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Recent housing affordability in urban China: A comprehensive overview☆

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ABSTRACT

In this study, we provide a comprehensive overview of housing affordability in China from both the macro and micro perspectives. We extend the scope of housing affordability analysis to all Chinese cities based on a unique panel dataset in 275 Chinese prefecture cities from 2014 to 2018. We also make a novel methodological contribution to the literature by employing micro-level data from an anonymous major Chinese city in 2015. Our results suggest that the overall level of housing affordability in Chinese cities remained relatively stable or even improved during the sample period. However, we identify a few "superstar cities," such as Beijing, Shanghai, Shenzhen, and Xiamen, which are associated with a serious housing affordability problem. This problem arises from both a shortage of supply in the space market and a potential mispricing in the asset market, and may have a spillover effect on surrounding cities due to home purchase restrictions in the superstar cities. Within these cities, the housing affordability problem leads to longer commuting time due to the separation of home and workplace, and lower housing space consumption for the residents.

1. Introduction

Housing affordability refers to households' ability to meet housing expenses without excessively limiting non-housing consumption (Hancock, 1993). The ongoing house price boom in Chinese cities and associated housing affordability problem have attracted global attention recently (International Monetary Fund, 2014). Indicators including price-to-income ratio, housing expenditure-to-income ratio, housing affordability index, and residual income approach have been employed to measure housing affordability of a city, most of which have also been adopted in urban China (Table 1). Several studies have pointed out a serious and deteriorating housing affordability problem in urban China (Shen, 2012; Wu, Gyourko, & Deng, 2012). However, previous papers only use a subsample of (the largest) cities to measure housing affordability in China because of data constraints (Wu,

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Table 1
Comparison of major housing affordability measures.

Measures	Price-to-income ratio	Housing expenditure-to-income ratio	Housing affordability index	Residual income approach
Definition	The ratio of the median/average house price to the median/average household income	The ratio of mortgage payments to income	The ratio of 25% of the median family income to repayment	The difference between housing cost and income after paying for non-housing expenditure
Literature on Chinese housing market	Chen et al. (2010) Fang et al. (2016) Lau and Li (2006) Wu et al. (2012, 2016) Yang and Chen (2014)	Cai and Lu (2015) Chen et al. (2010) Fang et al. (2016)	/	Yang and Shen (2008)
Considers house price and household income	Yes	Yes	Yes	Yes
Considers conventional mortgage term	No	Yes	Yes	Yes
Considers household expenditure on necessities	No	No	No	Yes
Suitable for rental market	No	Yes	Yes	Yes

Gyourko, & Deng, 2016).[1] The comprehensive measurement of housing affordability in *all* the Chinese cities remains scarce.

In addition to cross-city comparison on housing affordability, it is equally important to understand the spatial distribution of housing affordability *within* a city. Given that workspaces are more spatially agglomerated than homes, housing unaffordability near workspaces may discourage home purchase near workspaces, thus creating social problems such as congestion and long commuting time. However, no existing literature has documented within-city distribution of housing affordability possibly due to data inaccessibility.

It is also important to examine affordability for renters because the conditions may substantially differ for renters and homeowners. For example, Quigley and Raphael (2004) found little evidence of increasing housing unaffordability for owner-occupied housing in the U.S., but pronounced increases in the rent burdens for poor households. Even though the homeownership rate at the national level exceeded 78.95% in urban China according to the 2010 population census, the share of renters is still high in first- and second-tier cities.[2] However, little literature studies the renters' housing affordability in China so far.

In this study, we fill the literature gap by providing a new and comprehensive overview of housing affordability in urban China. Specifically, we use the "housing expenditure to income ratio" to measure housing affordability, which is defined as the ratio of repayment to income for homeowners, and the ratio of rent to income for renters. Based on several unique datasets, we not only extend the scope of the analysis to all Chinese cities at the macro level, but also provide micro-level analysis within a major city. In addition, we investigate the potential consequences of the affordability problem. The key findings are in three folds, as follows.

First, we provide the first affordability measurement covering almost all cities at prefecture level or above in mainland China. The results suggest that the overall level of housing affordability in Chinese cities remained relatively stable or even improved during the sample period between 2014 and 2018. For about 90% of cities, covering about 75% of the urban population in China, the overall housing affordability condition was acceptable during the whole sample period, for both homeowners and renters. We also point out that the previous literature might overestimate the affordability problem owing to sample selection bias.

Second, however, we highlight a serious affordability problem associated with a few superstar cities, such as Beijing, Shanghai, Shenzhen, and Xiamen. In 2018, the ratio between expenditures on housing and household income for homeowners in these superstar cities reached a historical peak of 1.29. Furthermore, the micro-level analysis, based on an anonymous superstar city in the sample, suggests that the actual affordability conditions are even worse than that revealed by the city-level data, especially when the spatial mismatch between job and residential locations is considered. Our further analysis points out that such a serious affordability problem results from both a shortage of supply in the space market and a potential mispricing in the asset market. We also provide evidence that this affordability problem has spread to surrounding cities, especially after these superstar cities started to curb home purchases from 2010.

Third, based on the micro-level analysis, we shed light on two of the most direct economic consequences of low housing affordability in the superstar cities. The housing affordability problem leads to longer commuting time within these superstar cities due to the separation between home and workplace. Meanwhile, urban households in working places with worse housing affordability have to choose smaller dwelling units to control their housing expenditure.

This study contributes to the growing body of literature on Chinese housing problems. Most existing housing affordability analyses in China have focused on a number of major cities (Cai & Lu, 2015; Chen, Hao, & Stephens, 2010; Fang, Gu, Xiong, & Zhou, 2016; Lau & Li, 2006; Wu et al., 2012, 2016; Yang & Shen, 2008). However, we believe that a comprehensive understanding of housing affordability status, including both the overall conditions of all cities and the unique features of superstar cities, is of paramount policy importance in the further development of Chinese housing markets. The study also makes a methodological contribution to the housing affordability literature. In particular, this study is among one of the first housing affordability measures and analyses based on micro-level data.[3] Finally, we contribute to the emerging field of economic and social consequences associated with deteriorating housing affordability (Ben-Shahar, Gabriel, & Golan, 2018; Bentley, Baker, Mason, Subramanian, & Kavanagh, 2011; Lux & Sunega, 2012; Wood, Turnham, & Mills, 2008) by providing new empirical evidence in the context of a developing economy.

The rest of the paper proceeds as follows. The following Section 2 provides institutional background on China's urban housing sector. The data and housing affordability indicator adopted in the analysis are described in Section 3. Section 4 presents and discusses the results on city-level affordability measures for all cities, and Section 5 highlights the affordability problems, as well as the potential consequences, in one of the superstar cities based on the micro-level analysis. Section 6 concludes the paper.

[1] Most research has focused on a few most important cities. Chen et al. (2010) found that the price-to-income ratio was around 8, while the ratio of monthly mortgage payments to disposable income was 0.60 in Shanghai in 2008. The price-to-income ratio in Beijing was 6.7 in 2002 (Lau & Li, 2006), but increased to 18.5 in early 2010 (Wu et al., 2012). Some recent research has extended the scope to more cities. Wu et al. (2016) calculated the price-to-income ratios of 12 major cities, identifying a potential affordability problem in cities including Beijing, Shanghai, and Hangzhou. Yang and Chen (2014) pointed out that, on average, the price-to-income ratio of 35 large and medium-sized cities from 2005 to 2010 was approximately 8 with significant regional variance. Fang et al. (2016) analyzed 124 cities, the largest sample at that stage, and found that the price-to-income ratio was around 8 or higher in most Chinese cities from 2003 to 2012, suggesting the existence of a substantial burden on housing purchases. It is worth to note that, > 200 smaller cities, rather than 70 large and medium cities, took up 52.7% of the urban population according to the 2010 nationwide population census. Thus, the housing affordability in all the cities needs further study, considering the diversity between the housing affordability in different cities.

