Rural-Urban Migration, Structural Transformation, and Housing Markets in China*

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Abstract

This paper investigates the interrelationship between urbanization, structural transformation, and the post-2000 Chinese housing boom through the lens of a newly developed multi-sector heterogeneous agent equilibrium model that features migration and a rich housing market structure with mortgages. Urbanization and structural transformation emerge as key drivers of China's house price boom, while at the same time rising house prices impede these forces of economic transition. Policies to boost urbanization can be undone by the endogenous price response. Land supply expansion ameliorates this negative feedback. Overall, housing acts as a potent source of economic transmission.

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1 Introduction

A plethora of countries at various stages of development have experienced large, sustained housing booms in recent decades. While some driving forces such as falling interest rates act as sources of commonality, rapid sectoral reallocation and population migration emerge as potential distinctive drivers in select developing economies. China stands out as one prominent case to evaluate. Its transition from a largely rural, agrarian society to an increasingly urban, industrialized economy manifests itself in the nearly forty percentage point drop in its agricultural employment share and thirty percentage point drop in its rural population share from 1980 to 2014—a trend that has persisted post-2000 despite a flat, albeit large, urban-rural income gap.[1] House prices have also skyrocketed since China implemented market-based land reforms around the turn of the century. Figure 1 summarizes these post-reform trends.[2]

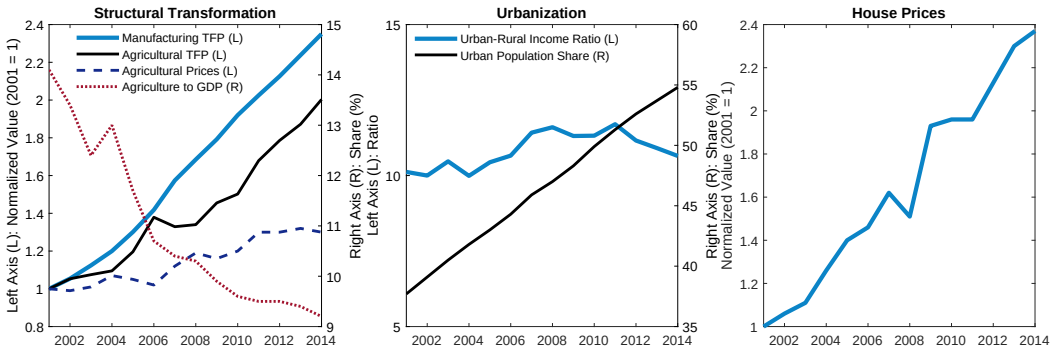

Figure 1: Stylized facts on China's economic transition and housing boom. Sources: (productivity, agricultural prices, agriculture to GDP, population, urban-rural income) CSY; (house prices) Fang et al. (2016).

[1] The urban-rural income gap is measured as the ratio of per-capita non-agricultural GDP to agricultural GDP multiplied by the relative price of agricultural to non-agricultural goods. Per-capita non-agricultural (agricultural) GDP is real non-agricultural (agricultural) GDP divided by urban (rural) population. The relative price of agricultural to non-agricultural goods is the ratio of the producer price of agricultural goods to the GDP deflator.

[2] This paper uses hedonic price data until 2014 from Fang, Gu, Xiong and Zhou (2016).

Using a novel dynamic spatial equilibrium model with heterogeneous agents, housing tenure choice, and long-term mortgages, this paper finds that relative rural-urban income dynamics, rising city amenities, and declining mobility costs rationalize China's structural transformation and urbanization from 2001 to 2014. In addition, these sectoral and population shifts can explain the vast majority of China's house price appreciation during this period. In explaining these significant economic changes, the analysis reveals a powerful two-way link between migration and housing. In one direction, migration flows stimulate housing demand and push up prices in the presence of relatively inelastic supply. Acting in the other direction, rising house prices influence migration decisions in two distinct and contrary ways: inflated costs of owning in the city make migration less appealing, but future price appreciation creates a motive to move early to purchase before the realization of price hikes and capitalize on the subsequent gains. The quantitative model suggests that, on net, rising house prices stunt migration flows. The channel from house prices to migration also plays a major role in determining the effectiveness of policies oriented toward accelerating China's economic transition, either by reducing their potency in the case of residency and credit policies that stimulate housing demand, or else acting as the primary source of positive transmission in the case of land policies that expand housing supply.

The dynamic spatial model underpinning this analysis features a rural area that engages only in agricultural production and a city where people work either in the manufacturing sector (denoted as such for simplicity but which actually includes all non-housing urban output in the quantitative analysis) or the residential construction sector. The agricultural and manufacturing sectors both employ labor via Ricardian technologies, but their output enters households' utility through a nested non-homothetic constant elasticity of

substitution consumption aggregator along with housing services. These features make it possible to capture the change in spending patterns over the sample period. In the city, construction firms use constant returns to scale technologies which utilize structures, labor, and land supplied by the government to produce apartments and houses. Absentee rental companies manage the stock of apartments for lease, while residents in the owner-occupied segment buy and sell houses.

Households in rural areas are hand-to-mouth income-earners that differ only with respect to the net migration cost they pay (measured in utility terms) if they move to the urban area, which nets out the premium placed on urban amenities from the gross costs of migration. In addition to the individual-specific permanent component, this net migration cost includes a common, unobserved factor that can vary over time.

Upon arriving to the city, new migrants only have the option to rent until they receive permission to buy a house in the form of a *hukou* permit. All city residents face income risk but have access to open financial markets to build savings for self-insurance and a housing down payment. Upon obtaining a hukou permit, renters may choose which house size to purchase and how much to finance out of savings and how much to borrow through long-term mortgages subject to meeting the minimum down payment requirement. Housing tenure choice and access to credit are distinguishing features of this model relative to static urban models that only include rental markets and hand-to-mouth consumption. Forward-looking behavior allows households to bring forward future income and separate the decision of when to move from the timing of income and prices. Moreover, the inclusion of tenure choice makes housing both a consumption good and an asset that allows homeowners to build wealth.

The baseline model is calibrated to match some cross-sectional observations

and subjected to a sequence of unanticipated shocks to sectoral productivities, city amenities, relative agricultural prices, land supply, and net mobility costs that give rise to equilibrium transition dynamics of migration and house prices. In particular, taking externally measured time series for all shocks except the migration costs, the baseline imputes the path of unobserved net mobility costs that rationalizes migration flows over the sample period, leaving house prices completely untargeted.[3] Quantitatively, the model rationalizes the increase in the urban population share from 45% to 62% and the nearly five percentage point decline in the agriculture-to-GDP ratio. Most importantly, the structural transformation and urbanization in the model generate a 134% increase in house prices, which is just below the 137% rise observed in the data. On the extensive housing margin, the surge of migrant renters without a hukou permit or savings for a down payment and the large rise in house prices depresses the homeownership rate by four percentage points in the model just as in the data.

In the baseline, the measured rural-urban income gap is stable, meaning that it alone cannot account for the significant rural-urban migration between 2001 and 2014. To rationalize this migration, the model needs the observed increase in city amenities and an approximate 36% decline in unobserved net mobility costs. Even though the income gap is stable, the migration decision is quite sensitive to this gap. A counterfactual reduction in rural income growth amplifies and accelerates movement to the city—generating a 46 rather than 17 percentage point shift in population, causing house prices to rise by 154% instead of the baseline 134%. Conversely, a slowdown in urban income growth curtails migration and has a particularly dramatic effect on prices because

[3]Exogenous agricultural prices allow for imports, which is consistent with Gale, Hansen and Jewison (2015). This baseline exercise requires assumptions about the value of shocks past the end of the sample period, but a robustness analysis finds that the equilibrium transition dynamics over the sample period are insensitive to these long-run assumptions.

demand falls both from current city residents and the drop in new migrants.

These results point to the existence of a *migration accelerator* whereby the endogenous population movements induced by an income shock amplifies the transmission to house prices and creates medium-term momentum followed by longer-run partial mean reversion. Intuitively, in response to a permanent income shock, housing demand increases because existing urban residents receive higher present and future income. In exchange, these income gains stimulate rural-urban migration that fuel further price appreciation. The momentum and mean reversion features of house price dynamics become even more apparent in response to an exogenous shock to net mobility costs, which is a unique feature of this model with forward-looking agents that does not appear in static spatial frameworks. This momentum-induced future appreciation drives existing urban households on the margin of buying to react quickly to the shock and buy before prices rise further as migrant renters acquire the legal permission and financial resources necessary to enter the owner-occupied market.

Causality also operates from housing to migration in the form of a *house price decelerator*. For both renters and homeowners, climbing housing costs make city living more expensive. However, for homeowners, their house is also an asset, and appreciation offers a path to wealth creation. Overall, cumulative rural-urban migration is 29% lower and sectoral reallocation away from agriculture is 21% less relative to a situation in which the increase in housing demand can be accommodated without any change in prices or rents. In short, house prices are acting as a drag on the process of urbanization and structural transformation. Moreover, rising house prices captured by the baseline model depresses homeownership by five percentage points.

These tight connections between rural-urban migration and house prices

have significant ramifications for the efficacy of policies oriented around accelerating structural transformation. In particular, housing markets emerge as a first-order factor that can help or hinder these policies. The considered policies fall into three categories: residency policies, credit policies, and land policies. The first two categories directly increase the appeal of living in the city—thus contributing to higher housing demand—whereas land policies only impact the decision to migrate indirectly through their effect on living costs.

Starting with the residency policy, reducing hukou waiting times makes moving to the city more attractive by allowing rural migrants to more quickly enjoy higher housing utility as they become owners earlier in the urbanization process before prices rise even higher. Absent any response of house prices, this relaxation adds 1.9 percentage points to the urban population share, but the policy-induced doubling of house price appreciation fueled by existing and income city residents more than offsets this effect and *slows down* structural transformation. In other words, the response of house prices renders the policy not just ineffective but counterproductive.

Similar dynamics emerge from credit policies that seek to ease access to housing either directly by alleviating constraints or indirectly by cooling the housing market. After loosening the minimum down payment ratio from 30% to 0%, the urban population share surges by 3.5 percentage points after only one year. However, the resulting price appreciation erases nearly all of this new migration. More stringent down payments cool the market, but the price effect is asymmetric, and migration still falls on net from tighter credit.

Lastly, land supply expansion proves capable of accelerating urbanization and structural transformation precisely by mitigating house price appreciation. An approximate doubling of land supply relative to the baseline significantly reduces house price appreciation, which increases rural-urban migration and

accelerates the reduction in the agriculture-to-GDP ratio. Endogenizing the government's land supply decision creates complementarities with other policies by inducing an automatic land supply accommodation to any demand-induced rise in prices.

In summary, the two-way link between housing and migration reveals that rapid urbanization puts tremendous pressure on house prices, and the ability to accommodate an influx of migrants without a steep escalation in prices shapes the path of economic development. Moreover, these channels have first-order implications for the efficacy of policy interventions.

Related Literature A large literature studies China's rapid development, while a small but growing body of papers are investigating China's housing boom. Zhu (2012) offers a summary of the scholarship on China's development, while Chen (2020) gives a comprehensive overview of the burgeoning research on Chinese housing markets. This paper is more in line with the approach in Wu, Gyourko and Deng (2016), though the interaction of credit and population shifts can generate bubble-like price behavior consistent with Chen and Wen (2017). A key innovation here is that structural transformation acts as a major driver of migration and price appreciation. Many studies on structural transformation use equilibrium models without spatial considerations, a summary of which is in Herrendorf, Rogerson and Valentinyi (2014). Hansen and Prescott (2002) and Ngai and Pissarides (2007) emphasize the role of different productivity growth rates in driving structural change. In this paper, migration is sensitive to such gaps, but other factors also prove necessary.

A notably smaller literature exists on dynamic rural-urban migration. Glomm (1992) studies migration caused by higher urban productivity from agglomeration effects. Robert E. Lucas (2004) identifies human capital

accumulation as a dynamic driver of migration. More recently, Bond, Riezman and Wang (2016) demonstrate that trade liberalization in capital-intensive, import-competing sectors prior to China's WTO accession has accelerated migration, capital accumulation, and economic growth. Tombe and Zhu (2019) find that reduction in internal trade and migration costs account for almost two-fifths of aggregate labor productivity growth in China from 2000 to 2005—even more important than international trade liberalization. Also focusing on China, Liao, Wang, Wang and Yip (2020) show that education-based migration plays an equally important role as work-based migration for urbanization. None of these papers considers the role of housing.

