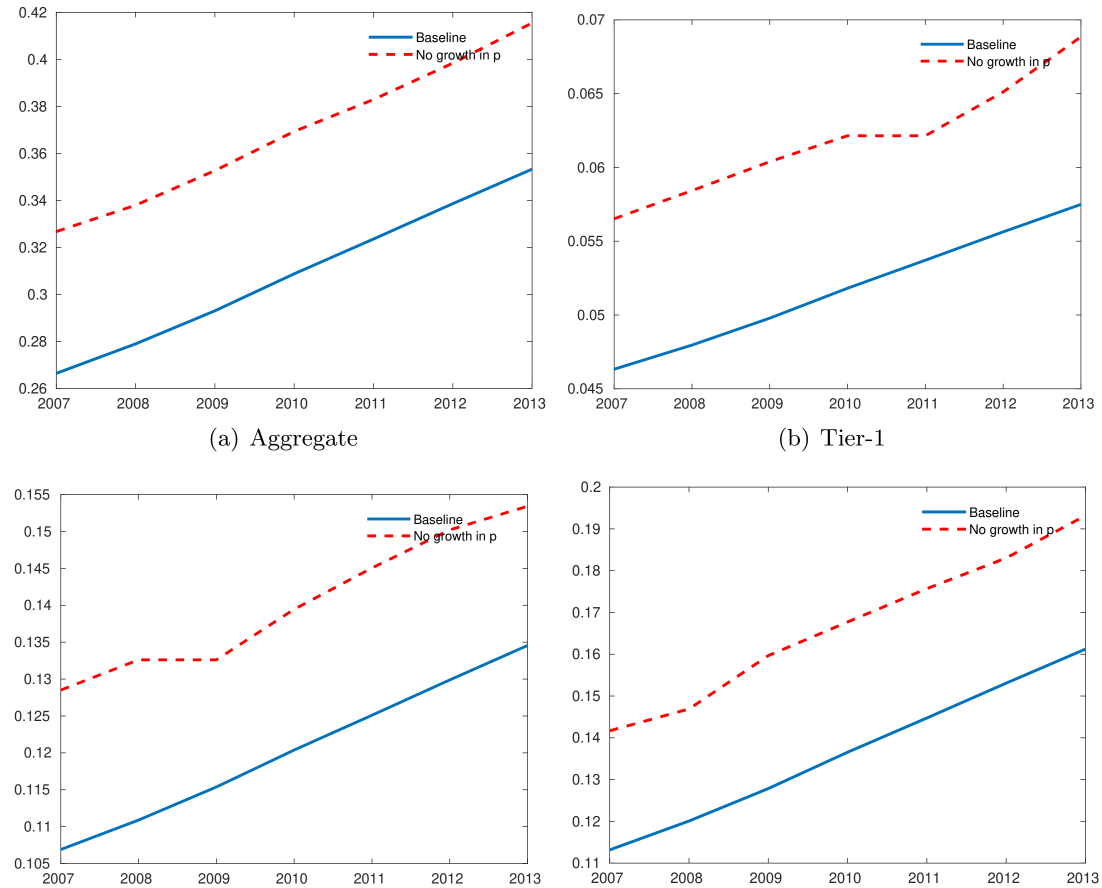
(c) Tier-2



(d) Tier-3

Figure E.29: Benchmark v.s. Uniform Migration Costs: Welfare

Notes: We set the scale of migration cost to be the national average level across all three city tiers and report the average welfare.



