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

Over the past three decades, several major developed and developing economies have experienced sizable housing booms over prolonged periods. China —the world's factory— is one of the most prominent cases of rapid growth. It has experienced a fast but still ongoing structural transformation from a largely agricultural society to a modern one whose agricultural employment share was reduced from almost 70 percent in 1980 to about 30 percent in 2014. Compared with the speed of its structural transformation, China's urbanization process has not been as drastic, with the rural population dropping from about three-quarters to about 45 percent over the same period. It is therefore to some degree puzzling why China has experienced one of the most noticeable price hike's in urban housing markets, leading its government to implement regulatory mortgage and sales policies to cool off the housing market even shortly after the financial tsunami.

The primary purpose of this paper is to provide an in-depth examination of the role structural transformation played in China's housing boom. We begin by exploring the data, from which we highlight a greater puzzle that provides a stronger motivation of our study. Since China's housing market and land auction reforms largely completed after the turn of the new millennium, we restrict our study over the period from 2001 to 2014. During this short time span of 13 years, its urban house prices measured by a simple series of the aggregate hedonic price index have quadrupled and land prices risen by 12 times. Relative to GDP deflator, such house and land price hikes translate to annual growth rate of 6.9% and 15.8%, respectively. Over the same period, the rural population share has dropped from about 62.3% to 45.2%, the agricultural output share from about 14.1% to 9.2%, and the agricultural

relative prices rising only at annual growth of 2.1%. That is, in contrast with many developing countries, agricultural output has declined by much less compared to agricultural employment. While urban workers on average have much higher incomes than do rural workers —by approximately a factor of 10.8— this gap has been surprisingly stable throughout the time span and the minor changes in the income gap cannot plausibly serve to explain the significant housing booms, especially given the reasonably high incremental land supply for residential housing uses that grows at an annual growth of 2.8%. This posts a greater puzzle, suggesting that there must be another major driver to explain the sizable rural-urban migration flows and the housing boom. In our paper, we propose a largely ignored mechanism: the ***net mobility cost*** is falling in China, as a result of several combined factors, such as relaxation in the household registration (hukou) system, improvement in urban accessibility (infrastructure) and betterment in urban amenities.

Accordingly, we develop a dynamic spatial equilibrium model that highlights three major channels through which structural change may have affected house prices. First, structural transformation increases manufacturing productivity and that generates higher incomes in urban areas and a greater ability to pay for housing and to switch from renting or owning a small house to purchasing a bigger house. Second, the housing supply is relatively inelastic due to incremental land supply and the market entrance of real estate developers. Based on the observation above, however, these two natural channels alone are not sufficient to explain China's house price hikes. We therefore incorporate a third novel channel, taking into account institutional factors that may reduce net mobility cost incurred by migrants. Specifically, rural households are ex-ante heterogeneous with respect to their net migration costs they pay in utility if they move to the urban area, but such costs are

allowed to fall with migration-related institutional improvements.

In addition to the above main features, we consider several dimensions of model structures to ensure the thoroughness of our quantitative analysis. Particularly, while both agricultural and manufactured goods are produced by labor under Ricardian technologies, they enter households' utility through a constant elasticity of substitution (CES) goods-aggregator which is further combined with housing consumption via another layer of CES aggregator. The two-tier CES utility function with subsistence in agricultural consumption allows us to match structural transformation, agricultural relative prices and housing expenditure shares. With hukou delays, new migrants to cities are only allowed to rent. Upon obtaining a hukou, a city apartment renter may then purchase a regular house or a larger villa by financing it with a long-term mortgage subject to a down payment. Rental apartment is modeled to bare necessity, produced with a simple Ricardian technology. Upon paying a permit fee and purchasing land from the government, a housing builder produce housing (flows) with labor and land under a decreasing returns to scale technology. Housing flows add to the existing stock of houses that is subject to depreciation. The model is closed with a development entry condition and generalized with a Leviathan government which chooses incremental land supply to maximize net revenues.

By calibrating our model to fit the Chinese economy over 2001-2014, we find that a reduction of net migration cost by 26 percent over the sample period enables us to match the urban population share under the computed trends in agricultural and manufacturing TFPs. Our model can predict almost perfectly the house price hike and mimic closely the declining trend in the agricultural GDP share. This suggests that a properly generalized model to incorporate net migration cost reduction can explain well China's

housing boom in the dynamic process of structural transformation. Under this generalized model, we conduct counterfactual-based decomposition analysis into changes in various shocks to technologies, land supplies and prices. We find that urban income growth is still the largest contributor to house price growth in China, explaining a 122% increase over the sample period, but migration also plays a non-trivial role by generating a 20% long-run increase in prices while changes in land supply restrain house price growth by approximately 20%.

To unpack the impact of migration on house price dynamics, we compare the impulse response of house price to a positive urban income shock with and without migration. The result indicates a housing migration accelerator whereby migration amplifies the initial jump in house prices and creates subsequent house price momentum with persistent a long run effects. On the contrary, one may investigate the impact of housing market conditions to migration by comparing the impulse response of migration with and without house price hikes. We find migration to be significantly higher absent the rise in housing costs.

We then conduct policy analysis by isolating the indirect effect via endogenous house price response from the direct effect of each policy. On the one hand, we consider an accelerating hukou permit policy and find indirect house price hikes to discourage migration more than the positive direct effect of hukou policy. On the other hand, we examine expansionary credit policy by eliminating mortgage down payment and find indirect house price hikes to cause the positive direct effect short lived (lasting for only two years). We also conduct policy analysis regarding land supply. Not surprisingly, an expansion in incremental land supply induces stronger migration and suppresses house price growth. This suggests it as a possibly effective tool to cool down housing

booms without harming the urbanization process, though the ownership rate drops in the short run as a result of a composition effect with more renters. One may then inquire what would happen if the government supplies land to maximize its revenue in response to an accelerating hukou policy. Recall that house price hikes discourage migration more than reverse the direct effect of hukou policy. With a Leviathan government, house price hikes become more moderate and as a result the rate of urbanization remains largely unchanged.

The main takeaway of the paper is: while rising agricultural and manufacturing TFPs together with rising agricultural relative price almost offset each other and lead to a relatively flat urban-rural income ratio, reduction in net migration cost interact with urban productivity has induced strong demand effects via a housing migration accelerator causing urban house prices to rise despite of residential land expansion. This resolves the great puzzle mentioned above. Our finding not only highlights the importance of the novel but largely ignored channel of net migration cost but also stresses the essentiality of using a dynamic general equilibrium framework with path-dependent decision-making that allows for such interactive feedbacks. In such ways, we hope to promote better understanding about the migration-housing nexus in the dynamic process of structural transformation.

Related Literature The Chinese economy has undergone many political and economic reforms since 1978. Its rapid growth has made it the second-largest economy in the world, with especially significant growth since 1992. There is a large literature studying the development of China. For brevity, the reader is referred to Zhu (2012) for an extensive summary of the various stages of economic development. There is a small but growing literature investigating China's housing boom, including research by Chen and

Wen (2017),Fang, Gu and Zhou (2019), and Wu, Gyourko and Deng (2016). In contrast to this literature, we highlight the structural transformation of the manufacturing sector as a key driver of rural migrants to the cities. There have been numerous studies on structural transformation using dynamic general equilibrium models without spatial considerations. For a comprehensive survey, the reader is referred to Herrendorf, Rogerson and Valentinyi (2014). Of particular relevance, Hansen and Prescott (2002) and Ngai and Pissarides (2007) emphasize the role of different total factor productivity (TFP) growth rates played in the process of structural change. In our paper, the productivity gap between urban and rural areas is a main driver of ongoing rural-urban migration.

The literature of dynamic rural-urban migration is much smaller. While Glomm (1992) studies rural-urban migration as a result of higher urban productivity due to agglomerative economies, Robert E. Lucas (2004) highlights a dynamic driver of such migration, the accumulation of human capital and hence the ongoing rise in city wages. More recently,Riezman, Wang and Bond (2012) show that trade liberalization in capital-intensive import-competing sectors prior to China's accession to the WTO has accelerated the migration process and capital accumulation, leading to faster urbanization and economic growth. Tombe and Zhu (2019) find that reduction in internal trade and migration costs accounted for almost two-fifth of aggregate labor productivity growth in China over 2000-2005, even more important than international trade liberalization. Also focusing on China, Liao, Wang, Wang and Yip (2017) find that education-based migration plays an equally important role with work-based migration in the process of urbanization. None of these papers study housing markets.

In our paper, migration increases the demand for residential housing and

thus affects prices. To isolate the contribution of migration flows to housing prices, in the model, housing demand is determined only by migrants moving from rural areas to cities (the extensive margin). This formalization contrasts with a large literature using general equilibrium asset pricing frameworks (e.g., Davis and Heathcote (2005)), where prices are determined by a representative individual who adjusts the quantity of housing consumed. From the housing supply perspective, our model emphasizes the role of government restrictions on the production of housing units. By further incorporating limited access to the financial market for housing purchases, the analysis in our paper is connected to a large literature that explores financial frictions as drivers of housing boom-bust episodes (e.g., see papers cited by Garriga, Manuelli and Peralta-Alva (2019)). In contrast to these housing papers, our paper focuses on the economic development angle with the migration decision endogenously determined in the model.

