

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

Carlos Garriga, Aaron Hedlund, Yang Tang, and Ping Wang

## Online Appendix

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# A Institutions

## A.1 Migration Institutions

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

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

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

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

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

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

- **Deng Xiaoping southern tour:** With the world-famous speech given by Deng Xiaoping in 1992 and the reforms that followed, the Chinese economy boomed. The eastern and southern coastal areas experienced unprecedented economic growth, and a number of special economic development zones were built, which attracted many foreign enterprises and investment. This growth created more jobs in cities in these zones, inducing more workers to leave rural areas.
- **Abandonment of the centrally planned food and housing allocation system:** Prior to 1995, the central government generally controlled the allocation of food and housing among citizens; workers without a legal permit to live in the city were not able to obtain food and housing. Even though they could afford them because there were essentially no markets for them to trade in. The establishment of markets for basic living necessities such as food and housing greatly facilitated the entry of rural people into the city.
- **Temporary work permits in larger cities:** Toward the end of the 1990s, migration accelerated as a result of policies that allowed migrants holding temporary permits to work in large cities. For instance, in 1997 the General Office of the State Council permitted some big cities, such as Shanghai and Guangzhou, to print “blue household registration cards” or “temporary permits” for rural workers according to the city’s needs. It is estimated that in Zhejiang province, one of the richest provinces in China, the rural migrant population reached 1.9 million from 1998 to 2001. Some provinces abolished all official restrictions between rural and urban areas by declaring everyone a “citizen of that province” with equal treatment under the same set of policies. The salient feature of the rural-urban migration in this period was likely the concentration of economic development in the eastern and southern coastal areas, which had faster economic growth and higher wages.

## A.2 Housing Market Institutions

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

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

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

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

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

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

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

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

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

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

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

### **A.3 Land Market Institutions**

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

last for up to 70 years. The allocations of use rights were largely by private negotiations between developers and government agents. The reported prices are therefore subject to large distortions that would result in significant biases.

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

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

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

## B Data and Institutions for Justification of Housing and Migration Choice Setups

**Hukou Restriction** Although temporary blue permits are granted to migrant workers, their mobility remain highly restricted ([Meng \(2012\)](#)). More relevantly, migrant workers with temporary blue permits remain highly segmented in the housing markets. Not only are migrant workers temporarily prohibited from house purchases and are not qualified for housing subsidies ([Chan \(2013\)](#), [Chan \(2019\)](#); [Song \(2014\)](#)), but quality and environments of rental units for migrant workers are also far worse than regular housing units for permanent red permit holders ([Démurger, Gurgand, Li and Yue \(2009\)](#)). This by and large leads to *segmented rental markets*, consistent with the evidence in [Wang and Zuo \(1999\)](#).

**Price-to-Rent Ratios** While it is not our interest in analyzing price-to-rent ratios (PRRs), we use initial and final PRPs to discipline our calibration.

Basically, PRPs in Chinese cities are very high by international standards and have led to a largely unsolved puzzle in the literature. By reconstructing a new data from a leading real estate data vendor (GXD) across 145 cities in China over the period of 2015Q1-2020Q3, [Li, Qin and Wu \(2020\)](#) show that price-to-rent ratios exhibit large cross-sectional variation, ranging from 20 to 60. They find that ownership premium as a result of hukou benefits can

only result in 1-2 units in PRR multiple, insufficient to account for the high level of PRR. [Chen, Chen, Hill and Hu \(2022\)](#) show an extremely high PRR in Shanghai at 67, but find quality differences between owner-occupied and rental properties (measured by hedonics) can only reduce the PRR by 14%. Such gap may be due to rent controls, though such regulations have not been strictly enforced until recently (rents should not be raised more than 5% annually, announced 9/1/2021). Despite hukou reform, [Zhang, Wang and Lu \(2019\)](#) construct a Hukou registration index to measure the stringency of location-specific Hukou regulation over the period of 2000-2016 and find surprisingly the level of stringency rising over time. These seem to indicate the failure of the conventional asset-pricing based rent-price relationships even by taking into account institutional factors. We argue that such failure is likely due to the ignorance of largely segmented rental markets in China.