A substantial contribution of this paper to the housing literature involves the finding that structural transformation and urbanization can generate sustained housing booms. Moreover, the underlying transmission mechanisms give rise to dynamic impulse responses that feature medium-term momentum and long-run partial mean reversion, which the structural housing literature often has a difficult time producing. Relative to the bulk of spatial economics papers that are static in nature, this paper reveals the importance of dynamic forward-looking behavior,tenure choice that creates a dual consumption-asset role for housing, and credit access that disentangles migration and home purchase decisions from the timing of income and prices. In this sense, the paper here relates to a large literature that explores financial frictions as drivers of housing boom-bust episodes (e.g., see Garriga, Manuelli and Peralta-Alva (2019) and Garriga and Hedlund (2018), or Davis and Van Nieuwerburgh (2015) and Piazzesi and Schneider (2016) for summaries).

2 The Model

The model economy contains a unit measure of infinitely-lived households who reside in either a rural or urban area. Rural households own and operate farms in the tradable agricultural/farm sector (f). Households living in the city work either in the urban production sector (labeled as manufacturing (m) but which encompasses all non-housing urban output) or in residential construction and have access to open financial markets. Agents work where they live, but rural workers can migrate to the city. The urban good m is the numeraire.

2.1 Production

Rural households each produce Z_{ft} farm goods, where Z_{ft} denotes agricultural productivity. Thus, total farm output $Y_{ft} = Z_{ft}N_{ft}$ depends on Z_{ft} and the rural population N_{ft}. Urban "manufacturers" produce $Y_{mt} = Z_{mt}N_{mt}$ goods from urban labor N_{mt} hired at wage rate $w_t = Z_{mt}$ that can be used as final consumption or as intermediate structures to build houses and apartments.

The residential construction sector sells tenant-occupied apartments ($j = a$) and owner-occupied housing ($j = h$) at price p_{jt} produced from new land L_{jt} issued by the government at price p_{ljt}, structures S_{jt} from the numeraire "manufacturing" sector, and urban labor N_{jt} using a constant returns to scale technology, $Y_{jt} = Z_j F_j(L_{jt}, \Upsilon(S_{jt}, N_{jt}))$. Profit maximization implies

$$p_{ljt} = p_{jt} Z_j \frac{\partial F_j}{\partial L_j}, \tag{1}$$

$$1 = p_{jt} Z_j \frac{\partial F_j}{\partial \Upsilon} \frac{\partial \Upsilon}{\partial S_j}, \tag{2}$$

$$w_t = p_{jt} Z_j \frac{\partial F_j}{\partial \Upsilon} \frac{\partial \Upsilon}{\partial N_j} \tag{3}$$

The law of motion for the two stocks is $K_{jt} = (1 - \delta_j)K_{j,t-1} + Y_{jt}$, where δ_j is depreciation, and $\delta_a > \delta_h$ reflects greater wear and tear by tenants.[4]

Absentee rental companies lease apartments to urban residents at rent r_{at}. Rental companies must be indifferent between selling an apartment and retaining it for rental purposes and future resale, which implies the following relationship between apartment prices and rents:

$$p_{at} = r_{at} + \frac{1 - \delta_a}{1 + i_{t+1}} p_{a,t+1}. \tag{4}$$

2.2 Households

Agents receive utility $u(x_{ft}, x_{mt}, x_{ht})$ from farm goods x_{ft}, manufactured goods x_{mt}, and housing services x_{ht} and discount at the rate β. Also, depending on whether they live in the rural or urban area, agents differ in terms of the level and riskiness of income, housing options, and access to financial markets.

2.2.1 Rural Households

Rural households receive deterministic farm income Z_{ft}, and they costlessly obtain housing services $x_{ht} = h_f$ from nontradable, self-built farm houses h_f. Rural households also lack access to financial markets, which implies that they are hand-to-mouth consumers. Even so, they must still choose how to allocate their spending between manufactured and farm goods, the latter of which trade at relative price p_{ft} and require minimum subsistence consumption $\underline{x}_f$.

Households in rural areas are identical hand-to-mouth income-earners except that they differ with respect to the net migration cost $\xi_t \epsilon$ they pay if

[4] Residential depreciation helps ensure stationarity. At the individual owner level, housing depreciation manifests in the form of stochastic house fires with probability δ_h. However, by assumption, the government fully insures these events by purchasing new houses for the owners and charging $\delta_h p_{ht} h$ each period for the insurance.

they move to the urban area, where ξ_t is a common, time-varying component and ϵ is a permanent type drawn from distribution $\Psi(\epsilon)$ with support $[\underline{\epsilon}, \infty)$. Smaller values of ϵ signify either lower gross mobility costs or a higher premium placed on urban amenities. For simplicity, urban-to-rural migration is not allowed, though this restriction never binds in any of the quantitative exercises.

2.2.2 Urban Households

Urban households receive stochastic labor market earnings $w_t e_t s_t$, where s_t is a persistent shock that follows transitions $\pi(s_{t+1}|s_t)$, e_t is a transitory shock drawn from $G(e_t)$, and w_t is the wage. Newly arrived migrants from the rural area draw their initial s_t from the stationary distribution $\Pi(s_t)$. Because labor markets are competitive and the manufacturing technology is linear, it must be the case that $w_t = Z_{mt}$. In addition, the government supplements income with transfers $\mathcal{T}_t$ to provide a consumption floor.[5]

City residents can be either renters or owners. Renters pay r_{at} each period for an apartment h_a that provides services $x_{ht} = h_a$. With probability η_t, urban residents receive a hukou permit that allows them to buy an owner-occupied house $h \in \mathcal{H} = \{h_1, h_2, \ldots, h_N\} > h_a$ at unit price p_{ht} that provide flows $x_{ht} = \zeta h$, $\zeta \geq 1$.[6] Lastly, urban residents can save and owners can borrow using mortgages. The respective interest rates i_t and r_{dt} on savings and mortgages are exogenous, reflecting that they are primarily controlled by the government. Mortgages are long-term contracts with a minimum down payment ratio θ_t and an amortization schedule that decays geometrically at rate γ.

[5]The transfer also prevents low income renters from facing an empty budget set.

[6]The model abstracts from multiple ownership, but capital gains from rising prices still provide an investment motive to buy. Empirically, the 2011 China Household Finance Survey finds that only 15% owned multiple houses, likely due to high minimum down payments on non-primary residences of $60 - 70\%$, as reported by Chen, Wang, Xu and Zha (2020).

2.2.3 Household Decision Problems

Rural workers are characterized by their net mobility cost ϵ. In the city, renters have cash at hand y_t (the sum of earnings $w_t e_t s_t$, transfers $\mathcal{T}_t$, and savings b_t), persistent shock s_t, and an indicator for hukou permit status denoted as a superscript. Owners also have house h_t and mortgage d_t.

Rural Rural workers make consumption and migration decisions that solve

$$V_t^{rural}(\epsilon) = \max_{x_{mt}, x_{ft} \geq 0} u(x_{mt}, x_{ft}, h_f) + \beta \max\left\{V_{t+1}^{rural}(\epsilon), \mathbb{E}V_{t+1}^{rent,0}(y_{t+1}, s_{t+1}) - \xi_{t+1}\epsilon\right\}$$

$$\text{subject to}$$

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} &= p_{ft}Z_{ft} \\ y_{t+1} &= w_{t+1}e_{t+1}s_{t+1} + \mathcal{T}_{t+1}, \end{aligned} \tag{5}$$

which gives a cutoff ϵ_{t+1}^* for the marginal migrant. Remaining rural households entering period $t+1$ (those with $\epsilon > \epsilon_t^*$) migrate if $\epsilon \leq \epsilon_{t+1}^*$, where

$$\epsilon_{t+1}^* \equiv \max\left\{\epsilon_t^*, \left[\mathbb{E}V_{t+1}^{rent,0}(y_{t+1}, s_{t+1}) - V_{t+1}^{rural}\left(\epsilon_{t+1}^*\right)\right]/\xi_{t+1}\right\}. \tag{6}$$

Urban Renters in the city without hukou permits make consumption and savings decisions that solve

$$V_t^{rent,0}(y_t, s_t) = \max_{\substack{x_{ft}, x_{mt}, \\ b_{t+1} \geq 0}} u(x_{ft}, x_{mt}, h_a) + \beta\mathbb{E}\left[\begin{array}{c} \eta_t \max\{V_{t+1}^{rent,1}(y_{t+1}, s_{t+1}), V_{t+1}^{buy}(y_{t+1}, s_{t+1})\} \\ +(1-\eta_t)V_{t+1}^{rent,0}(y_{t+1}, s_{t+1}) \end{array}\right]$$

$$\text{subject to}$$

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + p_a h_a + b_{t+1} &= y_t \\ y_{t+1} &= w_{t+1}e_{t+1}s_{t+1} + (1+i_{t+1})b_{t+1} + \mathcal{T}_{t+1}, \end{aligned} \tag{7}$$

where renters who receive a permit next period decide whether or not to buy.

Urban renters with hukou permits choose consumption, savings, and—after receiving their shocks next period—whether to remain as renters. They solve

$$V_t^{rent,1}(y_t, s_t) = \max_{\substack{x_{ft}, x_{mt}, \\ b_{t+1}}} u(x_{ft}, x_{mt}, h_a) + \beta \mathbb{E}\left[\max\{V_{t+1}^{rent,1}(y_{t+1}, s_{t+1}), V_{t+1}^{buy}(y_{t+1}, s_{t+1})\}\right]$$

subject to

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + p_a h_a + b_{t+1} &= y_t \\ y_{t+1} &= w_{t+1}e_{t+1}s_{t+1} + (1 + i_{t+1})\, b_{t+1} + \mathcal{T}_{t+1}, \end{aligned} \tag{8}$$

which features the same constraints as in household problem (7).

Homebuyers choose their desired house type, mortgage size (subject to the minimum down payment ratio), consumption, and savings to solve

$$V_t^{buy}(y_t, s_t) = \max_{\substack{x_{ft}, x_{mt}, \\ b_{t+1}, d_{t+1}, \\ h_{t+1} \in \mathcal{H}}} u(x_{ft}, x_{mt}, \zeta h_{t+1}) + \beta \mathbb{E}\left[\begin{array}{c} \max\left\{(1-\rho)V_{t+1}^{rent,0}\left(y_{t+1}^{rent}, s_{t+1}\right)\right. \\ +\rho V_{t+1}^{rent,1}\left(y_{t+1}^{rent}, s_{t+1}\right), \\ \left. V_{t+1}^{own}\left(y_{t+1}^{own}, h_{t+1}, d_{t+1}, s_{t+1}\right)\right\} \end{array}\right]$$

subject to

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + (1 + \tau_b + \delta_h)p_{ht}h_{t+1} + b_{t+1} &= y_t + d_{t+1} \\ d_{t+1} &\leq (1 - \theta_t)p_{ht}h_{t+1} \\ y_{t+1}^{rent} &= w_{t+1}e_{t+1}s_{t+1} + (1 + i_{t+1})\, b_{t+1} + (1 - \tau_s)p_{h,t+1}h_{t+1} - (1 + r_{d,t+1})\, d_{t+1} + \mathcal{T}_{t+1} \\ y_{t+1}^{own} &= w_{t+1}e_{t+1}s_{t+1} + (1 + i_{t+1})\, b_{t+1}, \end{aligned} \tag{9}$$

where in the continuation, the buyer can remain an owner or sell and become a renter, retaining a hukou permit with probability $\rho \in [0, 1]$.[7]

[7] This parsimoniously captures the probability that a household moves within the same city and keeps their hukou permit or moves to a different city and loses their hukou permit.

Lastly, existing owners choose their consumption and savings while their mortgage amortizes at the rate γ. Their value function is

$$V_t^{own}\left(y_t, h, d_t, s_t\right) = \max_{\substack{x_{ft}, x_{mt}, \\ b_{t+1}}} u(x_{ft}, x_{mt}, \zeta h) + \beta \mathbb{E}\left[\begin{array}{c} \max\left\{(1-\rho)V_{t+1}^{rent,0}\left(y_{t+1}^{rent}, s_{t+1}\right)\right. \\ +\rho V_{t+1}^{rent,1}\left(y_{t+1}^{rent}, s_{t+1}\right), \\ \left. V_{t+1}^{own}\left(y_{t+1}^{own}, h, d_{t+1}, s_{t+1}\right)\right\} \end{array}\right]$$

subject to

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + \delta_h p_{ht} h + b_{t+1} + (\gamma + r_{dt})d_t &= y_t \\ d_{t+1} &= (1-\gamma)d_t \\ y_{t+1}^{rent} &= w_{t+1}e_{t+1}s_{t+1} + (1+i_{t+1})\, b_{t+1} + (1-\tau_s)p_{h,t+1}h - (1+r_{d,t+1})\, d_{t+1} + \mathcal{T}_{t+1} \\ y_{t+1}^{own} &= w_{t+1}e_{t+1}s_{t+1} + (1+i_{t+1})\, b_{t+1}, \end{aligned} \tag{10}$$

where y_{t+1}^{own} and y_{t+1}^{rent} are as in household problem (9), except with house h (owner state variable) on the right side instead of h_{t+1} (buyer choice variable).