2 Institutions

To better understand the motivation of our paper as well as our modeling and calibration strategy, we provide a brief overview of the institutional development in China while relegating the details to Appendix A. In particular, we are interested in key institutions associated with migration as well as housing and land markets.

Despite rapid structural transformation after the pro-market economic reform in 1978, especially since Deng Xiaoping's Southern Tour in 2002, internal mobility in China has been tightly controlled by a household registration system, called "hukou," which is still in use, although it has changed significantly through the years. Individuals were broadly categorized

as "rural" or "urban" workers. Turning from rural to urban hukou has been subject to severe barriers. Not until the second half of the 1990s, such barrers have been gradually mitigated via the issuance of "blue" permits that legalized illegal migrants and eventually allowed rural migrants to obtain permanent "red" permits.

Moreover, China has also been conservative in open-up the housing market and even more so in the land market. Not until the end of at the end of 1998, the previously operated public housing system was banned and replaced with commercialized housing market. A few years after in mid-2002, the Ministry of Land and Resources (MLR) banned previously adopted private negotiations, replaced with three commonly used auctions open to all developers. Even by now, use rights of land are by leaseholds with limited duration. While land is owned by the nation, the release of new land is essentially controlled by the government.

3 Data

To suit the purpose of our study, we have merged several datasets, including various issues of the China Statistical Yearbook (CSY), the the Hang Lung Institute of Real Estate Studies (IRES) dataset that contains many key real estate related measures, the city-level hedonic housing prices by Fang, Gu, Xiong and Zhou (2016), three waves of the China Family Panel Survey (CFPS) conducted in 2012, 2014 and 2016, and two census conducted in 2000 and 2010. Constrained by data avaiability, we set our sample period to 2001-2014, where we need to extrapolate a few series to cover the entire time span. The detailed documentation and definition of measures used in this paper are relegated to Appendix B.

In addition to the main stylized facts summarized in the introduction including urbanization rates, urban output shares and various series of real housing prices, we would like to briefly demonstrate a few related observations in the interest of our quantitative exercises.

To begin, we look at the sectoral performance of the macroeconomy. Over the sample period from 2001 to 2014, agricultural relative price rises by 30.2 percent with an average annual growth rate of 2.13 percent. Our imputed manufacturing productivity grows only slightly faster than agricultural productivity, with growth factor being 2.35 compared to 2.00 and the annual growth rate 6.81 compared to 5.60 percent.

Next, we turn to real estate data. Though with limited data for the 4 tier-1 cities from 2009Q3 to 2015Q4, it is clear that Chinese major cities features very high price-rent ratio: with the average price-rent ratio in these cities at 42.6. Over our sample period, incremental land supplies grew by a factor of 1.426 (normalizing 2001 = 1), whereas real land price grew by a factor of 6.72, translating to annual growth rates ate 2.8 and 15.8 percent, respectively. Thus, the flow supply of land is modest and the real price of land outgrows the real hedonic price of housing. Based on the two census data, home ownership rates in China are high despite a moderate downward trend: our imputed overall ownership rates extrapolated to 2001 and 2014 are 82.2 and 76.6 percent, respectively. Due mainly to rapid housing price hike, the drop in ownership rate is larger in bigger cities.

4 The Model

The model economy is set in discrete time and is populated by a unit measure of infinitely-lived households who reside in one of two geographic areas. In the rural area, households own and operate farms in the agricultural sector. In the city, households work either in the construction or manufacturing sectors. Goods produced in the agricultural and manufacturing sectors are tradable, and financial markets are open. Agents work where they live, but rural workers have the option to permanently migrate to the city (described in detail later).

4.1 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}. In the city, manufacturers produce $Y_{mt} = Z_{mt}N_{mt}$ goods from labor N_{mt} hired at wage rate w_t that can be used as final consumption or as intermediates for building apartment space and housing. In the construction sector, absentee rental firms utilize a reversible technology $Y_{at} = Z_a S_{at}$ that converts manufactured structures S_{at} into apartment space that depreciates at rate δ_a. Rental firms can either sell this space at price $\mathcal{P}_{at}$ or lease discrete units of size h_a to urban tenants at rent p_{at}. In the owner-occupied segment, home builders sell houses in discrete sizes $h \in \mathcal{H} = \{h_1, h_2, \ldots, h_N\} > h_a$ at price p_{ht}, which they produce using a constant returns to scale technology $Y_{ht} = Z_{ht}F(S_{ht}, N_{ht}, L_{ht})$ from structures S_{ht}, labor N_{ht}, and land permits L_{ht} that they purchase from the government at price p_{lt}. Housing depreciates at the rate δ_h and follows the law of motion $H_t = (1 - \delta_h)H_{t-1} + Y_{ht}$.[1]

[1]The main purpose of depreciation in the model is to ensure a stationary housing stock. At the individual level, depreciation manifests itself in the form of destructive house fires

4.1.1 Firm Decisions

Profit maximization for manufacturing implies that the wage w_t must satisfy

$$w_t = Z_{mt}. \tag{1}$$

Profit maximization for rental firms implies

$$\mathcal{P}_a = \frac{1}{Z_a} = p_{at} + \frac{1 - \delta_a}{1 + i_{t+1}} \mathcal{P}_a, \tag{2}$$

where i_{t+1} is the exogenous risk-free rate. Thus, rent must satisfy

$$p_{at} = \frac{1}{Z_a} \frac{i_{t+1} + \delta_a}{1 + i_{t+1}}. \tag{3}$$

Lastly, profit maximization for home builders implies

$$p_{lt} = p_{ht} Z_{ht} F_L(S_{ht}, N_{ht}, L_{ht}) \tag{4}$$

$$w_t = p_{ht} Z_{ht} F_N(S_{ht}, N_{ht}, L_{ht}) \tag{5}$$

$$1 = p_{ht} Z_{ht} F_S(S_{ht}, N_{ht}, L_{ht}), \tag{6}$$

where the presence of land implies that supply and demand conditions—rather than construction costs alone—determine house prices, as discussed later.

4.2 Households

All agents receive utility $u(x_{ft}, x_{mt}, x_{ht})$ from the consumption of farm goods x_{ft}, manufactured goods x_{mt}, and housing services x_{ht}. However, depending

that occur with probability δ_h. However, by assumption, the government fully insures these events by purchasing new houses for the owners.

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.

4.2.1 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 $\underline{x}_f$.

Rural households are identical in terms of income and (lack of) assets, but they are ex-ante heterogeneous with respect to the net migration cost they pay in utility if they move to the urban area. Specifically, rural households draw a permanent ϵ from the distribution $\Psi(\epsilon)$, where smaller values of the net cost ϵ signify either lower gross mobility costs or that the household attaches a higher premium to urban amenities. By assumption, there is no reverse migration.

4.2.2 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.[2]

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

Another distinction between the rural and urban areas is that agents in the city can be either renters or owners. Renters pay p_{at} each period for an apartment h_a and receive housing services $x_{ht} = h_a$. With probability η, urban residents receive a hukou permit that allows them to purchase a house. Permit holders who wish to buy a house choose $h \in \mathcal{H} = \{h_1, h_2, \ldots, h_N\} > h_a$, pay unit price p_{ht}, and receive housing services $x_{ht} = \zeta h$ each period, $\zeta \geq 1$. Those who prefer to rent can keep their permit until they make a future purchase.

Lastly, unlike rural households, urban residents have access to credit markets for saving and, in the case of homeowners, to borrow by mortgaging their house. The exogenous interest rates on savings and mortgage debt are i_t and r_t, respectively, reflecting the fact that they are primarily controlled by the government in China. Mortgages are long-term contracts that feature balances which decay geometrically at the rate γ. The minimum down payment ratio at origination is θ_t, which may vary over time. Mortgage default is not allowed.

4.2.3 Household Decision Problems

Rural workers choose how many manufactured and farm goods to consume as well as whether or not to migrate next period. Their value function is

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

$$\text{such that}$$

$$p_{ft}x_{ft} + x_{mt} = p_{ft}Z_{ft}$$

$$y_{t+1} = w_{t+1}e_{t+1}s_{t+1} + \mathcal{T}_{t+1} \tag{7}$$

where the migration decision is embedded in the continuation utility, and ξ_{t+1} is a dynamic aggregate scaling factor to net migration costs. The decision to

migrate is characterized by a cutoff value: rural households migrate in period $t+1$ if and only if their net mobility cost satisfies $\epsilon \leq \epsilon^*_{t+1}$, where

$$\epsilon^*_{t+1} = \frac{\mathbb{E}V^{rent,0}_{t+1}\left(y_{t+1}, s_{t+1}\right) - V^{rural}_{t+1}\left(\epsilon^*_{t+1}\right)}{\xi_{t+1}}. \tag{8}$$

In the city, renters without hukou permits—who therefore cannot buy a house—choose their consumption, savings, and have value function

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

such that

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + p_a h_a + b_{t+1} &= y_t \\ y_{t+1} &= w_{t+1}e_{t+1}s_{t+1} + \left(1 + i_{t+1}\right)b_{t+1} + \mathcal{T}_{t+1} \end{aligned} \tag{9}$$

where η is the probability of receiving a hukou permit next period, and the superscripts 0 and 1 denote hukou permit status. Renters who receive a permit next period then choose whether to remain renters or become homeowners.

