

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

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Abstract: This paper explores the role played by structural transformation and the resulting relocation of workers from rural to urban areas in the recent housing boom in China. This development process has fostered an ongoing increase in urban housing demand, which, combined with a relatively inelastic supply due to land and entry restrictions, has raised housing and land prices. We examine the issue using a multi-sector dynamic general-equilibrium model with endogenous rural-urban migration and endogenous housing demand and supply. Our quantitative results suggest that the development process accounts for two-thirds of housing and land price movements across all urban areas. This mechanism is amplified in an extension calibrated to the two largest cities indicating that market fundamentals remain a key driver of housing and land prices.

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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. These booms have been believed to be driven primarily by sustained growth, credit market liberalization, and optimistic expectations. 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. Compared with the speed of its structural transformation, its urbanization process has been relatively moderate, with more than half of its population still living in rural areas. Some research, including two recent papers by Wu, Gyourko, and Deng (2012) and Chen and Wen (2014), has thereby argued that the relatively low level of urbanization is inconsistent with the observed boom in housing prices.¹

The present paper challenges this view by exploring the role structural transformation played in China’s housing boom. We highlight three major channels through which structural change may have affected housing prices. First, structural transformation increases manufacturing productivity and that generates higher incomes in urban areas and greater ability to pay. Second, the housing supply is relatively inelastic due to heavy regulations on land supply and entry in the market entry for real estate developers. As a consequence of structural transformation, the third channel is an ongoing rural-urban migration that increases demand for urban housing. Our view is that structural transformation implies job reallocation from agricultural to non-agricultural sectors and also induces migration from rural to urban areas where most production takes place.

Our main mechanism is consistent with the data shown in Figure 1. The left panel plots the average annual growth rate of housing prices against the average annual growth rate of migration from rural areas to China’s 29 major cities from 1998-2007 (which include all the first-tier and second-tier cities in China). The positive relationship suggests that housing prices grow faster in cities with larger inflows of migrants from rural areas. The right panel plots the average annual growth rate of the employment share in the non-agriculture sector against the average annual growth rate of migration from rural areas to the 29 cities. The positive relationship implies most migrants from rural areas work in the non-agricultural sector in the cities. These two observations together are consistent with the idea that workers migrating from rural areas to cities most likely have to switch from agricultural to non-agricultural jobs. As such, cities offering more non-agricultural jobs

¹A typical view of the popular press can be found in “Property in China: Haunted Housing,” (*The Economist*, 11/16/2013). Wu, Gyourko, and Deng (2012) study empirically the possible presence of bubbles in China’s housing markets. Chen and Wen (2014) construct a model of bubbles to explain China’s housing price hike, focusing on the post-financial tsunami period (2007-2012). Our quantitative exercises study over a longer horizon from 1992 to 2008. To stretch our analysis to include the period of 2009-2012 would require modeling a major downturn shock together with a much tightened downpayment requirement.

can potentially attract more migrants, which in turn can lead to faster housing price growth rates.

One may perceive this migration flow as growth of the workforce in urban areas. Might a simple a back-of-the-envelope computation show how demographics together with the growth of productivity and the housing supply cause housing price growth? We show that this exercise can only account for about 1/3 of housing price growth in China. One may argue that structural transformation and migration fail to explain China's housing boom, and there is a possibility of bubbles. Yet, one has to be cautious about this argument because it ignores potentially important interactions between enhanced labor productivity, rural-urban migration, and the rise of urban housing markets. Therefore, a deep-structural model is needed to fully examine the influence of structural transformation on urban housing development

Specifically, we consider an economy that is geographically divided into two regions: a rural area that produces agricultural goods and an urban area (a city) that produces manufactured goods (inclusive of urban services in the remainder of the paper). Ongoing technological progress drives workers away from the rural agricultural sector to the urban manufacturing sector. When arriving in a city, workers must purchase a house with a down payment and a long-term mortgage. In the model, while a house is required for urban living, it has no resale value. Thus, by construction, we rule out the possibility of bubbles. New homes are built by real estate developers who purchase land and construction permits from the government.

Our basic framework considers only a single urban area and then it is generalized to multiple cities. This extension allows us to assess the contribution of different migration flows to changes in housing and land price growth rates across cities. More importantly, evaluating what contributed to the structural transformation of large cities further allows us to determine whether or not any portion of the appreciation in housing prices is supported by fundamentals.

To disentangle the contributions of various underlying forces (down payment constraints/mortgage financing, entry fees, land supply policy, and the productivity of the manufacturing sector), we calibrate the model to mimic the early stages of development in China from 1980 to 2010. The future projected path for China's structural transformation through 2100 is based on the U.S. experience from 1950 to 1990. We are particularly interested in China's transformation during the period 1998 to 2007. Before 1998, China's housing market was largely controlled by the government and housing prices were heavily regulated. After 2007, housing prices were affected by "hot money" inflows after many countries adopted loose monetary policy in response to the global financial tsunami and then by a series of housing market regulations implemented by the Chinese government.

The main findings can be summarized as follows. At the national level, the model suggests that the process of structural change accounts for more than 2/3 of the increase in housing prices and land prices. Productivity (income) is the main driver of this change, accounting for almost $\frac{1}{2}$ of the increases. While supply conditions (developer entry and land supply regulations) and access to

credit each account for about 1/4 of housing price movements, supply conditions alone account for almost 1/2 of land price movements.

In the multi-city case, the model is calibrated to match the migration flows to the two largest cities in China (Beijing and Shanghai). The model's performance improves substantially when looking at these two cities, accounting for 5/6 of housing price and 3/4 of land price movements. This finding suggests that market fundamentals driven by structural transformation remain a key driver of housing prices. For both cities, productivity growth and land supply continued to be important drivers of land prices, their relative contribution is smaller than for the country. At the micro level, an issue that is frequently brought up is the possibility of the burst of "ghost cities." It is noted, however, that this is not a wide spread phenomena and it refers to low-tier cities often overly built by the government. There is some speculation whether these cities may experience housing bubbles, but these are not representative of the major metropolitan areas in China.

In summary, by incorporating endogenous rural-urban migration decision, we find that the process of relocating workers to cities combined with the typical stages of economic development can account for a major portion of the housing boom in China.

Literature Review

Since 1978, the Chinese economy has undergone many political and economic reforms. 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 example, Chow (1993) analyzes the path of development of different sectors in the economy. Brandt, Hsieh, and Zhu (2008) further document the process of industrial transformation and the role played by institutions and barriers to factor allocation. Hsieh and Klenow (2009) highlight that the misallocation of capital and output distortions have resulted in sizeable loses in China's productivity. Song, Storesletten, and Zilibotti (2011) argue that the reduction in the distortions associated with state-owned enterprises may be responsible for the rapid economic growth starting in 1992. Zhu (2012) provides an extensive summary of the various stages of economic development in the Chinese economy, separating periods of factor accumulation from episodes of large increases in total factor productivity.

Aside from providing institutional details about China, this paper combines three different strands of literature: (i) structural transformation, (ii) surplus labor and rural-urban migration, and (iii) housing.²

The literature on structural transformation goes back to classic works including Rostow (1960) and Kuznets (1966). Recently, this literature has placed more emphasis on the use of dynamic

²The quantitative analysis incorporates some key institutional factors into the discussion of the role structural transformation and rural-urban migration play in housing markets. Yet, our methodology is within the dynamic macro framework, which is very different from the approach used in conventional institutional economics. This latter remotely related literature is therefore omitted.

general equilibrium models. For example, Laitner (2000) highlights savings as a key driver of modernization, whereas Hansen and Prescott (2001) and Ngai and Pissaridis (2007) emphasize the role different technology growth rates have played on the process of structural change. Gollin, Parente, and Rogerson (2002) note that advancement in agricultural productivity is essential for providing subsistence and hence reallocates labor toward the modern sector. Using a nonbalanced growth model, Kongsamut, Rebelo, and Xie (2003) illustrate that subsistence consumption of agricultural goods can lead to a downward trend in agricultural employment. With agricultural subsistence as an integral part of their model, Casselli and Coleman (2001) study structural transformation and regional convergence in the United States, while Duarte and Restuccia (2010) investigate structural transformation based on cross-country differences in labor productivity. Buera and Koboski (2009) examine whether sector-biased technological progress or non-homothetic preferences as a result of agricultural subsistence fit the data. Buera and Koboski (2012) further elaborate that scale technologies for mass production are important forces leading to industrialization. For a comprehensive survey, the reader is referred to Herrendorf, Rogerson, Valentinyi (2013).

The surplus labor literature starts with the pioneer work of Lewis (1954), Fei and Ranis (1961), and Sen (1966). This strand of research emphasizes the presence of rural surplus labor in many developing economies. Such surplus labor can yield important consequences for the urbanization process as well as for the performance of the entire economy. The presence of abundant labor in the rural area gives rise to rural-urban migration. In their pivotal work, Todaro (1969) and Harris and Todaro (1970) model the migration decision as a static trade-off between higher wages and possible unemployment in urban areas. Using a dynamic setup, Glomm (1992) studies rural-urban migration as a result of higher urban productivity due to agglomerative economies. More recently, Lucas (2004) highlights a dynamic driver of such migration, the accumulation of human capital and hence the ongoing rise in city wages. Bond, Riezman, and Wang (2013) show that trade liberalization in capital-intensive import-competing sectors can speed up such a migration process, leading to faster capital accumulation and economic growth.

In our analysis, the structural transformation of the manufacturing sector drives migration to the cities. 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).³ This formalization contrasts with a large literature on user cost models (e.g., Himmelberg, Mayer, and Sinai, 2005) and general equilibrium asset pricing models (e.g., Davis and Heathcote, 2005, and Kahn, 2010), where prices are determined by a representative individual that adjusts the quantity of housing consumed. From the housing supply perspective, our model emphasizes the role of government restrictions on the

³Focusing on the extensive margin allows separation of the contribution of structural transformation on the housing market from other considerations.

production of housing units. The case of China is consistent with the findings in the literature that emphasize the role of these artificial restrictions on determining housing prices (e.g., Saez, 2007, and Glaeser et al., 2005). Our multi-city model is consistent with the work of Gyouko et al. (2006), who argue that inelastically supplied land is a key driver of the phenomenon called “super cities.” By 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.; Burnside, Eichenbaum, and Rebelo, 2011; Landvoigt, Piazzesi, and Schneider, 2011; and Garriga, Manuelli, and Peralta-Alva, 2012.)

2 An Overview of Development in China

This section summarizes development in China by focusing on the processes of structural transformation and urbanization and their impact on the housing market. We begin by documenting some stylized facts and then discuss the importance of migration policies and the deregulation of housing markets.

2.1 Migration Policies

“The Third Session of the Eleventh Central Committee of the Party” in 1978 is widely believed to be the turning point in China’s path of development. After this meeting, 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 agriculture 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 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 agriculture 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 farm land mainly moved 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 agriculture 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 drastically improved the employment opportunities for rural workers. Cities grew as the mantra gradually changed to "leave both land and home." Meanwhile, instead of mainly moving 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 much as in the previous stage.

3. Highly active stage (1995-2000): Population movement in China became highly active beginning 1995. Over the 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 large 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 “temporarily 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 abolishing 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.