2.3 Government

The government exogenously issues quantities $\overline{L}_{jt}$ of land to the segmented apartment ($j = a$) and housing ($j = h$) markets. Land proceeds finance transfers $\mathcal{T}_t$ and insurance claims for depreciated housing, with the government consuming any residual revenues. Section 4.3.3 considers the case where the government endogenously supplies land.

2.4 Equilibrium

Given prices and interest rates $\{p_{ft}, i_t, r_{dt}\}$ as well as government policies $\{\overline{L}_{at}, \overline{L}_{ht}, \eta_t, \theta_t\}$, a dynamic spatial equilibrium (DSE) consists of prices $\{p_{at}, r_{at}, p_{ht}, p_{lat}, p_{lht}, w_t\}$, factor inputs $\{N_{ft}, N_{mt}, N_{at}, N_{ht}, S_{at}, S_{ht}, L_{at}, L_{ht}\}$,

household value functions $\{V_t^{rural}, V_t^{rent}, V_t^{buy}, V_t^{own}\}$ and associated policy functions, migration cutoffs $\{\epsilon_t^*\}$, and end-of-period distributions $\{\Phi_t^{rent}, \Phi_t^{own}\}$ that satisfy several conditions. First, households, firms, and rental companies optimize as in sections 2.1 and 2.2. Second, the rural population satisfies

$$N_{ft} = 1 - \Psi(\epsilon_t^*). \tag{11}$$

Third, the urban labor market clears,

$$N_{mt} + N_{at} + N_{ht} = \int d\Phi_t^{rent} + \int d\Phi_t^{own} = 1 - N_{ft}. \tag{12}$$

Fourth, the land markets clear for $j = a, h$,

$$L_{jt} = \overline{L}_{jt}. \tag{13}$$

Fifth, the urban housing and rental markets clear,

$$\int h_t d\Phi_t^{own} = (1 - \delta_h) K_{h,t-1} + Y_{ht} \tag{14}$$

$$h_a \int d\Phi_t^{rent} = (1 - \delta_a) K_{a,t-1} + Y_{at}. \tag{15}$$

Lastly, the end-of-period urban area distributions are generated by the household decision rules and stochastic processes.

3 Calibration

The results in section 4 analyze and compare different equilibrium transition paths over the sample period of 2001–2014 that are induced by changes either to the economic landscape or to policy. The calibration strategy for such an

analysis often involves determining parameters using a combination of direct external evidence and a joint procedure that minimizes the distance between the initial equilibrium of the model and a set of data moments. The approach here is similar except that it also uses the final equilibrium following a baseline set of shocks (described in section 4.1.1) to target some more recent data moments. The length of a model period is one year.

3.1 Production

This section describes the parametrization of producers in the economy.

3.1.1 Technology

Initial urban wages are normalized to 1 by setting $Z_{m0} = 1$. Rural productivity Z_{f0} is set to match the 2001 urban-rural income gap of $Z_{m0}/Z_{f0} = 10.12$ from the China Statistical Yearbook (CSY).[8]

The production function for residential construction is given by

$$F_j(L_{jt}, \Upsilon(S_{jt}, N_{jt})) = L_{jt}^{\alpha_{Lj}} \Upsilon(S_{jt}, N_{jt})^{1-\alpha_{Lj}} \tag{16}$$

$$\Upsilon(S_{jt}, N_{jt}) = S_{jt}^{\alpha_S} N_{jt}^{1-\alpha_S} \tag{17}$$

where the structures share $\alpha_S = 0.3$ is consistent with Favilukis, Ludvigson and Van Nieuwerburgh (2017), and α_{Lj} reflects the average ratio between the value of each residence type $j = a, h$ and land. For houses, $\alpha_{Lh} = 0.27$ is a population-weighted average across tier-1, tier-2, and tier-3 cities using

[8]The urban-rural income gap is measured as the ratio of per-capita non-agricultural GDP to agricultural GDP multiplied by the relative price of agricultural to non-agricultural goods. Per-capita non-agricultural (agricultural) GDP is real non-agricultural (agricultural) GDP divided by urban(rural) population. The relative price of agricultural to non-agricultural goods is the ratio of the producer price of agricultural goods to the GDP deflator.

estimates from Deng, Tang, Wang and Wu (2022), which is then scaled down by one-third to $\alpha_{La} = 0.18$ for tenant-occupied apartments given their higher density of structures to land. The productivities Z_{j0} are chosen to normalize initial house prices to $p_{h0} = 1$ and rents to $r_{a0} = 0.05$ so that $p_{h0}/r_{a0} = 20$.[9]

3.1.2 Housing

The annual depreciation rate for housing is set to $\delta_h = 0.025$ following Favilukis et al. (2017), whereas apartments depreciate at a higher rate of $\delta_a = 0.05$, which is consistent with the higher maintenance costs for tenant-occupied properties in Chambers, Garriga and Schlagenhauf (2009). The rural house size is normalized to $h_f = 1$.[10] The small urban house size is set to $h_1 = 3$ to be three times average urban earnings, while the apartment h_a and larger house h_2 are set such that $h_1/h_a = 1.31$ and $h_2/h_1 = 4.45$, respectively, to be consistent with quality-adjusted dwellings data from the Hang Lung Center for Real Estate at Tsinghua University (CRE).[11]

Home buyers pay a transaction cost $\tau_b = 0.005$ as in Garriga and Hedlund (2020). Sellers incur cost $\tau_s = 0.12$, which mirrors Guren, McKay, Nakamura and Steinsson (2020) and is inclusive of fees, moving costs, and liquidity discounts, as discussed in Piazzesi and Schneider (2016).

[9] In large cities, the ratio can exceed 50, while in small cities, the number can be below 10. The ratio of 20 can be viewed as an approximate national average in the early 2000s.

[10] The rural house size does not enter the rural budget constraint and cannot be separately identified from the minimum support of the mobility cost distribution in the joint calibration.

[11] The ratio of living space in owner-occupied to rental-occupied housing is between 1.3 and 1.4, even though the ratio of purchased space is closer to 2. Unlike single-family standalone units which are common in the U.S. and Europe, houses in China are more often apartments and condos. Purchased space includes common areas, stairs/elevators, etc, whereas actual living space is about two-thirds of the purchased space. The 4.45 ratio for the large house to small house is the product of the raw space ratio between villas and regular houses (2.03) in the CFPS and the quality ratio (2.19) between them.

3.2 Households

This section describes the parametrization of households in the economy.

3.2.1 Preferences

Households exhibit nested, non-homothetic CES and constant relative risk aversion preferences. Specifically, $u(x_f, x_m, x_h) = U(C(x_f, x_m), x_h)$, where

$$U(C, x_h) = \frac{\left[\left(\phi_c C^{\frac{\nu_c - 1}{\nu_c}} + (1-\phi_c) x_h^{\frac{\nu_c - 1}{\nu_c}}\right)^{\frac{\nu_c}{\nu_c - 1}}\right]^{1-\sigma}}{1-\sigma} \tag{18}$$

$$C(x_f, x_m) = \left(\phi_f [x_f - \underline{x}_f]^{\frac{\nu_f - 1}{\nu_f}} + (1-\phi_f) x_m^{\frac{\nu_f - 1}{\nu_f}}\right)^{\frac{\nu_f}{\nu_f - 1}}. \tag{19}$$

The coefficient of relative risk aversion is set to a standard $\sigma = 2$, and the intratemporal elasticity of substitution between consumption and housing is $\nu_c = 0.487$ based on Li, Liu, Yang and Yao (2016). The minimum subsistence threshold $\underline{x}_f$ for agricultural consumption is set to 25% of average per capita rural agricultural consumption.[12] The discount factor β, utility shares ϕ_c and ϕ_f, elasticity ν_f, and homeownership utility premium ζ are all determined in the joint calibration. The discount factor β is informative for the amount of liquid financial assets in the economy, and the share ϕ_c affects the fraction that urban households spend on housing. The agricultural share ϕ_f and elasticity ν_f help determine agricultural spending in the initial and final equilibria (the latter induced by the baseline shocks described in section 4.1.1). The ownership premium ζ has a first-order impact on the homeownership rate.

[12] Using U.S. historical data dating back to 1870, Alvarez-Peláez and Díaz (2005) estimate a minimum consumption to average consumption ratio in the range of 28% to 40%. The calibration uses 25% because China was more industrialized in 2001 than the U.S. in 1870.

3.2.2 Mobility Costs

The cumulative density function for net mobility costs is

$$\Psi(\epsilon) = 1 - \left(\frac{\underline{\epsilon}}{\epsilon}\right)^{\kappa}, \tag{20}$$

where $\kappa = 2.8$ is set to be within the common range for the migration literature, e.g. Liao et al. (2020). The unobserved common component ξ_t of net mobility costs is decomposed into $\ln(\xi_t) = -\ln(\xi_{qt}) + \ln(\widetilde{\xi}_t)$, where ξ_{qt} stands for urban housing quality (or city quality, for short) and is measured by the ratio of the aggregate hedonic house price index to the National Bureau of Statistics (NBS) non-hedonic house price index. The unobserved residual $\widetilde{\xi}_t$ encapsulates gross mobility costs net of all other difficult to measure urban amenities. The initial values of both components are normalized to 1. The minimum support $\underline{\epsilon}$ and the final residual net mobility cost $\widetilde{\xi}_{\infty}$ are outputs from the joint calibration and play an important role in matching the urban population share at the beginning and end of the sample. Section 3.4 explains in more detail.

3.2.3 Urban Income Process

The stochastic labor endowment $e_t s_t$ follows

$$\ln(s_t) = \rho_s \ln(s_{t-1}) + \varepsilon_t \tag{21}$$

$$\varepsilon_t \sim \mathcal{N}(0, \sigma_{\varepsilon}^2) \tag{22}$$

$$\ln(e_t) \sim \mathcal{N}(0, \sigma_e^2). \tag{23}$$

with parameters $\rho_s = 0.9172$, $\sigma_{\varepsilon}^2 = 0.0469$, and $\sigma_e^2 = 0.03$ from Fan, Song and Wang (2010). The persistent component is discretized using the Rouwenhorst method into a three-state Markov chain with transition matrix π.

3.3 Government and Finance

This section describes parameters related to policy and financial instruments.

3.3.1 Government Policy

The minimum down payment ratio is $\theta = 0.3$ in accordance with policy during 2001 – 2014.[13] The decay rate for outstanding mortgage balances is $\gamma = 0.0333$ to approximate a 30-year amortization. The probability that an urban resident receives a hukou permit is $\eta = 0.3$, which corresponds to an expected wait time of just over 3 years as reported by Liao et al. (2020), and the probability of keeping a hukou permit after selling is set to $\rho = 0.37$.[14] The initial land supplied by the government is normalized to $\overline{L}_{j0} = 1$ for $j = a, h$.

The means-tested transfers satisfy

$$\mathcal{T}_t(e_t s_t) = \max\{0, r_{at} h_a + p_{ft} \underline{x}_f + \chi w_t \underline{es} - w_t e_t s_t\} \tag{24}$$

with $\chi = 0.5$ and where $\underline{es}$ is the lowest income realization. This formulation ensures that urban residents can afford an apartment, subsistence agriculture, and have minimum income $\chi w_t \underline{es}$ left over.

3.3.2 Interest Rates

The literature reports a range of estimates for the rate of return to savings in China. This paper sets $i = 0.08$, which is slightly lower than the 10% used in Hsieh and Klenow (2009) because of the absence of physical capital and other high-return assets in the model here. The mortgage rate is $r_d = 0.06$.

[13] The down payment was temporarily lowered to 20% during the global financial crisis.

[14] Based on data from the 2005 One Percent Population Survey, 63% of urban-to-urban movers migrated to another city where they often lose their hukou permit, with 37% moving within the city where they keep their permit.