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

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

such that

$$\begin{aligned} p_{ft}x_{ft} + x_{mt} + p_a h_a + b_{t+1} &= y_t \\ y_{t+1} &= w_{t+1}e_{t+1}s_{t+1} + \left(1 + i_{t+1}\right)b_{t+1} + \mathcal{T}_{t+1} \end{aligned} \tag{10}$$

Homebuyers choose their desired house type, mortgage size (subject to the

minimum down payment ratio), consumption, and savings to solve

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

such that

$$\begin{aligned} p_{ft} x_{ft} + x_{mt} + (1+\tau_b) p_{ht} h_{t+1} + b_{t+1} &= y_t + d_{t+1} \\ d_{t+1} &\leq (1-\theta) p_{ht} h_{t+1} \\ y_{t+1}^{rent} &= w_{t+1} e_{t+1} s_{t+1} + (1+i_{t+1}) b_{t+1} + (1-\tau_s) p_{h,t+1} h_{t+1} - (1+r_{t+1}) d_{t+1} + \mathcal{T}_{t+1} \\ y_{t+1}^{own} &= w_{t+1} e_{t+1} s_{t+1} + (1+i_{t+1}) b_{t+1} \end{aligned} \tag{11}$$

where the continuation utility embeds the decision of whether to remain an owner or sell and become a renter after receiving next period's income shocks.

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

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

such that

$$\begin{aligned} p_{ft} x_{ft} + x_{mt} + b_{t+1} + (\gamma + r_t) d_t &= y_t \\ d_{t+1} &= (1-\gamma) d_t \\ y_{t+1}^{rent} &= w_{t+1} e_{t+1} s_{t+1} + (1+i_{t+1}) b_{t+1} + (1-\tau_s) p_{h,t+1} h - (1+r_{t+1}) d_{t+1} + \mathcal{T}_{t+1} \\ y_{t+1}^{own} &= w_{t+1} e_{t+1} s_{t+1} + (1+i_{t+1}) b_{t+1} \end{aligned} \tag{12}$$

4.3 Government

In the baseline, the government exogenously develops a time-varying amount L_{ht} of new land each period calibrated to the data. In an extension, the analysis allows for endogenous land supply. In this case, the government faces time-varying development costs $\frac{\eta_t}{2}L_{ht}^2$ and chooses L_{ht} to maximize its profits,

$$\max_{L_{ht}} p_{lt}L_{ht} - \frac{\eta_t}{2}L_{ht}^2. \tag{13}$$

Besides developing land, the government also provides the aforementioned urban income floor $\mathcal{T}_t$ and the catastrophic insurance that protects homeowners against total loss of their house following a stochastic depreciation shock.

4.4 Equilibrium

Section 6 uses the model to understand the forces driving China's economic transition—characterized by structural transformation, urbanization, and a booming housing market—since the turn of the millennium (specifically 2001 to 2014). The thrust of the analysis involves undertaking several quantitative experiments that require computing dynamic equilibrium transition paths over long horizons. This section defines a stationary equilibrium and gives the laws of motion that govern transitional dynamics in response to exogenous changes.

4.4.1 Stationary Equilibrium

Given agricultural prices p_f, interest rates i for saving and r for mortgages, and land supply L_h, an open economy stationary equilibrium consists of apartment prices $\mathcal{P}_a$ and rent p_a, house prices p_h, wages w, factor inputs N_f, N_m, N_h, and S_h, value functions $V^{rural}(\epsilon)$, $V^{rent,\mathbf{1}_{hukou}}(y,s)$, $V^{buy}(y,s)$, and $V^{own}(y,h,d,s)$,

mobility cutoff ϵ^*, and end-of-period distributions $\Phi^{rural}(\epsilon)$, $\Phi^{rent,\mathbf{1}_{hukou}}(y,s)$, and $\Phi^{own}(y,h,d,s)$ that satisfy several conditions. First, optimality conditions (1) – (12) must hold. Second, optimal mobility decisions imply that

$$N_f = 1 - \Psi(\epsilon^*) = \int d\Phi^{rural} \tag{14}$$

where $\Phi^{rural}(\epsilon) = \Psi(\epsilon)\mathbf{1}_{\epsilon>\epsilon^*}$ is the truncated mobility cost distribution because of household rural to urban migration. Third, the urban labor market clears,

$$N_m + N_h = \int d\Phi^{rent} + \int d\Phi^{own} = 1 - N_f, \tag{15}$$

where the end-of-period distributions are the invariant measures generated by the household decision rules and exogenous laws of motion in the urban area. Lastly, the urban housing market must clear,

$$\int h d\Phi_{own} = H_-(1-\delta_h) + Y_h \tag{16}$$

where H_- is the housing stock last period and Y_h is construction this period. Expressed equivalently in terms of purchases and sales flows,

$$\int h^{buy}(y,s)d\mu^{rent,1} + \delta_h H_- = \int h\mathbf{1}_{[V^{rent}(y^{rent},s)>V^{own}(y^{own},h,d,s)]}d\mu^{own} + Y_h \tag{17}$$

where μ^{rent} and μ^{own} denote the beginning-of-period household distributions. The left side represents housing purchases by new buyers and the government, respectively, and the right side is sales by owners and builders, respectively.[3]

[3]Government purchases are to replace housing lost to stochastic depreciation. Note that it is still possible for the housing stock to decrease, $H < H_-$, from one period to the next if the government buys some of the replacement housing $\delta_h H_-$ from existing owners.

5 Calibration

The results in section 6 analyze and compare different long-run equilibrium transition paths 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 6.1.1) to target some more recent data moments. The length of a model period is one year.

5.1 Production

This section describes the parametrization of producers in the economy.

5.1.1 Technology

Recall that rural agricultural output is $Y_{ft} = Z_{ft}N_{ft}$, and urban manufacturing output is $Y_{mt} = Z_{mt}N_{mt}$. Initial urban earnings 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).[4]

The production function for building new urban housing is

$$Y_{ht} = Z_h L_{ht}^{\alpha_L} \left(S_{ht}^{\alpha_S} N_{ht}^{1-\alpha_S}\right)^{1-\alpha_L} \tag{18}$$

[4]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.

where $\alpha_L = 0.33$ reflects the average ratio between the value of housing and land according to Deng, Tang, Wang and Wu (2020), and $\alpha_S = 0.3$ follows Favilukis, Ludvigson and Van Nieuwerburgh (2017). Housing productivity Z_h is chosen to normalize initial equilibrium house prices to $p_{h0} = 1$. Apartment productivity Z_a is set to deliver an initial price-rent ratio of 20.[5]

5.1.2 Housing

The annual depreciation rates of housing and apartments are set to a standard value of 2.5%, $\delta_h = \delta_a = 0.025$. The rural house size is normalized to $h_f = 1$, which is innocuous because it 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. The small urban house size is set to $h_1 = 3$ to be three times average urban earnings, while the apartment size and larger house size 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).[6]

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).

[5] In certain large cities, the price-to-rent ratio can exceed 50, while in other small cities, the number can be below 10. The ratio of 20 can be viewed as an approximate national average in the early 2000s. The initial ratio is $p_{h0}/p_a = p_{h0}Z_a(1+i)/(i+\delta_a)$ with $p_{h0} = 1$, $i = 0.08$, $\delta_a = 0.025$. The interest rate discussion in section 5.3 explains $i = 0.08$.

[6] 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.

5.2 Households

This section describes the parametrization of households in the economy.

5.2.1 Preferences

Households exhibit nested, non-homothetic constant elasticity of substitution preferences over consumption bundles and constant relative risk aversion across periods. Specifically, $u(x_f, x_m, x_h) = U(C(x_f, x_m), x_h)$, where

$$U(C, x_h) = \frac{\left[\left(\phi_c C^{\frac{\nu_c - 1}{\nu_c}} + (1-\phi_c) x_h^{\frac{\nu_c - 1}{\nu_c}}\right)^{\frac{\nu_c}{\nu_c - 1}}\right]^{1-\sigma}}{1-\sigma} \tag{19}$$

$$C(x_f, x_m) = \left(\phi_f [x_f - \underline{x}_f]^{\frac{\nu_f - 1}{\nu_f}} + (1-\phi_f) x_m^{\frac{\nu_f - 1}{\nu_f}}\right)^{\frac{\nu_f}{\nu_f - 1}}. \tag{20}$$

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 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 6.1.1). The ownership premium ζ has a first-order impact on the homeownership rate. The minimum subsistence threshold $\underline{x}_f$ for agricultural consumption is set to 25% of per capita rural agricultural consumption.