**Housing Tenure Choice** Using data from a 2010 survey conducted in Jiangsu Province, [Tang, Feng and Li \(2017\)](#) find that rural land holding and differential locational preferences between owners and renters play an important role in housing tenure choice. In particular, rural land holding requirements grant less incentive for migrants to own urban houses. Moreover, compared with renters, rural migrants are less likely to buy houses in more developed areas (South Jiangsu) – although these more developed areas have high housing costs, they also offer high urban benefits to owners, so the gap is partly driven by preference heterogeneities. This preference factor is consistent with [Xing and Zhang \(2017\)](#) who argue for a large-city premium (related to amenities and benefits) in China; it is also consistent with [Wang \(2011\)](#) who finds a significant role played by preference-led switches from public housing to private housing after the 1994 housing reform.

[Wu \(2002\)](#) shows that, in Beijing and Shanghai, respectively, about 32 and 49% of temporary blue permit migrants rent private housing, 19 and 12% public housing, 42 and 29% dorms/worksheds, and 4 and 5% staying with other local residents, with no one owning (by hukou restrictions). By contrast, 32 and 51% of permanent red permit migrants in the two cities own private housing, with 27 and 34% renting public housing due to price incentives. Using 2013 China Household Finance Survey (CHFS) data, [Liao and Zhang \(2021\)](#) find urban residents with rural hukou are 20% less likely to own compared to those with urban hukou. They show such a gap is widened in tier-1 and tier-2 cities with stringent hukou regulations.

**Land Supply** While housing market reforms started much earlier, the government has been in full control of land allocations without providing any market mechanisms until the turn of the new millennium. Prior to this major reform, there were development rights regulations for incumbent and new users. Use rights for residential land were allocated via leaseholds that last for up to 70 years. The allocations of use rights were largely by private negotiations between developers and government agents. The reported prices are therefore subject to large distortions that would result in significant biases.

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Also notably, concerning residential use of land, incremental supply may be devoted to building owner-occupied housing or rental units. The latter constitute of both private and public provisions. The allocation of incremental land supply to housing and private rental developers may depend on how much the local government relies on rental units to ease the pressure of large migration inflows. Nonetheless, to accommodate a large stock of migrants, China has already relaxed residential floor-area ratio (FAR). In the Handbook Chapter, Brueckner and Lall (2015) compare FARs in CBDs of cities in several countries. They showing that, even for the largest city in China (Shanghai), the FAR at 8 is still far below many large U.S. cities (12-15 for Chicago, LA, and NYC) and large Asian cities (12-25 for Hong Kong, Singapore and Tokyo). The rising FAR makes land supply less binding. Thus, lacking reliable cross-sectional and time-series data, we judge that assuming constant land allocation over time to the two markets is reasonable.

**Housing Supply** Rental markets consist of private and public provisions. A common type of private rental properties is dorm/workshed, provided by employers mostly for single migrant workers to rent. Another common type is public rental units. Public rental properties may be converted in China. The first way is conversion from public rental housing (PRH) to privately owned housing. Chinese government offers four types of indemnificatory housing: (i) economically affordable housing (EAH), (ii) low-rental housing (LRH), (iii) price-fixed housing (PFH), and (iv) public rental housing (PRH) to ease the strong demands by migrant workers. Among these, only the last type has been more common for conversion, due to rigid regulation and pricing rules. The second way is conversion between commercial properties and rental apartments, called commercial property converted apartments (CPCAs). This is also allowed mainly for addressing housing shortage in large and fast-growing cities.

Under this environment, it is clear that the builders of regular or villa housing are rather distinct from those of commercial offices or dorms/worksheds. Even private rental properties are built to accommodate more tenants, with small space and in the absence of any amenities



(many are of the “commune” type with common bath/ toilet/cooking/dining facilities), where there is little conversion between private rental properties and regular/villa housing.