[2] For example, in 2010, 36.6% and 39.5% of urban households lived in rented units in Beijing and Shanghai, respectively.

[3] Fisher, Pollakowski, and Zabel (2009), who proposed an amenity-based housing affordability index at town level in the greater Boston metropolitan area, is another example of micro-level housing affordability analysis.

2. Institutional background

Technically, the concept of housing affordability did not exist in urban China for 4 decades after the founding of the People's Republic of China in 1949. During this era, the urban residential sector was nationalized and fully controlled by the State; housing services (not to mention housing assets) were not a commodity, but part of the compensation or welfare provided by the State. Dwelling units were built and owned by employers, most of which were state-owned enterprises and public service units, and allocated to employees based on their rank or/and seniority at an almost negligible rent. Accordingly, urban households did not need to worry about housing affordability, although standard of their housing conditions remained poor. For example, in 1990, the per capita living space was only 7.1 square meters for urban households in China, as reported by the 1990 population census.

The State's monopoly of the urban housing system gradually changed after the early 1980s; this housing reform significantly accelerated in the 1990s. There were three essential components of the housing reform. First, dwelling units previously owned by employers were sold to the employees residing in the units at heavily subsidized prices. Second, the employers were required to progressively terminate further housing developments and allocation; and the implicit housing benefits had to be integrated into employees' salaries. Third, the real estate industry and private housing markets started to develop, in which urban households could purchase or rent their dwelling units at market prices.[4]

The State Council issued the 23rd Decree in 1998, a watershed in China's urban housing system. Since then, urban households have been unable to acquire dwelling units from employers, but had to rely on the private market. The amount of private housing built as a share of the total annual flow supply doubled from 30.7% in 1997 to 61.4% in 2003, and then reached a peak of 72.4% in 2007. Such rapid reform triggered the problem of housing affordability. As a result of delays in wage system reform (including the integration of housing welfare), household income was relatively low compared with house prices at the beginning of this century (Mak, Choy, & Ho, 2007; Rosen & Ross, 2000). However, its effect has been limited, since most households already lived in recently privatized dwelling units. Thus, only a few needed to purchase housing, and the affordability problem shortly disappeared owing to continuous income growth and relatively stable house prices.

The housing affordability problem emerged again in 2006, when house prices started to surge. Most academic attempts to monitor house price changes in China have concluded that the average national housing at least doubled from 2006 until 2014 (Fang et al., 2016; Glaeser, Huang, Ma, & Shleifer, 2017; Guo, Zheng, Geltner, & Liu, 2014; Wu et al., 2016). Soaring prices were especially apparent in a few first-tier cities, such as Beijing, where growth rates were substantially beyond household income growth (Fang et al., 2016; Wu, Deng, & Liu, 2014). Soaring house prices naturally led to concern about urban households' housing affordability. Although the underlying data and indicators vary with research, in general, most quantitative analyses have concluded that there has been a serious housing affordability problem in urban China during this period.

Facing with this pressing affordability problem, “meeting the housing needs of all people” has become increasingly important in the Chinese government's policy agenda. The central and local governments both implement a large set of affordability-enhancing policies, especially after the State Council issued its 24th Decree in 2007.[5] On the demand side, the Housing Provident Fund (HPF) system is the key policy instrument. By law, all employees must participate in the HPF; each employee, as well as his/her employer, is required to contribute a designated percentage of monthly income to his/her individual account, and can withdraw from the account as down payment or monthly repayments of home loans. Moreover, contributors can apply for mortgage loans with a subsidized interest rate.[6] On the supply side, local governments have developed a huge amount of public and quasi-public housing units, including shared ownership housing (*gong you chan quan fang*), ceiling-priced commodity housing (*xian jia fang*), affordable housing (*jing ji shi yong fang*), and public housing for renters (*gong zu lin fang*). During the period of the 12th Five-Year Plan (2011–2015), > 40 million public and quasi-public housing units were built around the country.[7] In addition, the Chinese government was committed to boosting the development of the rental housing market after 2016 as another supply-side instrument to solve the affordability problem.

3. Data and methodology

3.1. City-level data

As mentioned in the introduction, a contribution of this study is that we are able to cover almost all cities in mainland China by introducing a new dataset at the city level. The data challenge mainly comes from the house price side (Wu et al., 2016). In this study, we introduce a large dataset of online resale housing listing information to calculate the annual average house prices between 2014 and 2018 for each of the 275 cites at prefectural level or above in mainland China.[8] Specifically, the web spider program

[4] Refer to Murray and Sun (2017, Section 2) for an overview of the evolution of housing policy in China since 1949.

[5] This decree, Several Opinions of the State Council on Resolving Housing Difficulties of Low-income Families in Cities, made some suggestions to solve the housing problems of urban low-income households in China. The full text of the decree is available at www.gov.cn/zwgk/2007-08/13/content_714481.htm.

[6] See Tang and Coulson (2017) for example for more details on the HPF system.

[7] Source: Report on the Work of the Government delivered by Premier Keqiang Li at the Fourth Session of the Twelfth National People's Congress in 2016. The full text is available on http://english.gov.cn/premier/news/2016/03/17/content_281475309417987.htm.

[8] By the end of 2017, there were in total 298 cities at or above prefecture level in mainland China. We are able to cover 275 of them, and the remaining 23 cities mainly come from western provinces such as Gansu, Ningxia, where the housing markets were undeveloped.

monitors > 2000 websites across the country, including brokerage companies' official websites and national-, regional-, or city-level professional platforms for housing resales, by automatically browsing each website every 15 min and collecting information on listing units. The collected listing information is further cleaned to exclude duplicates and manipulated data.[9] Finally, the average house price for each city-year is calculated as the ratio between the total value of all listed units and the total floor area of these units.

We rely on online listing information on housing resales to calculate the house price levels for four major reasons. First, online listing information, given its advertisement nature, offers best availability of all potential price information sources in China, thereby helping extend the research scope to almost all cities in the mainland. Second, most existing housing affordability analyses in China have derived house price information from the newly-built housing market. However, focusing on only this flow supply alone would underestimate the house price level, because newly-built housing complexes concentrate at the city edge in most cities; by contrast, our data on housing resales can reasonably cover the whole housing stock. Third, official records on housing resale transaction prices in China are not reliable, because a large share of buyers/sellers report fake and low transaction prices in the registered contracts with local housing authorities in order to evade substantial tax on housing resale transactions (Agarwal, Li, Qin, Wu, & Yan, 2018; Dai & Xu, 2018). But the listing information can well avoid such data manipulation problem. Finally, we can obtain the city-level average house rents between 2014 and 2018 based on online listing information via the same procedures, which enables us to investigate the affordability status of renters. One potential concern here is the transaction price might be systematically lower than the listing price due to the bargaining process. However, in Appendix A we show that, generally, such gap cannot qualitatively affect our affordability measurement results, while its inter-city variation or temporal change is also neglectable.

On the income side, we directly adopt the city-level official statistics on per capita disposable income for urban residents, which are calculated based on the Urban Household Survey conducted by local statistics bureaus. To the best of our knowledge, these statistics are the most reliable indicator of income level, and can regularly cover all cities at the annual basis. It is then converted to average household income assuming an average household size of three people.

Besides the key dataset as described above, we also try extending the panel to cover 20 years in order to provide analysis for a longer time horizon. For this purpose, we extend the annual series of the average house price to 1999 based on the annual growth rates of average transaction prices of newly-built housing units between 2000 and 2014, which are calculated and reported by local statistics bureaus. The source of the income data remains consistent. The analysis based on this extended panel is reported in Appendix B.[10]

3.2. Micro-level data from a representative major city

Besides the city-level dataset, we employ micro-level data in an anonymous major city, which is one of the four superstar cities defined later in Section 4.[11] The data for this city include both the house price side and the income side. We can obtain only a snapshot of cross-sectional data in 2015, and hence, the following analysis mainly focuses on the spatial distribution of affordability as well as its impacts on households' housing and locational choices.