2.2 The Development of the Housing Market

After the 1978 Central Committee Party, 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 carried out various experiments to commercialize the existing urban public housing. The path of urban housing reforms can be divided into three stages, which each represent distinct housing policies:

1. Probation and experimentation stage (1978-1988): In April 1980, Deng Xiaoping made a speech announcing 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, with a focus 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 invest-

ment. 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 state-owned enterprises 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.

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 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 quasi-urban 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 reform (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 that did not qualify for these government programs had

to purchase or rent houses in the private market.

2.3 Structural Transformation, Urbanization, and Housing Prices

The Chinese economy has not completed the process of structural transformation and urbanization, as shown in Figure 2. The share of employment in the agriculture sector has declined dramatically, from almost 70 percent in 1980 to below 40 percent in 2008. An implication of this decline is that over the same period the agricultural share of output fell from 30 percent to 12 percent. In addition, the share of employment in the manufacturing sector increased from 25 percent to 39 percent. Moreover, the population has continued to flow from rural to urban areas. As shown in the right-hand panel, the fraction of the urban population in the total population increased from the low level of 30 percent in 1980 to 60 percent in 2008, and the annual level of migration from rural areas to urban areas has ranged from 0.2 percent to 3.2 percent, with a 1.5 percent average.

This process of structural transformation and urbanization naturally has an impact on housing demand and prices. Based on the 2000 Census, about 87 percent of Chinese households owned houses. For the two largest cities in China, the ownership rate was about 60 percent. While the ownership rates are likely distorted before 1998 due to public housing provided by the government, real estate data suggest that the ownership rates in Beijing and Shanghai have risen sharply over the past decade. According to the National Bureau of Statistics of China, the aggregate market value of residential housing reached nearly 3.85 trillion RMB in 2009, which is 100 times more than it was in 1992. Figure 3 shows the evolution of real housing prices per square meter in China for 1991 to 2010. In 2009, the average housing price was 4,459 RMB per square meter, compared with 996 RMB per square meter in 1992.

To link structural transformation and urbanization to city housing prices, consider a barebones setup with a representative agent allocating labor income to consumption of a composite good and investment in housing. Under time-additive preferences, one may easily derive the following no-arbitrage condition that governs the evolution of house prices q_t (see the Appendix for details):

$$q_t = R_t + \frac{q_{t+1}}{1 + r_{t+1}},$$

where r_{t+1} is the (implicit) rate of interest measured by the marginal rate of intertemporal substitution of composite goods and R_t represents the (implicit) rental price measured by the marginal rate of substitution between composite goods and housing services. The equation above essentially states the no-arbitrage condition between buying a house today and renting today/buying tomorrow. Let the (quantity of) housing stock grow at an exogenous rate, g_H , and the growth of labor income be decomposed into (exogenous) labor productivity growth, g_A , and (exogenous) urban population growth, g_N . With log-linear periodic utility, one can then manipulate the no-arbitrage equation to

obtain the following $q_{t+1}/q_t = (1 + g_A)(1 + g_N)/(1 + g_H)$, or, approximately,

$$\frac{q_{t+1} - q_t}{q_t} = g_A + g_N - g_H.$$

Over the period to 1992 to 2007, China’s net migration flow to the urban area grew on average 2.2 percent per year. Labor productivity growth in the urban area (relative to the rural area) can be best proxied by the growth of the urban-rural wage ratio, which was percent 2.9 percent per year. A conservative measure of housing stock growth is incremental residential land growth, which was 2.4 percent. Thus, based on the equation above, urban housing prices should have grown no more than 3 percent annually, which is far below the 8.6 percent shown in the data. That is, about 2/3 of housing price growth cannot be accounted for by this simple decomposition based on the barebones setup. Does this imply that structural transformation and migration fail to explain China’s housing boom, and hence there is a possibility of bubbles? The answer is “not necessarily.” The simple decomposition conducted above ignores potentially important interactions between labor productivity enhancement, rural-urban migration, and the rise of urban housing markets. To account for such interactions properly, a deep-structure model is needed, to which we now turn.

3 The Model

The benchmark economy is geographically divided into two regions: a rural area and a city. Later the model is extended to the case of multiple cities. There are two types of goods produced in the two separate regions: the rural area produces agricultural goods and the city produces manufactured goods. The agents are also classified into two categories: workers (agricultural or manufacturing) and housing developers. Agricultural workers live in the rural area and manufacturing workers live in the city. To switch from agricultural to manufacturing jobs, workers migrate to the city.

The mass of workers is normalized to 1. Workers are infinitely-lived and each period they inelastically provide 1 unit of labor. All workers are identical in performing production activities. The only heterogeneity among workers stems from the level of disutility from migrating from the rural area to the city. The utility cost, ϵ , follows a distribution function $F(\epsilon)$. Moving from the city back to rural area is assumed to be costless. The interest rate for mortgage loans, r^* , is positive and exogenously determined. This determination is consistent with the interest rates in China being primarily controlled by the government.

In the following, we detail the different roles that rural workers, city workers, migrants, the government and housing developers play. The competitive spatial equilibrium is analyzed, and then the model is extended to allow rural agents to migrate to multiple cities.

3.1 Rural Workers

Workers in the rural area are self-employed, residing in their farm houses and producing agricultural goods. A single unit of labor can produce A_t^f units of agricultural goods. Therefore if there are N_t^f workers in the rural area, the total supply of agricultural goods is

$$f_t = A_t^f N_t^f. \quad (1)$$

Given the agricultural goods price, p_t , the income level of a rural worker is thus $p_t A_t^f$.

A worker derives utility from consumption of manufactured and agricultural goods. The bundle (x_t^m, x_t^f) defines the amount of manufactured and agricultural goods consumed by rural workers. The recursive optimization problem for a rural worker in period t can be written as follows:

$$\begin{aligned} V_t^R(\epsilon) = \max u(x_t^f, x_t^m) + \beta \max\{V_{t+1}^R(\epsilon), V_{t+1}^M(\epsilon) - \epsilon\}, \\ \text{s.t.} \quad p_t x_t^f + x_t^m = p_t A_t^f, \end{aligned} \quad (2)$$

where $V_t^R(\epsilon)$ denotes the lifetime payoff for the rural worker in period t . The worker derives current utility level $u(x_t^f, x_t^m)$. In the next period, $t + 1$, he can choose either to stay in the rural area or move to the city. $V_{t+1}^M(\epsilon)$ represents the payoff for a rural worker with disutility level ϵ who moves to the city in period $t + 1$ after paying the mobility cost, ϵ , measured in terms of utility.

The population in the rural area is an equilibrium object and its determination is specified later. Since housing in the rural area is not relevant, we abstract from its formalization.

3.2 City Workers

Rural and city workers are assumed to share the same preference toward manufactured and agricultural goods. We assume that housing is a necessity for living in the city, but does not provide utility. City workers gain utility from consuming manufactured and agricultural goods only when owning at least 1 unit of housing; otherwise, their utility levels are set at negative infinity.⁴ Specifically, (c_t^m, c_t^f) denotes the amount of manufactured and agricultural goods consumed by city workers and h_t denotes the number of housing units they own. A city worker's instantaneous utility function takes the following form:

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

This utility function implies that each worker is satiated owning 1 unit of housing and does not benefit from owning more. In equilibrium, manufacturing workers demand 1 unit of house.

⁴Workers must purchase a house on arrival to the city. For simplicity, the possibility of renting a house or purchase one in the secondary market is not available. Otherwise, one would have to track distributions from renting and secondary market purchases, making the model intractable.

The optimization problem for workers who have already purchased a house in $\tau < t$ is

$$V_t^C(\epsilon, b_\tau) = \max U(c_t^m, c_t^f, h_t) + \beta \max\{V_{t+1}^C(\epsilon, b_\tau), V_{t+1}^R(\epsilon)\}, \quad (3)$$

$$s.t. \quad p_t c_t^f + c_t^m + b_\tau r^* = w_t^m.$$

Workers who have been in the city for more than 1 period, have two state variables: their utility cost from migration, ϵ , and mortgage debt from purchasing a house at time τ , b_τ . Here, $V_t^C(\epsilon, b_\tau)$ represents the lifetime payoff for a worker with disutility level ϵ and mortgage debt b_τ . The worker derives current utility $U(c_t^m, c_t^f, h_t)$, and discounts future payoffs at rate β by choosing between staying in the city, $V_{t+1}^C(\epsilon, b_\tau)$, or returning to the rural area, $V_{t+1}^R(\epsilon)$. The worker spends his wage income, w_t^m , on consumption of manufactured and agricultural goods and mortgage debt repayment, $b_\tau r^*$.

3.3 Migration Decisions

During the initial period τ when a rural worker moves to the city, he must purchase a house at price q_τ . A home purchase is financed with an infinite console fixed rate mortgage and requires a down payment, which is an exogenous fraction ϕ of the housing price in the moving period τ . In the following periods, the specified repayment is a constant d_τ . d_τ can be derived by equating the size of the loan to the present discounted value of all mortgage payments:

$$(1 - \phi)q_\tau h_\tau = \sum_{t=\tau+1}^{\infty} \frac{d_\tau}{(1 + r^*)^{t-\tau}}. \quad (4)$$

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

$$d_\tau = (1 - \phi)r^*q_\tau h_\tau. \quad (5)$$

The mortgage contract satisfies

$$\phi > \frac{r^*}{1 + r^*}.$$

This condition ensures that the down payment exceeds the mortgage payment each period. Notably, one may consider a city economy with all workers renting houses from absentee landlords who purchase them in advance to fill the demand. Maintaining the same housing demand structure, one may then capture this pure rental case by setting $\phi = r^*/(1 + r^*)$, under which an agent migrating in period τ signs a long-term rental agreement paying a rent d_τ every period based on the housing price.⁵ Thus, the pure rental market can be viewed as a special case of our model. As elaborated

⁵Similar to the case of resales, allowing for a one-period rental agreement would make the model intractable because a migrant's decision would then depend on the entire path of current and future housing prices (and hence migration flows).

in Section 4, abstracting from the rental market in this model gives a conservative prediction of the changes in housing and land prices.

The optimization problem of rural workers who move to the city in period τ is represented by

$$\begin{aligned} V_\tau^M(\epsilon) &= \max U(c_\tau^m, c_\tau^f, h_\tau) + \beta \max\{V_{t+1}^C(\epsilon, b_\tau), V_{t+1}^R(\epsilon)\}, \\ \text{s.t.} \quad &c_\tau^m + p_\tau c_\tau^f + q_\tau h_\tau = w_\tau^m + b_\tau, \\ &b_\tau \leq (1 - \phi)q_\tau h_\tau. \end{aligned} \tag{6}$$

The optimization problem is subject to a traditional budget constraint that the migration stage includes down payment, the purchase of goods, and a borrowing constraint associated with mortgage financing.⁶ In the Appendix, we prove that infinite console fixed rate mortgage has zero amortization and that, in the case of no reverse migration, the borrowing constraint must always be binding.⁷

Given the expressions for $V_\tau^M(\epsilon)$, $V_\tau^R(\epsilon)$, we can determine the conditions under which workers with mobility cost ϵ move into the city at time τ as follows:

$$V_\tau^M(\epsilon) - \epsilon \geq V_\tau^R(\epsilon). \tag{7}$$

Workers will migrate to the city if and only if the payoff from migration is greater than from staying in the rural area. There exists an ϵ_τ^* solves $V_\tau^M(\epsilon_\tau^*) - V_\tau^R(\epsilon_\tau^*) = \epsilon_\tau^*$ and determines the cutoff level of rural workers that migrate to the city in any given period. As productivity in the city increases, the pay-off associated with migration rises, and the cut-off for the migration decision shifts to the right of the distribution $F(\epsilon)$. As a result, those workers initially unwilling to move now decide to migrate.