Table 1: Joint Parametrization

Description	Model	Data	Source
2001 Rural Population Share	62.3%	62.3%	CSY[a] 2016
2014 Rural Population Share*	45.2%	45.2%	CSY[a] 2016
2001 Agricultural Spend Share	14.1%	14.1%	CSY[a] 2016
2014 Agricultural Spend Share*	9.2%	9.2%	CSY[a] 2016
Homeownership Rate	82.4%	82.6%	Census[b] 2000
Financial Assets to GDP	1.5	1.5	UHS[c] 2007
Housing Spend Share (Owners)	24.4%	24.5%	CFPS[d] 2014, 2016

*Final equilibrium. [a]China Statistical Yearbook; [b]Average over tier-1, 2, and 3 cities; [c]Urban Household Survey; [d]China Family Panel Survey.

3.4 Joint Parametrization

The remaining parameters are determined jointly within the model to match characteristics of the Chinese economy over the sample period of 2001 to 2014. Table 1 provides the empirical moments, data sources, and closeness of fit. The procedure utilizes the initial equilibrium to target a set of moments that involve household portfolios, expenditure shares, and the population split across rural and urban areas in the early post-land-reform years. In addition, the model targets two moments from 2014—the rural population share and the agricultural spending share—using the long-run equilibrium that corresponds to the 2014 values of the shocks described in section 4.1.1.[15] Table 2 summarizes all of the model parameters.

[15]An even more precise procedure that computes the entire equilibrium transition path starting in 2001 for each parameter combination to target the 2014 data using the thirteenth period of the transition would be very costly and deliver minimal accuracy gains.

Table 2: Summary of Model Parameters

Description	Parameter	Value	Explanation
Technology			
Manufacturing Productivity	Z_{m0}	1	Section 3.1.1
Agricultural Productivity	Z_{f0}	0.099	Section 3.1.1
Housing Productivity	Z_h	0.699	Section 3.1.1
Apartment Productivity	Z_a	1.944	Section 3.1.1
Housing Land Share	α_{Lh}	0.27	Section 3.1.1
Apartment Land Share	α_{La}	0.18	Section 3.1.1
Structures Share	α_S	0.3	Section 3.1.1
Housing			
Housing Depreciation	δ_h	0.025	Section 3.1.2
Apartment Depreciation	δ_a	0.05	Section 3.1.2
Rural House Size	h_f	1	Section 3.1.2
Urban Apartment Size	h_a	2.29	Section 3.1.2
Small Urban House Size	h_1	3	Section 3.1.2
Large Urban House Size	h_2	13.35	Section 3.1.2
Buyer Transaction Cost	τ_b	0.005	Section 3.1.2
Seller Transaction Cost	τ_s	0.12	Section 3.1.2
Preferences			
Risk Aversion	σ	2	Section 3.2.1
Discount Factor	β	0.842	Joint Calibration
$U(C, x_h)$: Intratemporal Substitution	ν_C	0.487	Section 3.2.1
$U(C, x_h)$: Weight on C	ϕ_c	0.047	Joint Calibration
$U(C, x_h)$: Homeownership Premium	ζ	1.3	Joint Calibration
$C(x_f, x_m)$: Intratemporal Substitution	ν_f	2.107	Joint Calibration
$C(x_f, x_m)$: Weight on x_f	ϕ_f	0.287	Joint Calibration
$C(x_f, x_m)$: Subsistence x_f	$\underline{x}_f$	0.004	Section 3.2.1
Net Mobility Costs			
Curvature of CDF	κ	2.8	Section 3.2.2
Lower Support of CDF	$\underline{\epsilon}$	7.263	Joint Calibration
Initial City Quality	$\xi_{q,0}$	1	Section 3.2.2
Initial Common Net Mobility Cost	ξ_0	1	Section 3.2.2
Final City Quality	$\xi_{q,\infty}$	1.277	Section 3.2.2
Final Common Net Mobility Cost	ξ_∞	0.736	Joint Calibration
Urban Income Process			
Autocorrelation of Persistent Shock	ρ_s	0.9172	Section 3.2.3
Variance of Persistent Shock	σ^2_ε	0.0469	Section 3.2.3
Variance of Transitory Shock	σ^2_e	0.03	Section 3.2.3
Government Policy			
Income Floor Ratio	χ	0.5	Section 3.3.1
Minimum Down Payment Ratio	θ	0.3	Section 3.3.1
Mortgage Amortization Rate	γ	0.0333	Section 3.3.1
Hukou Receipt Probability	η	0.3	Section 3.3.1
Hukou Retention Probability	ρ	0.37	Section 3.3.1
Initial Housing Land	$\overline{L}_{h0}$	1	Section 3.3.1
Initial Apartment Land	$\overline{L}_{a0}$	1	Section 3.3.1
Interest Rates			
Savings Interest Rate	i	0.08	Section 3.3.2
Mortgage Interest Rate	r_d	0.06	Section 3.3.2

4 Results

The central issues investigated in this paper surround the relationship between structural transformation, urbanization, and the house price boom in China in the time period since the government implemented market-oriented housing and land policy reforms near the turn of this century. Through the lens of the model, this section employs quantitative exercises to understand the drivers of China's experience from 2001 to 2014, to address the bi-directional relationship between housing and migration, and to examine the impact of different potential policy interventions on the pace of economic change.

4.1 Reconstructing China's Economic Transition

This section employs the model to reproduce China's structural transformation and urbanization with the goals of quantifying the forces behind this transition and understanding the extent to which they explain the Chinese housing boom.

4.1.1 Baseline Model Fit

To reconstruct China's structural transformation during the relevant sample period, this section exposes the model to a set of unanticipated shocks that are directly extrapolated from the data with the exception of one shock sequence that targets migration dynamics.[16] The shocks induce the economy to gradually transition from its initial parametrized equilibrium to a new long-run equilibrium. However, the analysis restricts attention to the portion of the equilibrium transition path that falls within the sample period.[17]

[16] This procedure involves a logistic extrapolation with smooth pasting and an asymptotic value of the shock that is twice as far from the initial value as the observed change over the sample. Varying the asymptote has minimal impact on equilibrium sample period dynamics.

[17] Agents are surprised by the shocks but can then accurately forecast future dynamics.

Table 3: Reconstructing China's Structural Transformation

Description	Method	Explanation
Manufacturing TFP	Exogenous	$\{Z_{mt}\}_{t=1,...,T}$ from 2001 – 2014 data[a]
Agricultural TFP	Exogenous	$\{Z_{ft}\}_{t=1,...,T}$ from 2001 – 2014 data[a]
Agricultural Prices	Exogenous	$\{p_{ft}\}_{t=1,...,T}$ from 2001 – 2014 data[a]
Land Supply	Exogenous	$\{L_{jt}\}_{t=1,...,T}^{j=h,a}$ from 2001 – 2014 data[b]
City Quality	Exogenous	$\{\xi_{qt}\}_{t=1,...,T}$ from 2001 – 2014 data[c,a]
Rural Population	Targeted	$\left\{\widetilde{\xi}_t\right\}_{t=1,...,T}$ targets 2001–2014 data[c,a]

[a]Extrapolated. [b]One-time jump based on smoothed data. [c]Smoothed data.

The baseline simulation exercise takes as inputs the paths of measured total factor productivity in manufacturing and agriculture, the path of agricultural prices, and the (smoothed) trajectories of land supply and city quality from 2001 to 2014.[18] In the absence of segmented land supply data, the baseline assumes identical growth rates for $\overline{L}_{ht}$ and $\overline{L}_{at}$. The baseline also computes the residual sequence $\{\widetilde{\xi}_t\}$ of unobserved net mobility costs by targeting the three-year moving average of rural-urban migration in the data. Importantly, this sequence is fixed in subsequent decomposition exercises and counterfactuals to ensure that the pace of urbanization is *endogenous*. Table 3 summarizes these paths.

The first panel of figure 2 plots the time series for the exogenous paths of productivity, agricultural prices, and land supply. The implied urban-rural income ratio in the model, $\frac{Z_{mt}}{p_{ft}A_{ft}}$, closely tracks the measured income ratio from the data, with only a minor divergence opening up in the last couple of years. Importantly, while urban workers on average have much higher incomes than do rural workers—by approximately a factor of ten—this gap actually

[18]The baseline keeps η_t fixed given that the loosening of hukou restrictions began near the end of the sample period and was confined to small and medium-sized cities. Exogenous agricultural prices allow for imports, which is consistent with Gale et al. (2015).

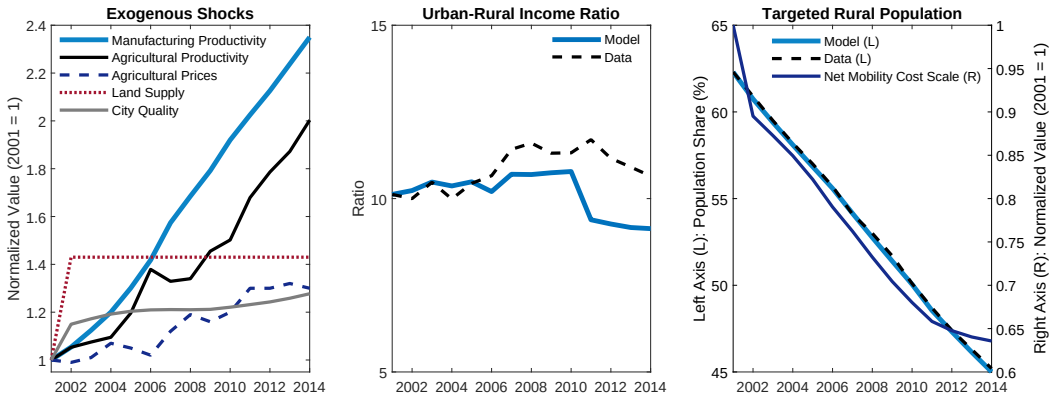

Figure 2: Baseline shocks. Sources: (productivity, agricultural prices, rural population, urban-rural income) CSY; (land supply, city quality) CRE.

remains relatively stable throughout the entire sample period. As a result, the model suggests that relative income dynamics and observed increases in city quality cannot account alone for the substantial decline in the rural population share from 62.3% to 45.2% between 2001 and 2014. To rationalize the observed decline, the third panel shows that the unobserved net mobility cost component $\{\widetilde{\xi}_t\}$ must also fall by 36%, representing either a drop-off in *gross* mobility costs or a rise in urban amenities not captured by the existing city quality measure.

Apart from matching this targeted population shift, the baseline simulation successfully reproduces the *untargeted* dynamics of house prices, as depicted in the left panel of figure 3. In particular, equilibrium house prices climb by 134% over thirteen model periods (years), which aligns well with the 137% increase in the data from 2001 to 2014.[19] Although the entire time series from the data for the homeownership rate is not readily available, the middle panel reveals that

[19]The price-rent ratio exhibits some short-run volatility but converges to 40 in the long run from an initial value of 20. As a robustness check, keeping rents flat with a perfectly elastic supply of apartment space has a negligible impact on the main findings. This result suggests that, in light of the segmentation between rental and owner-occupied markets, the tenure decision is driven more by the tension between the utility benefits of ownership and the presence of hukou and borrowing constraints than by the level of rents.

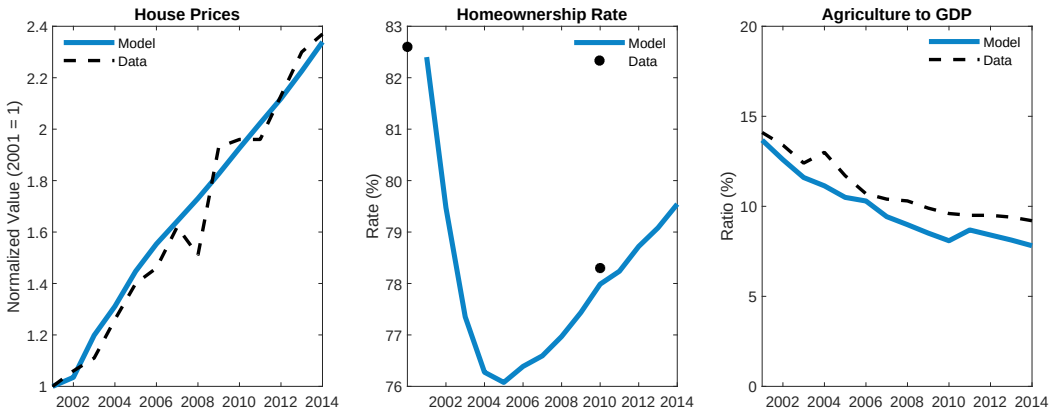

Figure 3: Baseline model vs. data. Sources: (house prices) Fang et al. (2016); (homeownership rate) Census; (agriculture to GDP) CSY.

model generates equilibrium homeownership dynamics consistent with the two empirical observations from the Census. In 2010, homeownership in the model comes out to 78.0% as compared to 78.3% in the data. The pattern of declining homeownership rates in the early years of the transition can be ascribed to the rapid influx of rural workers, who are initially renters and take time both to acquire a hukou permit and build up sufficient savings for a down payment. Lastly, the right panel of figure 3 reveals that the dynamics of the agriculture to GDP ratio in the model closely follow those of the data—falling by 5.9 and 4.9 percentage points, respectively, driven by the reduction in agricultural labor as rural workers migrate to the city and acquire manufacturing jobs.