(a) Aggregate

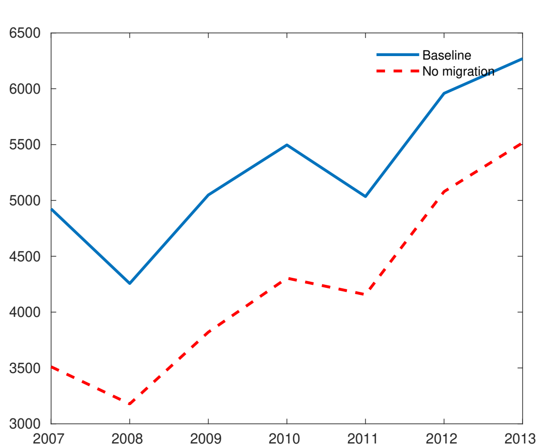
(b) Tier-1

(c) Tier-2

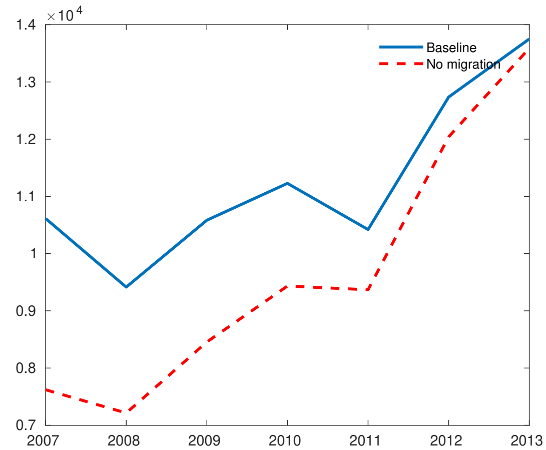
(d) Tier-3

Figure E.30: Benchmark v.s. No Housing Price Growth: Population

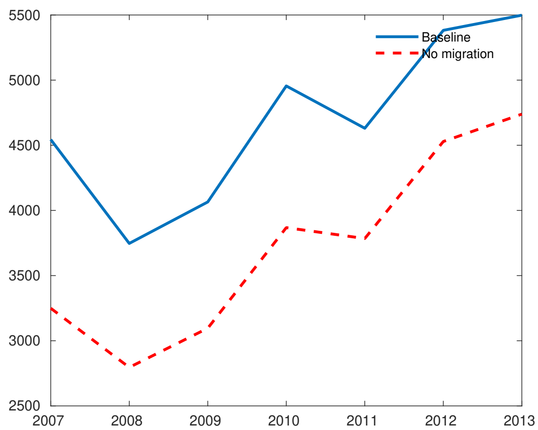
Notes: "No housing price growth" refer to the economy in which housing prices are kept at their initial levels in each city. The housing market is no longer clear in this economy.



