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ABSTRACT

Housing and land prices in China have experienced dramatic hikes over the past decade or two. Moreover, housing and land prices have also become more dispersed across Chinese cities. This paper intends to explore how housing and land market frictions may affect not only the aggregate but also the spatial distribution of housing and land prices and hence the extent of spatial misallocation. We first document the spatial variations of housing and land market frictions. In particular, larger tier-1 cities receive less housing and land subsidies, compared to tier-2 and tier-3 cities, whereas land frictions have been mitigated over time. We then embed both types of market frictions into a dynamic competitive spatial equilibrium framework featured with endogenous rural-urban migration. The calibrated model can reasonably mimic the price hikes in the data. Our counterfactual analysis reveals that, in a frictionless economy, the levels of housing and land prices would both be higher; while the housing price hike would slow down, the land price would grow more rapidly. Moreover, the housing price would not be slow down unless housing frictions can be largely mitigated.

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1 Introduction

Over the past several decades, the world has witnessed several 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 disproportionated rapid housing price growth over the past decade or two dwarfs China's urbanization process. Its rural population drops from about three-quarters to still 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 urban housing market. The unprecedented housing booms trigger the government to implement regulatory policies toward mortgage finance 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. We hypothesize that the large dispersion of housing and land prices are likely attributable to differences in local government institutions and management practices, which cause market frictions to vary across cities.

Table 1 presents some summary statistics of housing and land prices across a set of 287 Chinese prefectural cities during 2007-2013. The average housing and land prices in 2013 are 1.58 and 1.53 times their level in 2007, respectively. In addition, over time, the mean level is always higher than the median level, which suggests a distribution skewed to the right. In this paper, we develop a dynamic competitive spatial equilibrium framework that incorporates frictions in both the housing market and the land market. Our model highlights that land is never simply a derived demand for housing in China. The model is also featured with endogenous rural-urban migration to mimic the rapid structural transformation process undertaken in China. We highlight the existing frictions in housing and land markets may affect the population distribution. Since the housing supply is relatively inelastic due to the

[1] Based on the 2000 census, about 87 percent of Chinese households owned houses. According to the National Bureau of Statistics of China, the total residential investment in urban areas reached nearly 57.8 trillion RMB in 2012, which is 100 times more than it was in 1998. The rising demands have led to a surge in housing prices (as documented below). The processes of China's structural transformation and urbanization and its migration policies and the deregulation of housing markets are summarized in Appendix A.

Table 1: 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

Chinese government's strong intervention toward land supply and the government control over the market entrance of real estate developers. As a result, housing and land prices may vary significantly across cities. The growth pattern of prices is mainly driven by the improvement of manufacturing productivity over time, which generates higher incomes in urban areas and improved housing affordability.

To further motivate the respective frictions in the housing and the land markets, we delineate in Figure 1 the evolution of the average market share among the top 8 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, suggests that they are likely oligopolists in local housing markets. However, they may not exercise oligopsony power in local land markets when the government essentially controls the land. Nonetheless, such market imperfection can result in price wedges when comparing with competitive equilibrium benchmarks. We also find that the market shares tend to be lower in larger cities, such as those tier-1 and tier-2 cities, 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, which is an outcome from gradual urban land and housing market reform toward competitiveness.

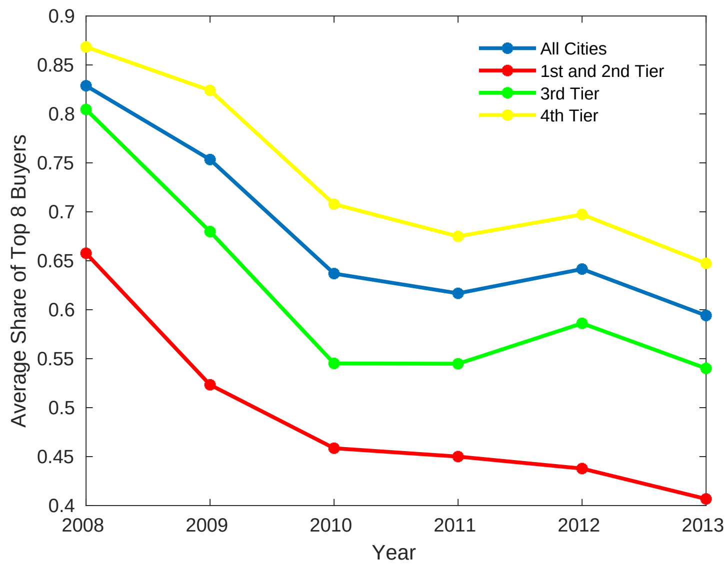


Figure 1: Average Share of Top 8 Buyers in Local Residential Land Markets

Source: Calculated based on data released by MLR, China

In our theoretical framework, we consider an economy that is geographically divided into two regions: a rural area that produces agricultural goods and an urban area (city) that produces manufactured goods (inclusive of urban services). Ongoing technological progress drives workers away from the rural agricultural sector to the urban manufacturing sector. In the baseline model, we assume that workers arriving in a city must purchase a house with a down payment and a long-term mortgage. For tractability, we further assume that a house is required for urban living, and it has no resale value. New homes are built by real estate developers who purchase land and construction permits from the government. Our basic framework considers only a single urban area, and then it is generalized to multiple cities. This extension allows us to assess the contribution of the spatial differences in frictions to changes in housing price growth rates across cities. More importantly, the multi-city framework provides theoretical guidance to our procedure in estimating city-level housing and land frictions.

We show that housing and land frictions vary substantially across cities. The average friction in the housing market is about -0.23 with a standard deviation of 0.58 percent, and the average friction in land market is about 0.32 with a standard deviation of 1.22 percent. This implies housing developers are subsidized at an amount equivalent to 23 percent of housing sales revenue but taxed at 32 percent of land purchases relative to their competitive benchmarks. Both frictions exhibit significant variations across the cities. The 75 percentile of the housing frictions across cities are taxed at about 15 percent of housing sales revenue. In comparison, the 25 percentile are subsidized around 45 percent of the housing sales revenue, yielding a 60 percentage points spread. The dispersion in land frictions is even more dispersed. Cities at the 75 percentile are taxed at a level equivalent to 63 percent of the land sales revenue while cities at the 25 percentile enjoy a 44 percent subsidy, with a 107 percentage points spread. The spatial spread of housing friction is persistent over the years, while the spread of land frictions drops by almost half.

To disentangle the contributions of both housing and land frictions in driving both the price growth and spatial dispersion of prices, we have performed various counterfactual exercises in which we either eliminate all the frictions, or only eliminate one friction at a time. We calibrate the model to mimic the early stages of development in China from 1980 to 2012. The 50-year projected path for China's structural transformation through 2063 is based on the U.S. experience from 1950 to 1990. We restrict our attention to the period from 2007 to 2013. This is because China's pre-2007 land market was not fully marketized, and land prices were heavily regulated.

The main findings can be summarized as follows. At the national level, the process of structural change can account for 94.2 (94.8) percent of housing (land) price growth factor from 2007 to 2013. In terms of the annual growth rate, the model can account for 82.4 and 81.0 percent of the changes in the data counterpart. When all the frictions are eliminated, the growth factor of housing and land prices are about 88.1 and 162 percent of their benchmark counterparts. Land friction exerts no role in housing prices, and thus, housing friction is substantial in driving housing price growth. However, the contribution of each friction to land price growth varies by year.

In the multiple-city case, the coefficient of variation for housing and land prices have decreased by 30 and 15 percent, respectively, if we eliminate all the frictions. Housing price inequality is considerably lowered when we only remove housing frictions. As for land prices, our results suggest that land frictions amplify land price dispersion. On average, once the land frictions are removed, the coefficient of variation of land price is about 90 percent of the benchmark level. In contrast, housing frictions tend to dampen land price inequality. Overall, the model underpredicts the housing price ratio in 60 cities. In contrast, it overpredicts the land price ratio in 40 cities. On average, housing and land price ratios are about 0.95 and 1.92 times of their data counterparts, respectively.

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. In mainland China, while local governments still retain ultimate ownership of all urban lands on behalf of the State, enterprises (such as housing developers) are 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, all future rental payments of the land parcel are included in an initial lump-sum payment by the developer, which can be treated 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 equaling 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 high-rise residential buildings on the parcel, which typically take 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.

Since land is an 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 to curb housing price surge. In 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 3rd or 4th tier cities. Besides the government's intervention policies, during the past decades, almost all the Chinese cities are 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 have been considered and reflected in the 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 of such briberies aim at lowering the acquisition costs at land purchase (Chen and Kung (2018)).

Literature Review

The Chinese economy has undergone many political and economic reforms since 1978. Its rapid growth has made it the second-largest economy in the world, with especially significant growth since 1992. There is an extensive literature studying the development of China. For brevity, the reader is referred to Zhu (2012) for a thorough summary of the various stages of economic development. There is a small but growing literature investigating China's housing boom, including research by Chen and Wen (2017), Fang et al. (2015) 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. There have been numerous studies on structural transformation using dynamic general equilibrium models without spatial considerations. For a comprehensive survey, the reader is referred to 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. While Glomm and Ravikumar (1992) studies rural-urban migration as a result of higher urban productivity due to agglomerative economies, Lucas (2004) highlights a dynamic driver of such migration, the accumulation of human capital and hence the ongoing rise in city wages. More recently, Riezman et al. (2012) show that 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. Focusing on China, Liao et al. (2017) find that education-based migration plays an equally important role in work-based migration in the process of urbanization. None of these papers study housing markets.

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 determined only by migrants moving from rural areas to cities (the extensive margin). 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 considers the scenario that 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 angle with the migration decision endogenously determined in the model.

2 Theoretical Framework

The economy consists of two regions, urban and rural area. Time is discrete and infinite indexed by $t = 0, 1, 2....$ 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 migration from rural to urban.

Because the main issue is urbanization-related spatial misallocation associated with urban housing and land markets, we simply the decision-making in rural areas by assuming that the payoff from staying in the rural is exogenously given by $\underline{U}$, which is a reservation payoff resulting from backyard farming. Moreover, the value obtained from residing in a farm house is normalized to zero.

In urban areas where the main actions occur, there is a single consumption good c^m produced with the use of both capital and labor. City workers obtain utilities from consumption and housing. Housing is assumed to be a necessity and satiated good for city workers. Specifically, we follow Berliant et al. (2002), postulating that the utility function for city workers takes the following form:

$$U(c_t^m, h_t) = \begin{cases} u(c_t^m) & \text{if} \quad h_t \geq 1 \\ -\infty & \text{otherwise,} \end{cases} \tag{1}$$

where we assume $u'(\cdot) > 0$ and $u''(\cdot) < 0$. That is, consumption is enjoyed and yield utility $u(c_t^m)$ when residing in a house; without a house, a city work would be in misery with $U(c_t^m, h_t) = -\infty$. Once with a house ($h_t \geq 1$), a worker does not value additional unit of houses. Thus, in the equilibrium each city worker demands for exactly one unit of house. This structure, as pointed out byBerliant et al. (2002), helps reducing the dense set of multiple equilibria and simplifies the analysis dramatically.

Incumbent city residents at time t will carry a mortgage debt from purchasing a house at time $\tau < t$, b_τ. Let $V_t^C(b_\tau)$ represent the lifetime payoff for a worker with mortgage debt b_τ. The worker derives current utility $U(c_t^m, h_t)$ as specified in (1) above and discounts future payoffs at rate β by choosing between staying in the city, $V_{t+1}^C(b_\tau)$, and returning to the rural area, V_{t+1}^R. The worker spends wage income, w_t, on consumption and mortgage debt repayment, $b_\tau r^*$, under an exogenous mortgage interest rate $r^* > 0$. The optimization problem for a worker that moved in $\tau < t$ can thus be specified as:

$$\begin{aligned} V_t^C(b_\tau) = \max U(c_t^m, h_t) \quad &+ \quad \beta \max\{V_{t+1}^C(b_\tau), V_{t+1}^R\} \\ s.t. \qquad c_t^m + b_\tau r^* \quad &= \quad w_t \end{aligned} \tag{2}$$

2.1 Migration Decisions

A new migrant from rural to urban at time τ must purchase a house at market price q_τ. The housing purchase is financed with an infinite consol fixed-rate mortgage that requires a down payment at rate ϕ. In the following periods, the specified repayment is a constant d_τ, which can be derived by equating the size of the loan to the present discounted value of all mortgage payments:

$$(1-\phi)q_\tau h_\tau = \sum_{t=\tau+1}^{\infty} \frac{d_\tau}{(1+r^*)^{t-\tau}}.$$

Given the constant interest rate, r^*, the constant payment is simply

$$d_\tau = (1-\phi)r^* q_\tau h_\tau. \tag{3}$$

Under this simple debt structure, the loan-to-value ratio is capped by $1-\phi$. We assume the mortgage contract satisfies $\phi > \frac{r^*}{1+r^*}$ to ensure that the down payment exceeds the mortgage payment each period. Notably, one may consider a city economy with all workers renting houses from absentee landlords who purchase them in advance to fill the demand. Maintaining the same housing demand structure, one may then capture this pure rental case by setting $\phi = r^*/(1+r^*)$, under which an agent migrating in period τ signs a long-term rental agreement paying a rent d_τ every period based on the housing price.[2] Thus, the pure rental market can be viewed as a special case of our model.

The optimization problem of new rural migrant to urban in period τ is thereby specified as follows:

$$\begin{aligned} V_\tau^M = \max U(c_\tau^m, h_\tau) \quad &+ \quad \beta \max\{V_{t+1}^C(b_\tau), V_{t+1}^R\} \\ s.t. \qquad c_\tau^m + p_\tau h_\tau \quad &= \quad w_\tau + b_\tau \\ b_\tau \quad &\leq \quad (1-\phi)p_\tau h_\tau. \end{aligned} \tag{4}$$

While the recursive formulation of the value function resembles that of an incumbent city

[2] Similar to the case of resales, allowing for a one-period rental agreement would make the model intractable because a migrant's decision would then depend on the entire path of current and future housing prices (and hence migration flows).

resident, the budget constraint is modified with mortgage loan, b_τ, added to the income side and the housing purchase, $p_\tau h_\tau$, to the expenditure side. Moreover, the mortgage contract requires a downpayment at rate ϕ, so the maximum loan to value is $1-\phi$.

Given the expressions for V_τ^M, and V_τ^R in (2) and (4), we can now determine the conditions under which workers with migration cost ϵ move into the city at time τ as follows:

$$V_\tau^M - \epsilon \geq \underline{U}.$$

That is, a rural worker will migrate to a city if and only if the payoff from migration, namely payoff from residing in a city net of the disutility cost of migration, is greater than from staying in the rural area. There exists an ϵ_τ^* 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:

$$V_\tau^M - \epsilon_\tau^* = \underline{U} \tag{5}$$

We summarize some analytical properties regarding to the cutoff migraiton cost in the following proposition.

Proposition 1 *(Migration Decision) In each period τ, there exists a unique cutoff migration cost ϵ_τ^*, below which workers will choose to migrate to the city in τ. The cutoff migration cost is increasing in urban wage but decreasing in urban housing prices.*

Intuitively, the higher the urban wage rate or the lower the urban housing price, the more attractive is for rural workers to migrate to urban areas.