4.1.2 Understanding the Drivers of China's Transition

To decompose the drivers of China's economic transition and housing boom, table 4 shows the results of modifying individual shocks and re-computing the dynamic equilibrium. To explain the seventeen percentage point increase in the urban population share despite a stable urban-rural urban income ratio

Table 4: The Dynamic Effects of Each Shock

Scenario	*Urban Pop*		*Ag-to-GDP*		*House Prices*		*Ownership*	
	$\Delta_{t=2}$	$\Delta_{t=13}$	$\Delta_{t=2}$	$\Delta_{t=13}$	$\Delta_{t=2}$	$\Delta_{t=13}$	$\Delta_{t=2}$	$\Delta_{t=13}$
Baseline	2.9	17.3	−2.1	−5.9	19.8	133.9	−5.0	−2.9
50% Slower ξ_{qt}	0.9	10.9	−1.1	−3.8	18.1	128.5	−1.7	−1.5
50% Slower Z_{mt}	1.9	12.8	−0.9	−1.2	8.2	72.2	−3.4	−3.7
Fixed Z_{ft}	10.6	45.7	−5.6	−12.7	25.9	154.4	−15.8	−8.8
Fixed p_{ft}	4.9	29.5	−3.1	−9.9	22.5	142.1	−8.1	−6.2
Fixed $\overline{L}_{jt}$	2.3	16.6	−1.8	−5.6	27.8	145.3	−4.5	−3.4

$\Delta_{t=n}$ are percentage point changes through year n of the transition. The final two rows reduce the growth factors of Z_{mt} and ξ_{qt} by 50% relative to the baseline path.

requires that net migration costs fall during this period. Concretely, the second row of table 4 shows what occurs with 50% slower growth in the city hedonic component ξ_{qt}. The lower migration stymies structural transformation, cutting the baseline 5.9 percentage point decline in the agriculture-to-GDP ratio by more than one third. In the housing market, lower migration flows shave more than five percentage points from cumulative house price appreciation. This importance of amenities for housing demand is in line with Han, Han and Zhu (2018). In the baseline, the homeownership rate decline indicates the presence of a composition effect: new migrants who lack hukou permits and the necessary savings for a down payment drive down the homeownership rate even as existing city-dwellers hasten their home purchases because of slower price growth. Thus, less migration mitigates the homeownership decline.

In the face of rising urban productivity Z_{mt}, holding fixed either the path of agricultural productivity Z_{ft} or prices p_{ft}—as presented in the fourth and fifth rows of table 4, respectively—leads to significantly *higher* rural-urban migration. With fixed agricultural productivity, the urban population share rises by 10.6 percentage points after just two years and by a dramatic forty-six percentage points after thirteen years—nearly tripling the intensity of

rural-urban migration in the baseline. This migration surge causes house prices to increase by 154.4% in year thirteen compared to 133.9% in the baseline. At the same time, the influx of rural migrants to the city temporarily depresses the homeownership rate by nearly sixteen percentage points, although it gradually recovers over time, as shown in appendix figure 11. The impact of fixing agricultural prices is qualitatively the same, albeit quantitatively smaller.

Taken together, these results indicate that reducing income growth in the rural area increases migration to the city, which exerts upward pressure on urban house prices. As one might anticipate, reducing urban income growth operates in the reverse manner. At the extreme, holding urban manufacturing productivity Z_{mt} completely fixed is rather uninteresting, because doing so eliminates all upward pressure on city house prices. In particular, flat urban productivity means no aggregate income growth for residents already in the city to fuel higher housing demand, and the lack of income growth also vitiates any incentive for rural residents to migrate to the city and purchase houses. Thus, instead of this extreme case, the third row of table 4 and appendix figure 11 consider a scenario that slows down manufacturing growth by 50%, which cuts baseline rural-migration by over one quarter. In this scenario, house prices only rise by 72.2% by the end of the sample. The last row of table 4 indicates that fixing land supply modestly lowers migration and raises house prices, as discussed further in section 4.3.3.

4.2 The Housing-Migration Nexus

Given that the baseline simulation successfully reproduces China's post-2000 economic transition—especially the untargeted large house price boom—this section engages in a deeper exploration of the two-way link between housing

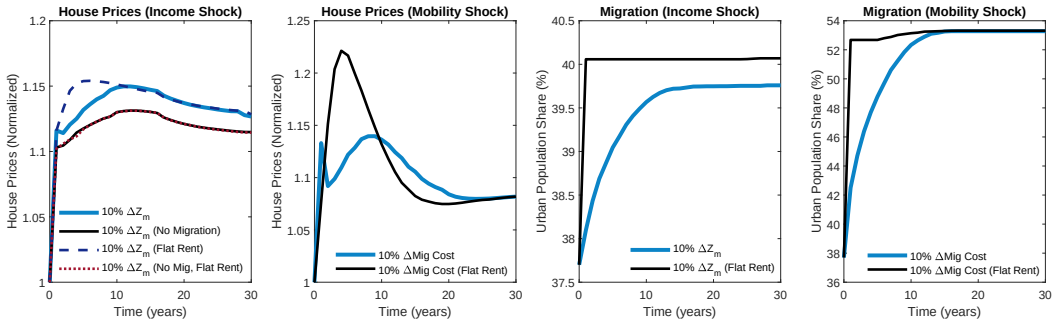

Figure 4: The impulse response of house prices and migration to either a permanent income or mobility shock, both with endogenous and flat rents.

and migration. At a glance, this section finds that the endogenous migration response amplifies and accelerates the reaction of house prices to income shocks, particularly in the medium run. At the same time, this house price acceleration impedes the flow of migration as rising housing costs erode some of the benefits of moving to the city.

4.2.1 From Migration to House Prices: The Migration Accelerator

To assess the impact of migration on house prices and study the mechanisms revealed in the baseline decomposition, the left panel of figure 4 plots the impulse response of house prices to an unanticipated, permanent 10% income shock in the full model relative to a version without the ability to migrate. The option to relocate gives rise to a *migration accelerator* that amplifies the initial response of house prices to higher income, creates medium-run momentum and overshooting via accelerated house price appreciation, and culminates in long-run partial mean reversion as the marginal impact of migration on house prices fades. These effects are especially evident by comparing the curves with an elastic supply of apartments that leads to flat rents.

The medium-run price momentum arises from time delays in housing

demand associated with obtaining a hukou permit and building savings for the 30% minimum down payment, which causes house prices to respond gradually to the rapid influx of migrants. A more elastic supply of apartments accentuates this price momentum by making it easier for new migrants to accumulate a down payment and purchase a house. The amplification of prices on impact emerges from the forward-looking behavior of initial city residents who buy immediately before price momentum drives costs even higher. Lastly, the long-run partial mean reversion in house prices is a product of time delays in the ability of housing supply to accommodate the rising demand.

The second panel provides an even more direct glimpse at the migration accelerator by depicting the impulse response of prices to an unanticipated permanent decline in mobility costs, both with endogenous rents and flat rents. In both cases, house prices exhibit substantial momentum, overshooting, and mean reversion, which gives the appearance of a "bubble" even though all the dynamics are driven by fundamentals. The flat rents case gives rise to greater momentum for two reasons. First, conditional on the amount of migration, new urban residents can more quickly save for a down payment, as discussed previously. Second, more people migrate to the city when rents are fixed, as is evident in the final two panels.

4.2.2 From Housing to Migration: The House Price Decelerator

Causality also operates from housing to migration. When house prices and apartment rents remain flat (as in the case of perfectly elastic supply), the positive urban income shock generates a 3.1 percentage point increase in the urban population. However, the endogenous rise in house prices (keeping rents fixed) attenuates 25% of this migration response—representing a *house*

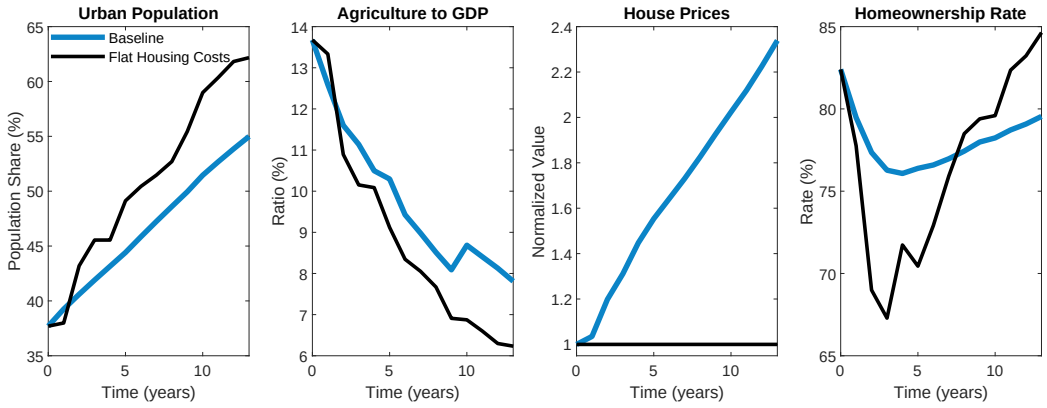

Figure 5: The impact of house price growth on structural transformation. Urban migration is significantly higher absent the rise in housing costs.

price decelerator that describes the negative effect of rising house prices on migration. Future appreciation also impacts current migration. For example, flat house prices for the first ten years after the income shock followed by an exogenous one-time, permanent doubling of prices erases 7% of the migration response. However, if the sudden appreciation occurs five years earlier, 49% of the migration response evaporates, indicating that the time horizon matters. Fewer migrants move if they anticipate that they will face difficulties obtaining a hukou permit and saving for a down payment before prices jump.

How different would China's economic transition look if the city could have accommodated migration without a steep rise in housing costs? Figure 5 compares the baseline to a case with a perfectly elastic supply of housing (both houses and apartments). Relative to the case with flat housing costs, the figure shows that the post-2000 housing boom in the baseline attenuates 29% of the cumulative rural-urban migration, 21% of the structural transformation (the sector reallocation measured as the decline in agriculture-to-GDP), and depresses homeownership by five percentage points after the transitory compositional impact of a surge in migrant renters dissipates.

4.3 Policies to Accelerate the Economic Transition

This section undertakes a positive analysis to explore policies designed to facilitate greater urbanization and structural transformation. Housing markets emerge as a key factor that can help or hinder these policies.

4.3.1 Residency Policies

Urban homeownership offers higher quality housing relative to the rural area, but only city residents with hukou permits can access this benefit. In the baseline simulation corresponding to 2001–2014, the expected waiting time to receive a hukou permit is just over three years. However, China has modified hukou restrictions at various points in time, such as in 2014 when it abolished the hukou system in small cities and towns and eased restrictions in midsize cities. To capture the essence of these reforms in the model, the policy experiment here cuts the waiting time for a hukou permit to about 18 months (by doubling η). Importantly, migrants must still save for a down payment.

Reducing hukou waiting times makes moving to the city more attractive by

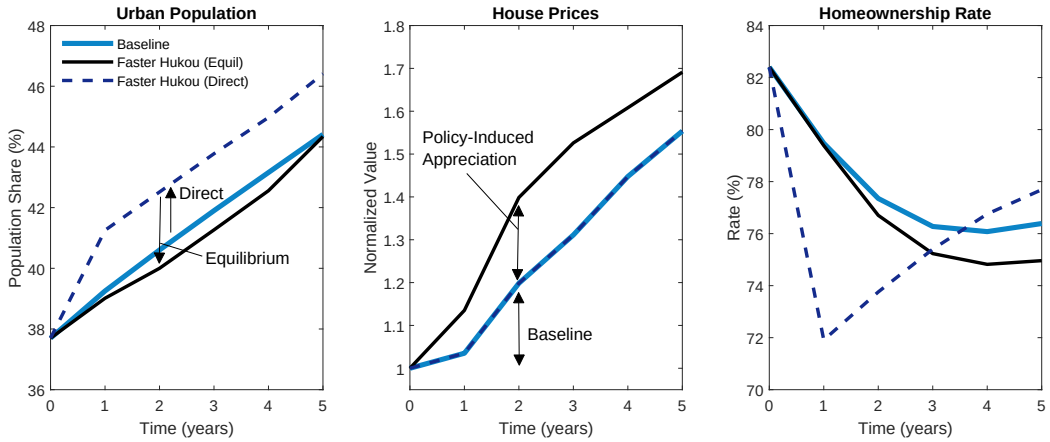

Figure 6: The effect of accelerating hukou permits. Higher equilibrium house prices that raise the cost of urban living more than reverse the direct effect.

allowing migrants to more quickly enjoy higher housing utility and to purchase earlier in the process of urbanization before prices rise even higher. Ignoring the endogenous house price response, the left panel of figure 6 shows that the policy directly increases the urban population by 1.9 percentage points after two years, which is on top of the three percentage points of baseline migration. However, the policy doubles the amount of house price appreciation in the first two years, which more than erases the direct effect, causing migration to be slower under the policy relative to the baseline.