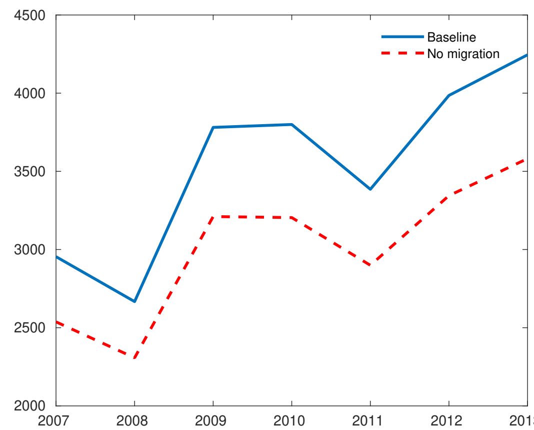
(a) Aggregate



(b) Tier-1



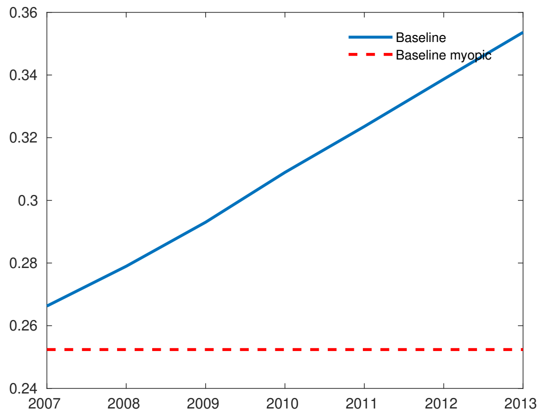
(c) Tier-2



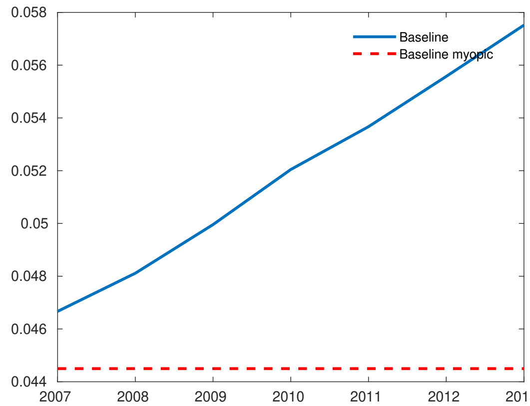
(d) Tier-3

Figure E.31: Benchmark v.s. No Migration: Housing Prices

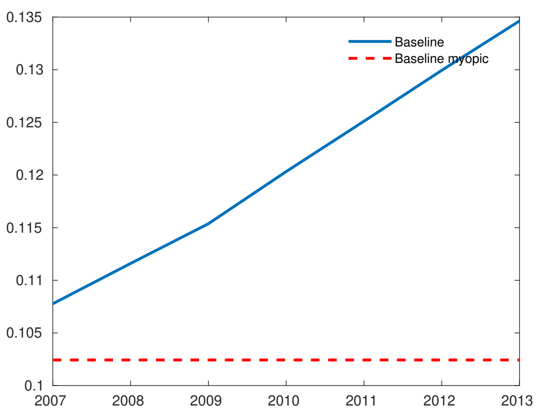
Notes: “No migration” refers to the situation in which populations are kept at their initial levels in each city. We achieve this by setting the scale of migration costs to be a sufficiently large number.



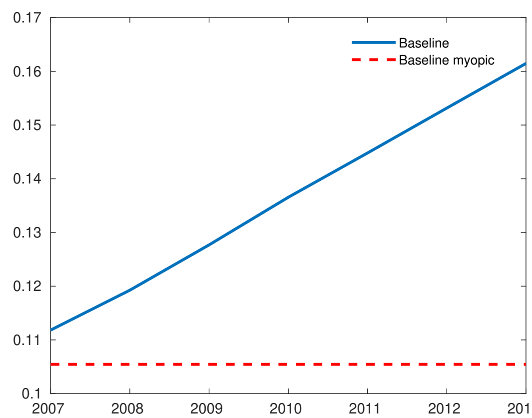
(a) Aggregate



(b) Tier-1



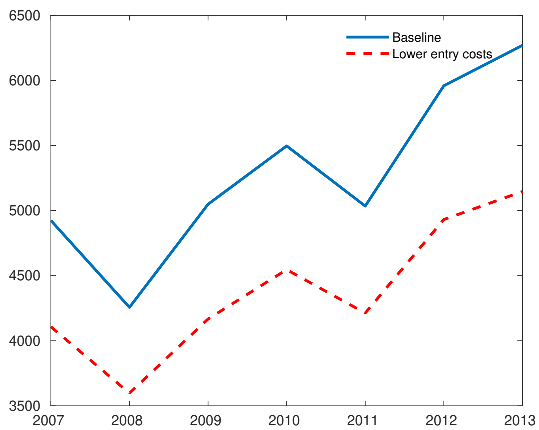
(c) Tier-2



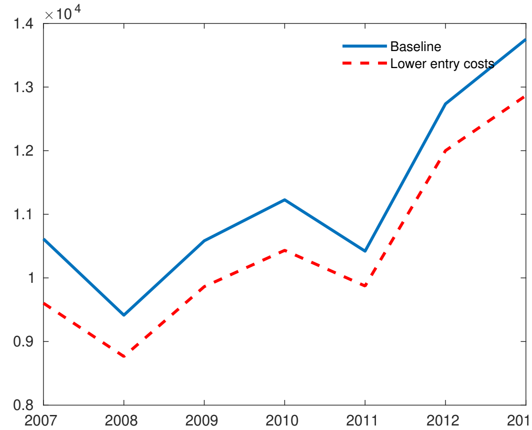
(d) Tier-3

Figure E.32: Myopic v.s. Perfect-foresight: Population

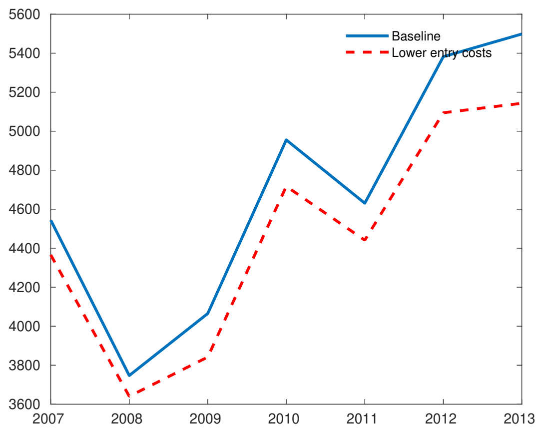
Notes: under the myopia assumption individuals make migration decisions by comparing the current payoff from staying in the rural with moving to the urban area. We revise the mortgage payment scheme to be consol mortgage, so that there is no state variable in the case of perfect foresight to make two cases comparable.