At the aggregate level, the incremental flow of migrants from the previous period is represented by

$$\Delta F_\tau^*(\epsilon_\tau^*, \epsilon_{\tau-1}^*) = F(\epsilon_\tau^*) - F(\epsilon_{\tau-1}^*). \tag{8}$$

The flow of migrants is the key driver of housing and land prices in the model.

3.4 Manufacturing Sector

The manufactured goods market is perfectly competitive. For simplicity, labor is the only input needed abstracting from capital. In the quantitative analysis, increases in the capital-labor ratio

⁶We ignore the possibility that workers may default on the mortgage payment d_t . We can justify this argument by assuming workers are either perfectly committed or the punishment for default is severe. We do not exclude the possibility that a city worker may return to the rural area, but they would lose their down payment. Therefore, ideally, the situation that a relatively productive worker gives up his job in the city and returns to the rural area happens only when wages from working in the manufacturing sector are too low compared with those in the agriculture sector.

⁷When there is no reverse migration, the borrowing constraint will always be binding if the utility function is strictly increasing, weakly concave in the consumption component, and the discount factor satisfies $\beta \leq \frac{1}{1+r^*}$.

would be included in productivity growth. The production technology of the manufacturing sector is linear in labor:

$$Y_t^m = A_t^m N_t^m, \quad (9)$$

where A_t^m denotes the labor productivity in the manufacturing sector at period t . The employment level in the city is endogenous and depends on the disutility cutoff for migration decisions, that is; $N_t^m = F(\epsilon_t^*)$. The price of manufactured goods is normalized to 1, and the optimality conditions imply

$$w_t^m = A_t^m. \quad (10)$$

3.5 Government

Land is supplied by the government. Each period, the government determines the amount of land available for housing developers. The total land area in the city is normalized to 1. The government decides to add $\ell_t \geq 0$ units of land for building houses at time t . The aggregate law of motion for land is represented by,

$$L_t = \ell_t + L_{t-1}, \quad (11)$$

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

$$H_t = H_{t-1} + \Delta F_t^*, \quad (12)$$

where H_{t-1} represents the number of houses that the government has granted permission up to period t .

The government not only controls the supply of land, but also charges a fee, Ψ_t , in units of manufactured goods, to housing developers, which determines the number of permits granted:

$$\Psi_t = \psi H_{t-1}, \quad \psi > 0. \quad (13)$$

A larger number of permits granted in the past, H_{t-1} , implies a higher fixed construction fee. This assumption captures public concern about congestion and overcrowding in cities.

3.6 Housing Developers

Each housing developer is endowed with technology to convert land into houses. The production function takes a simple form as follows:

$$h_t = A_t^h z_t^\alpha, \quad 0 < \alpha < 1. \quad (14)$$

The presence of decreasing returns to scale is necessary to allow for a developer to cover the fixed cost incurred from paying for a permit. Each housing developer is assumed to live for only one period and is replaced by an identical agent. This assumption, based on convenience, eliminates the complication of managing inventories of land. An incumbent developer needs to decide how much land to buy in order to maximizing the operative profit Π_t^d . Upon receiving revenue from selling houses, the developer must pay a fixed cost to the government.

A representative incumbent housing developer's optimization problem is characterized as follows:

$$\Pi_t^d = \max_{z_t} q_t A_t^h z_t^\alpha - v_t z_t, \quad (15)$$

where q_t represents the price a housing developer can sell the house for at the end of period t , and v_t is the land price that a housing developer must pay to the government.

We assume each period there are many housing developers. The equilibrium entry level of housing developers, M_t , is pinned down by the following free-entry condition:

$$\Pi_t^d = \Psi_t. \quad (16)$$

3.7 Competitive Spatial Equilibrium

Next, we formalize the definition of equilibrium in our two-region benchmark economy with a rural area and a city.

Equilibrium: Given the government policy parameters $\{\ell_t, \psi\}_{t=0}^\infty$ and the initial city housing stock H_0 , an equilibrium is a list of prices $\{p_t, q_t, w_t^m, v_t\}_{t=0}^\infty$, a list of individual $\{z_t, x_t^f, x_t^m, c_t^f, c_t^m\}_{t=0}^\infty$ and aggregate quantities $\{N_t^m, N_t^f, M_t, z_t, T_t\}_{t=0}^\infty$; and a migration cutoff value $\{\epsilon_t^*\}_{t=0}^\infty$ with the following properties:

1. Given the price sequence, workers maximize their lifetime utility and housing developers maximize their current-period profit.
2. The cutoff of the mobility cost, ϵ_t^* , is determined by

$$V_t^M(\epsilon_t^*) - \epsilon_t^* = V_t^R(\epsilon_t^*). \quad (17)$$

3. The number of housing developers is determined by the free-entry condition:

$$\Pi_t^d = \Psi_t. \quad (18)$$

4. The land market clears:

$$M_t z_t = \ell_t. \quad (19)$$

5. The housing market clears:

$$M_t A_t^h z_t^\alpha = \Delta F_t^*. \quad (20)$$

6. The manufactured goods market clears:

$$\int_0^{\epsilon_t^*} c_t^m(\epsilon) dF + x_t^m (1 - F(\epsilon_t^*)) + r^* \left[F(\epsilon_0^*) b_0 + \sum_{\tau=1}^{t-1} (F(\epsilon_t^*) - F(\epsilon_{t-1}^*)) b_\tau \right] + M_t \Psi_t = A_t^m F(\epsilon_t^*). \quad (21)$$

7. The agricultural goods market clears:

$$\int_0^{\epsilon_t^*} c_t^f(\epsilon) dF + x_t^f [1 - F(\epsilon_t^*)] = A_t^f (1 - F(\epsilon_t^*)). \quad (22)$$

Notice that, for the mortgage interest payment, the aggregation is over different cohorts based on their arrival to the city, τ .⁸ This information is necessary since the mortgage payment can be different across workers in the city. The equilibrium housing and land prices are given by

$$q_t = \frac{\Psi_t}{(1 - \alpha) A_t^h} \left[\frac{F(\epsilon_t^*) - F(\epsilon_{t-1}^*)}{A_t^h \ell_t} \right]^{\frac{\alpha}{1-\alpha}}, \quad (23)$$

$$v_t = \frac{\alpha [F(\epsilon_t^*) - F(\epsilon_{t-1}^*)]}{\ell_t} q_t. \quad (24)$$

Equations (23) and (24) indicate housing and land prices depend positively on the size of endogenous migration flows and construction fees but negatively on the availability of land. Migration flows are in turn, driven by productivity growth in the city and access to mortgage financing.

As we have discussed Section 2.3, the simple barebone setup would ignore potentially important interactions between labor productivity enhancement, rural-urban migration, and the rise of urban housing markets. For similar reasons, the reader should not decompose expressions (23) and (24) directly. Notably, there may be potentially sizable covariances between productivity, migration and housing supply via their interactive effects on migration stock (i.e., $F(\epsilon_{t-1}^*)$ via Ψ_t) and migration flow ($F(\epsilon_t^*) - F(\epsilon_{t-1}^*)$), where $F(\epsilon_t^*)$ and $F(\epsilon_{t-1}^*)$ are solved in dynamic competitive equilibrium; moreover, the coefficients associated with variances also involve endogenous variables.

Specifically, using the specification of Ψ_t , we rewrite (23) as:

$$q_t = \frac{\psi F(\epsilon_{t-1}^*)}{(1 - \alpha) A_t^h} \left[\frac{F(\epsilon_t^*) - F(\epsilon_{t-1}^*)}{A_t^h \ell_t} \right]^{\frac{\alpha}{1-\alpha}}$$

where ϵ_t^* solves the locational no-arbitrage (mobility) condition,

$$V_t^M(\epsilon_t^*; \{q_j\}_{j=t}^\infty) - \epsilon_t^* = V_t^R(\epsilon_t^*)$$

Note that both $V_t^M(\epsilon_t^*; \{q_j\}_{j=t}^\infty)$ and $V_t^R(\epsilon_t^*)$ depend on the sequences of relative productivity of manufacturing to agricultural production ($\{A_j^m\}_{j=t}^\infty$) and relative prices ($\{q_j, p_j\}_{j=t}^\infty$), the current flow of land supply (ℓ_t), as well as the downpayment requirement at any hypothetical time of purchase τ (ϕq_τ). Thus, (23) cannot be simply used to log-linearize, because it is a fixed point relationship with the RHS depending on q_t as well. Variance decomposition based on simple log-linearization of the reduced form can be significantly biased.

⁸Such aggregation would have been much more complicated with rental or secondary market purchases.

3.8 The Case with Multiple Cities

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

In the interest of tractability, city selection is determined by lottery. The probability that a rural worker will be assigned to city i is denoted by π_i , where $\sum_{i=1}^I \pi_i = 1$. The city labor markets are segmented because labor mobility across cities is not permitted.⁹ As a result, in equilibrium, wages across cities do not equalize. As such, once a rural worker is assigned to city i , his location choice afterward is to either continue to stay in city i or move back to the rural area.

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

$$\begin{aligned} V_{i,t}^M(\epsilon) &= \max U(c_{i,t}^m, c_{i,t}^f, h_{i,t}) + \beta \max\{V_{i,t+1}^C(\epsilon, b_{i,t}), V_{t+1}^R(\epsilon)\}, \\ \text{s.t.} \quad &c_{i,t}^m + p_t c_{i,t}^f + q_{i,t} h_{i,t} = w_{i,t}^m + b_{i,t}, \\ &b_{i,t} \leq (1 - \phi) q_{i,t} h_{i,t}. \end{aligned}$$

This problem is similar to the one for the single-city model, but in this case wages and housing prices are determined at the city level. The ex-ante value associated with migration is represented by $V_t^M(\epsilon)$, which equals the expected payoff from living in any one of the I cities,

$$V_t^M(\epsilon) = \sum_i \pi_i V_{i,t}^M(\epsilon).$$

Therefore, a worker of type ϵ will migrate to an urban area in period t if and only if the following holds:

$$V_t^M(\epsilon) - \epsilon \geq V_t^R(\epsilon).$$

In each period $t > 0$, there exists a cut-off ϵ_t^* , below which workers move to an urban area. The threshold ϵ_t^* can be pinned down from the following indifference condition:

$$V_t^M(\epsilon_t^*) - \epsilon_t^* = V_t^R(\epsilon_t^*).$$

Housing developers in each city are endowed with the same technology to convert land into houses. The entry fee collected by the government in each city will obey these rules, so the entry

⁹Based on city total migration flows over the sample period 1998-2008, we calculated net migration flows from Beijing to other cities (including Shanghai) and from Shanghai to other cities (including Beijing) and found them within ± 4 percent. Thus, ignoring the city-to-city migration does not seem to be at odd with the evidence.

fee collected by city i in period t positively depends on the existing housing stock in city i : $\Psi_{i,t} = \psi H_{i,t-1}$, where $\psi > 0$. Therefore, the number of housing developers in each city, $M_{i,t}$, will be determined by the following free-entry condition:

$$\Pi_{i,t}^d = \Psi_{i,t}.$$

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

$$\begin{aligned} M_{i,t} z_{i,t} &= \ell_{i,t}, \\ M_{i,t} A_{i,t}^h z_{i,t}^\alpha &= \Delta F_{i,t}^*. \end{aligned}$$

Similar to the previous analysis, housing prices and land prices can be explicitly solved as follows:

$$\begin{aligned} q_{i,t} &= \frac{\psi F(\epsilon_{t-1}^*) \pi_i}{(1-\alpha) A_{i,t}^h} \left[\frac{[F(\epsilon_t^*) - F(\epsilon_{t-1}^*)] \pi_i}{A_{i,t}^h \ell_{i,t}} \right]^{\frac{\alpha}{1-\alpha}}, \\ v_{i,t} &= \frac{\alpha [F(\epsilon_t^*) - F(\epsilon_{t-1}^*)] \pi_i}{\ell_{i,t}} q_{i,t}. \end{aligned}$$

Since manufactured goods are mobile, their markets should clear at the national level.