4.3.2 Credit Policies

Given the importance of housing to the migration decision, credit policy is another lever to impact the pace of economic transformation. As detailed in Chen et al. (2020) and Chen (2020), China has adjusted minimum down payments over time. For example, in 2014Q4, China reduced the minimum down payment from 70% to 30% for second homes and from 30% to 20% for primary homes before tightening in 2016. This paper abstracts from

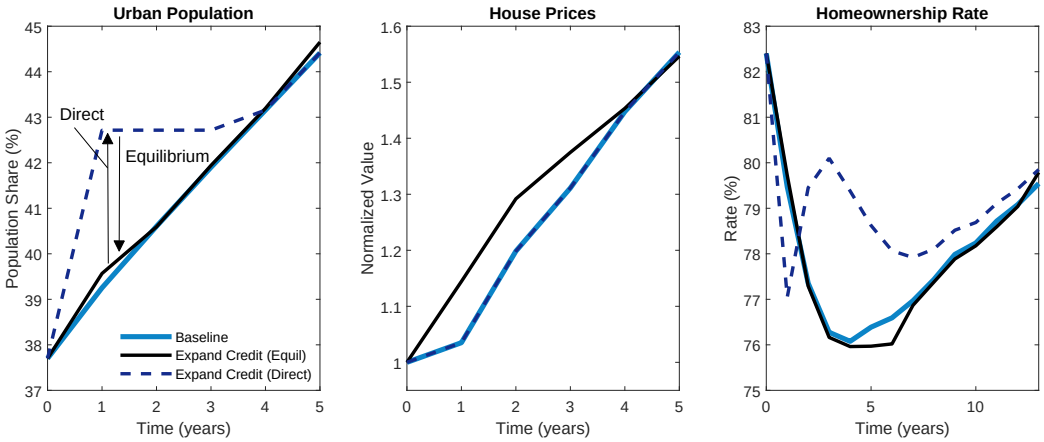

Figure 7: The impact of expanding credit with a 0% minimum down payment. The equilibrium increase in house prices attenuates the surge in migration.

multiple ownership but can evaluate the efficacy of credit policy on migration by comparing a time-0 permanent loosening of minimum down payments from 30% to 0% with a permanent tightening from 30% to 50%.

The relaxation in credit makes moving to the city more attractive, allowing migrants to purchase immediately upon receipt of a hukou permit before prices rise further. As evidenced in the left panel of figure 7, the direct effect of the credit relaxation is to rapidly accelerate short-run migration, adding 3.5 percentage points to the urban population after year one on top of the 1.6 percentage point baseline increase. On impact, the homeownership rate still declines mechanically due to the composition effect from migrant renters without hukou permits moving to the city. However, the homeownership recovers more quickly as prospective buyers more easily enter the market without needing to make a down payment. However, the surge in equilibrium house prices from looser credit neutralizes the migration influx, rendering the policy ineffective. Tightening credit to cool the housing market and stimulate migration also is not a success because of the negative direct effects of limiting

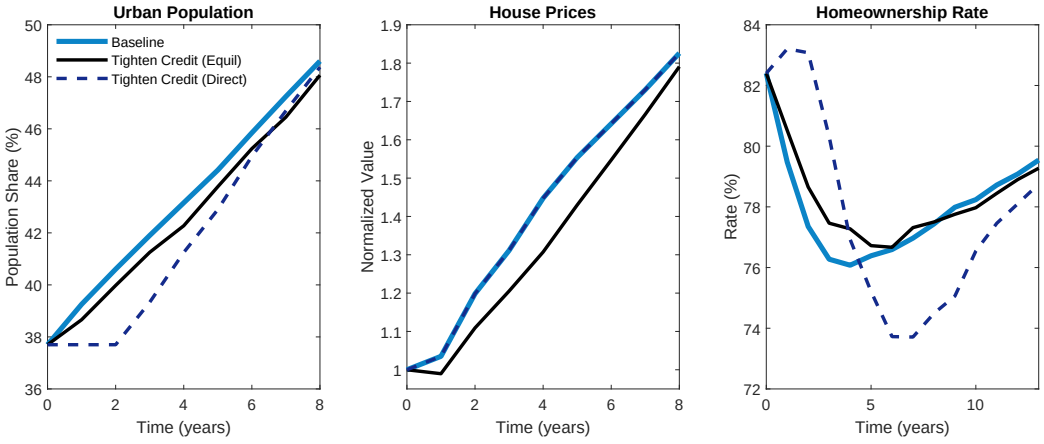

Figure 8: The impact of tightening credit with a 50% minimum down payment. The equilibrium drop in house prices mediates the decline in migration.

access to home buying. As seen in figure 8, slower house price growth partially offsets the direct effect, indicating an asymmetry in the potency of the price effect between credit loosening and credit tightening.

4.3.3 Land Policies

In the previous policy experiments, the housing-migration channel operated through changes to housing demand and created a negative feedback loop that partly or fully counteracted the direct effect of the policies on migration. This section introduces land supply as a mechanism to boost rural-urban migration by slowing house price growth.

In the first policy experiment, the government exogenously increases by a factor of three the quantity of new land available for construction relative to 2001. For the sake of comparison, new land supply in the baseline transition is 143% of 2001 levels. Unlike in the previous policy experiments, house prices are the *only* channel by which this policy affects migration, i.e. there is no direct effect. As shown in figure 9, the land supply expansion slows house price growth, which induces greater migration and structural transformation.

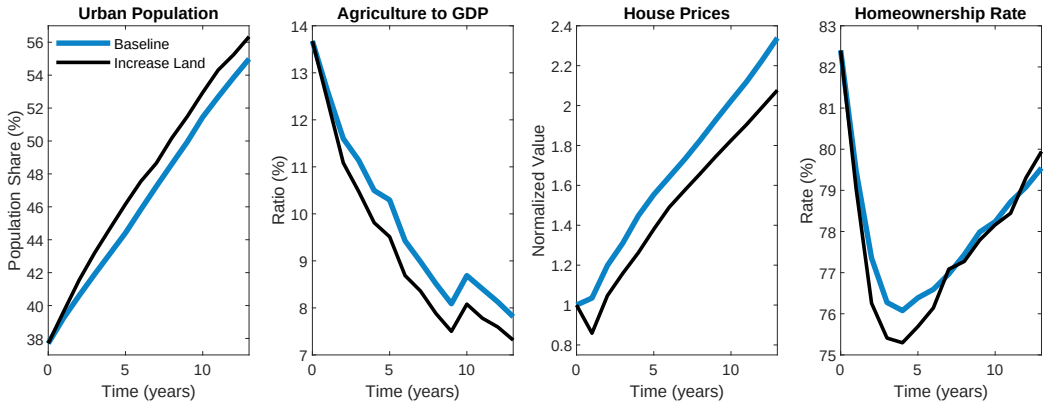

Figure 9: The response to a large expansion in land supply.

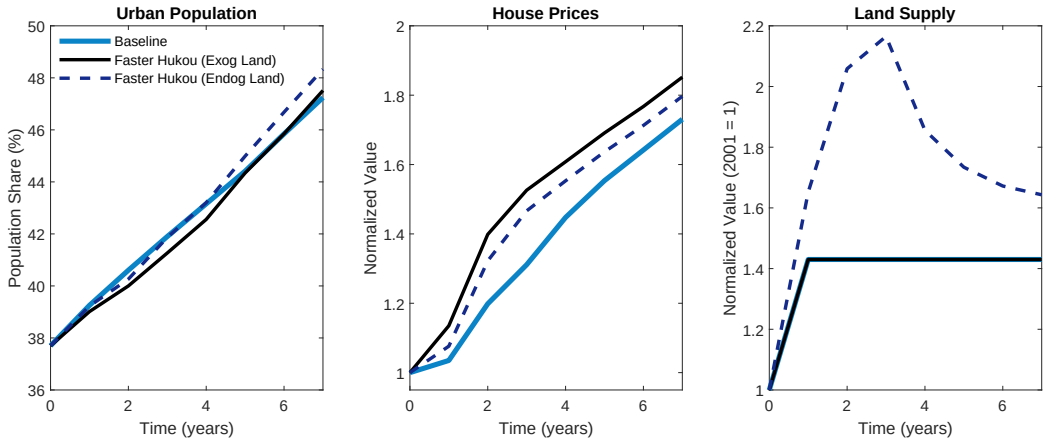

Figure 10: Endogenous land supply and the response to faster hukou permits.

Quantitatively, house prices appreciate by 108% after five years versus 134% in the baseline, causing an additional 1.3 percentage point rise in the urban population share and a 0.5 percentage point decline in the agriculture-to-GDP ratio. Short-run homeownership declines more rapidly because of the previous composition effect, with little long-run change relative to the baseline.

The salutary impact of land supply expansions on migration suggests that it may be an effective tool to utilize in concert with other policies to dampen house price increases induced by the policies. This price appreciation was particularly detrimental in the case of the faster hukou permitting from section 4.3.1, more than reversing the intent of the policy. Rather than exogenously increase land to counteract this reversal, this section allows the government to adjust land supply in response to housing market conditions. Specifically, the government chooses how much of each type of new land, L_{ht} and L_{at}, to make available to maximize revenues from land sales net of time-varying development costs by solving

$$\max_{L_{jt}} p_{ljt} L_{jt} - \frac{\vartheta_{jt}}{2} L_{jt}^2. \tag{25}$$

The costs ϑ_{jt} are calibrated to replicate the exogenous land supply paths in the baseline. With the development costs fixed at their baseline trajectories, the government optimally chooses to make more land available in response to rising prices after the implementation of faster hukou permitting, as shown in the right panel of figure 10. In turn, the greater availability of new land for construction dampens the rise in house prices attributable to the policy-induced surge in housing demand from faster hukou permitting. As a result, migration to the city increases relative to the case with exogenous land supply, eventually surpassing the baseline level after four years, albeit by a small magnitude. Thus, the endogenous land supply expansion neutralizes the negative feedback of price appreciation to urbanization.

5 Conclusion

This paper develops a dynamic multi-sector heterogeneous agent equilibrium model that features rural-urban migration and a rich housing market structure with mortgage borrowing to investigate the interaction between urbanization, structural transformation, and rapid house price appreciation in China. Urbanization and structural transformation emerge as key drivers of China's house price boom, with a housing migration accelerator magnifying the impact of urban income growth on prices. Concurrently, endogenously rising house prices deter rural-urban migration, impede structural transformation, and undermine—partly or completely—policies aimed at accelerating China's transition. Land supply expansion is a promising way to boost urbanization

and structural transformation by restraining price growth. Investigating other avenues through which housing regulations and financial market structure shape China's economic transition—both in the past and future—is for later.