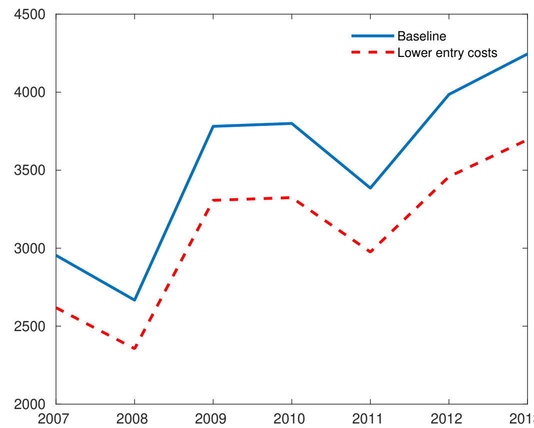
(a) Aggregate



(b) Tier-1



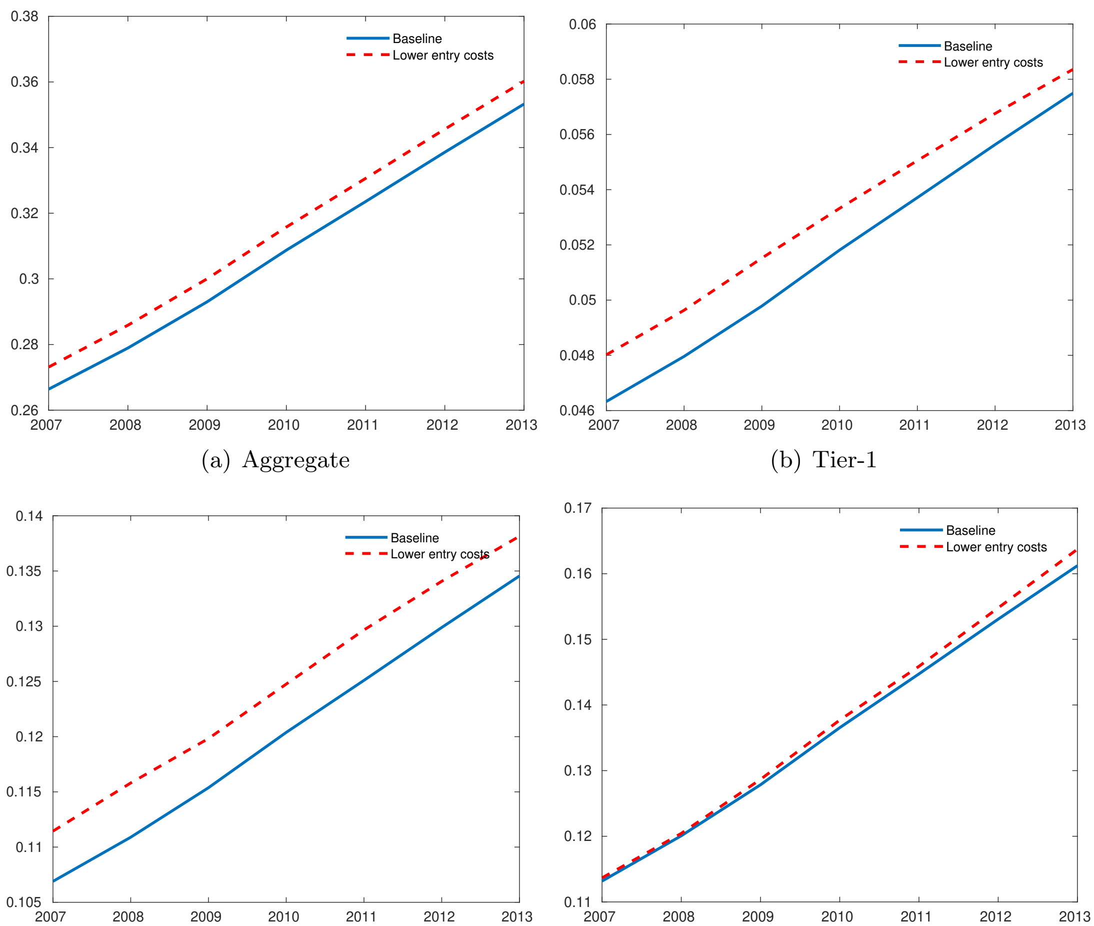
(c) Tier-2



(d) Tier-3

Figure E.33: Benchmark v.s. Lower Entry Costs: Housing Prices

Notes: “Lower entry costs” refers to the situation in which we uniformly lower the coefficient of the entry fee (ψ_i) by 10 percent from their baseline levels.