4 Quantitative Analysis

The objective of the quantitative analysis is to evaluate the role of structural transformation in China's housing boom. To that end, we first apply the U.S. experience to project the path along which China might complete its structural change; we then calibrate the model so that the simulated economy can mimic some stylized facts about the early stages of development in China. We compare the model's prediction with the data to assess how much housing price growth can be rationalized by the model. We also perform some counter-factual exercises to explore the roles of financial frictions and land policy in housing price growth. Finally, we extend the quantitative analysis to the multi-city case, which allows us to evaluate for various cities the different contributions structural change might make to housing price growth.

4.1 Projection of the Chinese Population and Land Distribution

In 1840 in the United States, almost 90 percent of the total population lived in rural areas. This percentage steadily declined to about 3 percent in 1990 and has remained at about 3 percent since. Because the fraction of the population living in rural areas is a main indicator of the progress of structural transformation, the United States is viewed as having completed its structural transformation by 1990. In 2010, almost half of China's population still lived in rural areas. To project the

path along which China will complete its structural change, we project from the U.S. experience. Our algorithm is simply as follows: In 1980 in China, the fraction of the population living in rural areas was nearly 70 percent, and in 1870 in the United States it was nearly the same level. It took the United States 120 years (from 1870 to 1990) to complete its structural transformation. The quantitative experiment assumes that the process of structural change in China will be completed in 2100 (from 1980 to 2100).¹⁰

As shown in Figure 4, based on currently available data for China, the fraction of the rural population and the ratio of residential land area to total urban land area are extrapolated to 2100. In the long-run, the fraction of rural workers is projected to remain at 8 percent. In terms of land use, with 9,600,000 square kilometers in China, about 183,618 square kilometers is currently urban area. The ratio of residential land to total urban land area shown in the figure is based on China maintaining the current ratio

4.2 Calibration of the Chinese Economy

Because of the role of structural transformation in the model, capturing the change in expenditure patterns from agricultural to manufactured goods is key. A simple way to rationalize this is to assume that the utility function takes the CES form

$$u(c_t^m, c_t^f) = [\theta(c_t^m)^\rho + (1 - \theta)(c_t^f)^\rho]^{\frac{1}{\rho}},$$

where the elasticity of substitution between the two goods is $1/(1 - \rho)$:

A worker's disutility level from migration is assumed to follow a Pareto distribution with the support on interval $[1, \infty)$:

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

Each period in the model corresponds to one year, the subjective discount rate, β , is set at 0.95, and the annual interest rate, r^* , is set at 4 percent. The down payment ratio ϕ , the fraction of the house value that the worker must pay in advance, is set at 0.3. We will perform sensitivity analyses in later sections with respect to different types of distribution functions, interest rates, and down payment ratios to check the robustness of our results. We normalize productivity in the agriculture sector A_t^f to 1. We further assume that housing productivity A_t^h is constant over time. Since A^h matters only for the unit of housing prices, by having housing prices expressed as an index, the value of A^h is immediately pinned down. Table 1 summarizes the set of predetermined parameters.

¹⁰Note that there may be more optimistic projections on the progress of structural transformation in China, with a much faster transition speed for China than the United States. The conjecture above is provided as a starting point. As robustness check, we have performed various exercises with more optimistic and pessimistic projected paths. The results have a minor impact on the simulated dynamics of housing prices between 1992 and 2007.

The remaining set of parameters $\{\theta, \rho, \alpha, \psi, \lambda, l_t, H_{-1}, A_t^m\}$ are calibrated to match stylized facts from the early-development stage of China from 1980 to 2010 and set to match seven targets: (i) the fraction of workers in the city, (ii) the decline in the relative price of manufactured goods to agricultural goods, (iii) the decline in the share of expenditures on agricultural goods, (iv) the ratio of disutility to the lifetime payoff from living in the city, (v) the value of the share of urban land used for housing, (vi) the ratio of the entry fee to housing-developer sales revenue, and (vii) the initial housing price level normalized to 1. Given the projected population distribution between rural and urban areas, the computation algorithm is briefly described as follows: According to the definition of the steady-state equilibrium, both relative productivity in the manufacturing sector and population distribution will remain constant in the steady state.

Parameters (θ, ρ) govern workers' preferences toward agricultural and manufactured goods. The parameter θ is chosen to match the rate of decline in the relative price of manufactured goods to agricultural goods in China from 1980 to 2010. The elasticity of substitution parameter, ρ , is picked to match the average speed of decline in the share of expenditures for agricultural goods. The parameter α measures the returns-to-scale for housing developers and is obtained by matching the ratio of land value to house value.

Figure 5 shows the migration flows the fraction of rural migrants in the urban population over the period 1981 to 2009. During these three decades, the fraction increased an average of about 1.5 percent per year. This sizeable flow increased the fraction of rural migrants in the urban population from an initial low level of 30 percent in 1980 to over 60 percent in 2010.

The relative manufacturing productivity $\{A_t^m\}_{t=1981}^{2009}$ is computed to match the migrant fraction of the urban population.¹¹ The terminal condition imposed on the long-run level of productivity, A_{2100}^m , is the hypothetical steady-state set to match the U.S. level of urbanization in 120 periods.¹² Figure 6 shows the dynamic path of the relative productivity of the manufacturing sector. More explicitly, the price of agricultural goods, p_t , can be solved as a function of relative manufacturing productivity, A_t^m , from the market-clearing condition for agricultural goods. Each A_t^m then can be pinned down from the indifference condition in each period. Figure 6 summarizes the implied path of productivity for the period 1981 to 2009. The implied sequence for $\{A_t^m\}_{t=1981}^{2009}$ increases from 4.59 to 11.77, showing that labor productivity in the manufacturing sector remains higher than in the agriculture sector.

Once the productivity parameters are determined, the values for λ , ψ , and H_{-1} can then be solved. Specifically, the parameter ψ is calibrated so that the ratio of the entry fee to housing-developer sales revenue is 0.1, whereas λ is computed as the average migration costs equal to 10

¹¹One may instead target a smoothed series of net migration flows, for example, adjusting by a 5-year moving average. We did this and our main results remained robust.

¹²We explored the sensitivity of the results to different but plausible time horizons of convergence (e.g., 60 years), and the main quantitative results of the paper remained valid.

percent of the value of living in the city. The entry fee, H_{-1} , is derived by normalizing the initial housing price to 1. The calibration results are reported in Table 2.

4.3 Quantitative Results: National Benchmark

The main quantitative analysis focuses on the model's ability to generate movements in housing and land prices. The model generates yearly predictions for the variables that can then be compared with the data. The evaluation of the model's performance is based on average growth rates and their average variations.

The results for the period 1992 to 2007 are reported in Table 3. The model is consistent with the observed growth rate for housing and land prices. In the model, an important driver of housing prices is the wage gap between urban and rural areas. The gap is about 3 percent per year in the data and about 2 percent per year in the model. This result is not surprising because the model abstracts from skill differentiation, with wages of skilled urban workers growing faster than those of unskilled urban workers. The model predicts the trends in the evolution of housing and land prices well. Figure 7 shows the model's performance along the entire dynamic path, with the initial values of each series normalized to 1. In this case, the predictive power of the model is reduced: The time series generated by the model has gaps relative to the actual data. The average predictions for housing and land prices and the wage gap are summarized in the bottom panel of Table 3. The model predicts about 67.1 percent of housing price movements, 68.4 percent of land price movements, and 87.3 percent of the wage gap. Overall, fundamental factors, such as structural transformation and supply restrictions, indeed account for more than 2/3 of the movements in housing and land prices. The relatively low growth in the wage gap in the model together with other missing factors are responsible for the underprediction of housing and land prices.

A deeper look at Figure 7 suggests that housing prices behave differently over the three sub-periods. In the period 1992 to 1996, housing prices grew fast, with an average annual growth rate of 9.4 percent. During this period, the housing market was still highly regulated and controlled by the government but qualified rural labor was allowed to move to the city. The cost of construction and city wages were still relatively low. For this sub-period, the model captures 70.9 percent of the growth in housing prices. The period 1997 to 2002 was characterized by a significant slowdown in housing prices, with an average annual growth rate of 3.2 percent. This finding is consistent with the Asian financial crisis in 1997, the layoff of State Owned Enterprises (SOE) employees over 1999-2002, and the burst of the dot-com bubble in 2001. Because we do not explicitly model the SOE layoffs, the model captures only 65.6 percent of housing price movements. In the third period, 2003 to 2007, housing price skyrocket, with an average annual growth rate of 15.1 percent. This finding is consistent with fast economic growth and further deregulation of migration policy and the financial sector in conjunction with the government's reduced control of urban land and housing

permits. For this subperiod, the model captures housing price movements from 2004 forward and explains only 65.1 percent of this movement because of underprediction carried from the previous subperiod.

In the data, the pattern of land price movements is somewhat different from that of housing price movements. Land prices grew dramatically from 1998 to 2005, with an annual average growth rate of 23.3 percent due to the marketization of housing. From 2005 to 2007, they significantly slowed down to an average annual growth rate of 5.4 percent. A large fraction of local governments' fiscal revenue comes from land sales. As a result, local governments tend to sell land for as high price as possible given the limited supply. To prevent this, the Chinese government implemented a series of policies, including the "Law of the People's Republic of China on Land Contract in Rural Areas" enacted on August 29, 2002. This law eventually slowed down the growth of land prices. In the model, the predictive power for the first subperiod is higher than for the second subperiod (71.9 percent vs. 65.6 percent). This fact could indicate the decreasing importance of land supply restrictions in the later part of the sample.

Remark: It is informative to consider the case of pure rental market, recalibrating the model by setting $\phi = r^*/(1 + r^*) = 3.85\%$. In this case, workers are indifferent to owning or renting. With no down payment requirement, it is easier for rural workers to migrate into the city. Our quantitative results suggest that the effects from this increased migration flow dominate the general equilibrium effects, resulting in the model predicting higher housing and land prices. In this case, the model accounts for 87.0 percent of the movement in housing prices and 72.3 percent of the movement in land prices. With tenant choices, the model's predictive power would be somewhere between the benchmark case and the pure rental case. Thus, one may conclude that our benchmark model provides a conservative prediction of the changes in housing and land prices.