5.2.2 Mobility Costs

The cumulative density function for mobility costs is

$$\Psi(\epsilon) = 1 - \left(\frac{\underline{\epsilon}}{\epsilon}\right)^{\kappa}, \tag{21}$$

where $\kappa = 2.8$ is falls within the common range for the migration literature, e.g. Liao et al. (2017). The net mobility cost scaling factor ξ_t 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 term $\widetilde{\xi}_t$ is a residual that represents gross mobility costs net of other more difficult to measure urban amenities. Both components are normalized to 1 in the initial equilibrium. 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 5.4 explains in more detail.

5.2.3 Urban Income Process

The stochastic labor endowment $e_t s_t$ follows

$$\ln(s_t) = \rho \ln(s_{t-1}) + \varepsilon_t \tag{22}$$

$$\varepsilon_t \sim \mathcal{N}(0, \sigma_\varepsilon^2) \tag{23}$$

$$\ln(e_t) \sim \mathcal{N}(0, \sigma_e^2). \tag{24}$$

with parameters $\rho = 0.9172$, $\sigma_\varepsilon^2 = 0.0469$, 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.

5.3 Government and Finance

This section describes parameters related to policy and financial instruments.

5.3.1 Government Policy

The government sends means-tested transfers to urban households to ensure that they can afford an apartment h_a, subsistence agriculture $\underline{x}_f$, and still have some income left over. Specifically, a household with earnings $w_t e_t s_t$ receives

$$\mathcal{T}_t(e_t s_t) = \max\{0, p_a h_a + p_{ft}\underline{x}_f + \chi w_t \underline{es} - w_t e_t s_t\} \tag{25}$$

where the income floor $\chi = 0.5$ is 50% of the worst earnings realization $w_t \underline{es}$.

The minimum down payment ratio is $\theta = 0.3$ in accordance with policy during 2001 – 2014.[7] 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. (2017). The initial land supplied by the government is normalized to $L_{h0} = 1$.

5.3.2 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 $r = 0.06$.

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

Table 1: Summary of Model Parameters

Description	Parameter	Value	Explanation
Technology			
Manufacturing Productivity	Z_{m0}	1	Section 5.1.1
Agricultural Productivity	Z_{f0}	0.099	Section 5.1.1
Housing Productivity	Z_h	0.699	Section 5.1.1
Apartment Productivity	Z_a	1.944	Section 5.1.1
Housing			
Housing Depreciation	δ_h	0.025	Section 5.1.2
Apartment Depreciation	δ_a	0.025	Section 5.1.2
Rural House Size	h_f	1	Section 5.1.2
Urban Apartment Size	h_a	2.29	Section 5.1.2
Small Urban House Size	h_1	3	Section 5.1.2
Large Urban House Size	h_2	13.35	Section 5.1.2
Buyer Transaction Cost	τ_b	0.005	Section 5.1.2
Seller Transaction Cost	τ_s	0.12	Section 5.1.2
Preferences			
Risk Aversion	σ	2	Section 5.2.1
Discount Factor	β	0.842	Joint Calibration
$U(C, x_h)$: Intratemporal Substitution	ν_C	0.487	Section 5.2.1
$U(C, x_h)$: 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 5.2.1
Net Mobility Costs			
Curvature of CDF	κ	2.8	Section 5.2.2
Lower Support of CDF	$\underline{\epsilon}$	7.263	Joint Calibration
Initial City Quality	$\xi_{q,0}$	1	Section 5.2.2
Initial Net Mobility Cost Scale	$\widetilde{\xi}_0$	1	Section 5.2.2
Final City Quality	$\xi_{q,\infty}$	1.277	Section 5.2.2
Final Net Mobility Cost Scale	$\widetilde{\xi}_\infty$	0.736	Joint Calibration
Urban Income Process			
Autocorrelation of Persistent Shock	ρ	0.9172	Section 5.2.3
Variance of Persistent Shock	σ^2_ε	0.0469	Section 5.2.3
Variance of Transitory Shock	σ^2_e	0.03	Section 5.2.3
Government Policy			
Income Floor Ratio	χ	0.5	Section 5.3.1
Minimum Down Payment Ratio	θ	0.3	Section 5.3.1
Mortgage Amortization Rate	γ	0.0333	Section 5.3.1
Hukou Permit Probability	η	0.3	Section 5.3.1
Initial Land Supply	L_{h0}	1	Section 5.3.1
Interest Rates			
Savings Interest Rate	i	0.08	Section 5.3.2
Mortgage Interest Rate	r	0.06	Section 5.3.2

Table 2: Joint Calibration

Description	Model	Data	Source
2001 Rural Population	62.3%	62.3%	CSY[a] 2016
2014 Rural Population*	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	82.0%	82.6%	Census[b] 2000
Financial Assets to GDP	1.48	1.5	UHS[c] 2007
Housing Spend Share (Owners)	24.9%	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.

5.4 Joint Calibration

The jointly calibrated parameters summarized in table 1 are determined using the model to match characteristics of the Chinese economy from both the late twentieth century and more recent years. The earlier empirical moments are targeted using the initial stationary equilibrium and come from several data sources. This data includes household financial assets, the housing spend share, and the homeownership rate in the early post-land-reform years. In conjunction with the initial equilibrium, the joint procedure also uses in a very limited manner the final equilibrium induced by the set of baseline shocks described in section 6.1.1 to target the rural population share and agricultural spend share in both 2001 and 2014.[8] Every other aspect of the final equilibrium is untargeted. Table 2 summarizes the data moments, sources, and model fit.

[8]For each parameter combination, the model solves for the initial stationary equilibrium and then the final stationary equilibrium induced by the set of shocks described in section 6.1.1. The endpoints for the rural population share and agricultural spend share are then compared to the 2001 and 2014 empirical values. Implicitly, this approach assumes that the model converges to the final equilibrium within 13 years. An even more precise procedure that computes the entire equilibrium transition path for each parameter combination to align these two moments from the thirteenth period of the transition with the data from 2014 would be very costly and deliver minimal gain in accuracy.

6 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 and to examine the impact of different potential policy interventions on the pace of economic change. Specifically, the analysis first reconstructs China's structural transformation and urbanization to uncover the extent to which it can explain China's housing boom. Next, the analysis addresses causality in the other direction by quantifying the extent to which housing conditions influence the magnitude and speed of structural transformation and urbanization. Lastly, the analysis evaluates the potential of migration, credit, and land policies to accelerate structural transformation.

6.1 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.

6.1.1 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 either measured directly from the data or targeted to some non-housing data moments. The shocks induce the economy to gradually transition from its initial calibrated equilibrium to a new long-run equilibrium that falls beyond

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	$\{L_{ht}\}_{t=1,...,T}$ 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[a]

[a]Assumed constant for $t > 14$. The appendix has other terminal conditions.
[b]One-time jump based off of smoothed data. [c]Smoothed using HP filter.

the time window of analysis. As a result, and in light of the ongoing nature of China's evolution, the analysis focuses on the equilibrium transition dynamics corresponding to 2001–2014 rather than this future long-run equilibrium.[9]

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.[10] The baseline simulation also solves for the sequence $\{\widetilde{\xi}_t\}$ of scaling factors for heterogeneous net mobility costs that aligns the equilibrium path of urban-rural migration with population dynamics in the data. Of note, this sequence is left exogenous in subsequent counterfactual exercises to ensure that the pace of urbanization is *endogenous* when decomposing the forces in the model or evaluating the impact of policy changes. Table 3 summarizes.

Although the data used in the analysis stops in 2014, the solution method for determining equilibrium dynamics requires assumptions about terminal conditions and, thus, the path of each of the shocks beyond this 2001–2014

[9]Agents are surprised by the arrival of the "MIT shocks" but can accurately forecast the equilibrium transition dynamics.

[10]Later, figure 10 shows the model variant with endogenous land supply with $\{\eta_t\}$ from equation 13 calibrated to replicate the baseline path for $\{L_{ht}\}$.

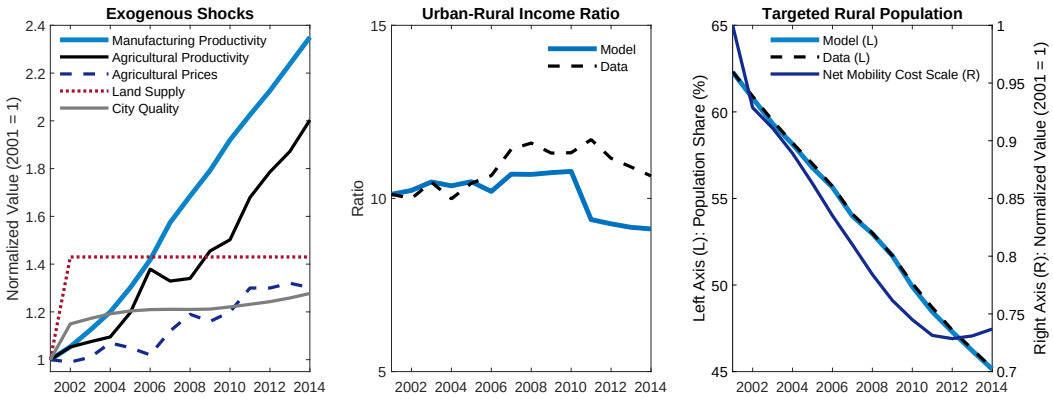

Figure 1: Baseline Shocks. Sources: (Productivity, Agricultural Prices, Rural Population, Urban-Rural Income) CSY; (Land Supply, City Quality) CRE.

time horizon. Figure 12 in the appendix evaluates two cases. In the first case, the shocks level off at 2014 values. The second case linearly extrapolates each of the shocks (or in the case of $\{\widetilde{\xi}_t\}$, the rural population share) for another thirteen years before they level off. While these two alternative assumptions give rise to very different long run equilibria, they generate nearly identical equilibrium transition dynamics during the thirteen year period corresponding to 2001–2014. Thus, going forward, the analysis settles on the first approach.