In the micro-level analysis of the anonymous city, we treat each working place (e.g., an office building) as one observation. Based on a unique micro-level social security contribution dataset, we are able to obtain information on number of jobs in each working place, as well as the average monthly wage in 2015 of each job.[12] The dataset covers about 4.4 million jobs in 90,486 working places in this city. We then calculate the average monthly wage for each working place, or the average household income with the assumption of two wage earners with the same wage per household. Note that the income indicator here is not exactly comparable to the income indicator in the city-level data, since non-wage income components, such as part-time income, are not included here.

The micro-level house price data, again, are based on online listing data on the housing resale market in this city. There were 8201 complexes in this sample city in 2015, and for each complex, we can calculate the average house price. Then the complex-level house price data are matched to each working place using an inverse-distance weighted average formula, as follows:

$$HP_i = \sum_{j=1}^{n} \left(\frac{1/r_{ij}^2}{\sum_{j=1}^{n} (1/r_{ij}^2)} \times hp_j \right) \tag{1}$$

where HP_i is the merged average house price for working place i; hp_j is the average house price for complex j; and r_{ij} is the straight-line

[9] We follow Wang et al. (2018) to identify the replicated and manipulated data. As for the replicated data, we calculate the dissimilarity between any two pieces of listing information within the same complex, and merge the identical or similar records into one record. As for the manipulated data, we construct a Hedonic model to identify the outliers based on Kontrimas and Verikas (2006) and Morano and Tajani (2014)'s strategy. For instance, according to these procedures, 52.9% of the original listing data in Beijing between 2015 and 2017 are identified as replicated data, and then 5.1% of the consolidated data are identified as manipulated data. More details on the housing listing dataset can be found in Wang et al. (2018).

[10] It is noteworthy that, although we provide evidence in Appendix B that the annual growth rates of newly-built housing units and resale units are highly correlated in 89 sample cities between 2015 and 2017, this pattern does not necessarily apply to all the 275 cities between 2000 and 2014. Therefore, we only adopt the extended panel for the supplementary analysis and place it in Appendix B.

[11] We have to omit the name of the city as required by the data provider.

[12] Currently, it is compulsory for each employee and his/her employer to contribute a designated percentage of the employee's monthly wage to his/her social security account. In the full-sample micro-level contribution dataset of this city, for each account, we know the monthly contribution amount in 2015, which can be converted to the employee's monthly wage in 2015 using the contribution rate. In addition, we can obtain access to his/her working place address, and thus, can aggregate the individual data to working-place level.

distance between working place i and complex j. Thus, complexes closer to a working place are weighted higher in calculating the merged average prices.

3.3. Housing affordability measures

In the following analysis, we adopt the "housing expenditure to-income ratio" as the major affordability measure. There are three types of household, corresponding to different housing expenses, including homeowners without mortgages, homeowners with mortgages, and renters (Hulchanski, 1995). Here, we study the latter two cases, which is defined as

$$\begin{aligned} &HETI = HP \times UNITSIZE \times (1 - DOWN) \times r/12 \times (1 + r/12)^{12\times TERM}/[(1 + r/12)^{12\times TERM} - 1]/INC \quad \text{for homeowners} \\ &HETI = HR \times UNITSIZE/INC \quad \text{for renters} \end{aligned} \tag{2}$$

where *HP* and *HR* are the average house price and average rental price, respectively; *UNITSIZE* is the average unit size, which is assumed to be 90 square meters[13]; *INC* refers to average household income; and *r*, *TERM,* and *DOWN* are mortgage loan conditions, referring to annual interest rate, loan term, and down payment ratio, respectively. Following the conventional mortgage loan condition in China, we assume that the loan term is 30 years and the down payment ratio is 30%, while the annual interest rate follows the basic interest rate for long-term loans (above 5 years) issued by the People's Bank of China. It is noteworthy that, in most existing literature in the U.S. or Europe, housing affordability measures are calculated based on the median values of housing prices and household incomes; however, in China, we have to rely on average values instead, because median values are seldom reported.

We choose to use the housing expenditure-to-income ratio as our key indicator for the following three reasons. First, the housing expenditure-to-income ratio is the only indicator that can reflect and directly compare the affordability status of both owners and renters, which is one of the contributions of this study. Second, the criterion to evaluate affordability status is clearer for the housing expenditure-to-income ratio (Hulchanski, 1995). A rule-of-thumb is that a household's housing expenditure-to-income ratio should be no > 25% (Weicher, 1977) or 30% (Lerman & Reeder, 1987). While the Chinese government has not explicitly set its target for the housing expenditure-to-income ratio, in practice, a housing expenditure-to-income ratio above 50% is regarded as too high.[14] Mostafa, Wong, and Hui (2006) also suggests that there is housing affordability problem if housing expenditure-to-income ratio exceeds 50%. Finally, as listed in Table 1, the housing expenditure-to-income ratio indicator covers information on house price, household income, and conventional mortgage terms. The only missing factor, household expenditure on necessities, should have limited impact on housing affordability status, since a housing expenditure-to-income ratio below 50% would leave enough income for households' expenditure on necessities. The results with regard to the housing expenditure-to-income ratio can be easily converted to other affordability measures, if needed. For example, Fig. C1 in the appendix depicts indifferent curves between the housing expenditure-to-income ratio and price-to-income ratio under various mortgage rates. In 2018, a housing expenditure-to-income ratio of 50% was equivalent to a price-to-income ratio of about 11.22, while a housing expenditure-to-income ratio of 100% was equivalent to a price-to-income ratio of about 22.44.

4. City-level analysis in all Chinese cities

4.1. Affordability measures for homeowners

We start with the city-level analysis on homeowners' housing expenditure-to-income ratio in 275 cities, from 2014 and 2018.[15] Fig. 1 plots the housing repayment-to-income ratio at different percentiles in our sample cities, by city and urban population from the 2010 population census, respectively. As shown in both sub-figures, the repayment-to-income ratio in the majority of cities shows a constant, if not declining trend. The median value of the repayment-to-income ratio, either by city or urban population, kept within the range of 0.22–0.31 with mild fluctuations during the sample period. If we adopt the criterion of 0.5 for the housing expenditure-to-income ratio, the results suggest that for about 90% of cities, which cover about 75% of the urban population in China, the overall housing affordability condition is at least acceptable during the whole sample period.

However, housing affordability in the top cities has been deteriorating, showing a divergent pattern between these top cities and the rest of the cities in China. For the top 1% of cities (i.e., top three cities), the repayment-to-income ratio for homeowners was around or even well above 1.00 during most years in the sample period, with a substantial gap with all the other cities. In 2018, the repayment-to-income ratio of the top 1% of cities jumped to the historical peak of 1.16, which certainly suggests a serious housing affordability problem, even compared with other global cities, such as New York, London, and Hong Kong.[16] According to the lower

[13] We adopt the average unit size of 90 square meters for the following reasons. First, urban per capita living space increased from 20.3 square meters in 2000 to 36.6 square meters in 2016 according to the National Bureau of Statistics. Second, State Official Document No.2006–37 requires that no < 70% of newly built private housing units be no larger than 90 square meters. Therefore, the average size of housing units is around 90 square meters while the average household size is about 3 peoples in China.

[14] According to current requirements of the China Banking Regulatory Commission, a mortgage application would be rejected unconditionally if the imputed repayment-to-income ratio exceeded 50%.

[15] We also provide analysis based on the extended panel from 1999 to 2018 in Appendix B.