The model can be used to understand the relative importance of the different driving forces of housing prices and land prices over the sample period 1992-2007. To do this, we decompose the contributions of the various factors (the down payment constraint, entry fee, land supply policy, and productivity of the manufacturing sector) relative to the benchmark model. This decomposition maintains the calibrated parameters of the benchmark values and changes one factor at a time. More specifically, the decomposition considers the following counterfactuals for each factor:

- **Entry fee:** The magnitude of the entry fee paid by land developers depends positively on the current city population. A higher value of ψ implies a higher entry fee and fewer developers. The benchmark value in the calibration is 3. In the counterfactual analysis, the value of ψ_t varies each period so that government revenue remains constant to its level in the initial period 0. When the population of the city grows, the computed value of ψ_t decreases over time, inducing the entry of housing developers and increasing housing production. In

equilibrium, more houses lead to lower housing prices and a higher level of migrants. By comparing the counterfactual price with the benchmark price, it is possible to compute the relative contribution of the entry fee. Similar exercises are conducted for land prices and migration flows. In the counterfactual exercise, the average growth rate of housing prices is 7.0 percent versus 8.6 percent for the benchmark case, and the average fraction of migrants in the city is 43.0 percent versus 41.5 percent.

- **Land supply:** In the counterfactual experiment, the flow of land supplied by the government to the market is fixed at the initial high level, $\ell_t = \ell_0$, for all t . The relative increase in land supply generates an upward shift in the housing supply, leading to a decrease in housing prices and an increase the number of migrants. In this case, the average annual growth rate of housing prices is 7.6 percent and the annual average fraction of migrants in the city population is 42.7 percent.
- **Mortgages financing (down payment constraint):** The counterfactual considers no mortgage financing, $\phi = 1$, instead of the benchmark value of 0.3. The elimination of mortgage financing should drive down housing demand and hence, housing prices. In this exercise, the annualized growth in housing prices and the average fraction of migrants in the city population are lower than in the benchmark, with values of 5.8 percent and 39.4 percent, respectively.
- **Productivity:** Productivity acts as the residual in the decomposition exercise. That is, within our framework, in the absence of other variations, beyond the above-mentioned factors, productivity growth explains the remaining portions of the increases in housing prices and the average fraction of migrants in the city population.

The results of the decomposition are summarized in Table 4, which shows by time period the percentage increases in housing prices, land prices, and the migrant population due to each single factor. For example, in the case of land supply controls, the decomposition compares the benchmark with an economy that has the same increased availability of land as in the initial years (1992-1997). The increased availability of land leads to a decrease in housing prices and an increase in the migrant population in the city. The data for the period 1992 to 2007 reveal the following: Tightening land supply policy in the benchmark case contributes to 11.7 percent of housing price growth and -10.8 percent of migration growth.

Overall, the model suggests that productivity is the most important factor for increases in both housing prices and migration, averaging of 46.1 percent for house prices and 114.3 percent for migration. Land supply policy and productivity are both crucial for understanding land price movements, averaging 32.4 percent and 46.3 percent, respectively. While access to mortgage financing explains about 1/4 of the increase in housing prices, its contributions to increases in land prices and migration are modest, averaging 6 percent and 10 percent, respectively. Finally, the contributions of the

entry fee and land supply—the two developer entry restrictions—each average below 20 percent in absolute value for each of the three indicators.

The data for the third subperiod (1997-2002) reveal the following: The two supply factors (the developer entry fee and land supply policy) become more important for housing prices because of tightened regulations. In addition, access to mortgage financing becomes more important because homes become extremely expensive in this subperiod.

For the full sample period, land supply and productivity together account for more than 75 percent of land price movements, but the relative contribution of productivity becomes more important in the third subperiod. The model suggests that the two supply factors have increasing importance for migration flows over time. In the third subperiod, their contributions accounts for only 45 percent of the increase in migration, so they discourage migration. Yet, their negative influence on migration is outweighed by productivity growth.

4.4 Quantitative Results: Multiple-City Model

One may question whether structural transformation can still explain the rapid growth of housing prices in large cities. This section explores the contribution of urbanization to the dynamics of housing and land prices at the city level. Although the size of migration flows could be responsible for the rapid increase in housing prices in many of the cities in China, other factors (i.e., different housing supply restrictions and land regulations) could also be important. For better illustration, the analysis is restricted to the two largest cities in China: Beijing and Shanghai. These two cities account for 6.5 percent of the entire urban population in 2011. Figure 8 compares the population growth trends of these two cities with that for the national level. The population of each city grew at a 3 percent annual rate, which was higher than the national rate.¹³ In contrast, the rural population declined at a 1.67 percent annual rate.

As shown in Figure 9, rapid population growth naturally led to housing booms in these two major cities with housing prices growing above the national average. Housing prices in Beijing had an initial period of rapid growth in the late 1990s, but remained stable until 2005; in contrast, housing prices in Shanghai grew continuously, with a more rapid trend starting in 2004. Land prices grew at comparable and faster rates across the two cities, after 2005.

The multi-city model has to be consistent not only with the rural-urban migration but also with the change in city population. The quantitative analysis maintains the values of the preference and technology parameters of the single-city model with these exceptions: the exogenous probability of migrating to city i from the rural area, π_i ; the relative manufacturing productivity in city i , $\{A_{i,t}\}$; and the total residential land area in city i , $\{L_{i,t}\}$. When there are $I > 1$ cities in the urban

¹³The only city with faster population growth than Beijing and Shanghai is Shenzhen, but the size of the city is substantially smaller.

area, the share of the population in city i , $n_{i,t}$, is denoted as follows, where $N_{i,t}$ denotes the total population in city i and N_t^R denotes the total population in the rural area:

$$n_{i,t} = \frac{N_{i,t}}{\sum_{i=1}^I N_{i,t} + N_t^R}.$$

When total population is normalized to 1, the growth rate of $n_{i,t}$ can be shown to be equivalent to the growth rate of $N_{i,t}$:

$$\frac{\Delta N_{i,t}}{N_{i,t}} = \frac{\Delta n_{i,t}}{n_{i,t}}.$$

Since each period a fraction π_i of migrants moves to city i it is implied that

$$\Delta N_{i,t} = -\pi_i N_t^R.$$

Therefore, the growth rate of $n_{i,t}$ can be represented as follows:

$$\frac{\Delta n_{i,t}}{n_{i,t}} = \frac{\Delta N_{i,t}}{N_{i,t}} = -\pi_i \frac{\Delta N_t^R}{N_t^R} \frac{N_t^R}{N_{i,t}}. \quad (25)$$

The rule for assigning migrants to a particular city π_i can be estimated from the equation above. The change in the fraction of migrants in the populations of Beijing and Shanghai between 1994 and 2011 was 52.75 percent and 45.65 percent, respectively.¹⁴ Therefore, using equation (25), for that period the fractions of migrants flowing to Beijing and Shanghai are 3.4 and 3.9 percent, respectively.

In 1994, 1.03 percent and 1.17 percent of the total population of China lived in Beijing and Shanghai, respectively; 26.8 percent lived in other cities, and 71.0 percent lived in rural areas. Given the values of $\{n_{B,0}, n_{S,0}, \pi_B, \pi_S\}$, it is straightforward to calculate the sequences of $\{n_{B,t}\}$ and $\{n_{S,t}\}$ from $n_{i,t+1} = n_{i,t} + \pi_i(n_t^R - n_{t+1}^R), i \in \{B, S, O\}$.

To complete the calibration of the multi-city model it is necessary to determine the land supply and the entry fee in each city. The total land area is 164,100 square kilometers in Beijing and 82,400 in Shanghai. Residential land is calculated as a fraction of the total land area in each city. From 1998-2007, residential land represented 20 percent in Beijing and 22 percent in Shanghai. In each city, an entry fee is collected by the local government. Similar to the single-city case, we assume the initial population in each city migrated from the rural area many periods ago and the initial entry fee for the housing developers in each city is the same as in the single-city case and equals ϕH_{-1} .

Figure 10 compares the evolution of total population growth in Beijing and Shanghai and the model with the data for the period 1998 to 2010. The model is designed to target the imputed data based on the average value of π_i . The model's implied growth rate of the two populations is similar to the data.

¹⁴We use a longer span of data to capture the long-run trend by mitigating large fluctuations in migration flows from events such as the SOE layoffs and the SARS epidemic (discussed below).

The flow of migration is combined with supply factors to generate a sequence of housing and land prices for each city for the period 1998-2008. As shown in Table 5, the model captures quite well the average growth in prices across the two cities, except for housing prices in Beijing during 2002 to 2004. For Beijing, the model accounts for 84.4 percent of the increase in housing prices and 75.4 percent of the increase in land prices. For Shanghai, the model accounts for 86.0 percent and 74.4 percent, respectively.

Figure 11 compares the dynamic evolution of predicted housing and land prices in the model with the data for the period 1998-2007. To understand the patterns in the data it is useful to decompose the sample into three subperiods:

- **1998-2001:** During this period the economy was affected by the financial crises in Asia and the burst of the dot-com bubble. During these years, China had high levels of unemployment, especially for SOE workers. The gradual but deepening economic reform encouraged more and more private enterprises to enter the market. Beijing, the capital of China, was the headquarters for many SOE, thus more workers were laid off in Beijing than in Shanghai.
- **2002-2004:** The spread of the SARS virus affected Beijing more severely in 2002 than it did Shanghai in 2003 and reduced migration to Beijing.
- **2005-2007:** This period was characterized by rapid growth leading up to the Olympic Games in Beijing. The sample stops before the worldwide financial crisis that impacted China and other developed economies.

The model captures a “flying geese” pattern of city development. As an early starter, Beijing has passed over more and more industrial production to Shanghai and hence, the latter has attracted a larger labor force. This fact explains why housing prices in Beijing were higher than in Shanghai in the subperiod 1998-2001. Across the two cities and the three subperiods, the model performs quite well except for Beijing in the second subperiod. As mentioned, the spread of the SARS virus significantly reduced migration to Beijing. Since in the model housing prices are critically driven by migration, the model predicts a much larger decline in housing prices than found in the data. This underprediction is also responsible for the relatively low average growth rate of housing prices.

Historically, Beijing and Shanghai have been the main industrialized cities in China. Ever since the implementation of reform and open policy in China, these cities have received the most rural migrants. The fact that the model can explain a sizeable fraction of housing price growth in both cities affirms the idea that structural change plays a crucial role in housing price growth in industrialized cities.

In the model, both cities have similar migration flows. The main differences in price dynamics have to be the result of institutional differences operating through the supply factors. To assess the

relative importance of all factors, but in particular on the supply side, we decompose the relative contribution of each factors for the full sample by subperiods, as shown in Table 6.

For both cities, productivity growth is the most important driver of the increase in housing prices, accounting for an average of 53.3 percent in Beijing and 57.1 percent in Shanghai. These numbers are higher than that for the nation reported in the single-city model. The analysis at the city level seems to indicate that the agglomerations could be very important drivers of housing prices. For land prices, both land supply and productivity are important. Together these factors account for more than 70 percent of the increase in housing prices in each city, which is lower than in the national decomposition. This lower impact on housing prices is mainly due to the larger impact access to mortgage financing has on land prices in the cities.