The first panel of figure 1 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 remains relatively stable throughout the entire sample period. Such minor changes in the income gap cannot plausibly explain the substantial decline in the rural population share from 62.3% to 45.2% between 2001 and 2014, as shown in the third panel. In fact, the third panel demonstrates that, in order for the model

to rationalize this decrease, the net mobility cost scaling factor ξ_t must fall by 26%, which can either be interpreted as a decline in *gross* mobility costs or as a rise in the urban amenities not included in the city quality measure that make city living more appealing.

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 2. In particular, equilibrium house prices climb by 130% over thirteen model periods (years), which aligns well with the 137% increase in the data from 2001 to 2014. Although the entire time series from the data for the homeownership rate is not readily available, the middle panel reveals that 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 2 reveals that the dynamics of the agriculture to GDP ratio in the model closely follow those of the data—falling by 5.7 and 4.9 percentage points, respectively, driven by the reduction in agricultural labor as rural workers migrate to the city and acquire manufacturing jobs.

6.1.2 Understanding the Drivers of China's Transition

To decompose the drivers of China's urbanization, structural transformation, and boom in house prices, table 4 quantifies the effects of isolating each shock by re-computing the equilibrium transition with one shock removed at a time. As mentioned before, to rationalize the seventeen percentage point increase in

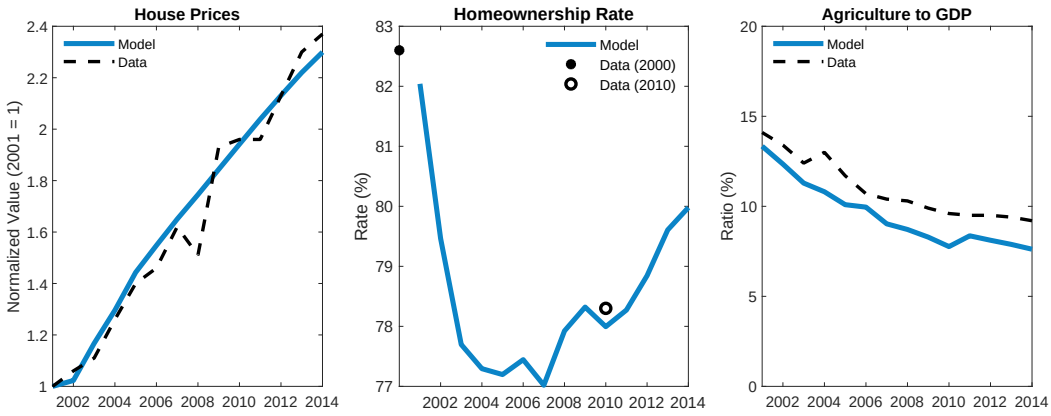

Figure 2: Baseline model vs. data. Sources: (House Prices) Fang et al. (2016); (Homeownership Rate) Census; (Agriculture to GDP) CSY.

the urban population share in the face of a stable urban-rural urban income ratio requires that net migration costs diminish during this period. Indeed, the second row of table 4 confirms that, with ξ_t held constant, the urban population experiences no change during the entire period ($\Delta_{t=2} = \Delta_{t=13} = 0$). The absence of migration in turn stymies structural transformation, with the agriculture-to-GDP ratio remaining mostly flat instead of declining by nearly six percentage points ($\Delta_{t=13} = -5.7$) in the baseline. In the housing market, prices in the case of a fixed ξ_t still rise by a considerable 110.9% because of growing urban income Z_{mt}, but the migration response in the baseline fuels an even larger 129.9% rise in house prices. Without migration, homeownership with fixed ξ_t increases instead of decreases during the transition, indicating that the baseline declines reflect a compositional 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.

In the presence of rising urban productivity Z_{mt}, holding fixed either the path of agricultural productivity Z_{ft} or prices p_{ft} has the opposite effect as fixing mobility costs ξ_t by leading to significantly higher rural-urban migration.

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	3.0	17.2	-2.0	-5.7	16.7	129.9	-4.3	-2.1
Fixed Z_{ft}	10.5	45.0	-5.4	-12.3	25.2	170.3	-14.6	-9.3
Fixed p_{ft}	3.8	28.0	-2.5	-9.5	17.6	150.2	-5.8	-3.9
Fixed L_{ht}	2.3	16.5	-1.7	-5.5	26.6	152.0	-3.5	-3.3
Slow Z_{mt}	1.0	8.0	0.0	4.8	-2.1	27.7	-1.4	-4.3
Slow ξ_{qt}	0.0	8.8	-0.7	-3.1	13.8	123.8	0.9	1.2

All numbers are percentage point changes. The horizon is 2 years for $\Delta_{t=2}$ and 13 years for $\Delta_{t=13}$. "Slow Z_{mt}" cuts manufacturing productivity growth by 80%. "Slow ξ_{qt}" cuts the growth rate of the city hedonic component of ξ_t by 30%.

With fixed agricultural productivity, the urban population share rises by 10.5 percentage points after just two years and by a dramatic forty-five percentage points after thirteen years—representing nearly three times the intensity of rural-urban migration in the baseline. This migration surge causes house prices to increase by 170.3% in year thirteen compared to 129.9% in the baseline. At the same time, the influx of rural migrants to the city temporarily depresses the homeownership rate by nearly fifteen 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, rather than focus on this extreme case, table 4 and appendix figure 11 consider a scenario that slows down manufacturing growth by 80%, which cuts baseline rural-migration by about half. In this scenario, house prices only rise by 27.7% by the end of the sample —only one-fifth of baseline appreciation. The fourth row of table 4 indicates that fixing land supply modestly lowers migration and raises house prices, as discussed further in section 6.3.3.

To summarize the above decomposition, urban income growth is the largest contributor to house price growth in China—explaining a 122% increase over the sample period—but migration also plays a non-trivial role by generating a 20% long-run increase in prices.[11] Observed changes in land supply, in turn, restrain house price growth by approximately 20%.

6.2 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 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.

[11]The contribution of migration is calculated as the difference between baseline house price growth and that which occurs if migration were to occur (by altering the sequence of ξ_t) without any rise in urban income. The contribution of wage growth is the difference between baseline house price growth and that which occurs when urban income follows its baseline path but migration is shut down. The land supply contribution is analogous.

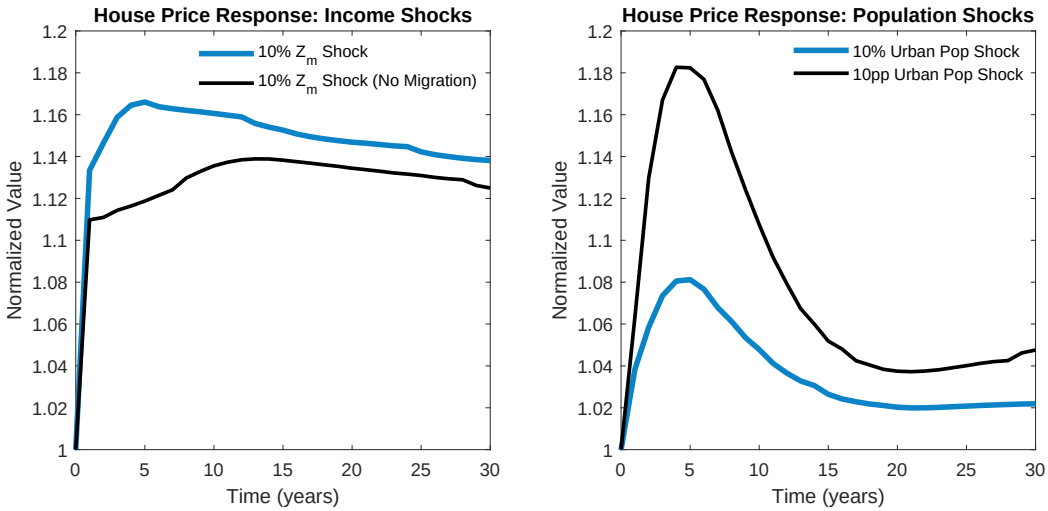

Figure 3: House prices following permanent income and population shocks.