2.2 Production

The manufacturing goods market is perfectly competitive. There is a continuum of manufacturing producers of mass one. Each is endowed with $K_0 > 0$ units of capital at $t = 0$, using the existing capital K_t at the begining of time t and labor N_t to produce the single manufactured good. The production function takes a prototypical Cobb-Douglas form:

$$Y_t = A_t^m K_t^\sigma N_t^{1-\sigma}, \tag{6}$$

where $\sigma \in (0,1)$ captures the capital share, A_t^m is an exogenous total factor productivity in the manufacturing sector at t. Throughout the production process over time t, capital is depreciated geometrically at rate $\delta \in (0,1)$, so the capital stock evolves over time according to:

$$K_{t+1} = K_t^{1-\delta} I_t^{\delta}. \tag{7}$$

It is noted that the geometric formulation of capital depreciation improves tractability of the analysis.

A manufacturing firm in each period makes capital investment I_t and labor demand decision to maximize its value. Specifically, given a discount factor $\beta \in (0,1)$, its optimization problem takes a recursive form:

$$\begin{aligned} V_t^F(K_t) = \max_{I_t, N_t} A_t^m K_t^{\sigma} N_t^{1-\sigma} - w_t N_t \quad &- \quad I_t + \beta V_{t+1}^F(K_{t+1}) \\ \text{s.t.} \quad K_{t+1} \quad &= \quad K_t^{1-\delta} I_t^{\delta} \end{aligned} \tag{8}$$

where a firm's value, depending on the current state K_t, is equal to its profit flow plus the continuation value, the discounted future value.

2.3 Government

We now turn to the supply side of the housing market. In the model economy, land is owned and supplied by the government. Total available area of land in the city is normalized to one. At the beginning of each period, the government determines the amount of land available for housing developers $\ell_t \geq 0$ to the pre-existing stock of land L_{t-1}, for the purpose of residential housing construction. The aggregate law of motion for land is thus given by,

$$L_t = \ell_t + L_{t-1}, \tag{9}$$

where the aggregate land area occupied by houses in the city cannot exceed 1 (i.e., $L_t \leq 1, \forall t$). Since the average house size is fixed, the law of motion for the housing stock is entirely characterized by the fraction of movers, ΔF_t^*, and existing residents in the city, H_{t-1}:

$$H_t = H_{t-1} + \Delta F_t^*, \tag{10}$$

Thus, H_t represents the number of houses that the government has granted permission to build until the end of period t, which we shall for brevity referred to as the housing stock at t.

The government not only controls the supply of land but also charges housing developers a housing development, or permit or leasing fee, Ψ_t, in units of manufactured goods, which determines the number of permits granted at the beginning of time t:

$$\Psi_t = \psi \left(H_{t-1}\right)^{\eta}, \tag{11}$$

where $\psi > 0$, $\eta > 0$, and the average land development fee is rising over time if $\eta > 1$. Thus, a larger number of permits granted in the past, H_{t-1}, implies a higher development fee, which captures public concern about urban congestion and issues associated with urban sprawl.

2.4 Housing Developers

A housing developer 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:

$$h_t = A_t^h (z_t - \underline{z}_t)^{\gamma} I_{ht}^{\alpha}, \tag{12}$$

where $\alpha > 0$, $\gamma > 0$, $0 < \alpha + \gamma < 1$, $A_t^h > 0$ represents housing construction technology, and $\underline{z}_t > 0$ captures the minimum land requirement for build house. In equilibrium, $\underline{z}_t = \zeta_t z_t$; that is, the minimum land requirement is a fraction of the equilibrium amount of land purchased by developers. 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 inventories management, we assume that each housing developer lives for only one period and is replaced by an identical developer upon constructing and selling the houses built over the period of time. Thus, a developer simply decides how much land and construction materials to buy to maximize the operative profit Π_t^d, whose optimization problem is specified as:

$$\Pi_t^d = \max_{z_t, I_{ht}} (1 - \tau_{ht}) p_t A_t^h (z_t - \underline{z}_t)^\gamma I_{ht}^\alpha - q_t z_t (1 + \tau_{zt}) - p_{It} I_{ht}, \tag{13}$$

where p_t represents the selling price of a new housing unit at the end of period t, q_t is the land price that a housing developer must pay to acquire the land parcels from the government, and p_{ht} is unit cost of construction materials which is exogenously given. There are two wedges: a housing price wedge τ_{ht} governing housing market distortions/frictions and a land price wedge τ_{zt} capturing land market distortions/frictions.

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 housing developers, S_t:

$$\Pi_t^d = \Psi_t. \tag{14}$$

3 Competitive Spatial Equilibrium

We first formalize the definition of equilibrium in our benchmark economy with a rural area and a urban area, then we proceed to characterize several equilibrium properties.

Definition: Given exogenous parameters $\{\ell_t, p_{ht}, A_t^m, A_t^h\}_{t=0}^\infty$ and initial conditions H_0 and K_0, a *competitive spatial equilibrium* consists of a list of prices $\{p_t, q_t, w_t\}_{t=0}^\infty$, individual quantities $\{h_t, c_t\}_{t=0}^\infty$, a migration cutoff value $\{\epsilon_t^*\}_{t=0}^\infty$, a capital stock path $\{K_t\}_{t=0}^\infty$ and an employment vector of workers and developers $\{N_t^m, S_t\}_{t=0}^\infty$ that satisfies the following conditions:

1. Workers, manufacturing firms and housing developers all solve their optimization problems (2), (8) and (13);

2. There is a cutoff of mobility cost ϵ_t^* pinned down by (4), with those below the cutoff migrating to the city;

3. The number of housing developers is determined by the equilibrium entry condition (14);

4. All markets clear:

   (a) land:

$$S_t z_t = \ell_t, \tag{15}$$

   (b) housing:

$$S_t A_t^h (z_t - \underline{z}_t)^\gamma I_{ht}^\alpha = F(\epsilon_t^*) - F(\epsilon_{t-1}^*), \tag{16}$$

   (c) manufactured goods: $D_t = Y_t$.

It is noted that the market clearing condition of the manufactured goods is redundant by Walras' law.

3.1 Labor Demand and Manufacture Output

Given wage rate w_t and existing capital stock K_t, manufacturing firm's hires labor at the marginal product, $(1-\sigma)A_t^m(\frac{K_t}{N_t})^\sigma = w_t$, which yields a labor demand schedule as follows:

$$N_t = \left[\frac{(1-\sigma)A_t^m}{w_t}\right]^{\frac{1}{\sigma}} K_t. \tag{17}$$

That is, labor demand is increasing in the existing capital stock and manufacturing productivity but decreasing in wage. Profit maximized output becomes:

$$Y_t(K_t) = (A_t^m)^{\frac{1}{\sigma}} \left(\frac{1-\sigma}{w_t}\right)^{\frac{1-\sigma}{\sigma}} K_t \tag{18}$$

depending only on the state variable. The value function can thus be rewritten as:

$$V_t(K_t) = \max_{I_t} \sigma Y_t(K_t) - I_t + \beta V_{t+1}(K_t^{1-\delta} I_t^\delta)$$

Solving manufacturing firm's optimization and imposing steady state with constant A^m and hence $K_t = K_s$ and $N_t = N_s$ for all t, we have:

$$\beta\delta\sigma^2 A^m \left(\frac{K_s}{N_s}\right)^{-(1-\sigma)} = 1 - \beta(1-\delta) \tag{19}$$

Thus, we are arrived at:

Proposition 2 *(Steady-State Capital-Labor Ratio) In steady-state equilibrium, the capital-labor ratio is a constant, depending positively on manufacturing productivity.*

3.2 Housing and Land

In the following, we turn to solving housing developer's optimization problem, with detailed manipulation relegated to Appendix A.

Housing developer's optimization is summarized by land and construction material demands:

$$\begin{aligned}(1-\tau_{ht})\, p_t \gamma A_t^h \left(z_t - \underline{z}_t\right)^{\gamma-1} I_{ht}^{\alpha} &= q_t \left(1+\tau_{zt}\right) && (20)\\ (1-\tau_{ht})\, p_t \alpha A_t^h \left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha-1} &= p_{It} && (21)\end{aligned}$$

From housing market clearing condition and $\underline{z}_t = \zeta_t z_t$, we have construction materials governed by,

$$I_{ht}^{\alpha} = \frac{\Delta F\left(\epsilon^*\right) z_t^{1-\gamma}}{\ell_t A_{ht}\left(1-\zeta_t\right)^{\gamma}} \tag{22}$$

which only depends on land, z, and net migration flows, $\Delta F\left(\epsilon^*\right)$. Equilibrium entry of housing developers implies:

$$\left(1-\alpha-\gamma\right)\left(1-\tau_{ht}\right) p_t A_{ht}\left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha} = \Psi_t \tag{23}$$

Combining (22) and (23), we get:

$$z_t = \frac{\Psi_t \ell_t}{\left(1-\alpha-\gamma\right)\left(1-\tau_{ht}\right) p_t \Delta F\left(\epsilon^*\right)} \tag{24}$$

which is a decreasing function of p and $\Delta F(\epsilon^*)$ alone.

We now substitute (22) and (24) into land and construction material demands (20) and (21) to obtain two fundamental relationships governing the housing-distortion augmented *net housing price*, $(1-\tau_{ht})\,p_t$, and the land-distortion augmented *net land price*, $(1+\tau_{zt})\,q_t$:

$$(1-\tau_{ht})\,p_t = \Xi_{ht}\Delta F(\epsilon^*)^{\gamma/(1-\gamma)} \equiv P_t\left(\overset{+}{\Delta F}(\epsilon_t^*)\right) \tag{25}$$

$$(1+\tau_{zt})\,q_t = \frac{\Xi_{qt}\Delta F(\epsilon^*)^{(\alpha+\gamma)/\alpha}}{[(1-\tau_{ht})\,p_t]^{(1-\alpha-\gamma)/\alpha}} \equiv Q_t\left(\overset{+}{\Delta F}(\epsilon_t^*);\overset{+}{\tau}_{ht}\right) \tag{26}$$

where $\Xi_{ht} \equiv \frac{\left[\frac{p_{It}}{\alpha}\right]^{\frac{\alpha}{1-\gamma}}\left[\frac{\Psi_t}{1-\alpha-\gamma}\right]^{\frac{(1-\alpha-\gamma)}{1-\gamma}}}{A_{ht}^{1/(1-\gamma)}[(1-\zeta_t)\ell_t]^{\frac{\gamma}{1-\gamma}}}$ and $\Xi_{qt} \equiv \frac{\gamma p_{It}\left[\frac{\Psi_t}{(1-\alpha-\gamma)}\right]^{(1-\alpha-\gamma)/\alpha}}{\alpha A_{ht}^{1/\alpha}[(1-\zeta_t)\ell_t]^{(\alpha+\gamma)/\alpha}}$ are both exogenous, depending only on the existing housing stock H_{t-1}.

A quick observation indicates that net housing price and net land price are both increasing in net migration flows, $\Delta F(\epsilon^*)$. Let us put aside the dynamic general equilibrium effects via housing evolution and migration dynamics, by focusing on *temporal spatial equilibrium* in which H_{t-1} and ϵ_{t-1}^* are both taken as given. Then, it can be seen that both housing distoriton τ_{ht} and land distortion τ_{zt} do not have any direct impact on either net price. The results can be summarized in the proposition below.

Proposition 3 *(Housing and Land Prices) In temporal spatial equilibrium,*

1. *both net housing price $(1-\tau_{ht})\,p_t$ and net land price $(1+\tau_{zt})\,q_t$ are rising with net migration flows $\Delta F(\epsilon^*)$;*

2. *land distortion τ_{zt} has no direct impact on either net housing price or net land price;*

3. *housing distortion τ_{ht} has no direct impact on either net housing price or net land price.*

It is convenient to refer to (25) as an *aggregate housing supply flow* (AS) locus :

$$p_t = AS_t(\overset{+}{\Delta F}(\epsilon_t^*);\overset{+}{\tau}_{ht}) \tag{27}$$

where $\Delta F(\epsilon^*) = \Delta H$ is the flow measure of aggregate housing supply. From Proposition 3 above, it is clear that AS is increasing in both net migration flow and housing distortion. Because net migration flow is indeed the flow of aggregate housing supply, the former property implies that AS is upward-sloping.

The locational no-arbitrage condition from the consumer side, on the other hand, gives an *aggregate housing demand flow* (AD) schedule:

$$p_t = AD_t(\Delta \overset{-}{F}(\epsilon_t^*)) \tag{28}$$

From Proposition 1, we know that the cutoff migration cost is increasing in urban wage but decreasing in urban housing price. Thus, AD is downward sloping, shifting upward when urban wage rises.

Equating AD and AS solves $\Delta F(\epsilon^*)$ and hence aggregate housing flow ΔH, as well as the cutoff migration cost ϵ^*. It is clear from the expressions above that the land market distortion τ_{zt} has no direct effect on the equilibrium housing price. Actually, the effects of land market distortions are only in dynamic general equilibrium through the evolution of housing stocks, the path of migration cutoffs and the intertemporal optimization of households. In temporal spatial equilibrium, we can thus establish:

Proposition 4 *(Housing and Migration) In temporal spatial equilibrium, an increase in housing distortion τ_{ht} leads to:*

1. *a higher housing price p_t;*
2. *a lower net migration flow $\Delta F(\epsilon^*)$ and aggregate housing flow ΔH;*
3. *a smaller migration cost cutoff ϵ^*.*

Utilizing Proposition 4, we can obtain:

Proposition 5 *(Land and Migration) In temporal spatial equilibrium,*

1. *an increase in housing distortion τ_{ht} leads to a lower land price q_t but a higher land demand z_t;*

2. an increase in land distortion τ_{zt} reduces land price but has no effect on land demand.

Thus, an increase in land distortion land price proportionately such that the augumented land price $(1+\tau_{zt})\,q_t$ is unaffected. As a result of this complete passthrough, land distortion has no direct effect on housing price, net migration flow or aggregate housing flow, nor the induced demand for land.

We should note that intertemporally any changes in (τ_{ht}, τ_{zt}) would affect Euler equations as well as law of motion equations, thereby feeding back to affect housing and land prices as well as migration. We shall leave these complicated dynamic effects to quantitative examination.

3.3 The Case of Multiple Cities

The model in the previous section restricts the analysis to a single city. We now extend the model to the case of multiple cities. Suppose there are cities $I > 1$. All of the cities are identical and have access to the same technology to produce manufactured goods that can be costlessly traded across cities. The cities differ in two aspects: (i) the availability of land (exogenously) supplied by the government, $\{\ell_i\}_{i=1}^{I}$; (ii) the city specific housing and land frictions, $\{\tau_i^h, \tau_i^z\}_{i=1}^{I}$. As a result, equilibrium wages and housing supply and demand are city specific.

In the interest of tractability, city selection is determined by lottery. The probability that a rural worker will be assigned to city i is denoted by π_i, where $\sum_{i=1}^{I} \pi_i = 1$. The city labor markets are segmented because labor mobility across cities is not permitted.[3] As a result, in equilibrium, wages across cities do not equalize. As such, once a rural worker is assigned to city i, his location choice afterward is to either continue to stay in city i or move back to the rural area.