[16] The survey, "14th Annual Demographia International Housing Affordability Survey: 2018," provided by Demographia measures the housing affordability in 92 major markets in 2017 using the price-to-income ratio. The price-to-income ratios are 5.7, 6.9 and 19.4, or the corresponding housing expenditure-to-income ratio are 0.254, 0.308, and 0.865 in New York, London and Hong Kong, respectively. The survey details are available at http://www.demographia.com/dhi.pdf.

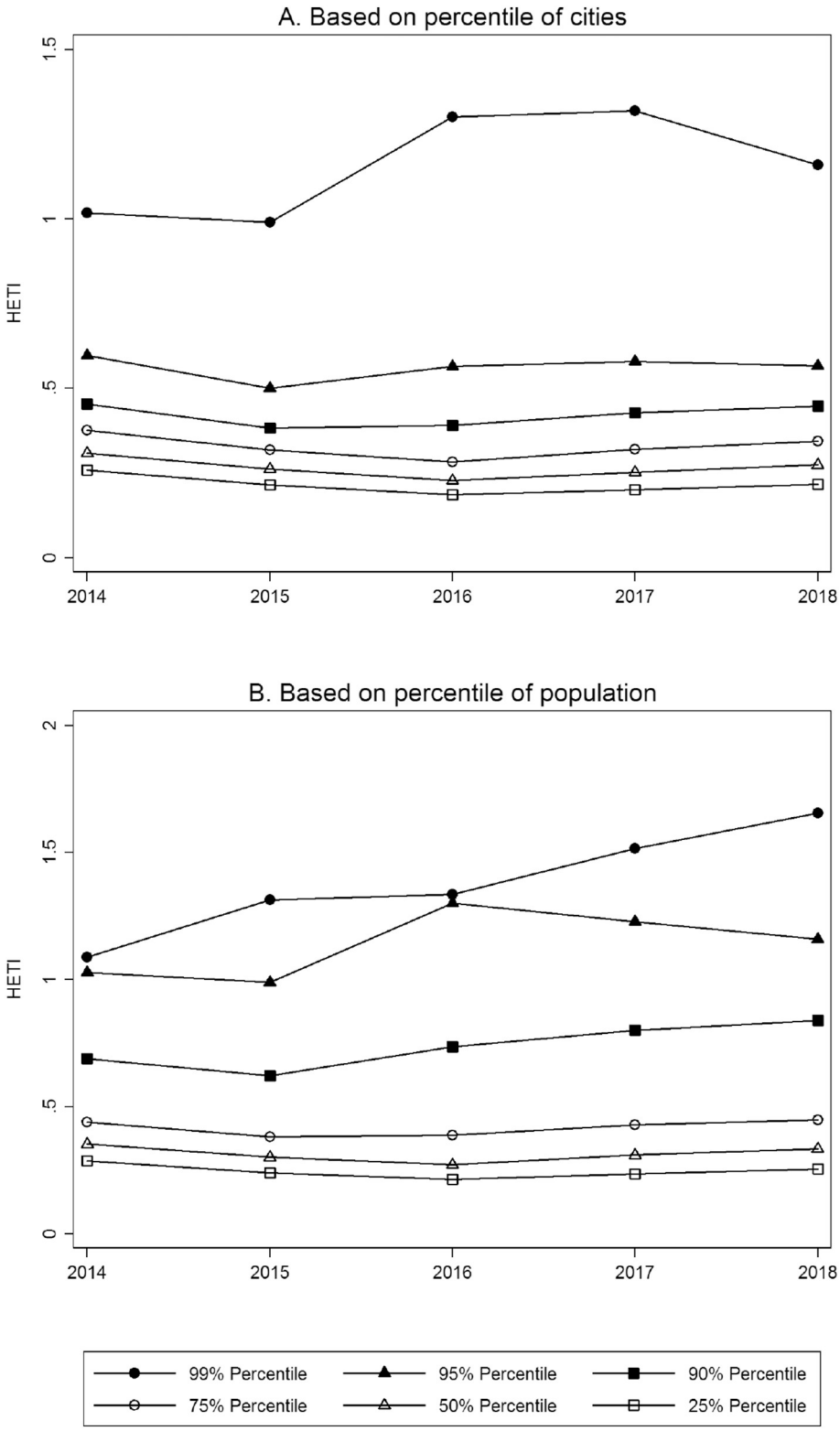

Fig. 1. Changes of repayment-to-income ratio in different percentiles of cities between 2014 and 2018.
Notes: See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.

panel of Fig. 1, these top 1% of Chinese cities would account for about 10% of the total urban population in China.

Panel A of Fig. 2 further provides a snapshot on spatial distribution of housing affordability in all the 275 cities in our sample in 2018. The cities with the worst housing affordability conditions measured by homeowners' repayment-to-income ratio, that is, those with the darkest color on the maps, comes from the capital city of Beijing, and several coastal cities in Eastern China, including Shanghai, Shenzhen, and Xiamen, and such pattern remained unchanged during the whole sample period. Accordingly, the substantial housing affordability problem in China concentrates on a few superstar cities.

The pattern discussed above implies that the previous affordability gauge may overestimate the affordability problem at the national level due to sampling bias. As mentioned in Section 2, because of data source limitations, most existing affordability analysis in China concentrates on large and medium-sized cities with relatively active housing markets, especially the superstar cities. As shown in Fig. 3, we compare the distributions of the repayment-to-income ratios based on all the 275 cities and subsamples adopted in previous works of Fang et al. (2016), Yang and Chen (2014), and Wu et al. (2012). The distributions of housing affordability in different subsample of cities are quite different. In particular, the distribution of housing affordability in China might be upward biased if only a subsample of major cities is used in the analysis.

4.2. Affordability measures for renters

Then, we turn to renters' housing expenditure-to-income ratio in all the 275 cities in terms of the rent-to-income ratio. Similar with Fig. 1, we plot the rent-to-income ratio at different percentiles in our sample cities in Fig. 4. The median value of the rent-to-income ratio, either by city or urban population, kept within the range of 0.13–0.25 with mild fluctuations during the sample period, which, again, suggests that the housing affordability condition is acceptable in almost all cities during the whole sample period for renters.

It is especially noteworthy that, in the superstar cities, renters' housing expenditure-to-income ratio (Fig. 2b) is substantially lower than that of homeowners (Fig. 2a). For example, in 2018, the renters' housing expenditure-to-income ratio was 0.55 on average in Beijing, while the homeowner's housing expenditure-to-income ratio reached 1.20. Accordingly, the spatial distribution of renters' housing expenditure-to-income ratio is less unequal than that of the homeowners. In Panel C of Fig. 2, we depict a city-level housing expenditure-to-income ratio measure incorporating both renters' and homeowners' housing costs, weighted by the population share of these two types of residents in the 2010 population census, which suggests an ameliorated picture of housing affordability in Chinese cities, especially for the superstar cities.

Admittedly, the share of homeowners in a city is endogenous to the house price level (and housing affordability) of the city. It is likely that lower housing affordability deters home purchase and increases the share of renters in a city (Fu, David, & Zhou, 2000). In Fig. C2 in the appendix, we plot the first difference (in 2000 and 2010) of city-level housing expenditure-to-income ratio for homeowners against the first difference (in 2000 and 2010) of the city-level homeownership rate. There exists a significant negative association between these two measures, suggesting that house prices are negatively associated with the homeownership rate in a city. However, we do not discuss the general equilibrium effect of house prices on housing tenure decision in detail, which is beyond the scope of the current study.

4.3. Sources of the housing affordability problem in superstar Cities

The next question is why these superstar cities have such a serious housing affordability problem. Our analysis suggests that the sources of the problem exist in both the housing space and asset markets.