The contribution of productivity across cities is comparable in the second and third subperiods. In the initial subperiod, the relatively higher income growth in Shanghai drives the variation in housing prices across the two cities. The relatively low productivity in Beijing captures the low growth in employment and migration due to the layoff of SOE workers. Even though the relative contribution of productivity in the two cities is comparable in the second subperiod, it is important to note the stagnation of housing prices in Beijing due to a productivity slow down. Again, the impact of the SARS virus is captured by low migration flows and hence, low income growth (productivity).

The two supply factors (the entry fee and land supply policy) become more important over time for explaining housing price movements. By the third subperiod, these factors combined accounted for 42 percent and 48 percent of the growth in housing prices in Beijing and Shanghai, respectively. Consequently, the role of productivity declined in the later part of the sample, from 54 percent to 45 percent in Beijing and from 71 percent to 42 percent in Shanghai. This finding suggests that productivity alone cannot account for the rapid increase in housing prices since 2004. The regulation of housing developments through fees and land supply also play an important role.

In the case of land prices, the supply factors become more important in Beijing, accounting for about 60 percent of land price movements in the last two subperiods. For Shanghai, their contribution is smaller, accounting for 45 percent. Over the full sample period, productivity plays reverse roles on land prices in the two cities. In Beijing, its contribution decreased from almost 50 percent to 23 percent, whereas in Shanghai it increased from 25 percent to 50 percent. This difference is due to the fact that more land was available in Shanghai than Beijing and the manufacturing sector was relatively more important in Shanghai than in Beijing in the third subperiod.

The quantitative findings indicate that the process of structural transformation can be an important driver of housing and land prices, not only at the national level but also for large cities such as Beijing and Shanghai.

5 Conclusions

This paper uses a dynamic general equilibrium framework to investigate the role structural transformation played in the rapid growth of housing and land prices in China. The benchmark economy incorporates three major channels: (i) structural transformation, the increased productivity of the manufacturing sector that leads to higher income and greater ability to pay, (ii) the relatively inelastic supply of housing due to incremental city land released by the government and the controlled entry of real estate developers through entry fees, and (iii) urbanization, ongoing rural-urban migration that increases demand for urban housing. The quantitative findings suggest that the process of structural transformation and the resulting urbanization are important drivers of housing and land price movements in China, together accounting for 67.1 percent of housing price and 68.4 percent of land price movements over the period 1992 to 2007. The model performance improves substantially for Beijing and Shanghai, suggesting that market fundamentals captured by structural transformation and the resulting rural-urban migration remain sizeable drivers of housing prices between 1998 and 2007.

What are the important implications for policy derived from this research? One is that China's housing prices do not seem to be at odds with market fundamentals, contrary to the beliefs of the majority of economic commentators. This does not necessarily imply that certain markets could not have prices deviating from fundamentals. Nonetheless, if China's urban housing boom is a concern, then our results suggest that for large cities, if the desire is to slow down growth of housing prices, supply policies will be more important than mortgage loan restriction. At the national level, the analysis implicitly includes smaller cities. For this case, where wage growth can be characterized as low or moderate, financial policies can be as important as supply regulations.

In our model economy, for tractability we neglected some potentially important margins, which may be explored in the future. The first, and perhaps the most important, extension would be to allow housing as a store of value and thus households' speculative behavior. In doing so, we can compare directly the fundamental and the potential bubble components. Moreover, we may extend the benchmark economy to include rural saving (for better modelling of the downpayment constraint), nonhomotheticity in the utility of agricultural consumption (for better accounting for the income effects in structural transformation) and dynamic inventory decision by developers (which would add another dimension of speculative behavior). All these modifications will allow us to quantify the rich intensive margin effects in addition to the extensive margin effect and we can now compute how much housing price growth in China is a result of each type of speculations by decomposition based on counterfactual analysis.

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Table 1: Predetermined Parameters

Parameter	Model	Value
β	Subjective discount rate	0.95
A_t^f	Productivity in agriculture sector	1.00
ϕ	down payment ratio	0.30
r^*	Annual interest rate	0.04

Table 2: Benchmark Parameter Values and Calibration

Variable	Parameter	Value
Relative productivity of the manufacturing sector	$\{A_t^m\}$	
Share of agricultural goods in the utility function	θ	0.78
Elasticity of substitution in the utility function	ρ	0.81
Curvature Pareto distribution: $F(\epsilon) = 1 - (\frac{1}{\epsilon})^\lambda$	λ	2.8
Technology developers	α	0.2
Entry fee	ψ	4.5
Initial entry fee	H_{-1}	0.25

Table 3: Model Prediction 1992-2007 (%)

Average growth rate	Data	Model
Housing prices	8.61	8.62
Land prices*	19.1	14.6
Urban/rural wage ratio	2.92	1.92

Level	Average prediction
Housing prices	67.1
Land prices*	68.4
Urban/rural wage ratio	87.3

* Land prices are compared for the period 1998 to 2007.

Table 4: Decomposition of Key Indicators (%)

	Period	Entry fee	Land supply	Mortgage financing	Productivity
	1992-2007	16.5	11.7	25.7	46.1
Housing prices	1992-1996	20.0	15.8	24.6	39.6
	1997-2002	10.7	7.0	22.3	60.0
	2003-2007	19.6	13.0	31.0	36.5
	1999-2007	15.3	32.4	6.0	46.3
Land prices	1999-2002	11.6	38.8	7.9	41.8
	2003-2007	18.6	26.8	4.4	50.2
	1999-2007	15.3	32.4	6.0	46.3
Migrant fraction of city population	1992-2007	-13.5	-10.8	10.0	114.3
	1992-1996	-2.0	-2.0	0.1	103.9
	1997-2002	-16.0	-12.0	9.0	119.0
	2003-2007	-25.0	-20.0	11.0	134.0

Table 5: Model Prediction 1998-2007 (%)

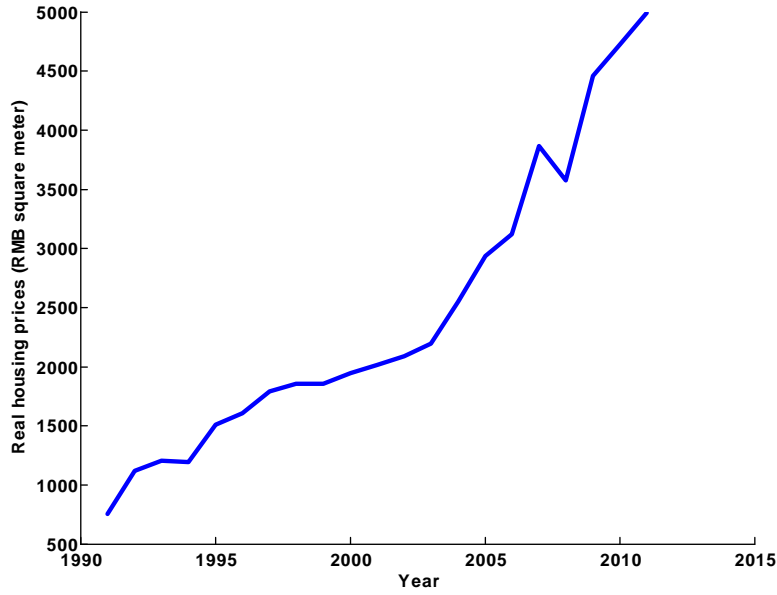
Average growth rate	Beijing		Shanghai	
	Data	Model	Data	Model
Housing prices	4.49	1.57	8.93	7.67
Land prices*	32.7	25.3	28.3	27.9
Level	Average prediction		Average prediction	
Housing prices	84.4		86.0	
Land prices*	75.4		74.4	

* Land prices are compared for the period 1998 to 2007.

**Table 6: Decomposition of Key Indicators
for Beijing and Shanghai (%)**

	Period	Entry fee	Land supply	Mortgage financing	Productivity
	1998-2007	19.6	13.7	13.8	53.0
Beijing	1998-2001	18.7	13.1	14.6	53.6
housing	2002-2004	14.3	10.0	11.3	64.4
prices	2005-2007	25.7	18.0	15.1	41.2
	1998-2007	13.5	36.7	15.6	34.3
Beijing	1998-2001	9.9	28.5	12.7	49.0
land	2002-2004	20.2	45.0	17.2	17.7
prices	2005-2007	13.2	41.6	18.5	26.7
	1998-2007	18.0	12.6	10.3	59.1
Shanghai	1998-2001	11.9	8.3	8.8	71.0
housing	2002-2004	14.5	10.1	11.8	63.7
prices	2005-2007	26.9	18.8	10.5	43.8
	1998-2007	11.7	32.8	15.2	40.3
Shanghai	1998-2001	18.8	35.0	21.6	24.5
land	2002-2004	14.8	32.6	16.1	36.4
prices	2005-2007	4.3	31.9	10.6	53.2

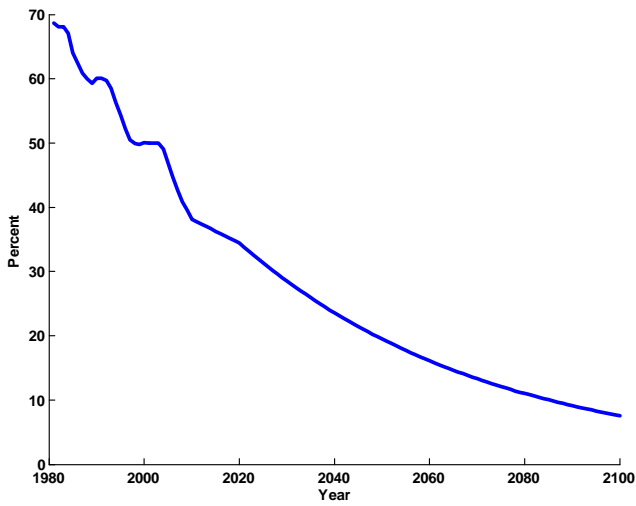
Figure 3: Housing Price Evolution in China



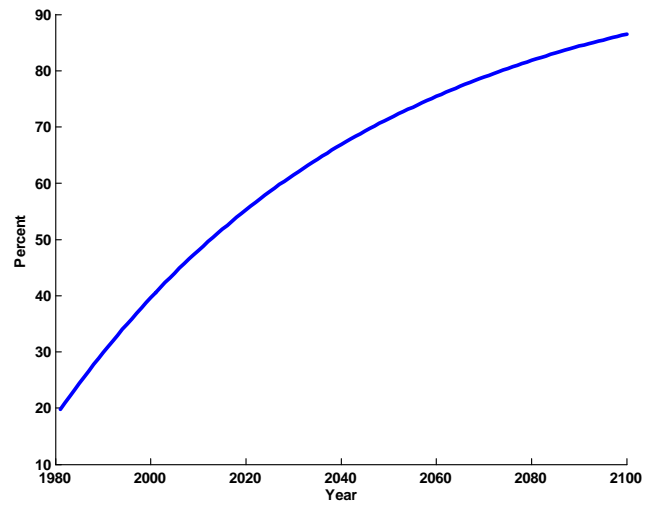
Source: National Bureau of Statistics of China.