For a worker of type ϵ, the utility cost of migrating from the rural area to any of the I cities is represented by ϵ. Let $V_{i,t}^{M}(\epsilon)$ denote the value function for a worker of type ϵ who

[3]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.

migrates to city i in period t and solves this optimization problem:

$$
\begin{aligned}
V^M_{i,t}(\epsilon) = \max U(c_{i,t}, h_{i,t}) + \beta \max\{V^C_{i,t+1}(\epsilon, b_{i,t}), V^R_{t+1}(\epsilon)\}, \\
s.t. \qquad c^m_{i,t} + p_{i,t}h_{i,t} = w_{i,t} + b_{i,t}, \\
b_{i,t} \leq (1-\phi)p_{i,t}h_{i,t}.
\end{aligned}
$$

This problem is similar to the one for the single-city model, but in this case wages and housing prices are determined at the city level. The ex-ante value associated with migration is represented by $V^M_t(\epsilon)$, which equals the expected payoff from living in any one of the I cities, $V^M_t(\epsilon) = \sum_i \pi_i V^M_{i,t}(\epsilon)$. Therefore, a worker of type ϵ will migrate to an urban area in period t when following condition is satisfied, $V^M_t(\epsilon) - \epsilon \geq \underline{U}$. In each period $t > 0$, there exists a cutoff ϵ^*_t, below which workers move to an urban area. The threshold ϵ^*_t can be pinned down from the following indifference condition:

$$
V^M_t(\epsilon^*_t) - \epsilon^*_t = \underline{U}
$$

Housing developers in each city are endowed with the same technology to convert land into houses. The entry fee collected by the government in each city will obey these rules, so the entry fee collected by city i in period t positively depends on the existing housing stock in city i: $\Psi_{i,t} = \psi H^\eta_{i,t-1}$, where $\psi > 0$. Therefore, the number of housing developers in each city, $M_{i,t}$, will be determined by the following free-entry condition, $\Pi^d_{i,t} = \Psi_{i,t}$.

The housing and land markets will clear in each city subject to the exogenous land supply controlled by the government in each city. The market-clearing conditions in city i can be derived as follows:

$$
\begin{aligned}
S_{i,t} z_{i,t} = \ell_{i,t}, \\
S_{i,t} A^h_{i,t} z^\gamma_{i,t} I^\alpha_{i,ht} = \Delta F^*_{i,t}.
\end{aligned}
$$

4 Calibration and Estimation

We now turn to quantitative analysis. There are two primary tasks: (1) to estimate and characterize city-specific housing and land distortionary wedges, , and (2) to conduct counterfactual analysis to quantify the roles of the two distortionary wedges.

4.1 Data

To estimate city-specific housing and land distortionary wedge or frictions, we need the following data at the city level: (1) Real average prices of newly-built housing units; (2) Real average prices of residential land parcels; (3) Floor areas of newly-built housing units sold; (4) Investments on housing development excluding land purchase; (5) Residential land sales; (6) Real unit construction costs. Due to the 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 roughly a fraction of 60 and 70 of the entire country. In Figure C.1 we map the selected cities in our sample.[4]

During 2007-2013, the average annual growth rate of housing and land prices among our selected cities is 8.92 and 19.92 percent, respectively. The top 3 cities with the highest housing price growth rate are Ganzhou, Jiujiang and Luzhou, and the bottom 3 cities with the lowest housing price growth rate are Tongling, Dalian, and Daqing. Similarly, the top 3 cities with the highest land price growth rate are Wuxi, Zhanjiang and Xining, while the bottom 3 cities are Baoji, Panzhihua and Tongling. We map the distribution of housing and land price growth rate in Figure C.3. We also provide the ratio of housing and land price in 2013 to that of 2007, also summarized in Figure C.3. In Figure C.4 we map both housing and land price levels in year 2013. The unit is RMB per square meters in 2010 RMB. The top 3 cities with the highest housing price level are Shenzhen, Beijing and Shanghai, respectively. They all belong to the tier-1 cities in China. There are in total 10 cities in our sample with housing price exceeding ten thousand RMB per square meter in 2013. The top 3 cities with the most expensive land are in turn: Shenzhen, Sanya and Xiamen, respectively.

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

4.2 Estimation of Housing and Land Frictions

According to the previous theoretical results, we can estimate the city-level housing and land market frictions as:

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

where $I_{ht} p_{It}$ refers to the investment on housing development excluding land purchase expenses in the data. $q_t(z_t - \underline{z}_t)$ is land sales revenue and $p_t A_t^h (z_t - \underline{z}_t)^\gamma I_{ht}^\alpha$ is housing sales revenue, which is computed using data on floor area of newly-built housing units sold combined with the relevant price information. In addition, we also need to back out the parameter value for α and γ, which is the construction material share and land share in the housing production. To achieve this end, we run the following panel regression:

$$\log(q_{it}) = c + \beta_1 \log(\ell_{it}) + \beta_2 \log(I_{it}) + \beta_3 t + \delta_i + \epsilon_{it} \tag{29}$$

where q_{it} is floor area of newly-built housing units sold measured in 10,000 sq.m. ℓ_{it} is residential land sales measured in 10,000 sq.m. I_{it} is construction material and we compute it by dividing the residential investment excluding land purchase by the real unit construction cost. We have included a time trend and controlled all the city fixed effects. The estimated coefficient then β_1 and β_2 corresponds to α and γ, respectively.

The summary statistics for our estimated city-level housing and land market frictions are presented in Table 2. Our results suggest the average friction in housing market is about -0.23 with a standard deviation of 0.58 percent, and the average friction in land market is about 0.32 with a standard deviation of 1.22 percent. This implies housing developers are taxed at an amount equivalent to 32 percent of the land sales revenue in order to acquire land input into housing production, but they are able to obtain additional revenue equivalent to 23 percent of housing sales revenue to compensate the extra land cost incurred. Throughout the years, the national median of each friction is always smaller than the mean, suggesting that the distributions across the cities are skewed to the right and some cities experience particularly high frictions. The frictions exhibit large variations across the cities. The 75 percentile of the housing frictions across cities are taxed at about 15 percent of housing sales revenue, while the 25 percentile are subsidized roughly equivalent to 45 percent of the housing sales revenue, 60 percentage points lower than those at the 75 percentile. Land frictions exhibit similar spread: cities at the 75 percentile are taxed at a level equivalent to 63 percent of the land sales revenue while cities at the 25 percentile enjoy a 44 percent subsidy, 107 percentage points lower than those at the 75th percentile. The spatial spread of housing frictions is persistent over the years, where the 75-25 spread of housing frictions is 0.26-(-.29) = 55 percent in 2007, and 56 percent in 2013. The comparable figures for land are 104 and 70 percent in 2007 and 2013, respectively. Overall, variations in land frictions are substantially higher than in housing frictions, but land friction variations exhibit a downward trend over time in contrast to housing friction variations.

Frictions by city-tier In Table C.1, Table C.2 and Table C.3, we have presented the summary statistics within the group of tier-1, tier-2 and tier-3 cities, respectively. The following features stand out: 1) housing frictions among tier-1 cities are positive, and negative among tier-2 and tier-3 cities, likely due to the fact that smaller cities are less affected by the strict housing market intervention policies; 2) land frictions are more severe in lower tier cities, likely due to less established land aution. We will also dicuss institutional backgrounds in greater details later.

To reconfirm these patterns, we further explore how frictions change with respect to city size, and the results are reported in Table 3. The first column only includes the city size measured by GDP on the right-hand-side, and it shows that larger cities are taxed more in the housing sales revenue and also taxed less in the costs of land inputs. Doubling the GDP increases the housing frictions by 22.3 percentage points. In contrast, doubling GDP decreases the land frictions by 20 percentage points. If we include both the linear time trend and the interaction between city size and the time trend to the RHS, for housing frictions the coefficient on the interaction term is not significantly from zero. This suggests that the gaps in housing frictions between large and small cities stayed roughly the same over the years. On the other hand, for land frictions the coefficient on the interaction term is

Table 2: Summarize Statistics for Estimated Frictions

(a) Housing Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	-0.08	0.58	-0.63	-0.29	0.05	0.26	0.41
2008	-0.48	0.60	-1.29	-0.69	-0.36	-0.09	0.13
2009	-0.13	0.63	-0.81	-0.35	-0.03	0.32	0.52
2010	-0.08	0.51	-0.68	-0.28	0.02	0.30	0.43
2011	-0.23	0.45	-0.76	-0.36	-0.15	0.08	0.18
2012	-0.33	0.66	-0.80	-0.54	-0.21	0.05	0.21
2013	-0.25	0.52	-0.84	-0.45	-0.15	0.11	0.31
Total	-0.23	0.58	-0.82	-0.45	-0.12	0.15	0.35

(b) Land Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.72	1.39	-0.44	-0.16	0.28	0.88	2.90
2008	1.36	1.91	-0.11	0.18	0.74	1.76	3.41
2009	0.30	1.01	-0.61	-0.38	0.06	0.75	1.48
2010	-0.12	0.70	-0.77	-0.61	-0.36	0.16	0.81
2011	-0.10	0.63	-0.65	-0.54	-0.28	0.08	0.67
2012	0.10	0.82	-0.58	-0.43	-0.17	0.42	1.02
2013	-0.04	0.78	-0.69	-0.55	-0.28	0.15	0.90
Total	0.32	1.22	-0.64	-0.44	-0.01	0.63	1.60

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

significantly positive, which implies the city size elasticity of land frictions gets closer to zero over time. Column 3 includes both year and city fixed effects to the RHS of the estimation. The coefficients on city size are no longer significantly different from zero. This suggests that those frictions are probably rooted in the time-insensitive city characteristics such as institution quality or the geographic locations that correlate with city size, and the frictions in both housing and land markets are not alleviated by economic development over time.

The positive relation between city size and housing frictions suggest that housing is still heavily subsidized in small cities. Since 2005, the Chinese governments have implemented several rounds of strict housing market intervention policies in major cities (especially the

Table 3: City size and estimated frictions

	Housing Frictions)			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(GDP)	0.223***	-2.940	0.600	-0.200***	-71.541**	0.245
	(0.066)	(41.538)	(0.413)	(0.041)	(28.436)	(0.326)
Year		-0.068			-0.349***	
		(0.165)			(0.109)	
Ln(GDP) × Year		0.002			0.036**	
		(0.021)			(0.014)	
N	651	651	651	651	651	651
R-squared	0.049	0.059	0.609	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. The table reports regressions of city-level housing and land frictions against GDP between 2007 and 2013. The unit of observation is city-year. The data source for GDP is the city-level statistical yearbooks, and the frictions are based on the estimation procedure outlined in Section 4.2.

first tier cities and a few second tier cities), with the purpose of curbing housing price surge. The major policies include restrictions on loan-to-value ratio and interest rate for housing mortgages, higher transaction taxes for housing resales, and, perhaps most importantly, restrictions on multiple home purchase for local households or any home purchase for non-resident households since 2010. However, during most periods these policies did not apply to the smaller third or fourth tier 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 city, mainly including transaction tax rebating, local registered permanent residence (hukou) awarding, lower mortgage interest rates, or even monetary subsidies for home purchase.

Table 4 reports the evolution of the frictions over time. The first column reports the regression against a linear time trend, and the results confirm an overall reduction in land frictions over time. Recall from Proposition 5 that an increase in land distortion reduces land price. Thus, the reduction in land frictions suggests that the land inputs become more expensive over time. The second column replaces the linear time trend with year dummies. Land frictions have been decreasing over the years steadily. On the contrary, there is no clear-cut trend in housing frictions. Most of the reduction in housing frictions occurred in year 2008, 2012 and 2013. The last column introduces city fixed effects in addition to the year dummies. The point estimates on year dummies are mostly unaffected, suggesting again that cities experienced similar trends of frictions over the years.

Table 4: The estimated frictions over time

LHS = Frictions	Housing Frictions			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	-0.012			-0.327***		
	(0.013)			(0.038)		
Year=2008		-0.463***	-0.463***		1.117***	1.117***
		(0.061)	(0.061)		(0.392)	(0.392)
Year=2009		-0.058	-0.058		-0.734***	-0.734***
		(0.048)	(0.048)		(0.277)	(0.276)
Year=2010		0.005	0.005		-1.481***	-1.481***
		(0.053)	(0.053)		(0.234)	(0.234)
Year=2011		-0.167**	-0.167**		-1.446***	-1.446***
		(0.065)	(0.065)		(0.244)	(0.244)
Year=2012		-0.281***	-0.281***		-1.085***	-1.085***
		(0.077)	(0.077)		(0.268)	(0.267)
Year=2013		-0.193***	-0.193***		-1.345***	-1.345***
		(0.066)	(0.066)		(0.256)	(0.255)
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.

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 leasehold purchases to be sold via some type of public auction process. This can be considered as 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. MLR also issued or revised several techniques codes or documents in 2004, 2006, 2007, 2009 and 2011, respectively, to further improve the competitiveness and transparency of urban land market. Generally, the urban residential land market is more competitive in larger cities, compared with the smaller cities, for at least two reasons. First, the rules associated with urban land market are typically better established in the leading cities. Second, typically there are much more developers in larger cities, and thus more potential competing buyers in the residential land market.

Table 5: 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 4, if housing is subsidized in most cities, then housing price is lower than that in a frictionless market. 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 thus considered as a subsidy to housing developers. The housing subsidies can also be a result of local governments' unexpected investments on urban amenities, which leads to additional returns to the developers.

Similary, based on Proposition 5, the fact that land are taxed in most cities implies that land price is also lower as opposed to its level in a frictionless market. This is also a result of immature land markets. For example, the price ceilings in land auctions. When the bidding price reaches the ceiling, the bidders cannot further hike the bidding price, and thus the transation price may be lower than the market equilibrium price.

In terms of cross-city comparison, we find that housing are less subsidized in larger cities, which suggests 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 requirement and mortgage rates for 2nd homes; higher transantion taxes for housing resales. In addition, since April 2010, 46 cities gradually implemented the Home Purchase Restriction policy, which imposes restrictions on multiple home purchase for local households or any home purchase for non-resident households. In contrast, in small cities explicit subsidies such as transaction tax rebating, lower mortgage rates, or monetary subsidies and hukou restriction relaxation are prevalent. In a similar manner, land are also taxed less in larger cities. This suggests land prices are higher and also closer to frictionless market prices in larger cities. This is likely due to the fact that better-functioned land aution market in larger cities is more competitive as demonstrated in Figure 1. We summary all the patterns and the related institutional backgrounds in the Table 5.