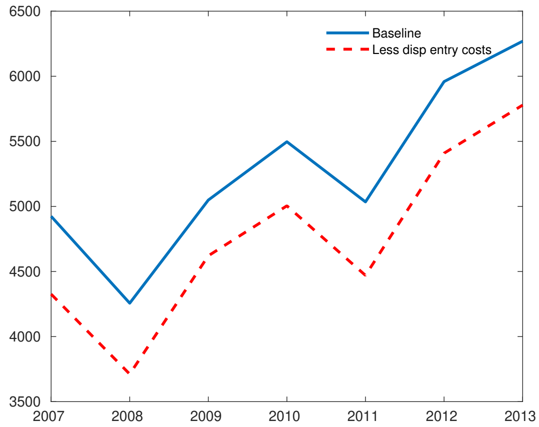


(a) Aggregate (b) Tier-1

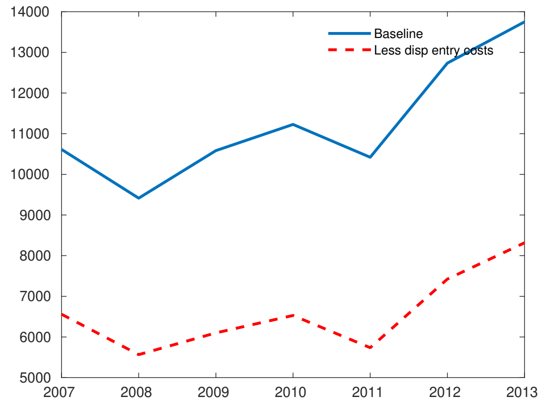
(c) Tier-2 (d) Tier-3

Figure E.34: Benchmark v.s. Lower Entry Costs: Population

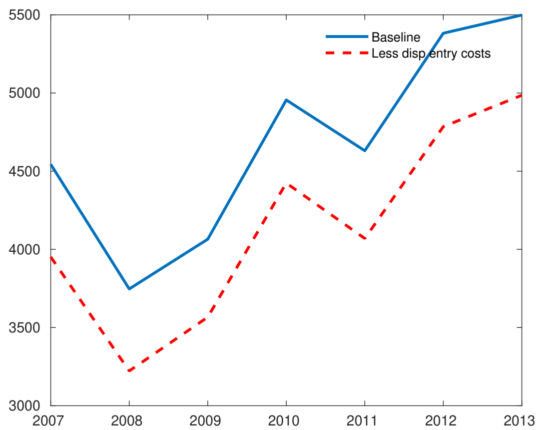
Notes: "Lower entry costs" refers to the situation in which we uniformly lower the coefficient of the entry fee (ψ_i) by 10 percent from their baseline levels.