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A Supplementary Tables and Figures

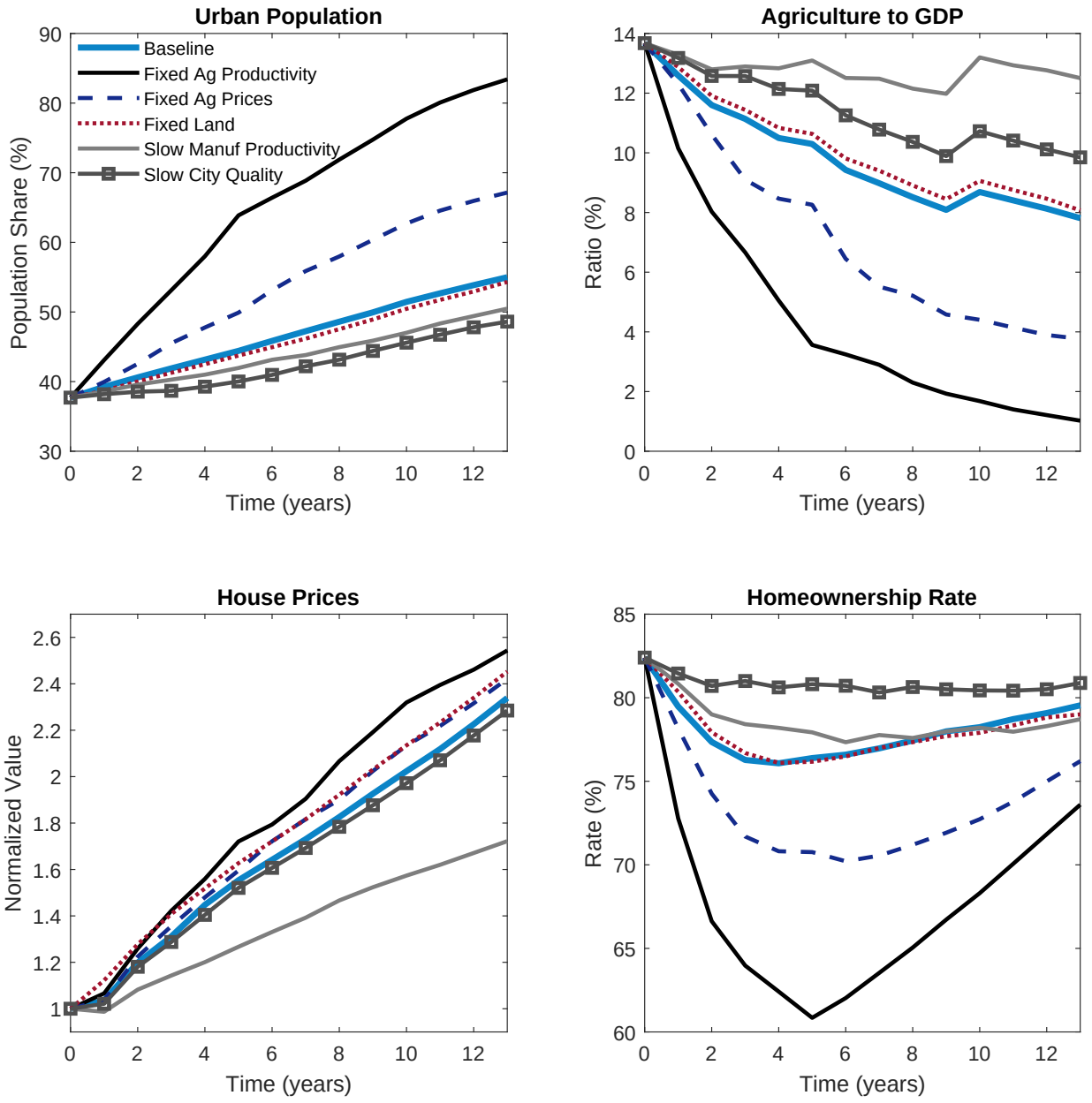

Figure 11: Comparing the shocks. Slow manufacturing productivity cuts the growth in Z_{mt} by 80%. The fixed mobility costs plots keep a constant δ_t.

This figure accompanies table 3 in section 4.1.1 in showing the contribution of each factor to the transition dynamics of China's macroeconomy and housing market.

B Institutions

B.1 Migration Institutions

China's pro-market economic reforms started with "The Third Plenary Session of the Eleventh Central Committee of the Communist Party in China" in 1978. After the meeting, the Chinese economy began a transition from a centrally planned to a market-oriented economy. A key feature of the market economy is the introduction of incentive mechanisms and the reduction of the monopoly power of state-owned enterprises. The encouragement of entrepreneurship stimulated unprecedented technological progress in all sectors. As labor productivity in the agricultural sector improved, surplus rural labor became available for urban employment. However, migration across regions remained heavily regulated by the household registration system in China.

The household registration system, called "hukou" in Chinese, is required by law and still in use, although it has changed significantly through the years. Each individual must have a registration record, which officially identifies him or her as a resident of an area and includes identifying information such as name, parents, spouse, and date of birth. In 1958, the Chinese government officially promulgated this system to control the movement of people between urban and rural areas. Individuals were broadly categorized as " rural" or "urban" workers. A worker seeking to move from the country to an urban area for non-agricultural work had to apply through the relevant bureaucracies. The number of workers allowed to make such moves was tightly controlled. Migrant workers needed six passes to work in provinces other than their own. People who worked outside their authorized domain or geographical area did not qualify for grain rations, employer-provided housing, or health care. There were additional controls over education, employment, marriage, and so on. Although there have been changes over time, the hukou system is widely regarded as an impediment to economic development, and removing its restrictions is often viewed as crucial for fostering the migration needed to support industrialization. Indeed, China's reform could not have begun without changes in economic institutions. China's rural-urban migration history can be divided into three stages based on changes in the central government's migration policy that began in 1978.

1. Steady stage (1978-1983): During this early stage of reform, all economic changes were still under probation and the key theme was slow progress. Because of the continued emphasis on agricultural self-sufficiency, most of the migration flows were within rural areas. Of the about 14 to 23 million migrants during this time, only 1 million migrated across provinces, which was less than 0.1 percent of the total population. Although agricultural productivity advanced during this period, those workers who left their farmland moved mainly to local township enterprises. This shift created a phenomenon called " leave the land without leaving home." Workers left the farm labor force but still resided in rural areas.

2. Gradual growth stage (1984-1994): As agricultural productivity continued to increase, more rural workers left the agricultural sector, and local township enterprises could not accommodate these surplus laborers. The leave-the-land-without-leaving-home mode required a breakthrough. As a result, to meet the needs of economic development, policies restricting migrants from moving from rural areas to cities were mitigated. In 1984, the

General Office of the State Council published a new document on the settlement of rural migrants in urban areas, making it easier to migrate to the city. This reform of the hukou system drastically improved the employment opportunities for rural workers. Cities grew as the mantra gradually changed to " leave both land and home." Meanwhile, instead of moving mainly to small towns, as in the early 1980s, rural workers started moving to bigger cities, including megalopolises such as Beijing and Shanghai. From 1984 to 1994, rural-urban migration generally kept a steady pace. The average number of rural migrants moving across provinces increased to 3.2 million per year, three times as many as in the previous stage.

3. Highly active stage (1995-2000): Population movement in China became highly active beginning in 1995. Over the period 1995 to 2000, the total number of rural migrants moving across provinces grew from 3.5 to 10 million. Growth in this stage was the result of three important policy changes:

- **Deng Xiaoping southern tour:** With the world-famous speech given by Deng Xiaoping in 1992 and the reforms that followed, the Chinese economy boomed. The eastern and southern coastal areas experienced unprecedented economic growth, and a number of special economic development zones were built, which attracted many foreign enterprises and investment. This growth created more jobs in cities in these zones, inducing more workers to leave rural areas.

- **Abandonment of the centrally planned food and housing allocation system:** Prior to 1995, the central government generally controlled the allocation of food and housing among citizens; workers without a legal permit to live in the city were not able to obtain food and housing. Even though they could afford them because there were essentially no markets for them to trade in. The establishment of markets for basic living necessities such as food and housing greatly facilitated the entry of rural people into the city.

- **Temporary work permits in larger cities:** Toward the end of the 1990s, migration accelerated as a result of policies that allowed migrants holding temporary permits to work in large cities. For instance, in 1997 the General Office of the State Council permitted some big cities, such as Shanghai and Guangzhou, to print " blue household registration cards" or " temporary permits" for rural workers according to the city's needs. It is estimated that in Zhejiang province, one of the richest provinces in China, the rural migrant population reached 1.9 million from 1998 to 2001. Some provinces abolished all official restrictions between rural and urban areas by declaring everyone a " citizen of that province" with equal treatment under the same set of policies. The salient feature of the rural-urban migration in this period was likely the concentration of economic development in the eastern and southern coastal areas, which had faster economic growth and higher wages.

B.2 Housing Market Institutions

After the 1978 Central Committee the Communist Party sessions, urban housing reforms became a major focus of the economic transformation. The central government has been

very cautious in applying new reform policies in the public housing sector and has conducted out various experiments to commercialize the existing urban public housing. All land (urban and rural) is owned by the state, where developers can lease the rights to use the land from the government.

According to the 2010 Population Census, the reported statistic for the national homeownership rate in China is around 85 percent. The national average roughly captures a close to 100 percent homeownership rate in rural areas (close to 50 percent of the households surveyed) with a relatively lower rate in large cities. More specifically, the homeownership rates in the two largest cities, Beijing and Shanghai, were close to 60 percent (with several provinces above 80 percent). These numbers are substantially higher than some of the largest cities in the United States (i.e., cities like Los Angeles and New York have home ownership rates below 40 percent). In addition to a high homeownership rate, Wu et al. (2016) use the Urban Household Survey in nine provinces from 2002 to 2009 to show that most Chinese cities have a modest vacancy rate. In particular, the vacancy rate in Beijing is about 5 percent, with the highest vacancy rate in Zhejiang province at only 7.9 percent. The high homeownership and low vacancy rate are considered in designing the structure of the model.

The path of urban housing and land market reforms can be divided into three stages:

1. Probation and experimentation stage (1978-1988): An April 1980 speech by Deng Xiaoping announced urban housing reform. He pointed out specifically that (i) urban residents should be allowed to purchase houses (old or new) and (ii) public housing rents should be adjusted in accordance with rising construction costs (which encouraged home buying rather than renting). These policies symbolized a major shift in long-standing policies for the public housing system. Following Deng Xiaoping's directive, limited experiments were conducted in selected cities between 1980 and 1998, focused on reorganizing housing production and promoting sales of public housing to ensure a sufficient return on housing investment. These experiments included encouraging new housing sales for building costs alone, subsidizing public housing sales, and increasing public housing rents steadily each year to promote sales.

These policies, however, provided little incentive for private or other forms of housing investment. In the centrally planned economy, housing investments were provided solely by the state through a redistribution process. During economic reform, the central government tried to adopt policies to decentralize managerial power and introduce market functions into the economy. With no experience operating in a market economy, however, the majority of SOEs became less competitive than the emerging collectively owned and private enterprises. As a consequence, public housing subsidized by the central government could not keep up with the increasing demand for public housing. Although the private sector increased steadily each year, there was not enough incentive for the private sector to move toward urban housing investment because of the risk. Therefore, private investment in housing production was low and insufficient total investment in urban housing was inevitable. The market for land use is nonexistent and developers purchase the rights of use directly from the government.

2. Further urban housing reform (1988-1998): At the beginning of 1988, the central government held the first national housing reform conference in Beijing. It was agreed that housing reform could lead to great economic and social benefits and that a bigger systematic housing reform plan was necessary. The major resolutions of the conference were

summarized in a document that was updated and published in 1991. This document marked a turning point in urban housing reform, from pilot tests and experiments in selected cities to implementation in all urban areas. Although there were no significant changes in the overall objectives, this was the first resolution to recognize ownership of private housing purchased from the public sector. Purchasers of public housing had two options: (i) Pay the market price and have complete ownership of the unit or (ii) pay the " standard price" (subsidized price) for partial ownership. This reform conveyed the message that the urban housing sector would eventually rely on market forces rather than central planning.

The Chinese government institutionalized an important housing reform in the mid-1990s called the "privatization of housing responsibilities," as discussed by Fu, Tse and Zhou (2000). Although a less than fully privatized housing market had been established, most participants in that market at that time were employers, not individual buyers. With different interests and more independent policies, employers and local governments purchased houses and then provided them to their employees at rents substantially below market rates. Thus, the overwhelming majority of urban residents lived in public housing that was also tied to their employment. As a consequence, there was less incentive for urban residents to purchase housing units.

3. Current stage of urban housing policies (1998-present): In July 1998, the new State Council adjusted the housing policy and issued an official document. One major change was the termination of material distribution of housing at the end of 1998, which was completely replaced by monetary distribution. According to the new plan, no newly built units were to be allotted. The new policy symbolized the end of the existing public housing system, with the ultimate goal of fully commercializing the housing market. Nonetheless, the government continued to provide cheap-rent housing for the lowest-income households, but the average floor space per person could not exceed 60 percent of the local average. Individuals who did not qualify for these government programs had to purchase or rent houses in the private market.

In response to the financial tsunami, the Chinese government implemented two additional policies with the objective of cooling off the housing boom. The main regulatory changes were the restriction on owning multiple housing units (including regulations that required a minimum down payment of 60 percent), mortgage restrictions on nonlocal households, and sales restrictions in second- and third-tier cities to only local or migrant households. Other housing policies aimed at slowing housing price growth included higher property tax rates in Shanghai and Chongqing as well as building and running public rental housing. Such tightened housing policy was recently reverted during the first quarter of 2015 to revive the sluggish growth of the housing market.