From the perspective of the market for housing space, superstar cities are characterized by both excess demand from population all over the country and inelastic housing supply. Specifically, local amenities and strong labor markets in superstar cities attract home buyers, leading to high housing demand (Roback, 1982; Rosen, 1979). On the other hand, regulations (Glaeser & Gyourko, 2003, 2018; Glaeser, Gyourko, & Saiz, 2008; Glaeser, Gyourko, & Saks, 2005a, 2005b; Glaeser & Ward, 2009; Quigley & Raphael, 2005), an important source of inelasticity in the supply of housing, is stricter in superstar cities, which limits the supply of new housing. For these reasons, superstar cities may experience persistently high house price growth relative to housing unit growth. Following Gyourko, Mayer, and Sinai (2013), Fig. 5 plots the average annual growth in housing area and housing prices from 2006 to 2016 in 40 large and medium-sized cities. According to Gyourko et al.'s (2013) criterion, the cities are supply inelastic (i.e. the ratio of housing price growth to housing area growth is in the top ten percentile) if located on the upper left of the solid line,[17] and are in great demand (i.e. the sum of housing price and housing area growth rate is above the sample median) if located on the upper right of the dashed line. Four cities are identified as superstars with increasing demand and inelastic supply according to these criterions, including Beijing, Shanghai, Shenzhen, and Xiamen (BSSX). As described in the previous section, we observe much lower housing affordability in these four specific cities compared with the other cities.

Then, we turn to the asset market perspective. Fig. 6 plots the repayment-to-income ratio against the rent-to-income ratio for each city in 2018. The dashed line is the 45-degree line equalizing the two ratios. The figure clearly shows that most cities are located close to the dashed line, indicating a similar repayment-to-income ratio and rent-to-income ratio in these cities. However, the repayment-

[17] The analysis in this paragraph can contain only 40 large and medium-sized cities due to data source limitations with regard to annual housing area. Accordingly, we require that superstar cities should be in the top 25% rather than the top decile of the ratio of price growth rate to housing unit growth rate, since we cannot pool all the Chinese cities into the analysis.

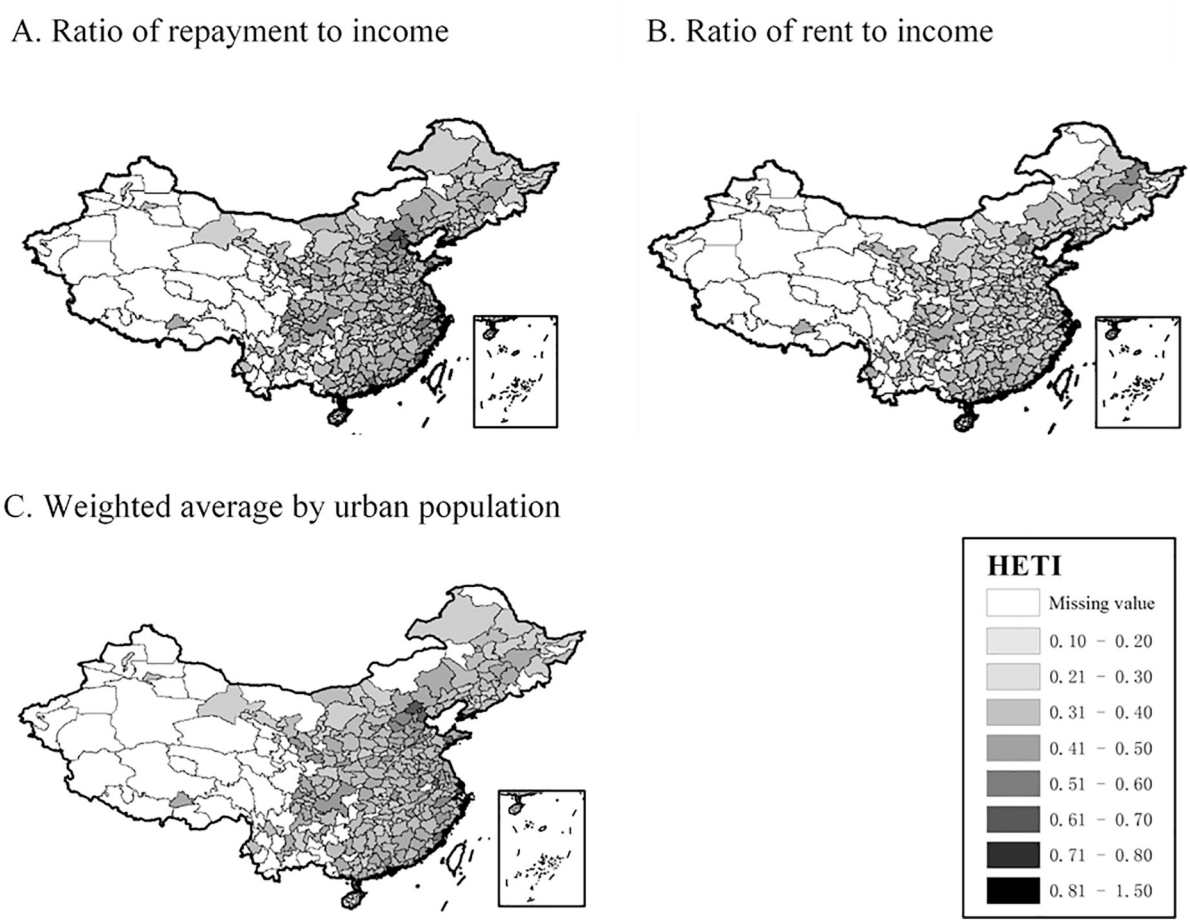

Fig. 2. Spatial distribution of different housing affordability measures of all cities in 2018.
Notes: See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.

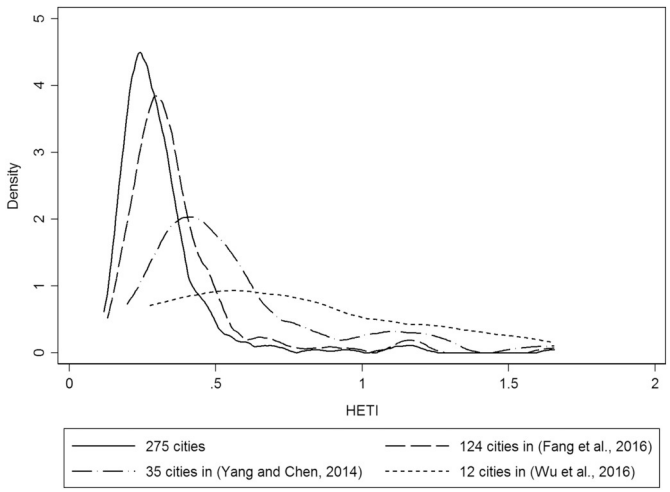

Fig. 3. Kernel density of housing affordability in different city subsamples in 2018.
Notes: See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.

to-income ratio is much higher than the rent-to-income ratio in the four superstar cities. On average, the repayment-to-income ratio is 1.29 in the four superstar cities, while the rent-to-income ratio is 0.45. These results suggest that the main source of excess demand in superstar cities in China is not consumption demand. Instead, investment demand and possibly speculative demand are the dominant