4.3 Estimation of Migration Probability

The multiple-city framework maintains most assumptions made in the benchmark model with the following exceptions: the exogenous probability of migrating to city i from the rural area, π_i; the relative manufacturing productivity in city i, $\{A_{i,t}\}$; and the total residential land area in city i, $\{L_{i,t}\}$. When there are $I > 1$ cities in the urban area, the share of the population in city i, $n_{i,t}$, is denoted as follows, where $N_{i,t}$ denotes the total population in city i and N_t^R denotes the total population in the rural area:

The growth rate of population in city i can be shown to be equivalent to:

$$\begin{aligned}
\frac{N_{i,t}}{N_{i,t-1}} &= \frac{N_{i,t-1} + \triangle N_{i,t}}{N_{i,t-1}}, \\
&= 1 + \frac{\triangle N_{R,t}\pi_i}{N_{i,t-1}} = 1 + \frac{(N_{R,t} - N_{R,t-1})\pi_i}{N_{R,t-1}} \frac{N_{R,t-1}}{N_{i,t-1}}, \\
&= 1 + (\frac{N_{R,t}}{N_{R,t-1}} - 1)\pi_i \frac{N_{R,t-1}}{N_{i,t-1}}.
\end{aligned}$$

From the first to the second equation above, it essentially implies the population growth rate in city i is

$$\frac{N_{i,t}}{N_{i,t-1}} = \frac{n_{i,t}}{n_{i,t-1}}, \frac{N_{R,t-1}}{N_{i,t-1}} = \frac{n_{R,t-1}}{n_{i,t-1}}, \frac{N_{R,t}}{N_{R,t-1}} = \frac{n_{R,t}}{n_{R,t-1}}.$$

Finally, we can obtain the migration probability from rural to city i in t satisfies the following:

$$\frac{n_{i,t}}{n_{i,t-1}} - 1 = (\frac{n_{R,t}}{n_{R,t-1}} - 1)\pi_{i,t}\frac{n_{R,t-1}}{n_{i,t-1}}$$

Our city-specific migration probability is a simple average of $\pi_{i,t}$ over our sample period. We also renormalize the size so that they sum up to be 1. We present the top and bottom 5 cities with the highest and lowest migration probability in Table C.10. The estimation results seem to be in line with the data. Beijing, Shanghai and Shenzhen, which usually are believed to be the main receiptant city of migrants, are all on the list of top 5 cities. Note that since the estimated migration probabilities captures the direction and magnitudes of rural population inflow into urban cities, and thus it also reflects the differences in productivities and amenities across urban cities.

The expression above also suggests in order to keep track the entire population distribution over time, we need information on initial city size distribution as well as the evolution of urban(rural) population over time. In the following, we perform urban population projection.

Projection of urban population In 1840 almost 90 percent of the total U.S. population lived in rural areas. This percentage steadily declined to about 3 percent in 1990 and has remained at about 3 percent ever since. Because the fraction of the population living in rural areas is a main indicator of the progress of structural transformation, the United States is viewed as having completed its structural transformation by 1990. In 2012, the agricultural share of employment in China is still over 30 percent and the fraction of urban employment is around 50 percent.[5]

Calculating the path of future prices requires making different assumptions about the length of the structural transformation process. In the baseline case, we assume that 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 thereafter. Our algorithm is simply as follows: We assume net migration flow into urban area will continue to grow until the year 2020, and afterwards, it will steadily decline as shown in the right

[5]While there is discrepancy in the definition of urban areas between these two large economies, the contrast is sharp regardless.

panel of Figure C.5. The definition of net migration flows from rural to urban areas include permanent and temporary permits where many of the latter, mostly renting, but are later granted permanent permits. Overall, the time path for the fraction of urban employment is plotted in the left panel of Figure C.5. By 2063, the fraction of urban employment will reach 95 percent.[6]

4.4 Calibration

We parameterize the model in this section. We let the utility function take the log form $u(c_t) = \ln(c_t)$. A worker's disutility level from migration is assumed to follow a Pareto distribution defined over interval interval $[\underline{\epsilon}, \infty)$:

$$F(\epsilon) = 1 - \left(\frac{\underline{\epsilon}}{\epsilon}\right)^{\lambda}.$$

where $\underline{\epsilon} = 1$ and $\lambda > 0$ 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; and the annual interest rate, r^*, is set at 5 percent. The down payment ratio ϕ, the fraction of the house value that the worker must pay in advance is set at 0.3, which is consistent with the data. α and γ in the housing production function have been estimated in Section 4.2. $1-\sigma$ and δ denote capital share and depreciation rate in the production sector, and we let it be 0.4 and 0.05, respectively, which are commonly used in the literature. λ captures the tail index of the migration cost distritution, and is calibrated to match the initial population size in 2007. ψ is the entry fee coefficient, and is calibrated to match a 3-percent entry cost to land sales ratio. η measures city size elasticity of entry fee, and we set it to be 0.5, which will be subjected to sensitivity analysis. $\underline{z}_t$ is the minimum land requirement, and we set it to be 10 percent of land purchased by each housing developer. We summarize the benchmark parameterization in Table 6.

[6] Note that there may be more optimistic projections on the progress of structural transformation in China, with a much faster transition for China than the United States. The conjecture above is provided as a starting point. As a robustness check, we performed various exercises with more optimistic and pessimistic projected paths. While the results have some effects in the very long-run, but they have only a minor impact on the simulated dynamics of housing prices between 2007 and 2013.

Table 6: Benchmark Parameterizations

Para.	**Model**	**Para. Value**
β	subject discount factor	0.95
σ	labor share	0.6
$\underline{\epsilon}$	minimum migration cost	69.2
λ	skewness of migration cost distribution	0.16
B	entry fee coefficient	2.17
g_m	productivity growth rate	0.04
η	average housing price growth rate	2.8
g_ς	housing/land price ratio growth rate	0.11

From the panel regression in Equation 29, we can obtain the residual term ϵ_{it}. The productivity in the housing sector, A_{ht}, is then assumed to be a geometry average of the ϵ_{it} across all the cities. We also examine whether there is a time trend in the estimated series within the sample period. If there is one, we extrapolate for those that are out of our sample periods. We also perform a similar projection algorithm for the residential land supply at city-level. We approximate city-level land sales by fitting the available land sales data with the following regression equation:

$$\log(\ell_{it}) = b_{0i} + b_{1i}t + \varepsilon_{it}, \quad i = 1, 2...J$$

Note that our data suggests the declining trend of residential land supply—$\hat{b_{1i}} < 0$—can only be perceived in 13 cities.[7] We again extrapolate the land data for 20 periods, and let the land supply in the remaining periods maintain at its mean level over the first 20 periods. We perform similar exercises for τ_{ht} and τ_{zt}. We follow same prediction as when we project urban population by letting the number of periods to complete the structure transformation be 50 year. Afterward, we force both urban population size and manufacturing productivity be constant. The capital eventually will adjust till they reach the steady-state level. We calibrate the sequence of manufacturing productivity A_{mt} to exactly match the population size in the urban area over time. The numerical algorithm can be found in Appendix **??**.

[7] They include Beijing, Ulanchabu, Kaili, Lianyungang, Ganzhou, Yantai, Zhengzhou, Nanyang, Yichang, Changsha, Zhongshan, Jieyang, and Guilin.

5 Quantitative Results

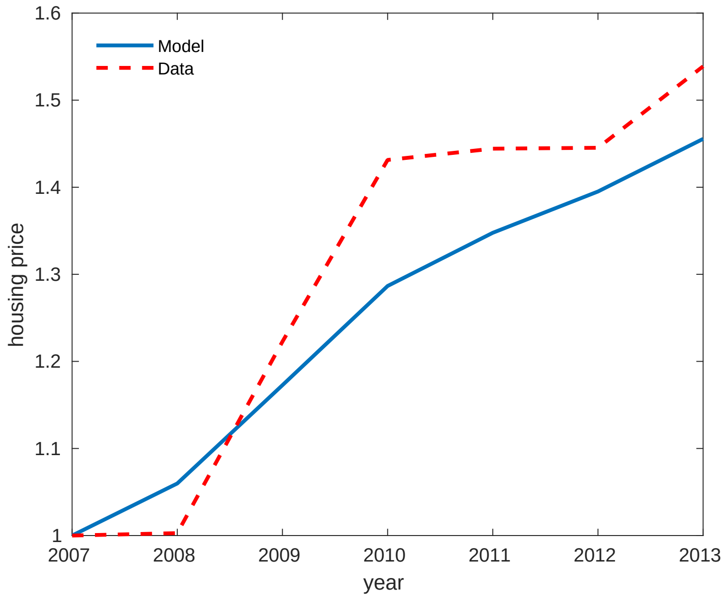
We quantitatively evaluate how city-level housing and land frictions affect price dynamics at both national and city-level in this subsection. Given the benchmark parameterization, we follow the procedure described in Appendix **??** to solve for the equilibrium outcome.

5.1 National Results

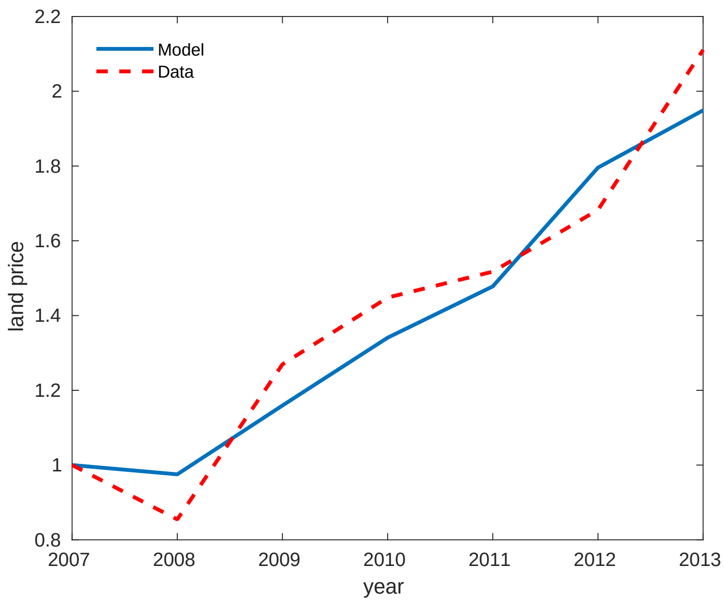
In Figure 2 we plot the model predicted housing and land prices together with the data counterparts during 2007-2013. Overall housing price in 2013 is 1.55 times of that in 2007, while the model predicts a ratio of 1.46, which can rationalize about $1.46/1.55 \approx 94.2$ percent of the change in the data. The model also slightly underpredicts the land price growth in the data. From 2007 to 2013, the model implied land price level has almost doubled, while in the data the land price in 2013 is 2.11 times of that in 2007. In terms of the average annual growth rate, housing and land prices steadily grow at a rate of 7.89 and 14.94 percent in the data, respectively. While the model predicts a growth rate of 6.5 and 12.1 percent, respectively, which can account for 82.4 percent and 81.0 percent of the changes in the data counterpart. To sum up, the model has decently mimicked the data series over time. It seems that for the land prices the model predicts a less dramatic decline between 2007 and 2008, and faster growth between 2011 and 2012.

We further explore how housing and land frictions tend to affect both housing and land price levels as well as their growth trends. We perform a counterfactual exercise in which we remove all the frictions by setting them to zero. In Figure C.6, we compare the counterfactual results in the frictionless world with the benchmarks.[8] Recall from previous discussion that on average housing frictions are negative and land frictions are positive and their direct effects tend to lower housing and land prices. Thus, when all the frictions are eliminated, housing and land prices both tend to be higher than their benchmark levels. Specifically, we find housing price rise by 20-30 percent and land price by 20-70 percent over their benchmark counterparts. But what happens to their growth trends? As shown in Table 7, housing price

[8] All the price levels in the counterfactual exercise have been renormalized according to the benchmark price level in 2007.



(a) Housing Prices



(b) Land Prices

Figure 2: Model v.s. Data

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

grows less rapidly than the benchmark economy. The ratio of housing price in 2013 to 2007 is about $1.283/1.456 \approx 88.1\%$ of the benchmark level, and the average annual growth rate drops from 6.5 to 4.3 percent. In contrast, land price grows faster in the frictionless economy. This is not surprising. In the data, land tend to be much less taxed over time, and the land price is expected to become more expensive over time in a frictionless world. Land price ratio is $3.161/1.949 \approx 1.62$ times of that in the benmark economy and the annual growth rate has also increased from 12.1 to 21.5 percent.

Table 7: Aggregate Results

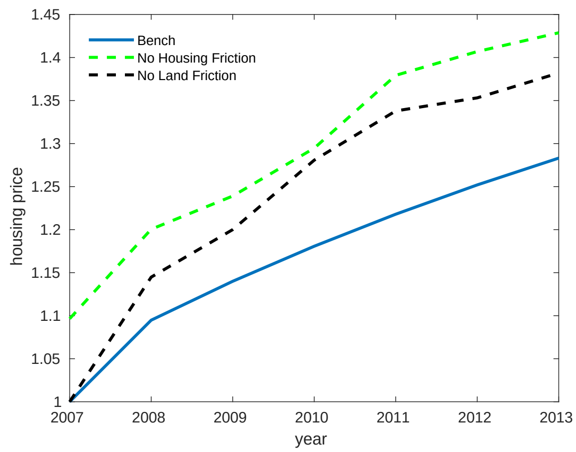
	Bench	Frictionless	No Housing	No Land
Housing Price Ratio	1.456	1.283	1.303	1.382
Land Price Ratio	1.949	3.161	1.393	4.081
Housing Price Growth	0.065	0.043	0.045	0.056
Land Price Growth	0.121	0.215	0.057	0.293

Notes: We present results for the following economy: benchmark economy; frictionless economy; the economy without housing frictions; the economy without land frictions. The results include: the ratio of housing or land prices in 2013 to that in 2007, and the average annual price growth rate.

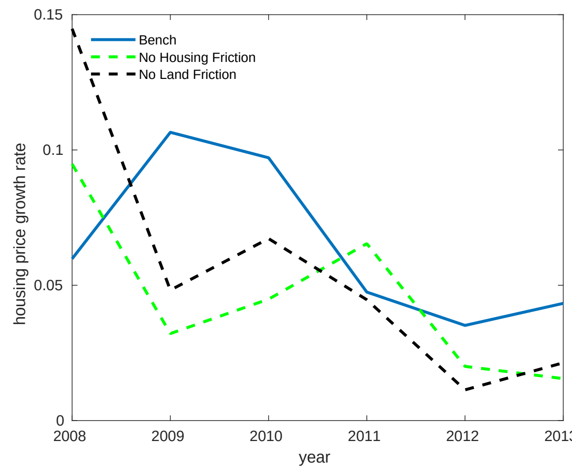
To isolate the role of housing and land frictions, we have performed another two sets of counterfactual exercises, in which we either only remove housing or land frictions and simulate the price levels over time accordingly. The results are reported in Figure 3.[9] The first impression is that housing prices change little when only land frictions are removed. The hints can be found in (28) and (27) that land friction does not directly affect the housing price levels, so its effects only work in general equilibrium by affecting the population inflow into the city. Overall, as suggested in Table 7, the price ratio slightly decreases from 1.456 to 1.382, and the average annual growth rate decreases from 6.5 to 5.6 percent. As for the housing price levels, we have shown in Proposition 4 that housing prices are increasing with housing frictions. Since housing are subsidized in most cities, and thus housing price slightly increases in the initial years when housing frictions are set to be zero. Housing price eventually becomes lower than the benchmark level because less population flow into the cities. In terms of the growth trend, housing price growth slow down when housing frictions are removed, with the price ratio and the average growth rate decreasing to 1.3 and 4.5 percent, respectively.