**Modeling Strategy** The above institutional background leads us to delineate a general modeling strategy:

- Rental construction may have similar inputs to housing construction, with different TFP (and possibly different land share)
- Segmented land supply to production of rental and owner-occupied properties
- Segmented rental market due to rare conversion between private rental properties and private regular/villa housing
- Differential housing demolition rates: reasonable to cut the structure life of rental properties by half

## C Data

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

### C.1 Macro and Sectoral Data

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

In the first panel of figure 1 we plot the evolution of the relative agriculture price index, manufacturing and agricultural productivity, respectively. Agricultural price chain data (last year = 100) are from the 2005, 2008, 2011 and 2015 issues of CSY, measured by the producer price of agricultural goods. The agricultural price index is then imputed, normalizing 2001 = 1. Manufacturing and agricultural productivity are measured as real per-capita non-agricultural output and agricultural output at 2001 price, respectively. We normalize the levels in 2001 to be 1 for both series. Agricultural relative price rises by 30.2%

with an average annual growth rate of 2.13 percent. Manufacturing productivity grows slightly faster than agricultural productivity. The growth factor is 2.35 versus 2.00, while the annual growth rate is 6.81 versus 5.60 percent between the two series.

## C.2 Real Estate Data

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

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

The CRE prices and housing supply data have been carefully constructed since 2000, with most data up to 2014 and some to 2015. There are two useful nominal housing price series: (i) a regular housing price index measured by average selling price of commercialized residential buildings (yuan/square meter) and (ii) a luxury housing price index measured by average selling price of high-grade villas (yuan/square meter). The growth factor is 2.94 for regular house and 2.98 for villa house.

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

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

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

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

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

where  $N_j$  and  $S_j$  denote the population size and ownership rate in city  $j$ , respectively. We

extrapolate to our sample period to obtain the overall ownership rate in 2001 and 2014 at 82.2% and 76.6%, respectively.

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

## 2. Hedonic housing price:

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

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

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

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

The right panel of figure 1 plots the computed hedonic price index from 2003 to 2012. We normalize the price level in the initial year to be 1 for all the three series. Over the 10-year span, the growth factor for villa house is 1.75, 1.57 for regular house, and 2.57 for hedonic price index. Our results suggest that hedonic price is about 64% higher than regular house price and 47% higher than villa house price.

## C.3 Interest Rates

Our real rate of return on saving is meant to capture the general rate of return beyond simple bank deposits. This is needed so as to be compatible with China's high personal saving rate (exceeding 40%) and low financial wealth-income ratio (about 1.5). Based on the 2011 wave of CHFS, Cooper and Zhu (2017) find more than half of financial assets held by Chinese households are in stocks, and the mean stock return is about 10.1%. Hsieh and Klenow (2009) and others use 10% as a benchmark value for the general rate of return (with

certainty). We use a slightly lower rate  $i = 8\%$  as we do not model capital explicitly. Turning now to the mortgage rate, it is average over the sample period about 6.41%. The issue has to do with how to adjust it with the cost of living excluding housing—to a homeowner this is the relevant figure. The CPI inflation rate  $p_{CPI}$  is averaged 2.5% over the sample period, the cost-based nominal house price annual growth rate  $p_{CH}$  is about 8.5% (CRE data without hedonic adjustment), and the housing expenditure share is about 1/4. We can thus backed out the the housing-excluded cost-of-living inflation rate  $p_{CL}$  from,

$$(1 + p_{CL})^{3/4} \cdot (1 + p_{CH})^{1/4} = 1 + p_{CPI}$$

which implies:

$$p_{CL} = (1 + p_{CPI})^{4/3} / (1 + p_{CH})^{1/3} - 1 = 0.0057$$

That is, the housing-excluded cost-of-living inflation rate is about 0.57% and the real mortgage rate about 5.84%. This is why we set  $r = 6\%$ .

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