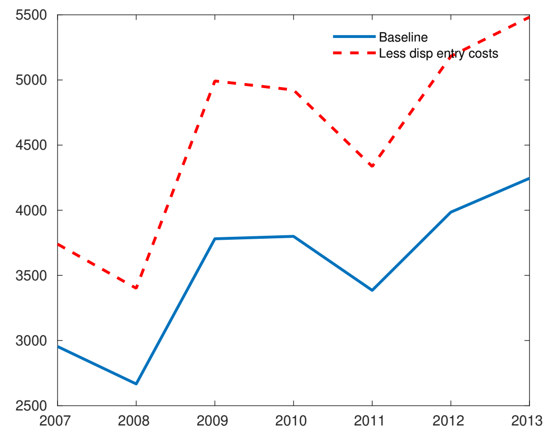
(a) Aggregate



(b) Tier-1



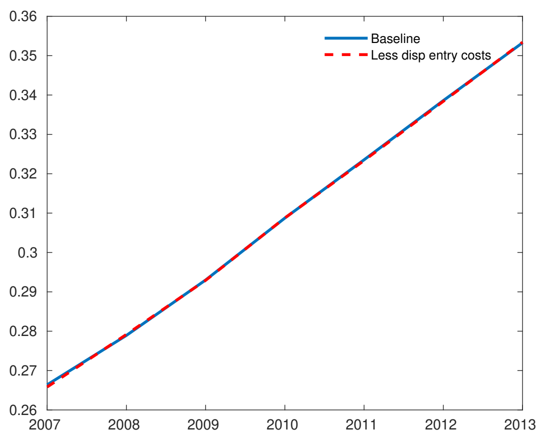
(c) Tier-2



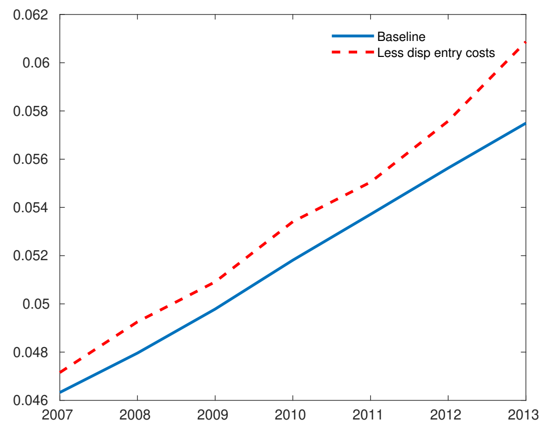
(d) Tier-3

Figure E.35: Benchmark v.s. Less Dispersed Population Elasticity of Entry Fee: Housing Prices

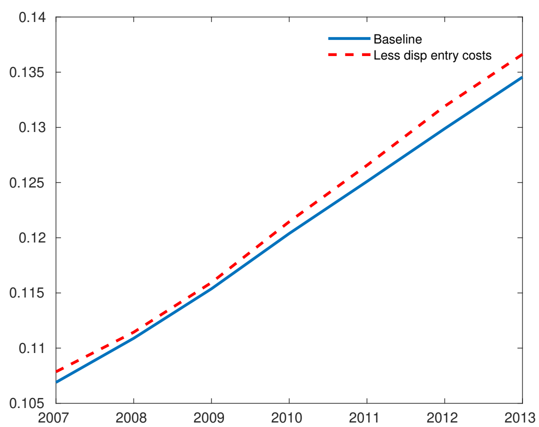
Notes: We move the population elasticity of entry fee (η_i) to be 10 percent closer to their national mean. Specifically, $\hat{\eta}_i = 0.9\eta_i + 0.1\bar{\eta}$, where $\bar{\eta}$ is the national average of η_i in the baseline economy.



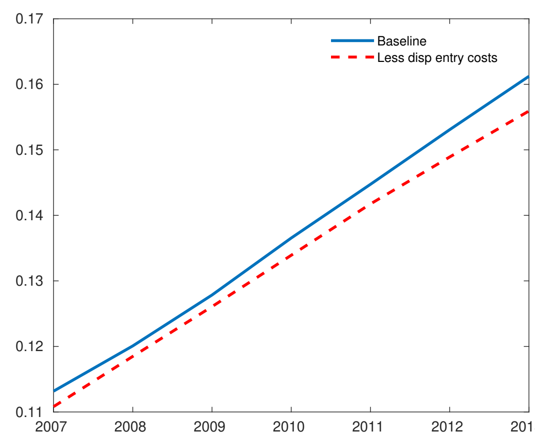
(a) Aggregate



(b) Tier-1



(c) Tier-2



(d) Tier-3

Figure E.36: Benchmark v.s. Less Dispersed Population Elasticity of Entry Fee: Population

Notes: We move the population elasticity of entry fee (η_i) to be 10 percent closer to their national mean. Specifically, $\hat{\eta}_i = 0.9\eta_i + 0.1\bar{\eta}$, where $\bar{\eta}$ is the national average of η_i in the baseline economy.

F Results with Tier-specific Housing Production Function

Table F.1: Housing production function by tiers

	Land share (α)	Construction material share (γ)
Tier-1 and 2	0.421	0.168
Tier-3	0.326	0.212

Notes: We re-run panel regression 23 separately for either tier-3 cities or other cities (tier-1 and 2 cities).