B.3 Land Market Institutions

While housing market reforms started much earlier, the government has been in full control of land allocations without providing any market mechanisms until the turn of the new millennium. Prior to this major reform, there were development rights regulations for incumbent and new users. Use rights for residential land were allocated via leaseholds that last for up to 70 years. The allocations of use rights were largely by private negotiations

between developers and government agents. The reported prices are therefore subject to large distortions that would result in significant biases.

In May 2002, there was a ruling by the Ministry of Land and Resources (MLR): all residential and commercial land parcel leasehold purchases subsequent to July 2002 are required to be sold by public auctions. That is, the MLR law banned previously adopted private negotiations. Since then, commonly used auctions have been of three types: English auctions (pai mai), two-stage auctions (gua pai), and sealed bids (zhao biao). To capture the initial change from negotiated to auctioned prices to avoid biases from the aforementioned distortions, we set our sample period to start in 2001.

It should be noted that, even after the reform, land is owned by the nation (officially called " the people as a whole") and the release of new land is essentially controlled by the government. Nonetheless, a critical element for the purpose of our study is whether there is an acceptable measure of prices of land. We find the auction prices suit our need. Since the official law institutionalized in 2002, government-run auctions of various types became widespread across all cities. By August 31, 2004, all urban land leasehold sales were through public auctions with internet posting to the public. Yet, local land bureaus remained in charge of annual allocation of land plots for development, the associated regulations including the floor area ratios, and the types and the reservation prices for auctions.

Also notably, land right sale revenue has been a major source of government finance. For instance, in Cai, Henderson and Zhang (2013) report that such revenue may amount to 2.6% to 5% of local GDP and account for as much as 70% of local government spending in Chengdu, Suzhou and Chongqing from 2004 and 2005.

C Data

In this appendix, we document various data sources and definitions.

C.1 Macro and Sectoral Data

Output, price and population data are based on various issues of the *China Statistical Yearbook* (CSY). There are discrepencies across different issues. Whenever it is possible, our primary source is from the 2016 issue. This includes nominal GDP, agricultural output, employment and population. In figure 1 we plot the evolution of rural population share, agricultural output share and urban-rural income ratio during 2001-2014. Real output at various constant prices are adjusted to be all at 2001 constant price. The agricultural sector covers all primary industries. The employment data cover all agencies and units providing employment services and job centers, for the whole country, as well as for the four national level cities (municipalities directly under the central government, namely, Beijing, Shanghai, Tianjin and Chongqing) and 31 provinces. Urban population and urban output shares are subsequently imputed. The growth factor of Real GDP over the sample period is 3.21 with an average annual growth rate of 9.4 percent. Rural population share declines from about 62.3% to 45.2%, and agricultural output share declines from about 14.1% to 9.2%. The urban-rural income ratio is relatively stable, ranging from 10.0 in 2004 to 11.7 in 2011 with an average around 10.8.

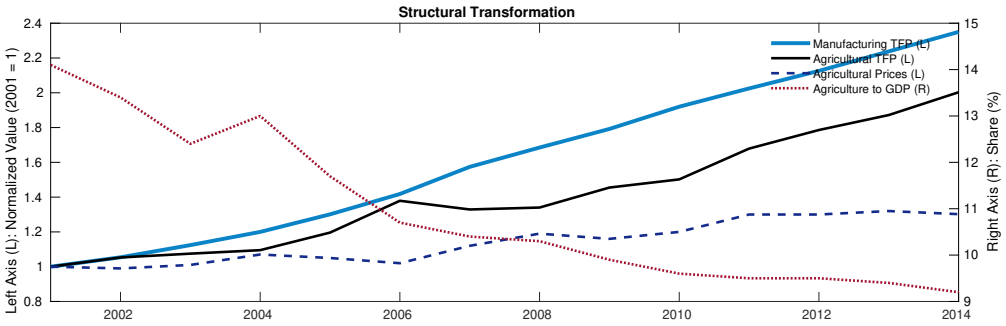

Figure 12

In Figure 12 we plot the evolution of the relative agriculture price index, manfacturing and agricultural productivity, respectively. Agricultural price chain data (last year = 100) are from the 2005, 2008, 2011 and 2015 issues of CSY, measured by the producer price of agricultural goods. The agricultural price index is then imputed, normalizing 2001 = 1. Manufacturing and agricultural productivity are measured as real per-capita non-agricultural output and agricltural output at 2001 price, respectively. We normalize the levels in 2001 to be 1 for both series. Agricultural relative price rises by 30.2% with an average annual growth rate of 2.13 percent. Manufacturing productivity grows slightly faster than agricultural productivity. The growth factor is 2.35 versus 2.00, while the annual growth rate is 6.81 versus 5.60 percent between the two series.

C.2 Real Estate Data

While the benchmark housing price measure used is based on our imputed aggregate hedonic price index, we supplement it with one obtained from the Hang Lung Center for Real Estate at Tsinghua University (CRE). Both measures are superior to the National Bureau of Statistics (NBS) measure for the their consideration of quality measures. All nominal housing price measures are divided by the GDP deflator constructed above to obtain the respective real measures.

1. CRE housing prices, housing supply, and mortgage:

The CRE prices and housing supply data have been carefully constructed since 2000, with most data up to 2014 and some to 2015. There are two useful nominal housing price series: (i) a regular housing price index measured by average selling price of commercialized residential buildings (yuan/square meter) and (ii) a luxury housing price index measured by average selling price of high-grade villas (yuan/square meter).

In Figure 13 we plot the land supply as well as nominal land prices during 2001-2014. Incremental land supply is defined as land space purchased this year by enterprises for real estate development for residential uses (measured in 10,000 square meters). Over our sample period, incremental land supplies grew by a factor of 1.43 (normalizing 2001 = 1), and nominal land price grew by a factor of 11.79, respectively.

We also plot nominal price (measured in RMB per square meter) for regular residential house and high-grade villa over the sample period in Figure 13. The growth factor is 2.94 for regular house and 2.98 for villa house.

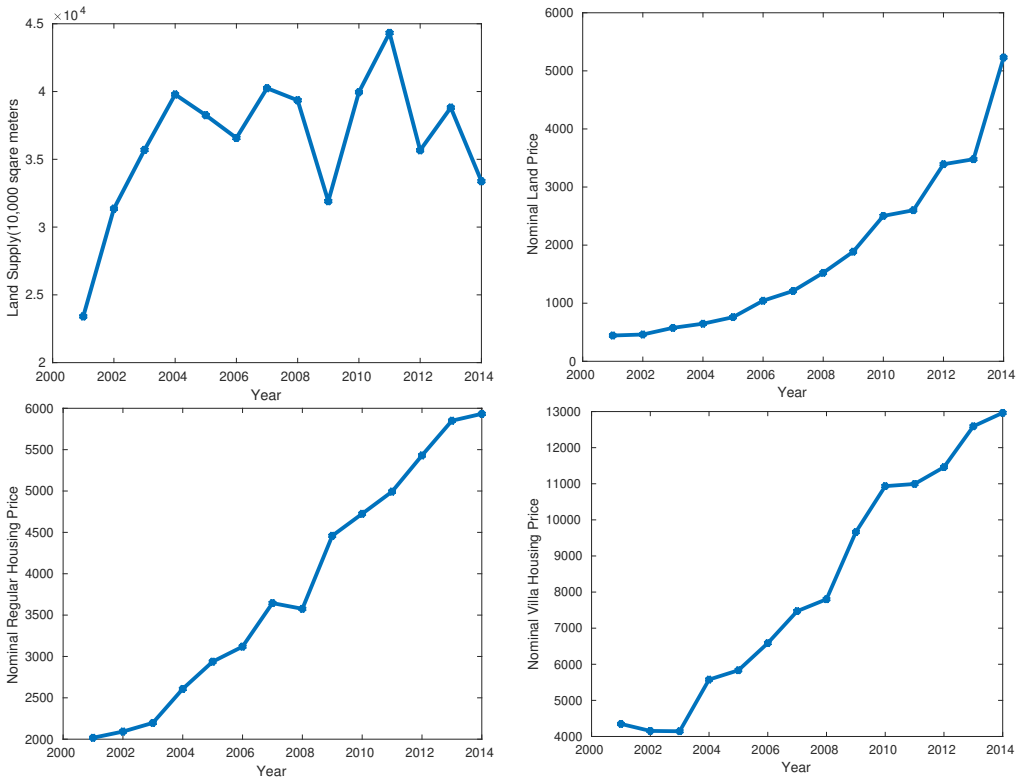

Figure 13: Housing Prices, Land Prices and Land Supply in the Data

The real price is the nominal price adjusted by the GDP deflator. The price level in 2001 is normalized to be 1 for both land price and regular housing price series. Over the sample period the real land price grew by a factor 6.72 with an average annual growth rate of 15.8 percent. The average price ratio of high-grade villa to regular house is 2.14. The real housing price grows at an annual rate of 4.69 percent for regular house, while it is 4.95 percent for the villa house.

We have also used data from the China Family Panel Survey (CFPS) conducted in 2012, 2014 and 2016 to document the size differences among houses of different type. The average size ratio of villa to regular housing is 2.03 and the average size ratio of regular housing to rental is also about 2.

In addition, IRES also collects ownership data for the two census years, 2000 and 2010 among 68 Chinese prefectural level cities. Our city sample includes 4 tier-1 cities, 24 tier-2 cities and 40 tier-3 cities. We compute the average homeownership rate within each city tier. Note that the reported ownership rate is not a simple average over selected cities within each tier. Instead, we take into account the difference in population sizes among cities. Specifically, ownership rate in city tier K can be expressed as:

$$S_K = \frac{\sum_{j \in K} N_j s_j}{\sum_j N_j},$$

where N_j and S_j denote the population size and ownership rate in city j, respectively. We extrapolate to our sample period to obtain the overall ownership rate in 2001 and 2014 at

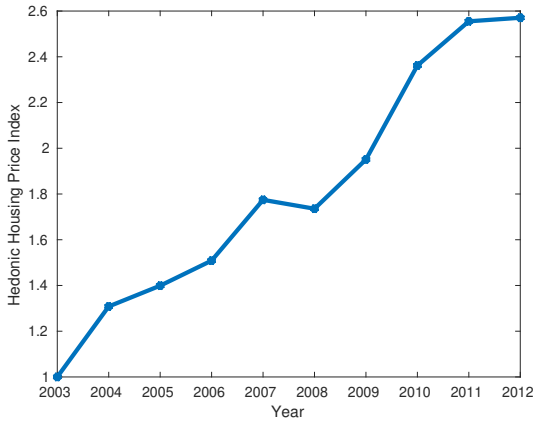

Figure 14: Hedonic Housing Price Index

82.2% and 76.6%, respectively.

IRES also provides limited quarterly price-rent ratio data for the 4 tier-1 cities from 2009Q3 to 2015Q4. The average price-rent ratio for the 4 tier-1 cities is 42.6.

2. Hedonic housing price:

Fang et al. (2016) construct hedonic housing prices for many cities in China over the time span of 2003-2012. To obtain an aggregate measure by appropriate population weights, we proceed with the following steps. We obtain city-level population in year 2000 and 2010 from population census. We also obtain province-level population data during 2000-2014 from various issues of CSY. We then compute the annual population growth rate at each year for every province during 2001-2014. We assume that cities within each province will grow at the same population growth rate. Given population level data in year 2000 and 2010, together with the annual population growth rate computed at each province, we can then project the entire series of city-level population data during 2000-2014. Merging the city-level hedonic housing price data from Fang, et al. with our projected population data, we end up with a balanced panel of 105 cities over the time span of 2003-2012. We then compute the city-level annual housing price growth rate during 2004-2012 and weight these city-level housing price growth rates by the population share of each city from our projected city population series to obtain the national housing price growth rate during 2004-2012. That is, the national housing price growth rate at year t is computed as:

$$g_t = \sum_i g_{it} \frac{N_{it}}{\sum_j N_{jt}}$$

where N_{it} is population size of city i in year t, and g_{it} is the housing price growth rate of city i in year t. This yields the aggregate hedonic price index, which is extrapolated using a second-order polynominal trend to cover the period of 2001-2014.

In our balanced panel of 105 cities, we have 4 tier-1 cities, 25 tier-2 cities, and the remaining 76 cities are tier-3 cities. We have also repeated the steps above by only focusing on tier-1 cities and tier-1 plus tier-2 cities to generate two additional aggregate hedonic price indexes for comparison purposes.

In Figure 14 we plot the computed hedonic price index from 2003 to 2012. We normalize

the price level in the inital year to be 1 for all the three series. Over the 10-year span, the growth factor for villa house is 1.75, 1.57 for regular house, and 2.57 for hedonic price index. Our results suggest that hedonic price is about 64% higher than regular house price and 47% higher than villa house price.