6.2.1 From Migration to House Prices

To unpack the impact of migration on house price dynamics, the left panel of figure 3 plots the impulse response of house prices to a 10% permanent income shock with and without allowing rural agents to migrate. Relative to the baseline that analyzes the transitional dynamics of structural transformation with steadily rising income, this exercise highlights the underlying mechanisms through a one-time unanticipated shock. The black curve corresponds to the case without allowing for migration while holding the urban population fixed, and the blue curve allows for endogenous migration. Comparing the two curves reveals a **housing migration accelerator** whereby migration amplifies the initial jump in house prices to the income shock and creates subsequent house price momentum, overshooting, and partial mean reversion. In the long run, house prices remain significantly elevated following the income shock, but the marginal impact of migration fades with time as the gap between the curves with and without migration narrows.

Intuitively, the medium-run price momentum arises from the gradual response of housing demand to the rapid influx of migrants because of the time required to obtain a hukou permit and accumulate savings to make at least the minimum 30% down payment. Moreover, the overshooting and partial mean reversion reflect the role of construction. Specifically, as prices rise, home builders ramp up construction but still face land supply limitations from the government. Over time, the housing stock eventually accommodates the surge in buying, putting downward pressure on prices. Foreseeing these price dynamics, urban households who already possess a hukou permit and adequate savings face the incentive to buy immediately upon the onset of the shock before price momentum makes buying even more costly.

To further explain the mechanics of the housing migration accelerator, the right panel of figure 3 depicts the impulse response of prices to an unanticipated exogenous migration shock that increases urban population. The blue curve shows the dynamic effects of a 10 percent elevation in the urban population share (from 37.7% to approximately 41.5%), with prices exhibiting substantial momentum, overshooting, and mean reversion. Quantitatively, house prices peak at 8% above their initial level after rising continuously for five years. As new supply gradually accommodates the influx of demand, house prices recede for about ten years before eventually settling at around 2% above their initial pre-shock value. Scaling up the migration shock to make it a 10 *percentage point* rise in the urban population share delivers a nearly proportional dynamic path of house prices with a peak increase of over 18%. In both demographic experiments displayed in the right panel, the momentum and overshooting are driven by the time delays associated with obtaining a hukou permit and accruing a down payment that spread out over time the response of housing demand to a rapid influx of population.

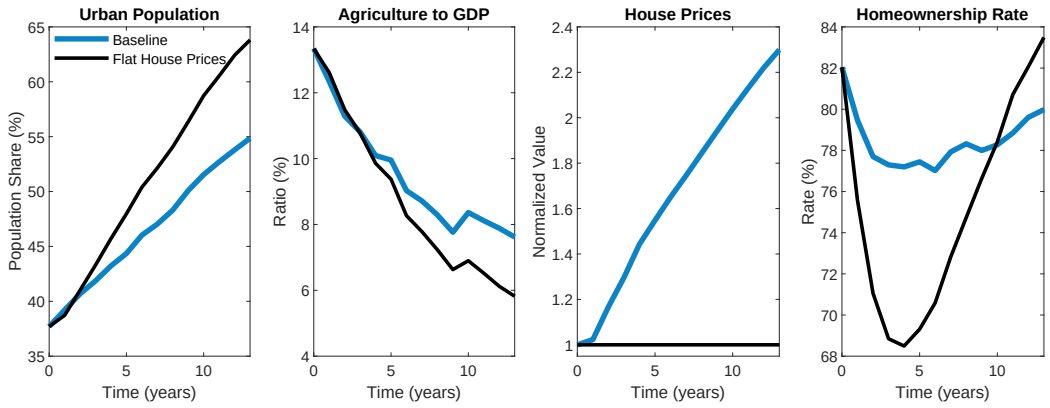

Figure 4: The impact of house price growth on structural transformation. Urban migration is significantly higher absent the rise in housing costs.

6.2.2 From House Prices to Migration

Causality also goes the other way from housing market conditions to migration. One approach to assess this mechanism, as captured in figure 4, is to revisit the baseline and hold house prices fixed instead of letting them follow their equilibrium path. In this exercise, improved housing affordability bolsters the process of urbanization and structural transformation. Specifically, the model predicts that the urban population share and agriculture to GDP ratios would be nearly 9 percentage points higher and 2 percentage points lower at the end of the sample period. Moreover, the long-run homeownership rate would be nearly 4 percentage points higher, albeit only after a ten year adjustment period during which the surge in migrant renters lacking hukou permits and savings depresses the homeownership rate because of a composition effect.

Alternatively, one can revisit the slow urban income growth decomposition from section 6.1.2. In the left and right panels of figure 5, the gap between the blue and black curves represents the equilibrium (total) effect of slower urban income growth. The gap is the sum of the direct negative effect of the shock

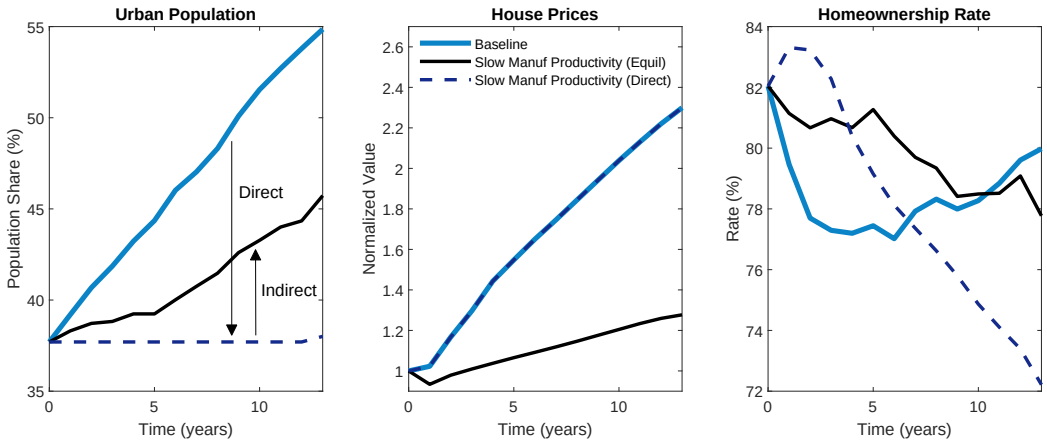

Figure 5: Slower manufacturing productivity and the importance of the house price channel. The partial equilibrium (PE) curves use the baseline price path. The equilibrium house price decline reverses nearly half the drop in migration.

ignoring the endogenous house price response to slower income growth (i.e. forcing prices to follow their baseline path) and the indirect positive effect of slower equilibrium house price growth on migration.

The left panel reveals that the direct effect of slower urban income growth (the downward shift from the blue curve to the dashed purple curve) nearly eradicates all rural-urban migration if house prices were to still follow their baseline trajectory. However, the resulting slowdown in house price growth reverses about half of this decline (the upward shift from the dashed purple curve to the black curve). The homeownership rate dynamics in the right panel reflect a confluence of factors. On the one hand, any reduction in migration implies a smaller influx of migrant renters, which boosts the homeownership rate simply due to a composition effect. On the other hand, the relative dynamics of urban income and house prices impact homeownership by altering its affordability over time. As evidenced in the right panel, these compositional and affordability factors roughly balance out by the end of the sample period.

6.3 Policies to Accelerate the Economic Transition

This section explores various policy experiments aimed at accelerating the process of urbanization and structural transformation taking said objective as given. One lesson that emerges from all the experiments is the importance that housing markets play in the transmission from the policy to the rest of the economy. In some cases the endogenous price response is central to a policy's success, while at other times it partially or completely undermines the policy.

6.3.1 Residency Policy

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, on occasion China has modified hukou restrictions, 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

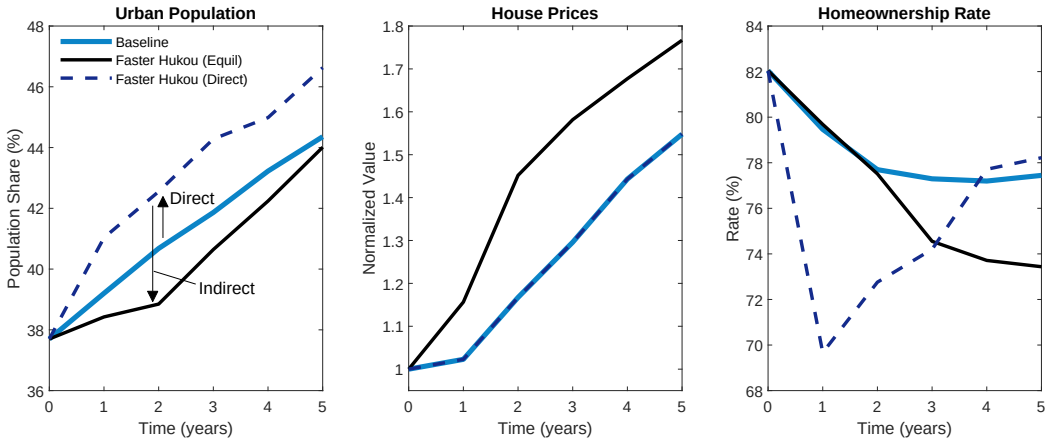

Figure 6: The effect of accelerating hukou permits. Higher equilibrium house prices that raise the cost of urban living more than reverse the direct effect.