Table F.2: Frictions in Tier-1 Cities with Tier-specific Housing Production Function

(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	0.12	0.16	0.00	0.08	0.24
2008	-0.22	0.11	-0.30	-0.22	-0.14
2009	0.34	0.15	0.24	0.38	0.44
2010	0.05	0.01	0.04	0.06	0.06
2011	-0.27	0.34	-0.48	-0.41	-0.06
2012	-0.15	0.16	-0.30	-0.15	-0.01
2013	-0.02	0.08	-0.07	-0.02	0.03
Total	-0.02	0.25	-0.22	-0.01	0.10

(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	1.03	1.00	0.38	0.74	1.67
2008	1.35	1.76	0.23	0.83	2.46
2009	0.04	0.47	-0.32	0.08	0.41
2010	0.07	0.71	-0.39	-0.10	0.53
2011	0.54	1.30	-0.32	0.07	1.40
2012	0.49	0.68	-0.10	0.45	1.07
2013	-0.05	0.44	-0.40	-0.16	0.30
Total	0.49	1.02	-0.18	0.21	0.91

Notes: This table reports the summary statistics for the estimated frictions among the four tier-1 Chinese cities. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.

Table F.3: Frictions in Tier-2 Cities with Tier-specific Housing Production Function

(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	-0.56	0.69	-1.16	-0.35	-0.10
2008	-1.33	0.86	-1.93	-1.23	-0.59
2009	-0.67	0.96	-1.03	-0.43	-0.03
2010	-0.63	0.88	-0.99	-0.49	-0.16
2011	-0.89	0.52	-1.04	-0.75	-0.55
2012	-0.89	0.72	-1.10	-0.82	-0.46
2013	-0.86	0.72	-1.09	-0.73	-0.42
Total	-0.83	0.80	-1.13	-0.70	-0.29

(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	1.19	1.91	-0.07	0.75	1.28
2008	1.52	1.67	0.39	0.94	1.96
2009	0.39	1.00	-0.38	0.22	0.95
2010	0.01	0.81	-0.50	-0.32	0.52
2011	0.29	1.13	-0.40	-0.28	0.53
2012	0.34	0.59	-0.05	0.16	0.64
2013	0.12	0.76	-0.41	-0.17	0.55
Total	0.55	1.30	-0.32	0.23	0.94

Notes: This table reports the summary statistics for the estimated frictions among the 25 tier-2 Chinese cities in our sample. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.

Table F.4: Frictions in Tier-3 Cities with Tier-specific Housing Production Function

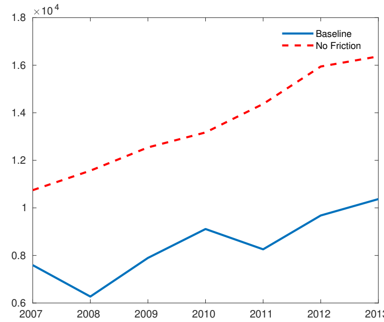
(a) Housing Frictions

Year	Mean	Sd	P25	Median	P75
2007	-1.51	1.32	-1.79	-1.17	-0.78
2008	-2.34	1.33	-2.63	-2.01	-1.44
2009	-1.63	1.35	-2.16	-1.36	-0.75
2010	-1.46	1.08	-1.90	-1.23	-0.65
2011	-1.77	1.05	-2.20	-1.60	-1.01
2012	-2.07	1.53	-2.43	-1.70	-1.15
2013	-1.86	1.14	-2.34	-1.65	-1.13
Total	-1.81	1.29	-2.27	-1.53	-1.01

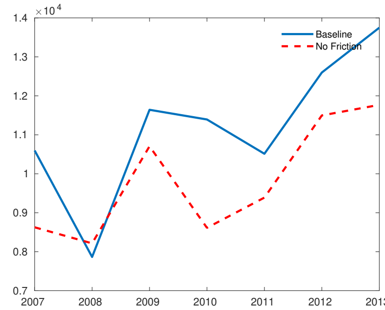
(b) Land Frictions

Year	Mean	Sd	P25	Median	P75
2007	3.08	3.28	1.05	2.04	3.47
2008	4.91	4.77	1.91	3.07	7.04
2009	2.29	2.47	0.58	1.67	3.36
2010	1.13	1.69	-0.08	0.73	1.77
2011	0.99	1.23	0.09	0.71	1.46
2012	1.63	2.13	0.18	0.84	2.26
2013	1.33	1.95	0.11	0.76	2.05
Total	2.19	3.01	0.32	1.36	2.92

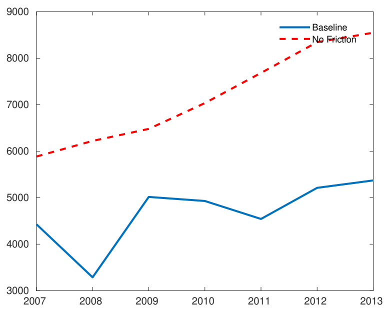
Notes: This table reports the summary statistics for the estimated frictions among the 73 tier-3 Chinese cities in our sample. The dataset is a combined one on Chinese housing and land markets. Mean is the simple average across all the cities within a given year, and Sd is the standard deviation. P10, P25, P75, and P90 refer to the respective percentile within the same year.