Land prices grow much faster when land frictions are removed, and this is still due to the removal of rising land subsidies. Table 7 suggests that land price ratio and annual growth rate increase from 1.95 to 4.08, and 12.1 to 29.3 percent, respectively. When only housing

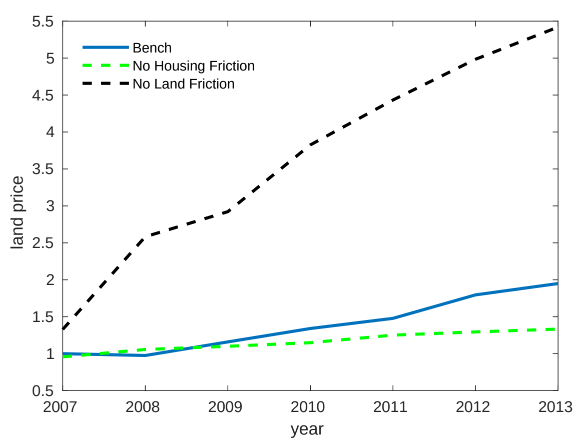
[9]We have similarly renormalized all the price levels according to their benchmark level at 2007.



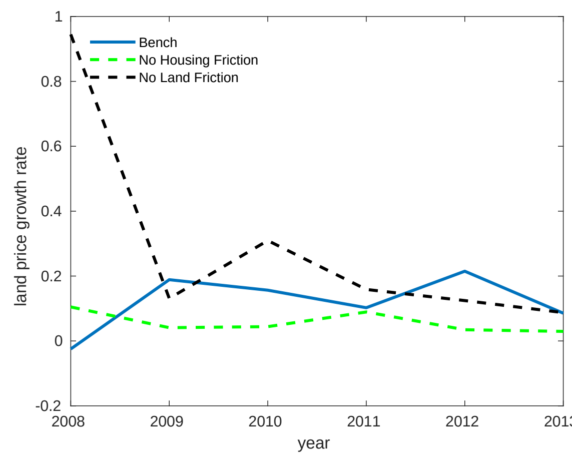
(a) Housing Prices



(b) Housing Prices Growth Rate



(c) Land Prices



(d) Land Prices Growth Rate

Figure 3: Decomposition of Frictions

Notes: This figure plots the housing and land price levels as well as their annual growth rate during 2007-2013 in a counterfactual economy where all the frictions are eliminated, or either housing or land frictions are eliminated. We have normalized both housing and land price level to be 1 in the frictionless 2007 economy.

frictions are removed, land prices become lower because housing sales revenue shrink due to the removal of housing subsidies. The growth trend are also significantly slowed down with a only 1.39 price ratio and 5.7 percent annual growth rate. This seems to suggest the elmination of housing frictions can effectively inhibit land price growth.

Overall, our results show that, in a frictionless world, housing price would grow less rapidly but land price would grow faster than the benchmark counterparts. By decomposing into each friction, we further identify that the reduced growth in housing price is due to a combination of the removal of both frictions, whereas the increased growth in land price is mainly due to the elimination of the land friction.

The role of capital market frictions We have also briefly examined the role of capital market frictions in driving housing and land prices. The imperfect capital market in our model is captured by the spread between mortage interests and the rate of return to capital, and the latter one is much higher. In the following, we performe a counter-factual exercise in which we double the mortgage interest rates from 5 percent to 10 percent to mimic an improvement in the capital market. The results are reported in Figure C.7. Both housing and land prices become much lower than the benchmark counterpart when mortgage rates are doubled. This is mainly because housing in the city become less affordable with higher mortgage rates as illustrated in Equation (3). This will thus deter the entry of rural migrants into the cities. Prices fall accordingly due to less demand. The growth rate of prices have also become lower due to slower speed of migration into the city.

5.2 City-level Results

We examine city-level results in this section by focusing on the following perspective: First, how different types of frictions affect the spatial distribution of housing and land prices. Second, the model performance in terms of matching housing and land price dynamics in each city, with a particular interests on those tier-1 cities. In Table 8, we measure how housing and land prices vary across cities for each of the following scenarios: 1) benchmark results, 2) frictionless economy, 3)4) either housing or land friction is eliminated. We use the coefficient of variation to measure the inequality, and report the results year by year.

When all the frictions are removed, the dispersion of both housing and land prices are largely removed in comparison with the benchmark scenario. This suggests the price dispersion are partially driven by the spatial differences of frictions. On average, the CV has decreased by 30 percent for housing prices 15 percent for land prices, respectively. Moreover, both distributions have become more stable over time, with a standard deviation of CV changing from 0.17 to almost zero for housing prices, and from 0.39 to 0.04 for land prices. We have previously argued land friction affects housing prices only through impacting the migration inflow, and thus housing price inequality remains similar to and only slightly(8%)

Table 8: City-level Results

	Benchmark	Frictionless	No Housing Frictions	No Land Frictions
		Housing Price CV		
2007	1.56	1.04	1.17	1.38
2008	1.85	1.03	1.13	1.69
2009	1.40	1.04	1.16	1.34
2010	1.33	1.04	1.10	1.23
2011	1.41	1.04	1.18	1.29
2012	1.49	1.03	1.15	1.41
2013	1.51	1.03	1.13	1.41
		Land Price CV		
2007	3.43	2.63	3.58	3.19
2008	2.43	2.56	2.50	2.23
2009	2.81	2.54	3.05	2.70
2010	2.94	2.60	3.01	2.66
2011	2.71	2.62	2.90	2.66
2012	2.94	2.52	3.13	2.54
2013	3.54	2.57	3.84	2.89

Notes: This table reports statistics on both housing and land price dispersion as well as their average levels among the selected sample cities in benchmark and several counterfactual exercises. We measure price inequality using the coefficient of variation. The counterfactual exercises include completely eliminating all the frictions; either eliminating housing or land frictions.

lower than the benchmark level when only land frictions are removed. On the contrary, when only housing frictions are removed, housing price inequality are greatly lowered to a level only 10-percent above the frictionless outcome. As for land prices, our results suggest that land friction contributes to the land price dispersion. On average, once the land frictions are removed, the CV of land price is about 90 percent of that in benchmark case. In contrast, housing frictions tend to dampen the land price inequality. On average, the CV of land price is about 1.06 times of that in the benchmark case.

We next turn to the comparison between model predicted prices and their data counterparts. In Figure C.8 we map the prediction power of the model in price ratio as well as the average annual price growth rate during 2007-2013 for each city in the sample. The prediction power is simply defined as the ratio of the model implied growth rate to that in the data. A number larger than 1 implies that the model overpredicts. The model underpredicts housing price ratio in 60 cities, and overpredicts land price ratio in 40 cities. On average housing and land price ratio is about 0.72 and 0.76 times of their data counterparts. In terms of the average annual price growth rate, the model predicts higher housing price growth in 14 cities than the data, and overpredicts land price growth for 24 cities. The model implied housing and land price growth rate is about 0.83 and 0.95 times of the benchmark counterparts.

We further explore the role of frictions at city-level in Figure C.9. The counter-factual and benchmark economy each can give rise to a price ratio. We essentially map the ratio of the counterfactual ratio to the benchmark ratio. A number larger than 1 implies price grow faster in the counter than the benchmark economy. When all the frictions are removed, housing price growth in all the cities become slower. The majority of the cities, especially those coastal and large cities, see a higher land price ratio than the benmark economy. This is consistent with the findings in aggregate results. In Figure C.10 and Figure C.11 we also present results where we either eliminate housing or land frictions. Both housing and land price ratio become lower than the benchmark one in the majority of the cities when housing frictions are removed. When land frictions are removed, land price ratio becomes much higher in the majority of the cities, whereas housing price ratio are still lower in most cities.

6 Conclusions

In this paper, we have examined how housing and land market frictions affect the growth of housing and land prices as well as the spatial distribution of both prices. We have estimated the city-specific housing and land fricitons among a set of prefectural Chinese cities. We show that both frictions vary systematically across cities and the spatial disparity is persistent over time. We have also evaluated the aggregate impacts of the frictions through a dynamic competitive spatial equilibrium framework featuring on-going rural-urban migration. The model turns out to fit well with housing and land price growth in the data. The counterfactual results suggest that housing and land prices tend to be higher than the benchmark once all the frictions are removed. In such a frictionless world, housing price grows less rapidly but land price grows faster than the benchmark counterparts. While the reduced growth in housing price is due to a combination of the removal of both frictions, the increased growth in land price is mainly due to the elimination of the land friction.

Along these lines, a natural extension is to conduct normative analysis to assess efficiency losses as a result of spatial misallocation. We would however like to warn the reader that performing such a task is non-trivial. This is because of dynamic responses of migration to changes in the wedges, so an efficiency allocation need not be achieved by simple elimination of the dispersion in marginal revenue products in a static setting as typically done in the misallocation literature. Moreover, due to household mobility restrictions imposed by the Chinese government, our study has been focusing on the interplays between labor markets and housing markets across space. One may inquire whether capital markets may also play a role because they are likely to be better-functioned in larger cities than small cities. Of course, this would require location-specific bank loan and credit market data, which is beyond the scope of the current study.

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Appendix

(Not Intended for Publication)

A Solving Housing Developer's Problem

$$\max_{z_t, I_t} \left(1-\tau_{ht}\right) p_t A_t^h \left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha} - q_t z_t \left(1+\tau_{zt}\right) - p_{It} I_{ht}$$

The two first-order conditions are:

$$\left(1-\tau_{ht}\right) p_t \gamma A_t^h \left(z_t - \underline{z}_t\right)^{\gamma-1} I_{ht}^{\alpha} = q_t \left(1+\tau_{zt}\right)$$

$$\left(1-\tau_{ht}\right) p_t \alpha A_t^h \left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha-1} = p_{It}$$

Moreover, the housing market clearing condition is:

$$S_t A_{ht} \left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha} = N_t^d \tag{30}$$

whereas the land market clearing condition is:

$$S_t z_t = \ell_t \tag{31}$$

Substitute out I_{ht} or, sometimes more conveniently I_{ht}^{α}, using (30) and $\underline{z}_t = \zeta_t z_t$,

$$N_t^d = \Delta H_t = \Delta F\left(\epsilon^*\right) = \frac{\ell_t A_{ht} \left(z_t - \underline{z}_t\right)^{\gamma} I_{ht}^{\alpha}}{z_t} = \frac{\ell_t A_{ht} \left(1-\zeta_t\right)^{\gamma} I_{ht}^{\alpha}}{z_t^{1-\gamma}}$$

or,

$$I_{ht}^{\alpha} = \frac{\Delta F\left(\epsilon^*\right) z_t^{1-\gamma}}{\ell_t A_{ht} \left(1-\zeta_t\right)^{\gamma}} \tag{32}$$

which only depends on z and $\Delta F\left(\epsilon^*\right)$.

From the free entry condition for S_t developers after solving maximized profit using

FOCs, we have:

$$(1-\alpha-\gamma)(1-\tau_{ht})\,p_t A_{ht}(z_t-\underline{z}_t)^{\gamma} I_{ht}^{\alpha}=\Psi_t \tag{33}$$

Substituting out z_t using (33) gives,

$$\begin{aligned}
\Psi_t &= (1-\alpha-\gamma)(1-\tau_{ht})\,p_t A_{ht}(z_t-\underline{z}_t)^{\gamma} I_{ht}^{\alpha}\\
&= (1-\alpha-\gamma)(1-\tau_{ht})\,p_t A_{ht}(z_t-\underline{z}_t)^{\gamma}\frac{\Delta F(\epsilon^*)\,z_t^{1-\gamma}}{\ell_t A_{ht}(1-\zeta_t)^{\gamma}}\\
&= (1-\alpha-\gamma)(1-\tau_{ht})\,\Delta F(\epsilon^*)\,p_t\frac{z_t}{\ell_t}
\end{aligned}$$

or, (24), which is a decreasing function of p and $\Delta F(\epsilon^*)$.

We thus have 2 endogenous variables left, $\{p,q\}$, which can be solved by the two FOCs. We can first also sove housing price recursively from two first-order conditions using (32) and (24):

$$\begin{aligned}
p_t &= \frac{p_{It}}{(1-\tau_{ht})\,\alpha A_{ht} z_t^{\gamma}(1-\zeta_t)^{\gamma} I_{ht}^{\alpha-1}} = \frac{p_{It}}{(1-\tau_{ht})\,\alpha A_{ht} z_t^{\gamma}(1-\zeta_t)^{\gamma}\left[\frac{\Delta F(\epsilon^*) z_t^{1-\gamma}}{\ell_t A_{ht}(1-\zeta_t)^{\gamma}}\right]^{1-1/\alpha}}\\
&= \frac{p_{It}\ell_t \Delta F(\epsilon^*)^{(1-\alpha)/\alpha}\left[\frac{z_t^{1-\gamma}}{\ell_t A_{ht}(1-\zeta_t)^{\gamma}}\right]^{1/\alpha}}{(1-\tau_{ht})\,\alpha z_t} = \frac{p_{It}\Delta F(\epsilon^*)^{(1-\alpha)/\alpha} z_t^{(1-\alpha-\gamma)/\alpha}}{\alpha(1-\tau_{ht})\,\ell_t^{(1-\alpha)/\alpha}(1-\zeta_t)^{\gamma/\alpha}A_{ht}^{1/\alpha}}\\
&= \frac{p_{It}}{\alpha(1-\tau_{ht})A_{ht}^{1/\alpha}}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\,\ell_t}\right]^{(1-\alpha)/\alpha}\left[(1-\zeta_t)\,z_t\right]^{(1-\alpha-\gamma)/\alpha}\\
&= \frac{p_{It}}{\alpha(1-\tau_{ht})A_{ht}^{1/\alpha}}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\,\ell_t}\right]^{(1-\alpha)/\alpha}\left[\frac{\Psi_t(1-\zeta_t)\,\ell_t}{(1-\alpha-\gamma)(1-\tau_{ht})\,\Delta F(\epsilon^*)\,p_t}\right]^{(1-\alpha-\gamma)/\alpha}\\
&= \frac{p_{It}}{\alpha(1-\tau_{ht})A_{ht}^{1/\alpha}}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\,\ell_t}\right]^{\gamma/\alpha}\left[\frac{\Psi_t}{(1-\alpha-\gamma)(1-\tau_{ht})\,p_t}\right]^{(1-\alpha-\gamma)/\alpha}
\end{aligned}$$

or,

$$p_t=\frac{1}{(1-\tau_h)\,A_{ht}^{1/(1-\gamma)}}\left[\frac{p_{It}}{\alpha}\right]^{\frac{\alpha}{1-\gamma}}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\,\ell_t}\right]^{\frac{\gamma}{1-\gamma}}\left[\frac{\Psi_t}{1-\alpha-\gamma}\right]^{\frac{(1-\alpha-\gamma)}{1-\gamma}} \tag{34}$$

which is increasing in $\Delta F(\epsilon^*)$ and τ_{ht}; moreover, the housing-distortion augmented "net housing price" is

$$(1-\tau_{ht})\,p_t = \frac{(1-\tau_{ht})^{(\alpha-\gamma)/(1-\gamma)}}{A_{ht}^{1/(1-\gamma)}}\left(\frac{p_{It}}{\alpha}\right)^{\alpha/(1-\gamma)}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\,\ell_t}\right]^{\gamma/(1-\gamma)}\left[\frac{\Psi_t}{1-\alpha-\gamma}\right]^{(1-\alpha-\gamma)/(1-\gamma)} \tag{35}$$

which is independent of τ_{ht}.