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 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 policy directly increases the urban population by 1.9 percentage points after two years, as shown in the left panel of figure 6. This population increase is on top of the 3 percentage point amount of baseline migration. However, the middle panel shows that the policy fuels higher house prices, which erases 76% of the total migration that occurs under the policy with just the direct effect. The net result is *less* migration relative to the baseline. After five years, the two effects nearly cancel each other out.

6.3.2 Credit Policy

Given the importance of housing to the migration decision, credit policy is another lever to impact the pace of economic transformation. As detailed

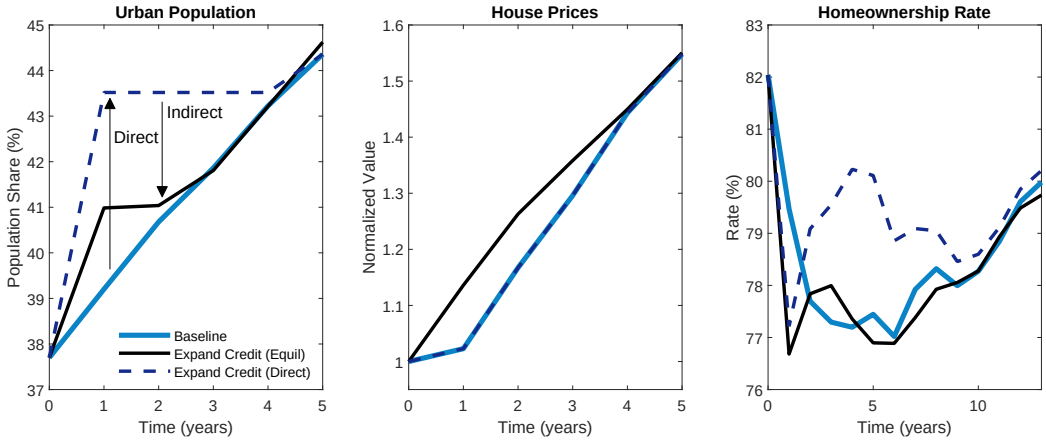

Figure 7: The impact of expanding credit with a 0% minimum down payment. The equilibrium increase in house prices attenuates the surge in migration.

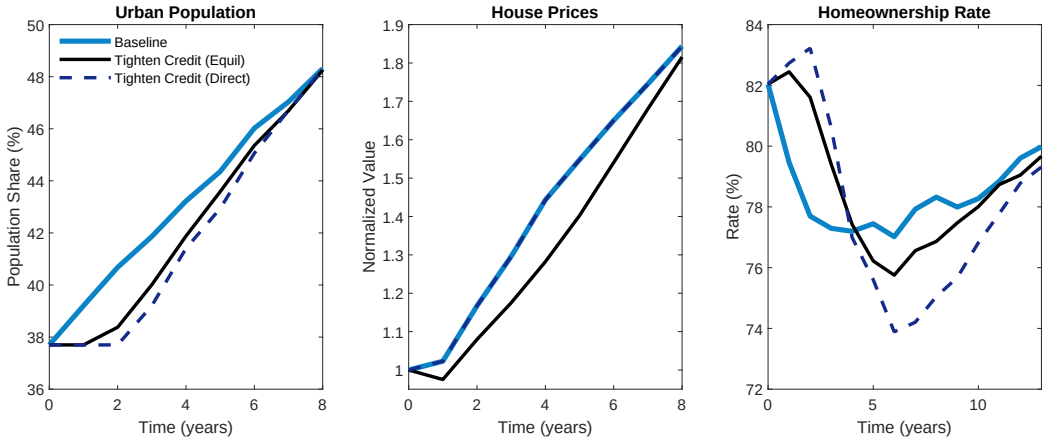

Figure 8: The impact of tightening credit with a 50% minimum down payment. The equilibrium drop in house prices mediates the decline in migration.

in Chen, Wang, Xu and Zha (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 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 4.3 percentage points to the urban population after year one on top of the 1.5 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 rate more quickly converges to its long-run level—which is determined by

fundamentals rather than credit conditions—without the need for prospective buyers to accumulate a down payment. Factoring in that house prices rise in response to the influx of population, the indirect effect of the policy offsets 59% of the direct migration effect. In the event of a credit tightening, similar mechanisms operate in reverse—albeit not symmetrically, with a less potent indirect price-to-migration effect—as shown in figure 8.

6.3.3 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

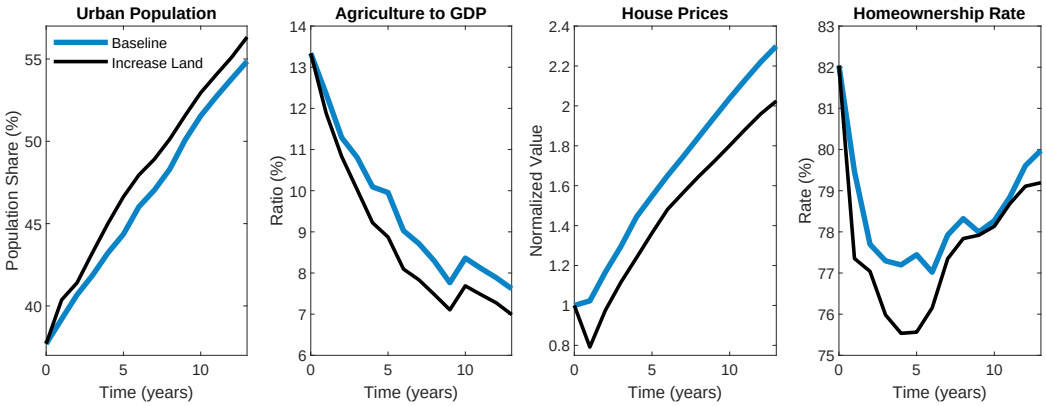

Figure 9: The response to a large expansion in land supply.

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. Quantitatively, house prices appreciate by 102% after five years versus 130% in the baseline, causing an additional 1.5 percentage point rise in the urban population share and 0.6 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 6.3.1, more than reversing the intent of the policy. Rather than exogenously increase land to counteract this reversal, this section allows the government to adjust the supply of land in response to housing market conditions as introduced in section 4.3. Specifically, the government chooses how much new land to make available to maximize revenue from land sales net of time-varying

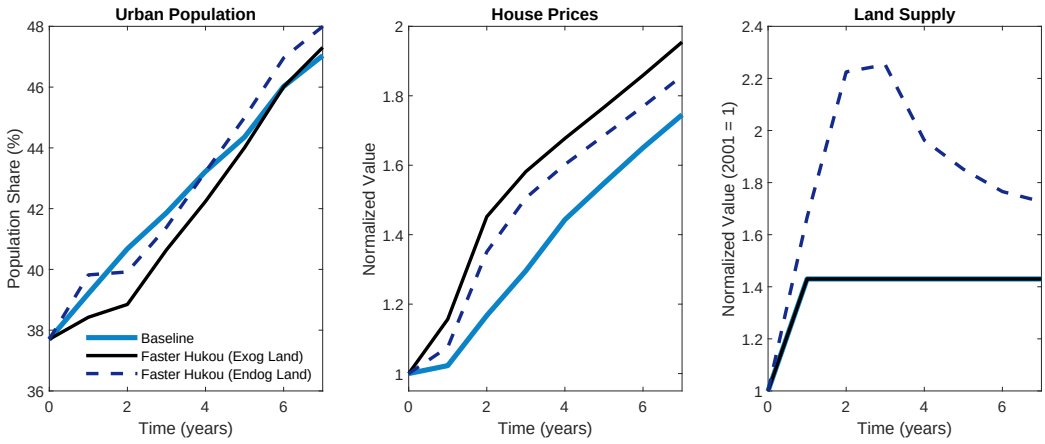

Figure 10: Endogenous land supply and the response to faster hukou permits.

development costs. These costs η_t are calibrated to replicate the exogenous path of land supply in the baseline that is consistent with the data.

With the path η_t fixed at its baseline trajectory, 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 increased availability of new land for construction dampens the rise in house prices attributable to the surge in housing demand from the influx of migrants seeking to purchase houses. As a result, migration to the city increases relative to the case with exogenous land supply, eventually surpassing the baseline level after four years. Thus, the endogenous land supply expansion neutralizes the negative feedback of price appreciation to urbanization.