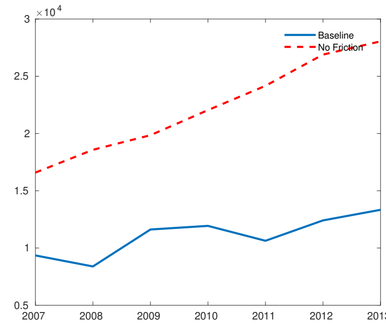
(a) Aggregate housing price



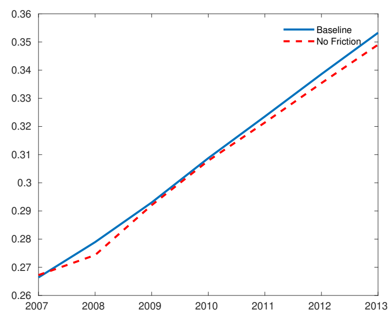
(b) Tier-1 housing price



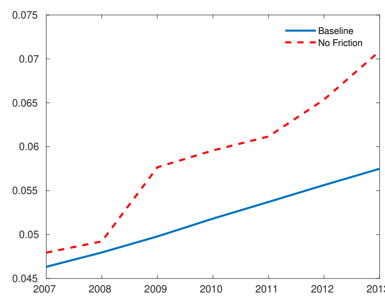
(c) Tier-2 housing price



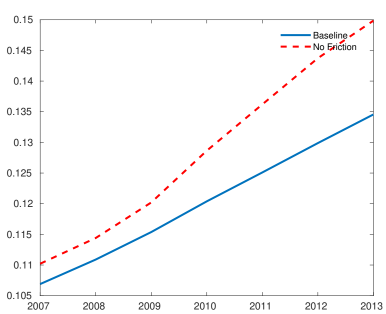
(d) Tier-3 housing price



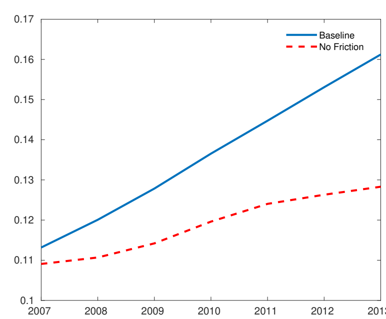
(e) Aggregate housing price



(f) Tier-1 housing price



(g) Tier-2 housing price



(h) Tier-3 housing price

Figure F.1: Eliminate either or both frictions: Housing and Land Prices

Notes: We eliminate either one or both types of frictions and report housing prices at the tier level. The prices at the tier level are a population-weighted average of the prices in each city.

Table F.5: Average welfare change among the different subgroups of individuals

Variable	2007-2013	2008-2009	2012-2013
National	-0.069	-0.061	-0.202
Rural	0.012	0.017	0.039
Urban all	0.198	0.133	0.292
Urban owner	0.183	0.124	0.194
Urban buyer	1.370	1.870	1.038
Tier-1 all	-0.059	-0.062	0.056
Tier-1 owner	-0.059	-0.061	0.055
Tier-1 buyer	-0.057	-0.059	-0.055
Tier-2 all	0.052	0.053	0.048
Tier-2 owner	0.051	0.053	0.048
Tier-2 buyer	-0.061	-0.063	-0.058
Tier-3 all	0.180	0.195	0.185
Tier-3 owner	0.187	0.195	0.181
Tier-3 buyer	-0.064	-0.067	-0.061

Notes: We report the percentage change in welfare from benchmark levels when we remove both frictions for different groups of individuals. We focus on the changes in the average welfare both during the entire sample period and during the two sub-periods: 2008-2009 and 2012-2013. The numbers in the table are in the unit of the percentage points.