By manipulating two first-order conditions using (32) and (24), we can then express land price as a function of housing price:

$$\begin{aligned} q_t &= \frac{\gamma p_{It} I_{ht}}{\alpha(1+\tau_{zt})(1-\zeta_t)\,z_t} \\ &= \frac{\gamma p_{It}\Delta F(\epsilon^*)^{1/\alpha}\, z_t^{(1-\alpha-\gamma)/\alpha}}{\alpha(1+\tau_{zt})(1-\zeta_t)^{(\alpha+\gamma)/\alpha}(\ell_t A_{ht})^{1/\alpha}} \\ &= \frac{\gamma p_{It}\left[\frac{\Delta F(\epsilon^*)}{(1-\zeta_t)\ell_t}\right]^{(\alpha+\gamma)/\alpha}\left[\frac{\Psi_t}{(1-\alpha-\gamma)(1-\tau_{ht})}\right]^{(1-\alpha-\gamma)/\alpha}}{\alpha(1+\tau_{zt})\,A_{ht}^{1/\alpha}\, p_t^{(1-\alpha-\gamma)/\alpha}} \end{aligned}$$

or, simply,

$$q_t = \frac{\Xi_t \Delta F(\epsilon^*)^{(\alpha+\gamma)/\alpha}}{(1+\tau_{zt})\left[(1-\tau_{ht})\,p_t\right]^{(1-\alpha-\gamma)/\alpha}} \tag{36}$$

where $\Xi_t \equiv \frac{\gamma p_{It}\left[\frac{\Psi_t}{(1-\alpha-\gamma)}\right]^{(1-\alpha-\gamma)/\alpha}}{\alpha A_{ht}^{1/\alpha}[(1-\zeta_t)\ell_t]^{(\alpha+\gamma)/\alpha}}$ is an exogenous scaling variable. Thus,

$$q_t = \frac{\Xi_t \Delta F(\epsilon^*)^{(\alpha+\gamma)/\alpha}}{(1+\tau_{zt})\left[(1-\tau_{ht})\,AS_t(\overset{+}{\Delta F}(\epsilon_t^*);\overset{+}{\tau_{ht}})\right]^{(1-\alpha-\gamma)/\alpha}} = Q_t\left(\overset{+}{\Delta F}(\epsilon_t^*);\overset{+}{\tau_{ht}},\overset{-}{\tau_{zt}}\right) \tag{37}$$

and $(1+\tau_{zt})\,q_t$ is independent of τ_{zt}.

B Proofs

B.1 Proposition 1

Proof: The migrant's value function can be expressed as:

$$V_\tau^M = u(w_\tau - \phi p_\tau h_\tau) + \beta \max\{V_{\tau+1}^C(b_\tau), V_{\tau+1}^R\}.$$

Because V_t^M is independent on ϵ_t^*, and thus the left-hand-side of the locational no-arbitrage condition is monotonically decreasing with ϵ_t^*. This guarantees the uniqueness of the cutoff ϵ_t^*. Because the migrant's flow utility is rising with the urban wage rate but falling with the urban housing price, other things being equal, a higher urban wage or a lower urban housing price raises migrant's value and thus the disutility cutoff of migration. ■

B.2 Proposition 2

Proof: production function is:

$$Y_t = A_t^m K_t^\sigma N_t^{1-\sigma}.$$

Wage rate equals to the marginal product of labor, that is,

$$w_t = (1-\sigma) A_t^m K_t^\sigma N_t^{-\sigma}.$$

Firm's value function can be written as:

$$\begin{aligned} V_t(K_t) &= Max\ \sigma A_t^m K_t^\sigma N_t^{1-\sigma} - I_t + \beta V_{t+1}(K_{t+1}), \\ s.t.\ K_{t+1} &= K_t^{1-\delta} I_t^\delta, \end{aligned}$$

In a stationary scenario, where $A_t^m = A^m$ and $N_t = N$, we have:

$$V(K) = Max\ \sigma A^m K^\sigma N^{1-\sigma} - \left(\frac{K'}{K^{1-\delta}}\right)^{\frac{1}{\delta}} + \beta V\left(K'\right).$$

The first order condition is obtained as:

$$\beta V'\left(K'\right) = \frac{1}{\delta}(K')^{\frac{1-\delta}{\delta}} K^{\frac{\delta-1}{\delta}}.$$

The B.S. equation is:

$$V'(K) = \sigma^2 A^m K^{\sigma-1} N^{1-\sigma} - K'^{\frac{1}{\delta}} \frac{\delta-1}{\delta} K^{\frac{-1}{\delta}}.$$

In steady-state, $K' = K$, then we have:

$$\sigma^2 A^m K^{\sigma-1} N^{1-\sigma} - \frac{\delta - 1}{\delta} = \frac{1}{\delta\beta},$$

which is equivalent to:

$$\delta\beta\sigma^2 A^m \left(\frac{K}{N}\right)^{\sigma-1} = 1 - \beta\left(1 - \delta\right).$$

This completes the proof. ■

B.3 Proposition 3

Proof: Equation 35 can be written into:

$$p_t\left(1 - \tau_h\right) = \Delta F\left(\epsilon^*\right)^{\frac{\gamma}{1-\gamma}} \Xi_{ht}, \tag{38}$$

where

$$\Xi_{ht} = \frac{1}{A_{ht}^{1/(1-\gamma)}} \left[\frac{p_{It}}{\alpha}\right]^{\frac{\alpha}{1-\gamma}} \left[\frac{1}{\left(1-\zeta_t\right)\ell_t}\right]^{\frac{\gamma}{1-\gamma}} \left[\frac{\Psi_t}{1-\alpha-\gamma}\right]^{\frac{(1-\alpha-\gamma)}{1-\gamma}}.$$

Therefore, net housing prices increase with $\Delta F\left(\epsilon^*\right)$, and both housing and land distortion have no impact on net housing price.

Similarly, from equation (36) we have:

$$q_t\left(1 + \tau_{zt}\right) = \frac{\Xi_{qt}\Delta F\left(\epsilon^*\right)^{(\alpha+\gamma)/\alpha}}{\left[\left(1 - \tau_{ht}\right)p_t\right]^{(1-\alpha-\gamma)/\alpha}}, \tag{39}$$

where

$$\Xi_{qt} \equiv \frac{\gamma p_{It}\left[\frac{\Psi_t}{(1-\alpha-\gamma)}\right]^{(1-\alpha-\gamma)/\alpha}}{\alpha A_{ht}^{1/\alpha}\left[\left(1-\zeta_t\right)\ell_t\right]^{(\alpha+\gamma)/\alpha}}$$

is an exogenous scaling variable. Plugging in equation 38 into equation 39, we have:

$$q_t\left(1 + \tau_{zt}\right) = \frac{\Xi_{qt}\Delta F\left(\epsilon^*\right)^{1/(1-\gamma)}}{\Xi_{ht}^{(1-\alpha-\gamma)/\gamma}}$$

Therefore, net land price is also increasing with $\Delta F\left(\epsilon^*\right)$. Both housing and land distortion have no impact on net land price. This also completes the proof of Proposition 3. ■

B.4 Proposition 4

Proof: From equation (27) and (28), housing market clearing condition implies

$$AS_t(\Delta \overset{+}{F}(\epsilon_t^*); \overset{+}{\tau}_{ht}) = AD_t(\Delta \overset{-}{F}(\epsilon_t^*)) \tag{40}$$

If we draw both the aggregate demand and upply curve in a diagram with housng price p_t as the y-axis and net migration inflow $\Delta F(\epsilon_t^*)$ as the x-axis, then a higher τ_h will shift up the aggregate supply curve and has no impact on the aggregate demand curve. These together imply a higher housing price and lower migration inflow.

We can further differentiate equation (40) against τ_{ht}, we have:

$$\frac{\partial AS_t}{\partial \Delta F(\epsilon_t^*)} \frac{\partial \Delta F(\epsilon_t^*)}{\partial \tau_{ht}} + \frac{\partial AS_t}{\partial \tau_{ht}} = \frac{\partial AD_t}{\partial \Delta F(\epsilon_t^*)}.$$

Therefore, it is straightforward to show:

$$\frac{\partial \Delta F(\epsilon_t^*)}{\partial \tau_{ht}} = \frac{\left(\frac{\partial AD_t}{\partial \Delta F(\epsilon_t^*)} - \frac{\partial AS_t}{\partial \tau_{ht}}\right)}{\frac{\partial AS_t}{\partial \Delta F(\epsilon_t^*)}} < 0.$$

Hence, higher housing friction leads to lower migration inflow, which in turn implies a smaller migration cutoff ϵ^*. ■

B.5 Proposition 5

Proof: Substituting (35) into (24), we further get:

$$z_t = \frac{\Psi_t \ell_t}{(1-\alpha-\gamma)\,\Xi_{ht}\Delta F(\epsilon^*)^{1/(1-\gamma)}}.$$

Together with equation (39), we can show that a higher τ_{zt} leads to lower land prices and has no impact on land demand. In addition, utilizing results from Proposition 4, if higher housing friction induces less migration inflow $\Delta F\left(\epsilon^{*}\right)$, then this further implies higher land demand and lower land prices. $\blacksquare$

C Tables and Figures

Table C.1: Frictions in Tier-1 Cities

(a) Housing Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.47	0.10	0.39	0.40	0.45	0.54	0.60
2008	0.27	0.07	0.19	0.22	0.27	0.32	0.35
2009	0.60	0.09	0.47	0.54	0.63	0.67	0.69
2010	0.43	0.01	0.42	0.43	0.43	0.44	0.44
2011	0.24	0.21	0.10	0.11	0.15	0.36	0.54
2012	0.31	0.10	0.21	0.22	0.31	0.39	0.40
2013	0.39	0.05	0.33	0.36	0.39	0.42	0.44
Total	0.39	0.15	0.18	0.27	0.39	0.46	0.61

(b) Land Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.45	0.72	-0.17	-0.01	0.25	0.92	1.48
2008	0.68	1.26	-0.39	-0.12	0.31	1.48	2.50
2009	-0.25	0.34	-0.67	-0.51	-0.23	0.01	0.12
2010	-0.23	0.51	-0.70	-0.56	-0.36	0.10	0.48
2011	0.10	0.93	-0.58	-0.51	-0.24	0.72	1.46
2012	0.06	0.49	-0.40	-0.35	0.04	0.48	0.57
2013	-0.32	0.32	-0.58	-0.57	-0.40	-0.07	0.09
Total	0.07	0.73	-0.58	-0.41	-0.14	0.37	1.46

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,P90 refer to the respective percentile within the same year.

Table C.2: Frictions in Tier-2 Cities

(a) Housing Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.06	0.42	-0.63	-0.30	0.19	0.34	0.46
2008	-0.40	0.52	-0.92	-0.76	-0.34	0.04	0.16
2009	-0.00	0.57	-0.73	-0.22	0.14	0.38	0.54
2010	0.02	0.53	-0.30	-0.20	0.11	0.30	0.51
2011	-0.13	0.31	-0.45	-0.23	-0.05	0.07	0.14
2012	-0.14	0.44	-0.57	-0.26	-0.09	0.12	0.19
2013	-0.12	0.44	-0.74	-0.25	-0.04	0.15	0.33
Total	-0.10	0.48	-0.73	-0.28	-0.02	0.22	0.38

(b) Land Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.57	1.37	-0.52	-0.33	0.25	0.64	2.81
2008	0.81	1.20	-0.11	-0.00	0.39	1.12	1.90
2009	-0.00	0.72	-0.67	-0.56	-0.13	0.40	0.49
2010	-0.27	0.58	-0.79	-0.64	-0.51	0.09	0.66
2011	-0.08	0.81	-0.63	-0.57	-0.48	0.09	0.67
2012	-0.04	0.42	-0.52	-0.32	-0.17	0.18	0.53
2013	-0.20	0.54	-0.69	-0.58	-0.41	0.11	0.78
Total	0.11	0.93	-0.63	-0.51	-0.12	0.39	1.08

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,P90 refer to the respective percentile within the same year.

Table C.3: Frictions in Tier-3 Cities

(a) Housing Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	-0.17	0.62	-0.74	-0.30	-0.01	0.17	0.29
2008	-0.55	0.62	-1.35	-0.69	-0.40	-0.14	0.02
2009	-0.22	0.63	-0.98	-0.47	-0.10	0.19	0.41
2010	-0.15	0.50	-0.83	-0.35	-0.04	0.23	0.42
2011	-0.29	0.49	-1.02	-0.49	-0.21	0.06	0.18
2012	-0.43	0.71	-0.82	-0.60	-0.25	0.00	0.17
2013	-0.33	0.53	-0.86	-0.56	-0.23	0.01	0.24
Total	-0.31	0.60	-0.98	-0.52	-0.18	0.06	0.26

(b) Land Frictions

Year	Mean	Sd	P10	P25	Median	P75	P90
2007	0.80	1.44	-0.42	-0.10	0.34	0.97	3.66
2008	1.60	2.10	-0.11	0.28	0.79	2.54	4.36
2009	0.45	1.09	-0.55	-0.31	0.18	0.92	1.73
2010	-0.06	0.74	-0.75	-0.60	-0.24	0.22	0.92
2011	-0.12	0.54	-0.69	-0.52	-0.25	0.08	0.61
2012	0.16	0.94	-0.65	-0.48	-0.19	0.43	1.59
2013	0.03	0.86	-0.69	-0.51	-0.22	0.34	1.09
Total	0.40	1.32	-0.64	-0.42	0.04	0.73	1.76

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,P90 refer to the respective percentile within the same year.

Table C.4: The estimated frictions across tiers

LHS = Frictions	Housing Frictions			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
tier	-0.435***			0.132**		
	(0.106)			(0.054)		
Year	-0.016	-0.016	-0.012	-0.105***	-0.105***	-0.025
	(0.017)	(0.017)	(0.055)	(0.012)	(0.012)	(0.044)
tier=2		-0.784***			0.024	
		(0.141)			(0.104)	
tier=3		-1.114***			0.188*	
		(0.097)			(0.100)	
Tier × Year			-0.002			-0.030
			(0.024)			(0.018)
N	651	651	651	651	651	651
R-squared	0.065	0.069	0.552	0.102	0.101	0.285
Year FE	No	No	No	No	No	No
Tier FE	No	Yes	Yes	No	Yes	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 housing and land frictions against tiers, or the tier dummies, or interaction between tier and year.

Table C.5: The estimated frictions across tiers and years

LHS = Frictions	Housing Frictions	Land Frictions
	(1)	(2)
tier=2	-0.784***	0.024
	(0.142)	(0.104)
tier=3	-1.114***	0.188*
	(0.097)	(0.100)
Year=2008	-0.638***	0.359***
	(0.084)	(0.126)
Year=2009	-0.081	-0.236***
	(0.066)	(0.089)
Year=2010	0.006	-0.476***
	(0.074)	(0.075)
Year=2011	-0.230**	-0.464***
	(0.090)	(0.078)
Year=2012	-0.388***	-0.349***
	(0.106)	(0.086)
Year=2013	-0.266***	-0.432***
	(0.091)	(0.082)
N	651	651
R-squared	0.114	0.174

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 housing and land frictions against year and tier dummies.