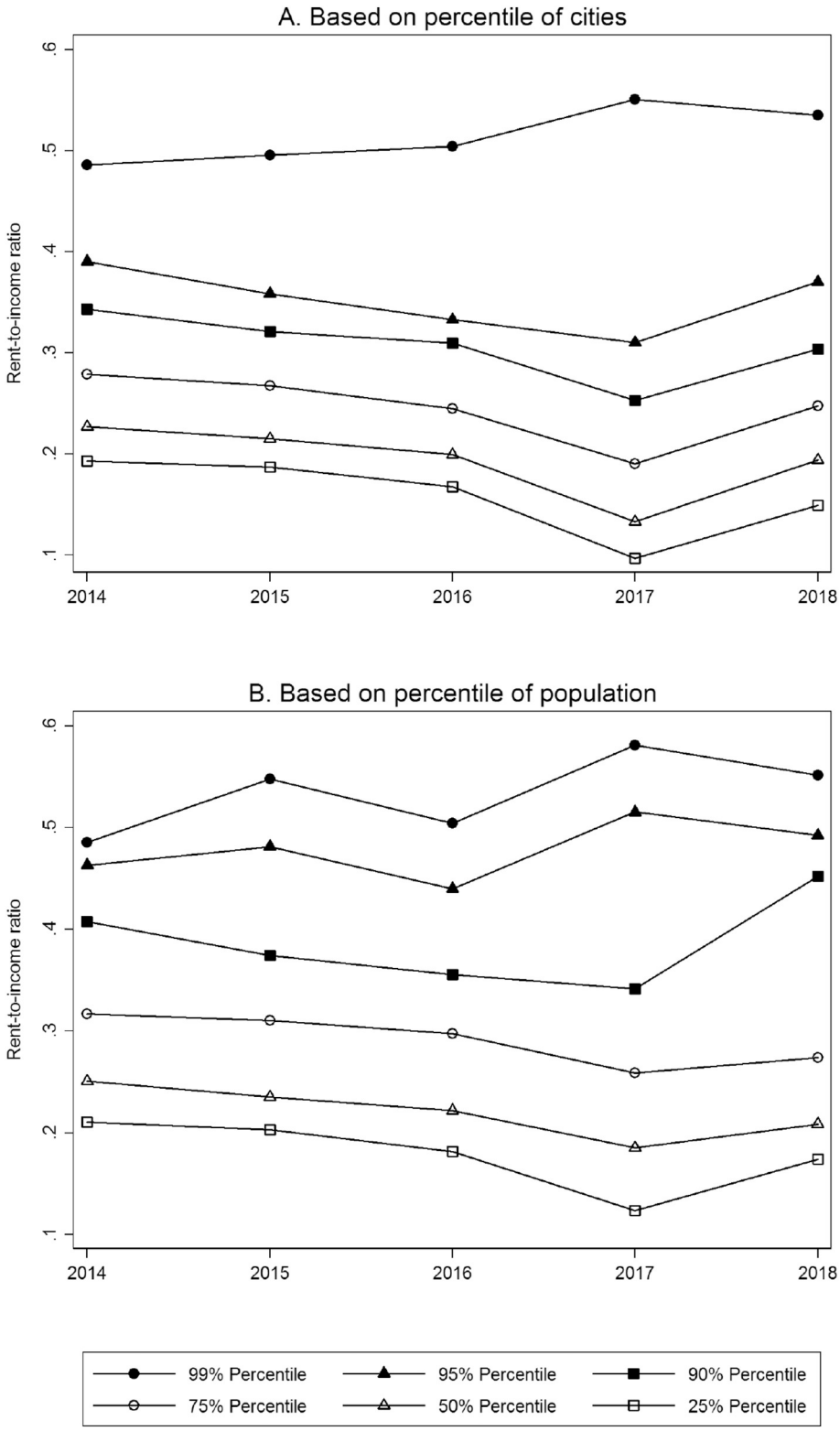

Fig. 4. Changes of rent-to-income ratio in different percentiles of cities between 2014 and 2018.
Notes: See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.

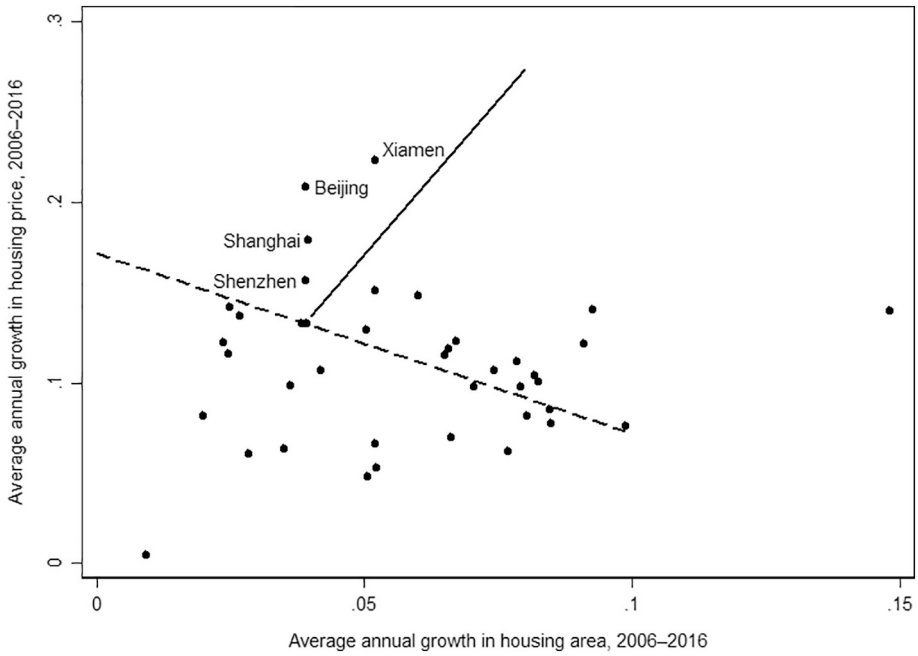

Fig. 5. Annual housing price growth versus housing area growth in 40 Chinese cities, 2006–2016.
Notes
1. Housing price and housing area is from the Ministry of Housing and Urban-Rural Development.
2. This graph follows Fig. 4 in Gyourko et al. (2013). The cities are supply inelastic if located on the upper left of the solid line, and are in great demand if located on the upper right of the dashed line.

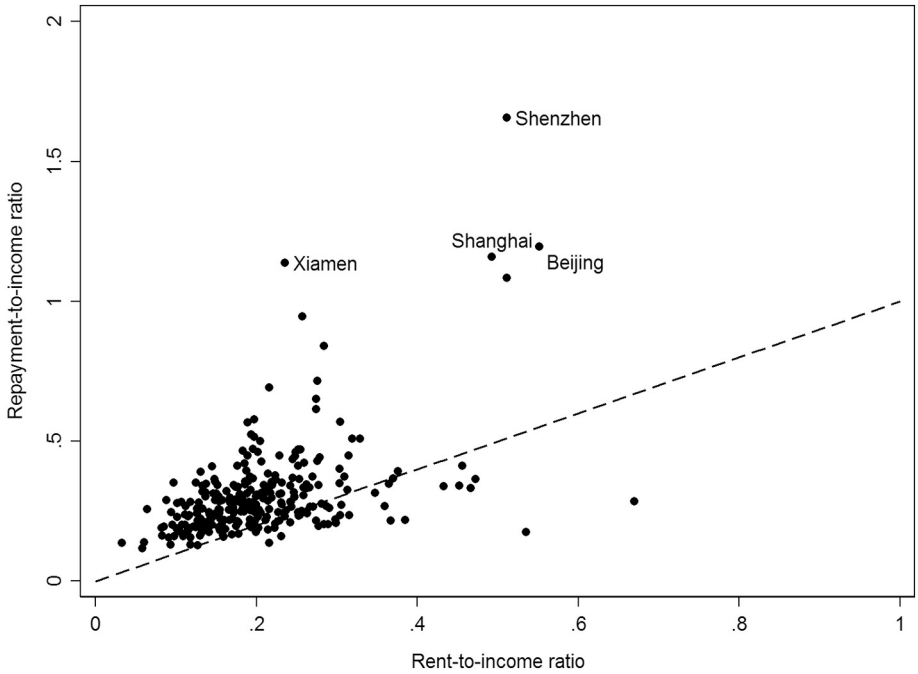

Fig. 6. Repayment-to-income ratio and rent-to-income in 2018.
Notes
1. See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.
2. The ratio of repayment to income and the ratio of rent to income are equal if the dot is located on the dashed line.

drivers of high housing price (and thereby low housing affordability for homeowners) in these cities.

In summary, the combination of excess demand and shortage of supply leads to the high housing expenditure-to-income ratio in the superstar cities, which is further worsened by the potential mispricing in these markets.