Figure 4: Projected Structural Change

Employment Share of the Agriculture Sector

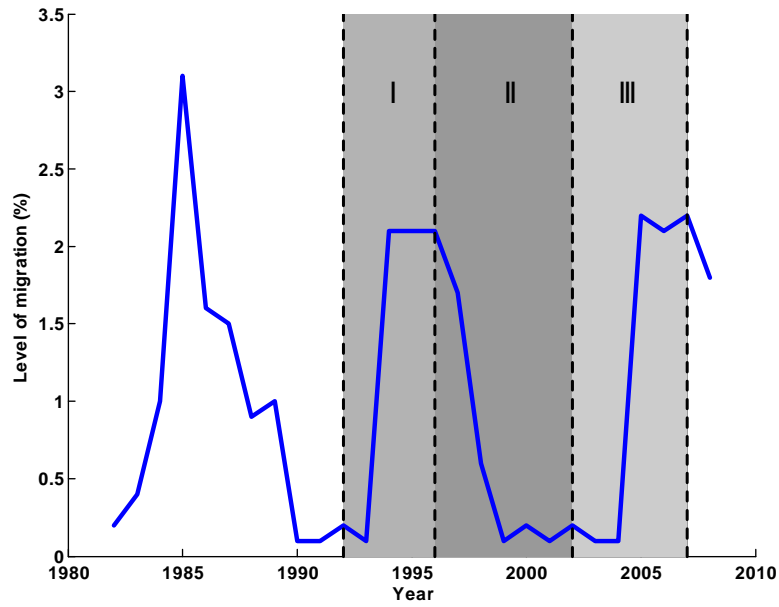


Ratio of Residential Land to Urban Land



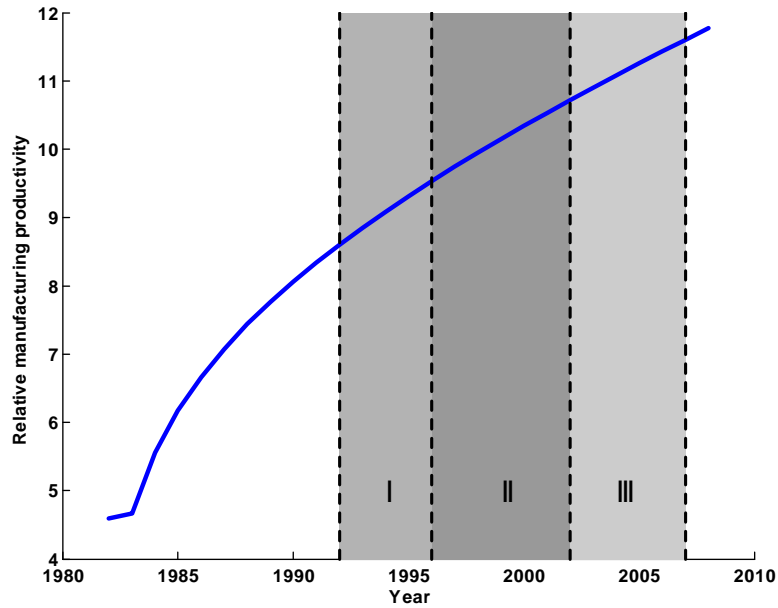
Source: National Bureau of Statistics of China and model-implied data.

Figure 5: Migration Flows



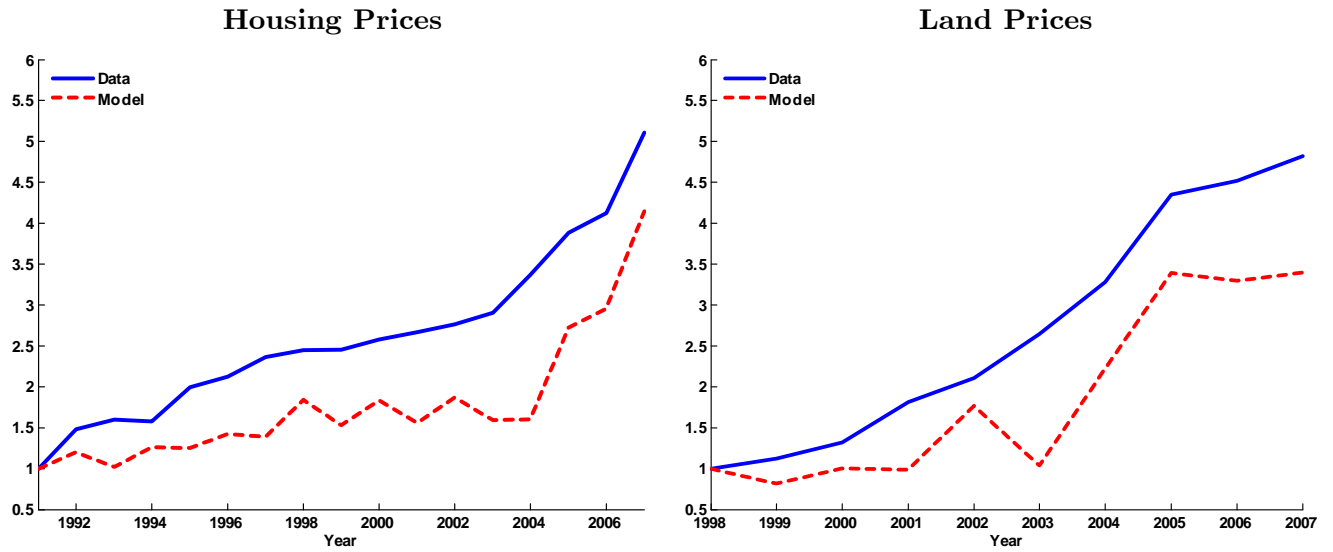
Source: Model-implied data.

Figure 6: Relative Productivity of the Manufacturing Sector



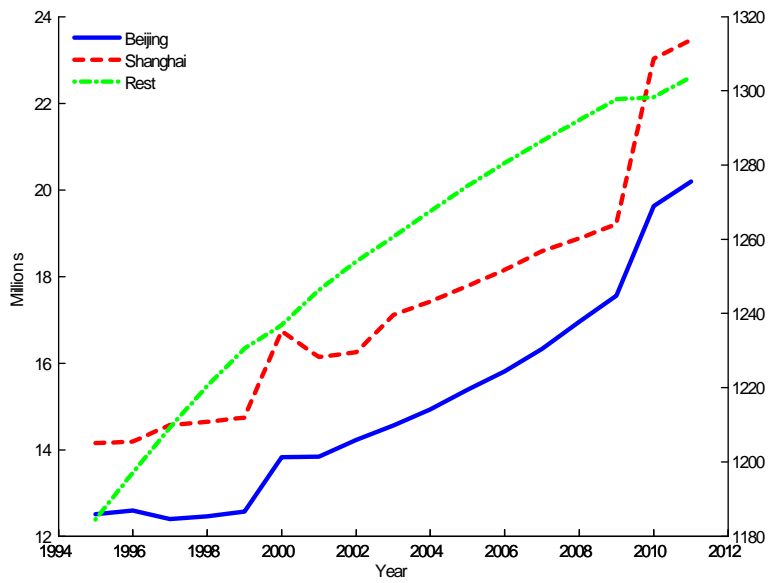
Source: Model-implied data.

Figure 7: Housing and Land Prices



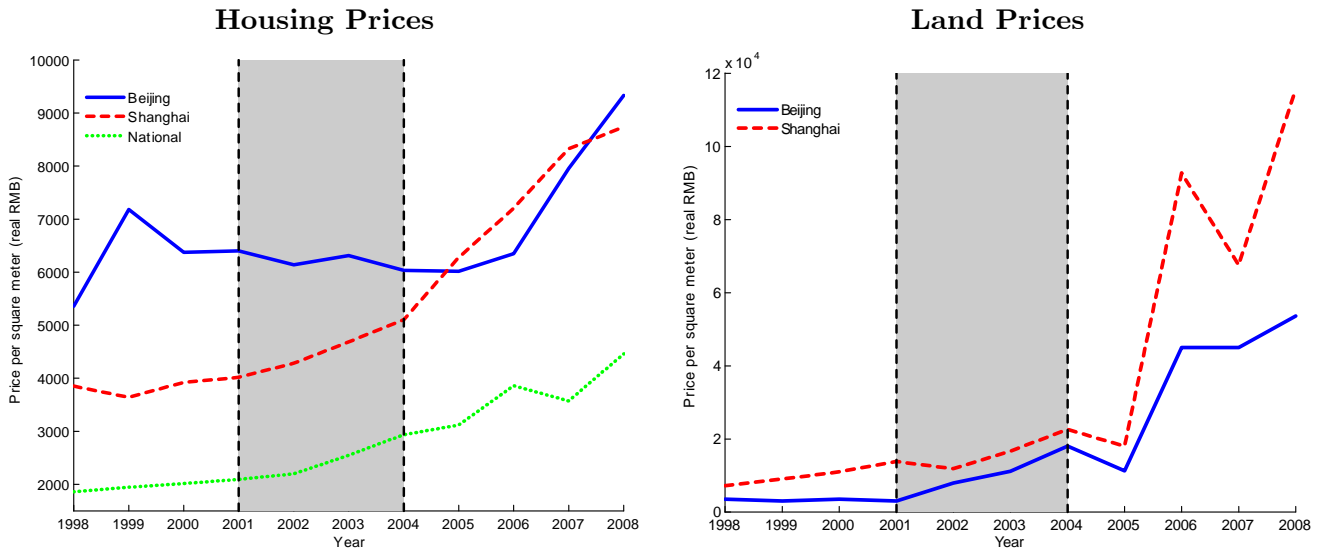
Source: National Bureau of Statistics of China and model-implied data.

Figure 8: Total Population in Beijing, Shanghai, and the Rest



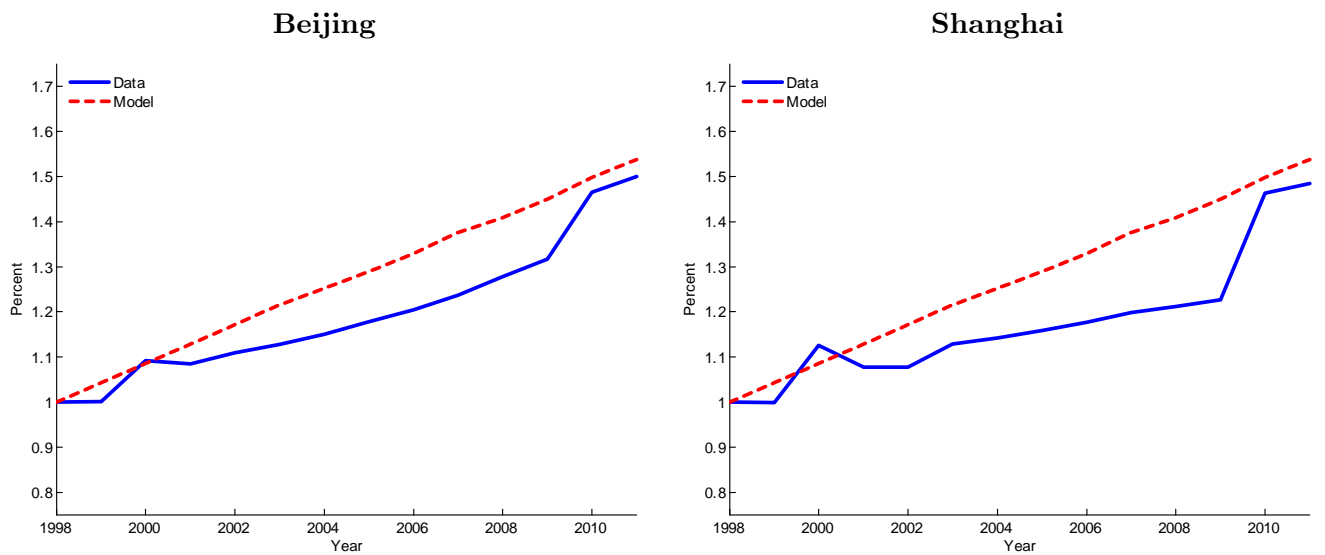
Source: National Bureau of Statistics of China.