Table C.6: City size and estimated frictions among tier-2 cities

	Housing Frictions)			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(GDP)	0.070	57.854	1.052	-0.370***	-145.631***	0.964
	(0.127)	(78.132)	(0.638)	(0.044)	(34.224)	(0.619)
Year		0.213			-0.628***	
		(0.315)			(0.145)	
Ln(GDP) × Year		-0.029			0.072***	
		(0.039)			(0.017)	
N	161	161	161	161	161	161
R-squared	-0.003	-0.010	0.764	0.213	0.247	0.314
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. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. The table reports regressions of city-level housing and land frictions against GDP between 2007 and 2013. The unit of observation is city-year. The data source for GDP is the city-level statistical yearbooks, and the frictions are based on the estimation procedure outlined in Section 4.2.

Table C.7: The estimated frictions over time among tier-2 cities

LHS = Frictions	Housing Frictions			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	-0.008			-0.082***		
	(0.024)			(0.017)		
Year=2008		-0.743***	-0.743***		0.135	0.135
		(0.109)	(0.109)		(0.230)	(0.230)
Year=2009		-0.102	-0.102		-0.321*	-0.321*
		(0.103)	(0.103)		(0.175)	(0.174)
Year=2010		-0.061	-0.061		-0.473***	-0.473***
		(0.120)	(0.119)		(0.128)	(0.128)
Year=2011		-0.312**	-0.312**		-0.363***	-0.363***
		(0.114)	(0.113)		(0.112)	(0.112)
Year=2012		-0.319**	-0.319**		-0.342**	-0.342**
		(0.120)	(0.119)		(0.159)	(0.159)
Year=2013		-0.291**	-0.291**		-0.430***	-0.430***
		(0.125)	(0.125)		(0.135)	(0.135)
N	161	161	161	161	161	161
R-squared	-0.006	0.054	0.761	0.092	0.134	0.313
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 C.8: City size and estimated frictions among tier-3 cities

	Housing Frictions)			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(GDP)	0.094	-14.178	0.553	-0.257***	-82.181	0.211
	(0.109)	(75.579)	(0.479)	(0.074)	(53.251)	(0.384)
Year		-0.090			-0.384**	
		(0.284)			(0.188)	
Ln(GDP) × Year		0.007			0.041	
		(0.038)			(0.026)	
N	462	462	462	462	462	462
R-squared	0.002	0.004	0.538	0.055	0.109	0.376
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. The table reports regressions of city-level housing and land frictions against GDP between 2007 and 2013. The unit of observation is city-year. The data source for GDP is the city-level statistical yearbooks, and the frictions are based on the estimation procedure outlined in Section 4.2.

Table C.9: The estimated frictions over time among tier-3 cities

LHS = Frictions	Housing Frictions			Land Frictions		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	-0.018			-0.116***		
	(0.023)			(0.016)		
Year=2008		-0.620***	-0.620***		0.451***	0.451***
		(0.112)	(0.111)		(0.157)	(0.157)
Year=2009		-0.091	-0.091		-0.197*	-0.197*
		(0.085)	(0.085)		(0.110)	(0.110)
Year=2010		0.034	0.034		-0.482***	-0.482***
		(0.096)	(0.096)		(0.096)	(0.096)
Year=2011		-0.193	-0.193		-0.516***	-0.516***
		(0.120)	(0.119)		(0.102)	(0.101)
Year=2012		-0.419***	-0.419***		-0.359***	-0.359***
		(0.144)	(0.143)		(0.109)	(0.108)
Year=2013		-0.265**	-0.265**		-0.432***	-0.432***
		(0.121)	(0.121)		(0.106)	(0.106)
N	462	462	462	462	462	462
R-squared	-0.001	0.038	0.539	0.095	0.175	0.379
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 C.10: Migration Probability Rank

	top 5	**bottom 5**
1	Beijing	Zhanjiang City
2	Shanghai	Xiangfan City
3	Chongqing	Beihai City
4	Shenzhen City	Jilin city
5	Chengdu City	Bengbu City

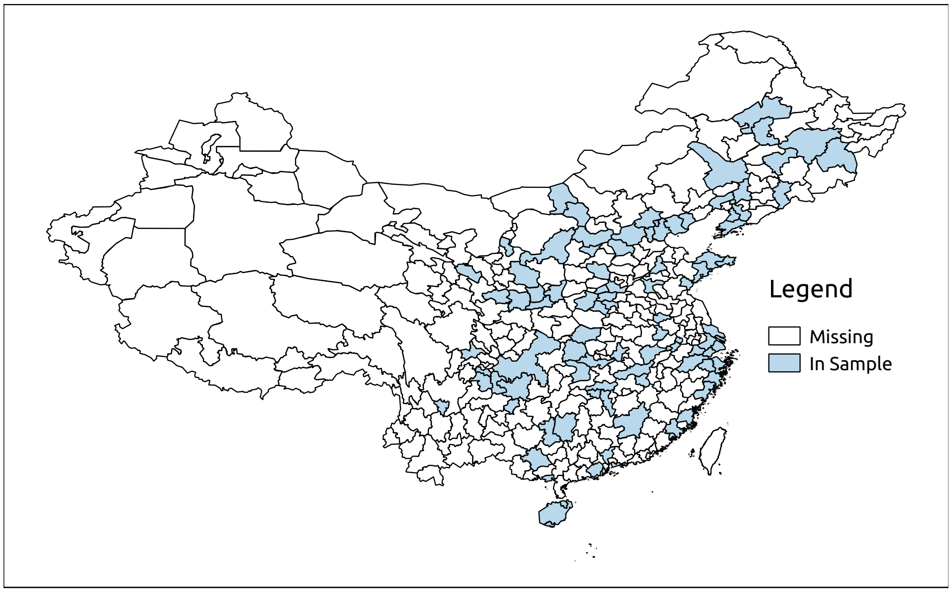
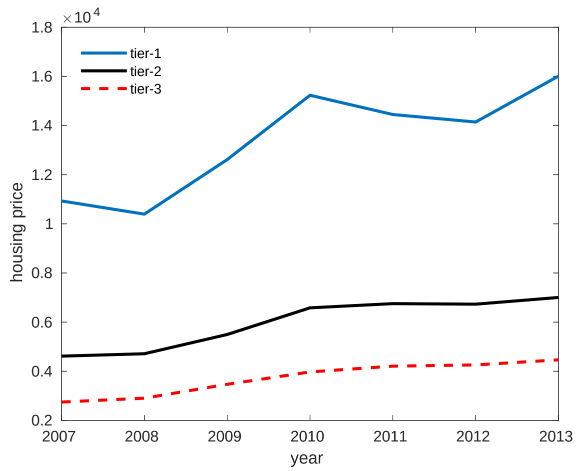
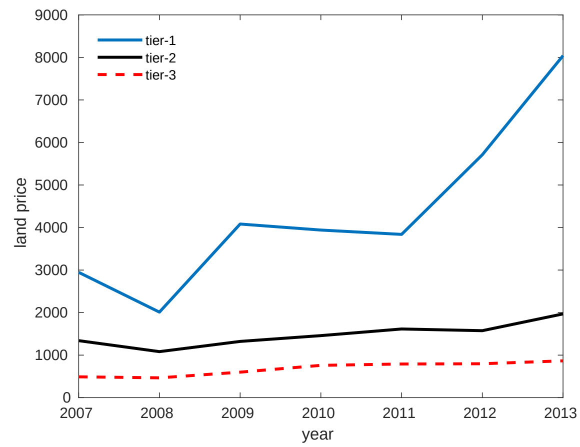


Figure C.1: Selected Sample

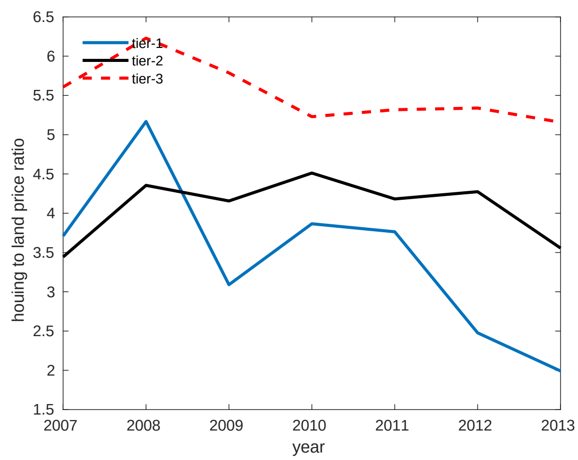
Notes: This graph plots the 93 prefecture-level cities in our sample. All the cities that are included contain the following data information during 2007-2013: (1) Real average price of newly-built housing units; (2) Real average price of residential land parcels; (3) Floor area of newly-built housing units sold; (4) Investment on housing development (exclude land purchase); (5) Residential land sales; (6) Real unit construction cost.



(a) Housing Prices



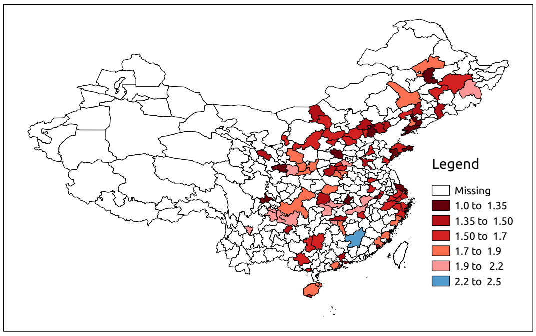
(b) Land Prices



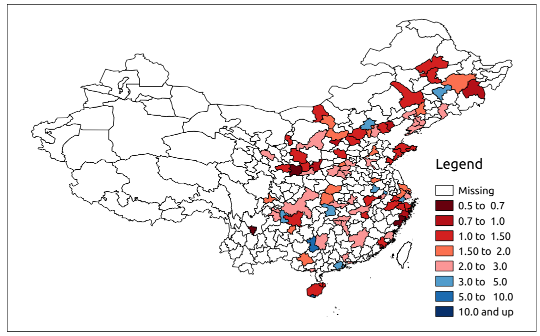
(c) Housing to Land Price Ratio

Figure C.2: Housing and Land Prices by City-tier

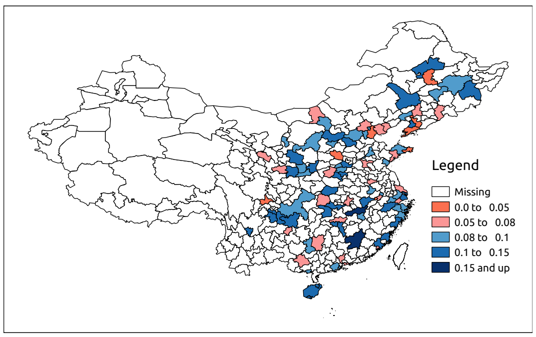
Notes:



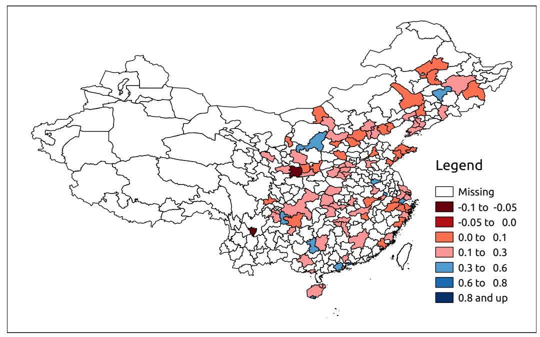
(a) Housing Price Ratio



(b) Land Price Ratio



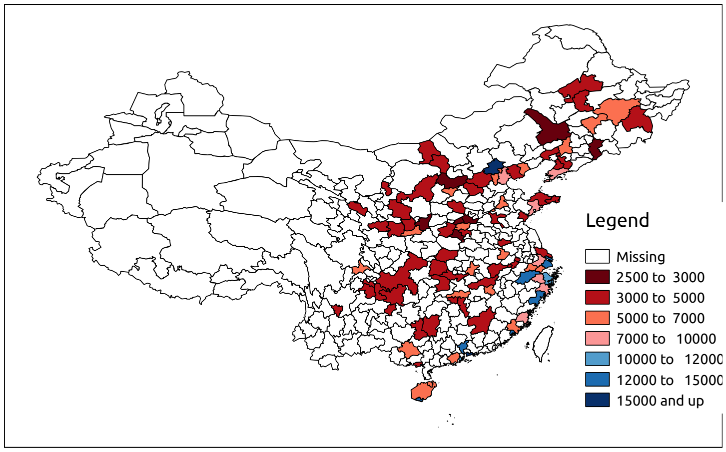
(c) Housing Price Growth



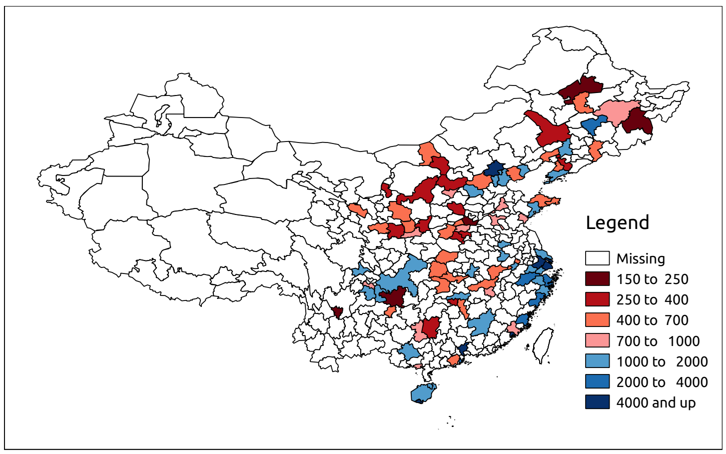
(d) Land Price Growth

Figure C.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. Price ratio denotes the ratio of price levels in 2013 to 2007. Growth rate is the average annual growth rate during 2007-2013.



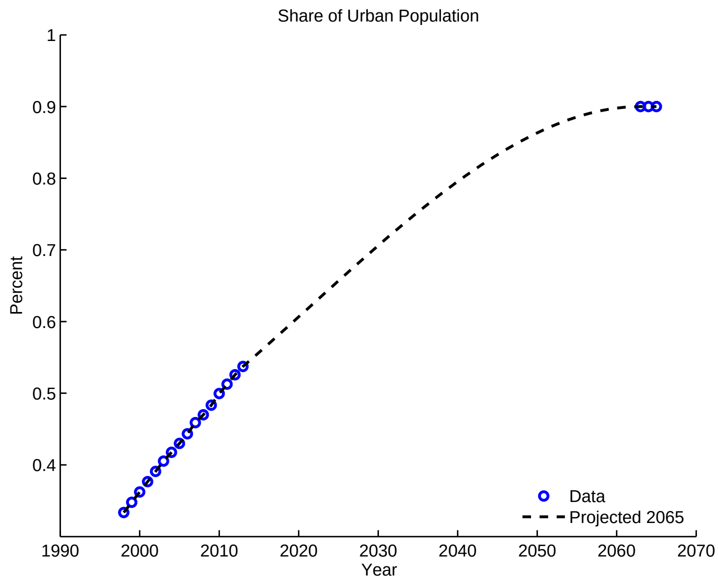
(a) Housing Prices



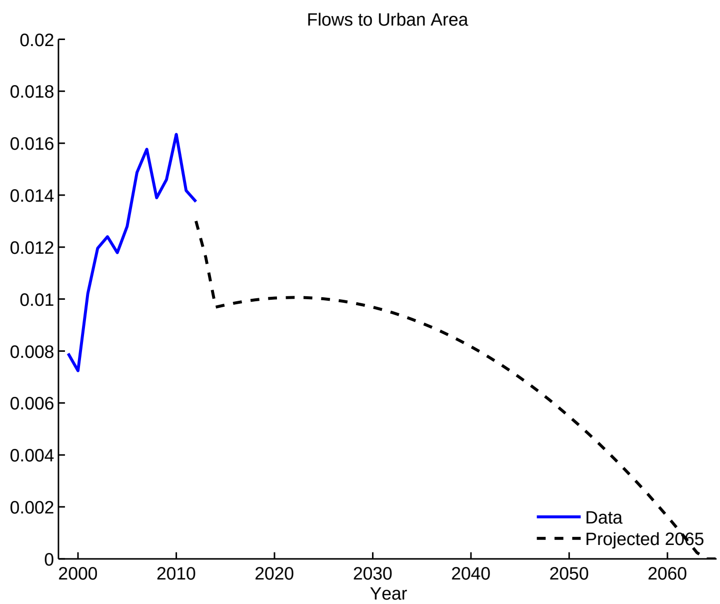
(b) Land Prices

Figure C.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 measured in 2010 price level.