7 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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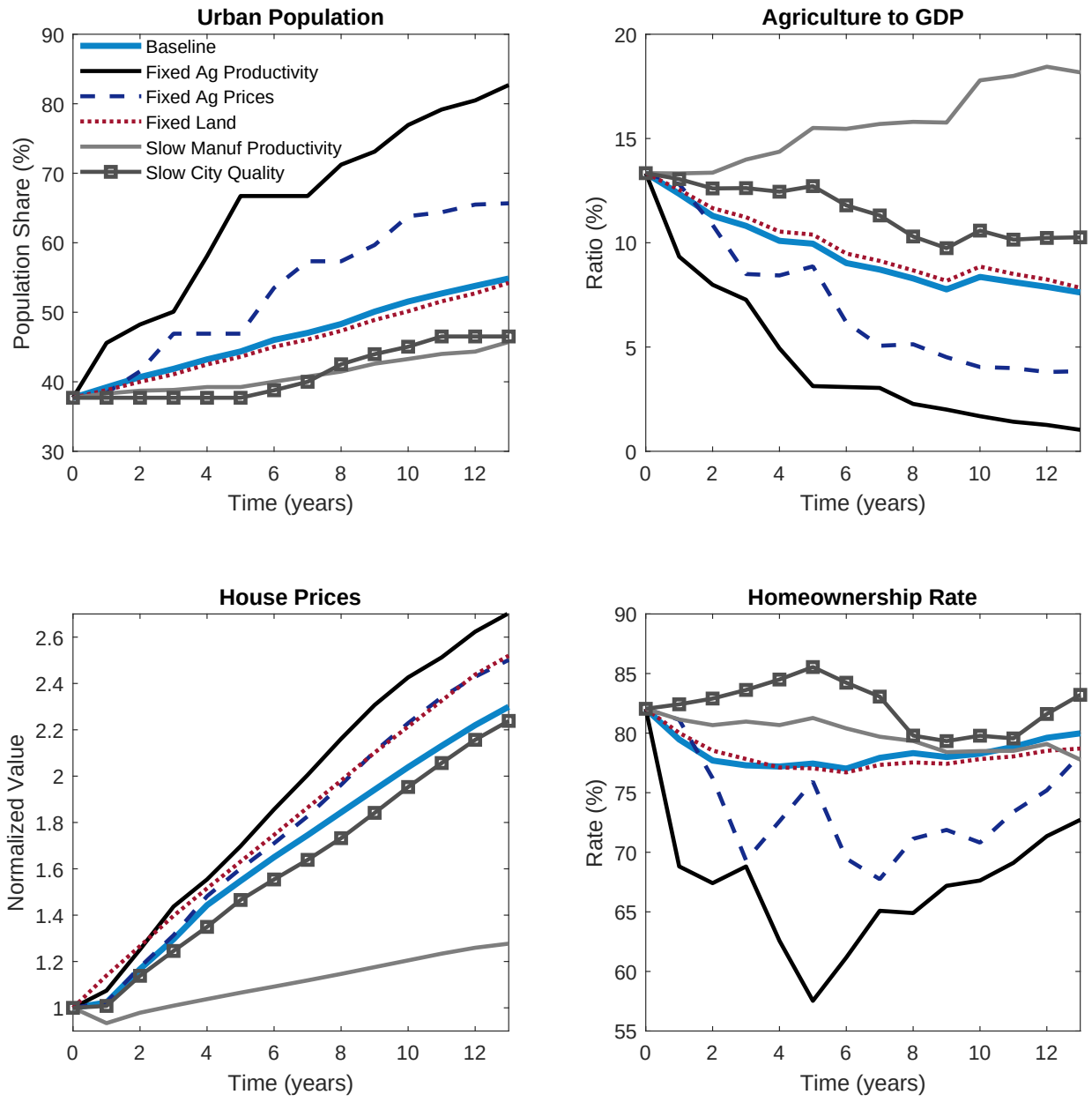

Figure 11: Comparing the shocks. Slow manufacturing productivity cuts the growth in Z_{mt} by 80%. The fixed mobility costs plots keep a constant δ_t.

A Supplementary Tables and Figures

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,

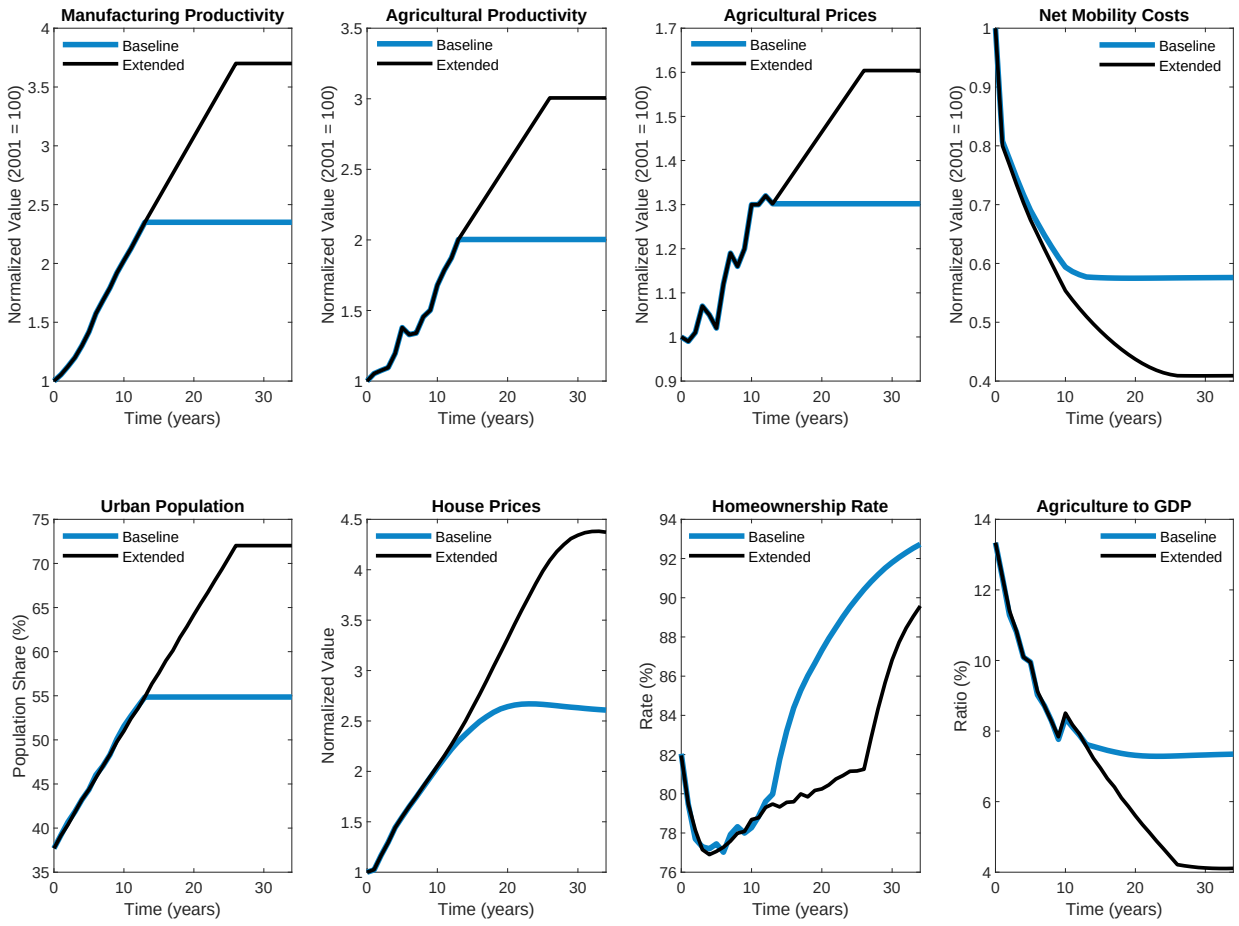

Figure 12: Baseline model compared to an extended transition path with alternative terminal conditions. The extended transition features the same path of exogenous land supply.

the Chinese economy began to 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 individual 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 coastal area 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 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 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, Deng, Gyourko, and Wu (2015) 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 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 with a market economy, however, the majority of SOE became less competitive than the emerging collectively owned and private enterprises. Consequently, 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 in that conference 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.

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, 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. Nonetheless, 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 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 **??** we plot the evolution of real GDP, 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. Real GDP is thereby defined as the ratio of nominal GDP to 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 has experienced modest trend of 5% over 13 years (with annual growth of 0.4%), ranging from 10.0 in 2004 to 11.7 in 2011 with an average around 10.8.

In Figure **??** we plot the evolution of relative agriculprice 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. We have also summarized the growth factor and average growth rate for selected key variables in Table **??**.

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 Institute of Real Estate Studies (IRES) of Tsinghua University. 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. IRES housing prices, housing supply and mortgage:

The IRES 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 villas high-grade apartments (yuan/square meter).

In Figure **??** 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 of 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 1.426 (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 **??**. The growth factor is xx for regular house and xx for villa house.

In Figure **??** we plot the real land price index, and real housing price index for regular house and villa, respectively. 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 6.722 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 China Family Panel Survey(CFPS) conducted in 2012, 2014 and 2016 to document the size differences among houses of different type. As shown in Table **??** 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. In Table **??** 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 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. In Table **??** we have summarized the average ratio for each city over the sample period. The average price-rent ratio for the 4 tier-1 cities is in turn 42.6.

2. Hedonic housing price:

Fang, Gu, Xiong and Zhou (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 have made the assumption 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 **??** we plot the computed hedonic price index together with the real housing price index for regular residential house and villa during 2003-2012. 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.