4.4. Spillover effect from superstar cities

Fig. 2, besides highlighting the superstar cities themselves, shows a noteworthy phenomenon that nearby (small) cities also had relatively higher housing expenditure-to-income ratio than other cities did.[18] In this subsection, we provide evidence that this result was very likely due to the spillover effect from superstar cities to surrounding cities.

Specifically, we focus on the effect of home purchase restrictions in superstar cities. Home purchase restrictions were published in April 2010 for the first time in the regions where housing prices were rising too fast due to supply shortages, such as BSSX, and were reinforced in January 2011, February 2013, and September 2016, respectively.[19] Previous studies have concluded there is a significant impact of home purchase restrictions on local housing markets (e.g., Du & Zhang, 2015; Li, Cheng, & Cheong, 2017; Sun, Zheng, Geltner, & Wang, 2017). However, the policy's effect may not be confined to the targeted local housing market, but may have a spillover effect on the nearby cities. The intuition is straightforward: after losing eligibility for home purchase in superstar cities, their residents might purchase houses right across the border, which might lead to house price increase and thus deterioration of housing affordability in nearby cities. As the stylized fact, Fig. 7 plots the average repayment-to-income ratios for cities nearby and farther away from the superstar cities. Although the ratios in both groups increase after 2016, it rises faster in cities nearby the superstar cities.

We construct a difference-in-difference regression model to study the causal impact of home purchase restrictions in superstar cities on housing affordability in nearby cities; that is:

$$HETI_{it} = \beta_0 + \beta \times treat_i \times after_t + \theta_i + \eta_t + \varepsilon_{it} \tag{3}$$

where $HETI_{it}$ is the housing expenditure-to-income ratio of city i in year t; $treat_i$ equals 1 if city i borders BSSX, and 0, otherwise; $after_t$ is a dummy variable indicating whether year t is after 2016, that is, the year the home purchase restrictions reinforced in superstar cities; θ_i and η_t are city fixed effects and year fixed effects, respectively; and ε_{it} is the error term. The standard errors are clustered at the city level. We restrict the sample to 230 cities between 2014 and 2018, excluding cities with home purchase restriction policies, including all the four superstar cities. The results are shown in Table 2. In the first specification (column 1), we include all the 230 cities without home purchase restrictions in the sample. In the second specification (column 2), we further restrict the control group to 171 cities, including only cities in provinces that neighbor the superstar cities and cities in provinces that neighbor the superstar cities. The results suggest that the housing expenditure-to-income ratio in nearby cities significantly increases by 4.5% to 4.8% because of the home purchase restrictions in superstar cities.

We also conduct an event study with a regression model to verify the parallel trend assumption of the difference-in-difference regression; that is:

$$HETI_{it} = \beta_0 + \sum_{k=2015}^{2018} \beta_k \times treat_i \times 1\{Year_{i,k} = k\} + \theta_i + \eta_t + \varepsilon_{it} \tag{4}$$

Fig. 8 plots the event study coefficients, β_k, as well as the 95% confidence interval. Compared with other cities, the housing expenditure-to-income ratio in the nearby cities increased right after the policy, with little difference in prior growth trends. These results provide evidence that the affordability problem in superstar cities can have even broader effects, especially after the housing market intervention policies in these superstar cities.

5. Micro-level analysis within ine superstar city

5.1. Housing affordability measure in the superstar city

The results presented in Section 4 highlight that the potential housing affordability problem concentrates on a few superstar cities. In this subsection, we shed more light on these cities by adopting micro-level affordability measures in one of these superstar cities in 2015.

As described in Subsection 3.2, in this sample city, we have income data for 4.4 million jobs in 90,486 working places in 2015, and average price data for all the city's 8201 housing complexes in 2015. Based on these data, the average annual household income was 141,671 yuan and the average housing price was 35,623 yuan, resulting in a city-level housing repayment-to-income ratio of

[18] As the suggestive evidence, the Moran's I of city-level housing expenditure-to-income ratios is significant in all the sample years, suggesting a substantial spatial autocorrelation. For instance, in 2018, Moran's I reaches 0.086 for the repayment-to-income ratio, which is statistically significant at 1%.

[19] The 45 cities, with home purchase restriction reinforced in 2016, are Beijing, Chengdu, Chizhou, Dandong, Deyang, Dongguan, Foshan, Fuzhou, Guangzhou, Haikou, Hangzhou, Hefei, Huzhou, Huanggang, Huizhou, Jinan, Jiamusi, Jiaozuo, Jinhua, Jinzhou, Lanzhou, Linfen, Nanchang, Nanjing, Ningbo, Ordos, Rizhao, Sanming, Xiamen, Shanghai, Shenzhen, Shenyang, Shijiazhuang, Suzhou, Tianjin, Tongchuan, Wuxi, Wuhan, Xi'an, Xiangtan, Yulin, Zhangjiakou, Zhengzhou, Zhoukou, and Zhuhai.

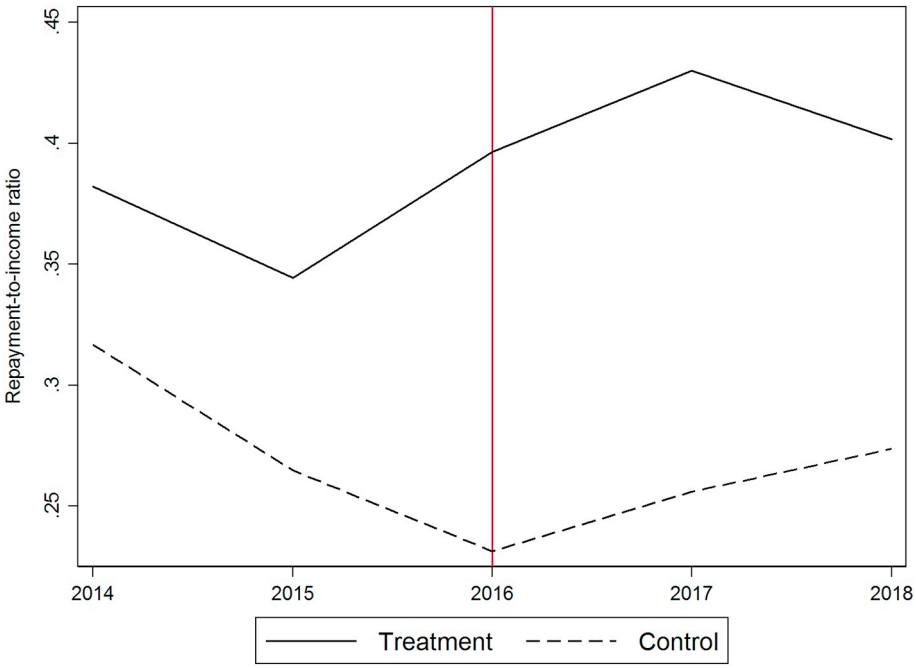

Fig. 7. Repayment-to-income ratios in cities nearby and farther away from the superstar cities.
Notes
1. See Subsections 3.1 and 3.3 for details on the method and data sources on calculating the housing expenditure-to-income ratio.
2. The treatment group includes 7 cities adjacent to the superstar cities. The control sample includes 223 cities not adjacent to the superstar cities.

Table 2
Regression result of spillover effect from superstar cities.

	(1)	(2)
Variables	HETI	HETI
treat × after	0.048***	0.045***
	(0.007)	(0.007)
Year FE	Yes	Yes
City FE	Yes	Yes
Observations	1150	855
R-squared	0.931	0.927

Robust standard errors in parentheses.
1. The standard errors are clustered at city level.
2. The sample in column (1) contains only 230 cities without the housing purchase restriction policy. The sample in column (2) restricts the control group to 171 cities, containing only the cities in the provinces that are neighboring superstar cities and those in provinces that neighbor the superstar cities. There are 7 treatment cities in both columns (1) and (2).
*** $p < 0.01$.