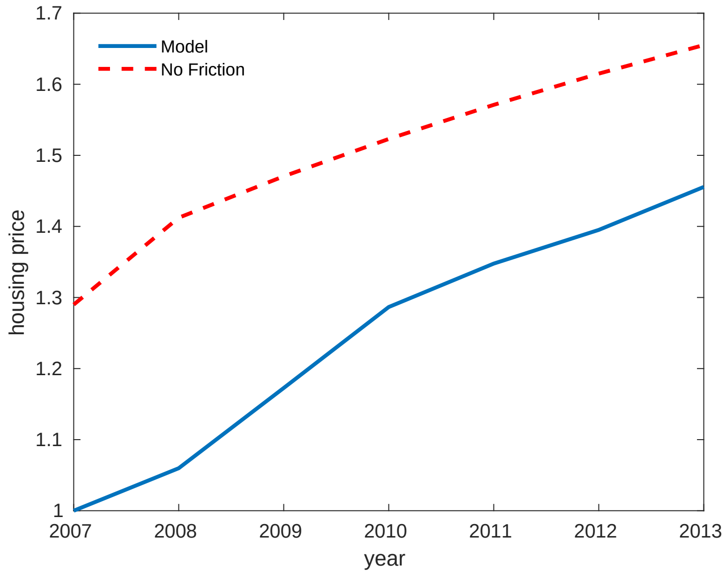
(a) Urban Population



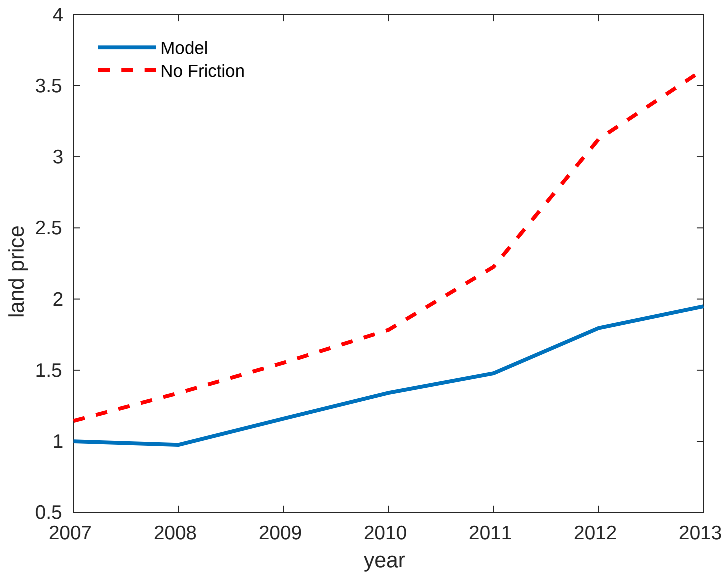
(b) Migration Flow

Figure C.5: Population Projection

Notes: In this figure, we project the urban population trend by assuming that the structural transformation in China will complete year 2063. Specifically, we assume net migration flow into urban area will continue to grow until the year 2020, and afterwards it will steadily decline.



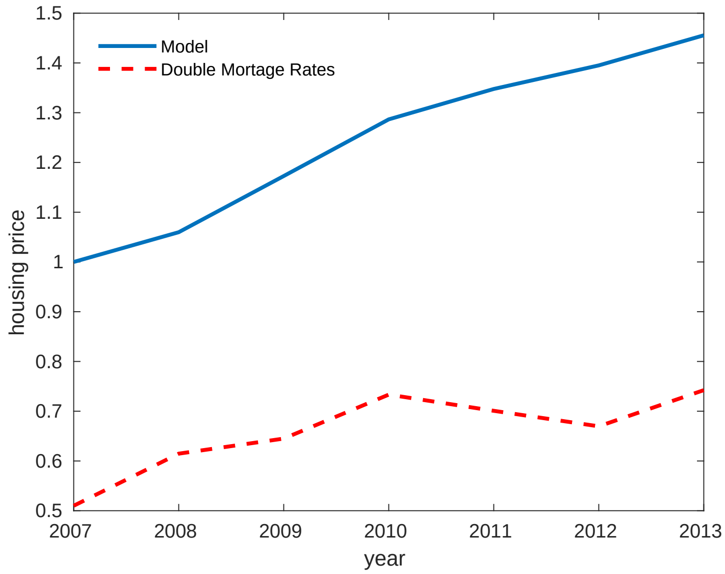
(a) Housing Prices



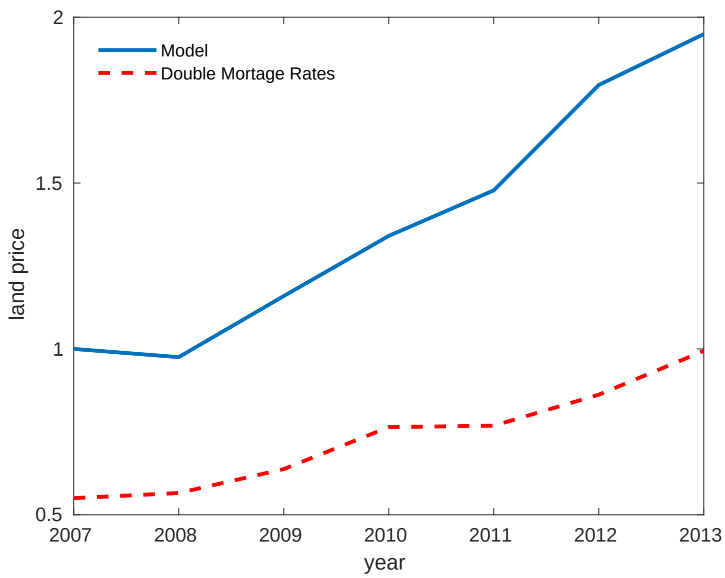
(b) Land Prices

Figure C.6: Model v.s. Frictionless Economy

Notes: This figure plots the model predicted housing and land price levels during 2007-2013 against their counterparts in a counterfactual economy where all the frictions are eliminated. We have normalized both housing and land price to be 1 in the benchmark 2007 economy.



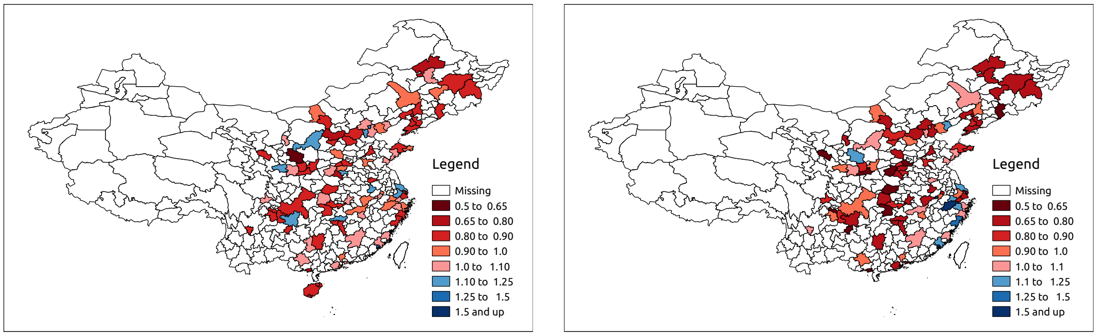
(a) Housing Prices



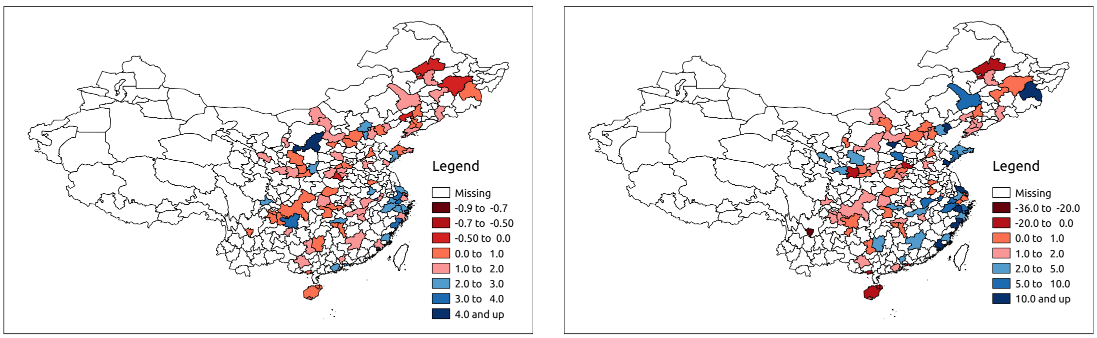
(b) Land Prices

Figure C.7: Benchmark v.s. Doubled Mortgage Interest Rates

Notes: This figure plots the model predicted housing and land price levels during 2007-2013 against their counterparts in a counterfactual economy where mortgage interest rate are doubled. We have normalized both housing and land price to be 1 in the benchmark 2007 economy.



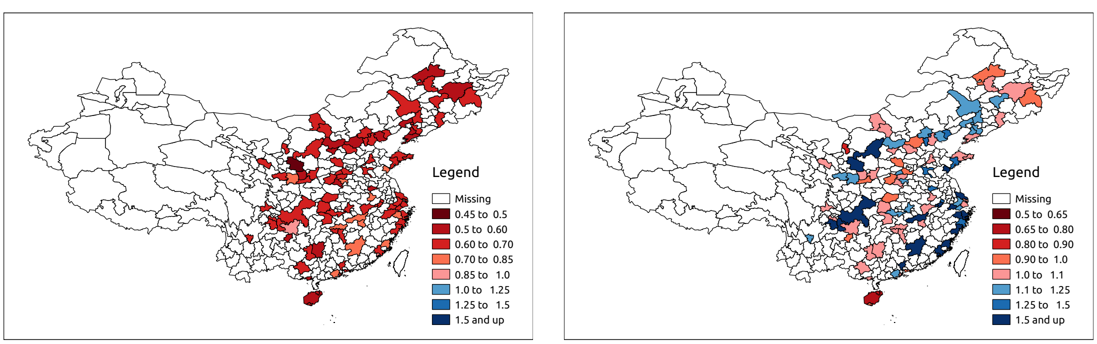
(a) Housing Prices Ratio (b) Land Prices Ratio



(c) Housing Prices Growth Rate (d) Land Prices Growth Rate

Figure C.8: City-level Prices: Model v.s. Data

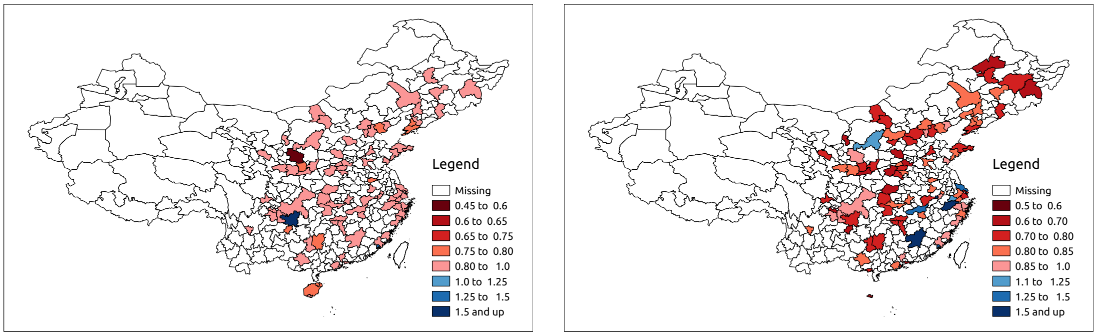
Notes: This figure maps the prediction power of our model in explaining housing and land price growth during 2007-2013. The explanation power is simply the ratio of model implied growth rate to that in the data at each city. We measure growth rate using both price ratio in 2013 to 2007 and the average annual price growth rate.



(a) Housing Prices Ratio (b) Land Prices Ratio

Figure C.9: City-level Prices: Frictionless v.s. Model

Notes: We compute price ratio between 2007 and 2013 for both benchmark and frictionless economy at each city. In the figure, we map the ratio of the "frictionless" ratio to the benchmark ratio. A number larger than 1 implies price ratio become higher in the frictionless economy.

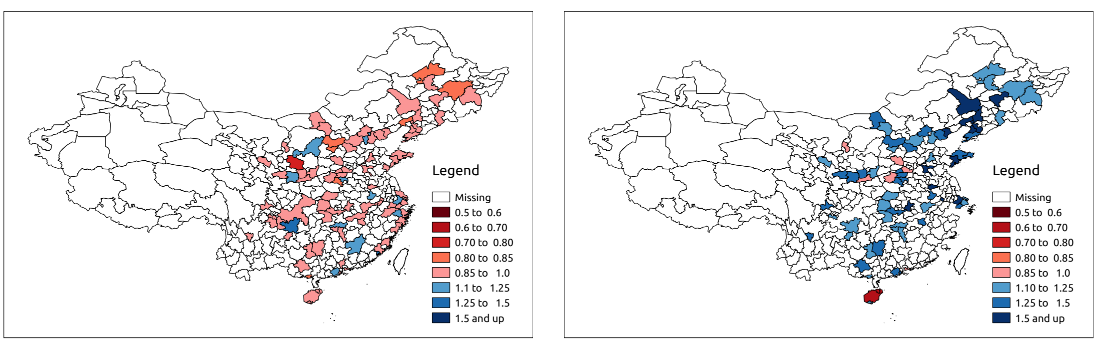


(a) Housing Prices Ratio

(b) Land Prices Ratio

Figure C.10: City-level Prices: No Housing Friction v.s. Model

Notes: We compute price ratio between 2007 and 2013 for both benchmark and economy without housing frictions at each city. In the figure, we map the ratio of the "counter-factual" ratio to the benchmark ratio. A number larger than 1 implies price ratio become higher in the counter-factual economy.



(a) Housing Prices Ratio

(b) Land Prices Ratio

Figure C.11: City-level Prices: No Land Friction v.s. Model

Notes: We compute price ratio between 2007 and 2013 for both benchmark and economy without land frictions at each city. In the figure, we map the ratio of the "counter-factual" ratio to the benchmark ratio. A number larger than 1 implies price ratio become higher in the counter-factual economy.