Figure 9: Real Housing and Land Prices in Beijing and Shanghai



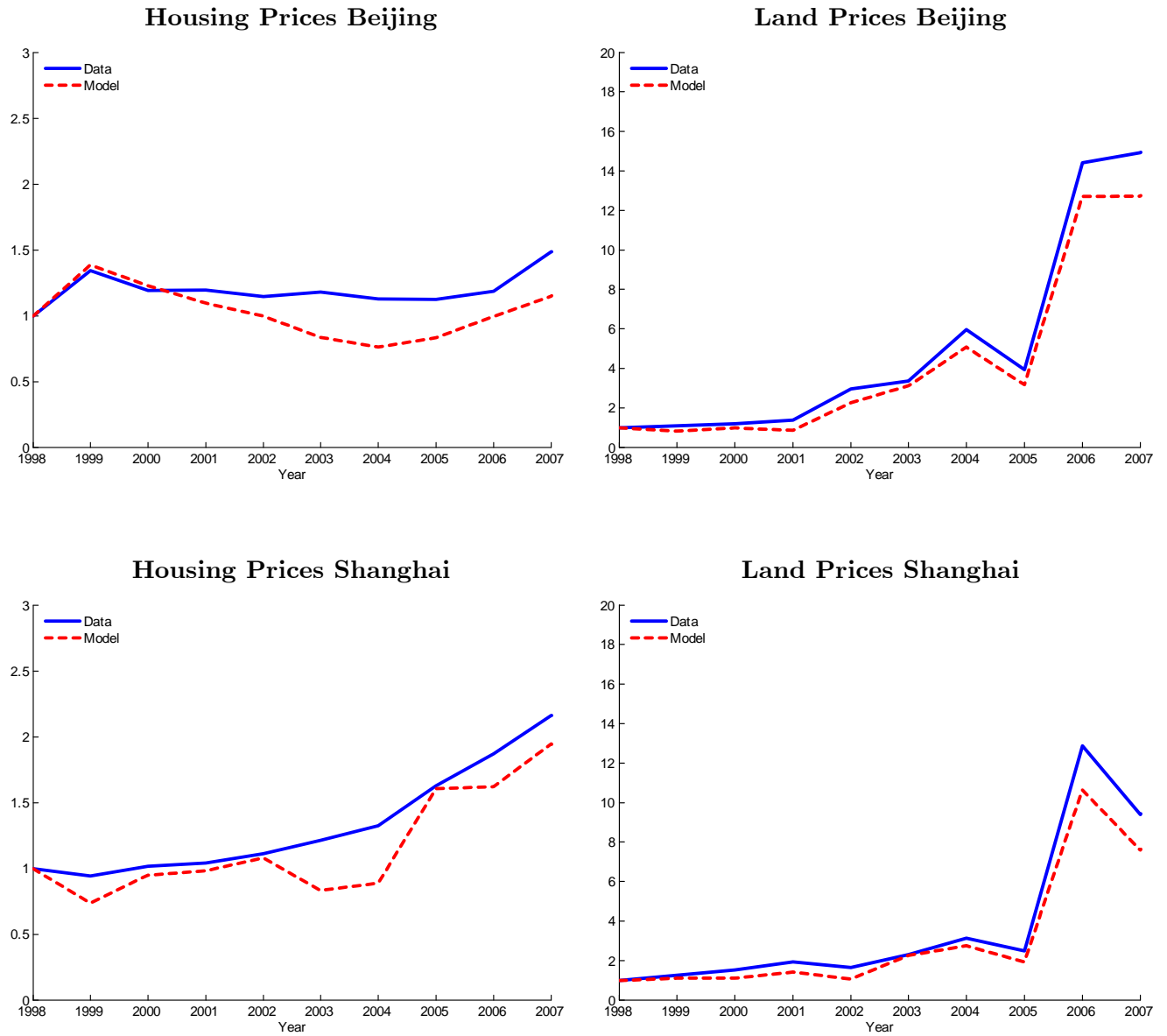
Source: National Bureau of Statistics of China.

Figure 10: Fraction of Migrants in Total City Population



Source: National Bureau of Statistics of China and model-implied data.

Figure 11: Housing and Land Prices in Beijing and Shanghai



Appendix

(A major portion of the Appendix is not intended for publication)

I. A Barebones Model: Consider an urban economy populated with identical agents whose mass evolves exogenously according to $N_{t+1} = (1 + g_N)N_t$. Each agent provides 1 unit of labor each period and earns a competitive market wage, w_t . Denote the composite good as c_t and housing at the beginning of the period as h_t (so incremental housing to be purchased in period t is $h_{t+1} - h_t$ and the housing service to be enjoyed in period t is h_{t+1}). The optimization problem of the representative agent is given by,¹⁵

$$\max_{c_t, h_{t+1}} \sum_{t=1}^{\infty} \beta^{t-1} u(c_t, h_{t+1}) \quad \text{s.t.} \quad c_t + q_t(h_{t+1} - h_t) = w_t$$

Solving the optimal decision for housing yields the no-arbitrage expression for housing prices reported in the text, where $R_t = u_2(c_t, h_{t+1})/u_1(c_t, h_{t+1})$. Iterating forward yields

$$q_t = \sum_{\tau=0}^{\infty} \frac{R_{t+\tau}}{\prod_{\tau'=0}^{\tau} (1 + r_{t+\tau'})},$$

This expression states that the value of a house is equal to the discounted flow value of future housing services (implicit rents).

The production technology for consumption goods is linear in labor, $y_t = A_t N_t$, so all workers are paid the marginal product, $w_t = A_t$. Productivity evolves exogenously, according to $A_{t+1} = (1 + g_A)A_t$. The model is closed by assuming public provided houses to the market at a rate g_H , so housing stock evolves as follows: $H_{t+1} = (1 + g_H)H_t$. Under logarithmic preferences, $R_t \propto A_t N_t / H_{t+1}$ and the housing price equation above yields $q_{t+1}/q_t = (1 + g_A)(1 + g_N)/(1 + g_H)$.

II. Console Mortgage: The consol fixed rate mortgage (FRM) considered in our paper possesses the following properties:

Proposition 1: Consol FRM has zero amortization, $b_t = b_{t+1}$.

Proof: A mortgage payment contains two parts: the amortization and the interest payment. Amortization is defined to be the difference between today's debt and tomorrow's debt:

$$m_t = a_t + i_t,$$

$$a_t = b_t - b_{t+1}.$$

The debt level in period 0 is $b_0 = (1 - \phi)q_0 h$, and the interest payment in period 1 is $i_1 = (\frac{1}{\beta} - 1)(1 - \phi)q_0 h$. Assume the mortgage payment decreases at a constant rate g over time. The absence of arbitrage condition implies:

$$(1 - \phi)q_0 h = \sum_{t=1}^{\infty} \beta^t d_1 (1 - g)^t.$$

¹⁵It is equivalent to assuming that the representative can borrow/save using a risk-free (beginning-of-period) bond b_t and solving the following problem:

$$\max_{c_t, h_{t+1}, b_{t+1}} \sum_{t=1}^{\infty} \beta^{t-1} u(c_t, h_{t+1}) \quad \text{s.t.} \quad c_t + q_t(h_{t+1} - h_t) = w_t + (1 + r_t)b_t - b_{t+1}$$

We can solve d_1 as follows:

$$d_1 = (1 - \phi)q_0h \frac{1 - \beta(1 - g)}{\beta(1 - g)}.$$

Therefore, amortization in period 1 can be derived as

$$a_1 = d_1 - i_1 = g(1 - \phi)q_0h.$$

Under a constant debt-repayment scheme, amortization is zero.

Proposition 2: The down payment constraint is always binding.

Proof: Consider parameter values $\{A_t^m\}$ such that there are no reversals from the city to the rural area. In this case, the relevant optimization problem becomes

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

Rewriting the optimization problem sequentially gives

$$\begin{aligned} \max \quad & \sum_{t=0}^{\infty} \beta^t U(c_{\tau+t}^m, c_{\tau+t}^f, h_\tau), \\ \text{s.t.} \quad & c_\tau^m + p_\tau c_\tau^f + q_\tau h_\tau = w_\tau^m + b_\tau, \\ & c_{t+\tau}^m + p_{t+\tau} c_{t+\tau}^f + b_\tau r^* = w_{t+\tau}^m, \quad \forall t > 1, \\ & b_\tau \leq (1 - \phi)q_\tau h_\tau. \end{aligned}$$

The Lagrangian has the form

$$\begin{aligned} \mathcal{L} &= U(c_\tau^m, c_\tau^f, h_\tau) + \lambda_0(w_\tau^m + b_\tau - c_\tau^m - p_\tau c_\tau^f - q_\tau h_\tau) + \\ & \sum_{t=1}^{\infty} \beta^t [U(c_{\tau+t}^m, c_{\tau+t}^f, h_\tau) + \lambda_t(w_{t+\tau}^m - c_{t+\tau}^m - p_{t+\tau} c_{t+\tau}^f - b_\tau r^*) + \gamma((1 - \phi)q_\tau h_\tau - b_\tau)]. \end{aligned}$$

First-order conditions with respect to $\{c_{t+\tau}^m, c_{t+\tau}^f\}$ and b_τ give the following:

$$\begin{aligned} c_{t+\tau}^m &: U_1'(c_{\tau+t}^m, c_{\tau+t}^f, h_\tau) = \lambda_t, \\ h_\tau &: U_3'(c_\tau^m, c_\tau^f, h_\tau) - \lambda_0 q_\tau + \sum_{t=1}^{\infty} \beta^t U_3'(c_{\tau+t}^m, c_{\tau+t}^f, h_\tau) + \gamma(1 - \phi)q_\tau = 0, \\ b_\tau &: \lambda_0 - \sum_{t=1}^{\infty} \beta^t \lambda_t r^* - \gamma = 0. \end{aligned}$$

When $\gamma > 0$, the borrowing constraint will be binding. Collecting the terms gives

$$\gamma = \lambda_0 - \sum_{t=1}^{\infty} \beta^t \lambda_t r^* = U_1'(c_\tau^m, c_\tau^f, h_\tau) [1 - r^* \sum_{t=1}^{\infty} \beta^t \frac{U_1'(c_{\tau+t}^m, c_{\tau+t}^f, h_\tau)}{U_1'(c_\tau^m, c_\tau^f, h_\tau)}].$$

Therefore, γ is positive as long as the utility function is strictly increasing, weakly concave in the consumption component, and the discount factor satisfies $\beta \leq \frac{1}{1+r^*}$.