1.00. While this result is consistent with the city-level measure in the previous subsection and is certainly an extremely high repayment-to-income ratio, we are more interested in its micro-level distribution, especially when the potential mismatch between job and residential locations is taken into consideration.

The spatial distribution of workplaces is more concentrated near the city center than is the distribution of dwelling units in Chinese cities due to the undergoing housing market suburbanization (Zheng, Fu, & Liu, 2006). This pattern also applies to our sample city, as suggested in the cumulative distribution plot in Appendix Fig. C3. Table 3 directly reflects the micro-level affordability measure based on the average income of each workplace and the merged house prices. Columns 1 and 2 of Table 3 show the housing affordability measure by workplace and population, respectively. On average, the micro-level housing expenditure-to-income ratio was 1.308 by workplace and 1.138 by population. Both are higher than the repayment-to-income ratio calculated based on the average house price and household income (1.00, as described in the previous paragraph); in other words, the city-level affordability measure might still underestimate the housing affordability problem in the superstar cities because of job-housing mismatches.

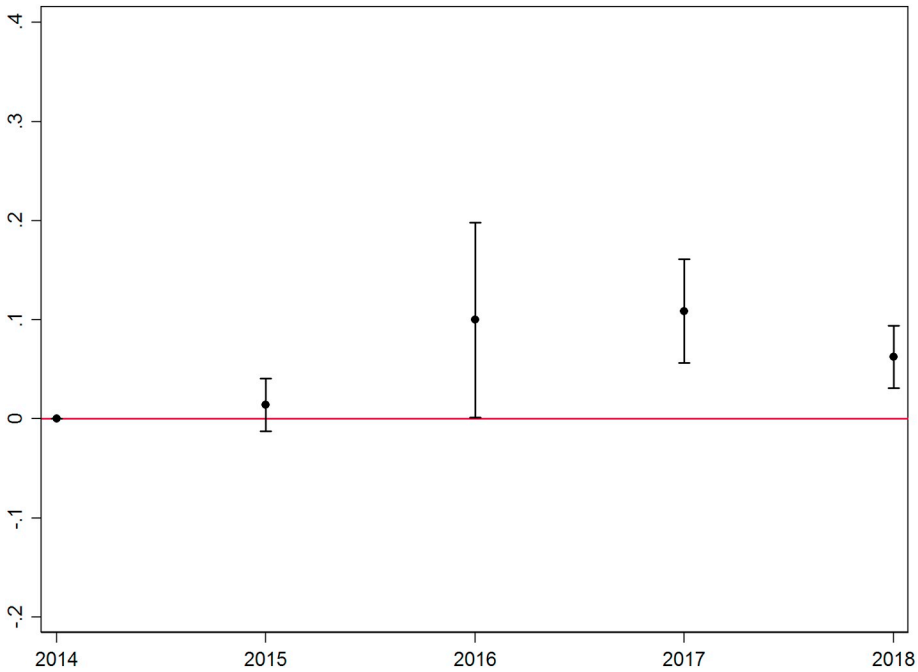

Fig. 8. Event study of spillover effect from superstar cities.
Notes
1. The figure visualizes the coefficients as well as the 95% confidence interval in Eq. (4)

Table 3
Housing affordability in different percentiles within a superstar city in 2015.

Percentile	Based on percentile of workplace	Based on percentile of population
99	3.719	3.311
95	2.919	2.444
90	2.445	2.039
75	1.727	1.421
50	1.112	0.991
25	0.709	0.662
Average	1.308	1.138

1. See the text for more details on the method and data sources on calculating the housing expenditure-to-income ratio.
2. Each employee with a housing expenditure-to-income ratio for his/her workplace is treated as an observation.

Meanwhile, the average value of the repayment-to-income ratio was much larger than its median value, by either workplace or population. For the top 10% of workplaces or population, the repayment-to-income ratio was beyond 2. Meanwhile, for > 75% of the workplace or population, the housing expenditure-to-income ratio exceeded the criterion of 0.5 for housing expenditure-to-income ratio. The results suggest that overall housing affordability was extremely high and unequal.

One might wonder how households in superstar cities can survive under such terrible housing affordability status. Certain factors should be considered in interpreting the housing expenditure-to-income ratio results in superstar cities. First, owing to rapid economic growth, most urban Chinese households have experienced (and are still expecting) continuous and substantial income growth,[20] and thus, could tolerate higher temporary housing expenditure-to-income ratio. For example, even if a household starts with a high repayment-to-income ratio of 1.00 as a result of a recent home purchase, the burden could be reduced to below 0.50 within 7 or 8 years if the household's income growth follows the average speed. Second, China's urban housing reform started with a high homeownership rate,[21] and thus, a large share of households could trade up in the housing market. That said, the housing expenditure-to-income ratios in these superstar cities are still extremely high, at least compared with other cities.

[20] The compound growth rate of disposable income for urban residents is 10.83% at national level from 2000 to 2016 according to the National Bureau of Statistics. The growth rates were even higher in the superstar cities.

[21] According to the 2000 population census, the homeownership rate is 74% at national level in 2000. As for the four superstar cities, the homeownership rates are 61%, 67%, 51% and 60% in Beijing, Shanghai, Shenzhen and Xiamen in 2000, respectively.

5.2. Consequences of unaffordable housing

In this section, we discuss the direct consequences of unaffordable housing in superstar cities. Facing high housing burden, households may choose to consume less housing space (i.e., live in smaller units). In addition, given the increasing housing prices in prime locations in superstar cities, people might not be able to afford high housing prices in prime areas, and therefore, might be required to buy houses in suburbs where housing prices are cheaper. However, given that there are disproportionally many more job opportunities in prime areas than in suburbs, commuting time might consequently increase.[22]

We examine these consequences of housing unaffordability within our anonymous superstar city. For this purpose, besides the results shown in Subsection 3.2, we further introduce micro-level mortgage application data provided by a leading mortgage supplier in this city. The sample covers transactions of newly-built and resold houses from January 2010 to December 2013, with detailed information on the address of the house purchased, the address of the workplace, transaction price, housing area, and a few demographic variables of the buyers, including their age, gender, and birth place. We match each observation in the dataset with the micro-level housing expenditure-to-income ratio for homeowners at each workplace. In addition, we use travel time by public transit and driving time to measure commuting time between the location of workplace and home, both of which are obtained by map Application Programming Interface (API) on Baidu maps, which helps retrieve commuting time for each origin–destination pair. The definition and descriptive statistics of variables are reported in Table 4. On average, the repayment-to-income ratio is 1.29, suggesting that housing affordability is extremely poor in the city. As for commuting time, the average travel time by public transit is 1.58 h and driving time is 0.58 h. The average housing area is 86.86 square meters.

We adopt a simple ordinary least square regression model to study the elasticity between repayment-to-income ratio at workplace and commuting time or housing area; that is:

$$ln(Y_{ij}) = \alpha ln(HETI_j) + \beta ln(inc_i) + \pi X_{it} + \eta_t + \varepsilon_{it} \tag{5}$$

where Y_{ij} is commuting time or housing area; $HETI_j$ is the repayment-to-income ratio of the workplace j; inc_i represents the monthly pre-tax income of the buyer i; X_{it} is the transaction price and a series of demographic variables of the buyers, including age, gender, and birth place; η_t is a year fixed effect; and ε_{it} is the error term. Therefore, α measures the elasticity between the housing affordability measure and commuting time or living area in different specifications.

Table 5 presents the regression results. Specifically, the dependent variable is the average travel time by public transit in column (1), the driving time in column (2), and housing area in column (3), all in log form. The core independent variable is the log of the repayment-to-income ratio, which is statistically significant in all the specifications. The coefficients indicate that a 1% increase in repayment-to-income ratio is associated with a 0.097% increase in commuting time by public transit, a 0.214% increase in commuting time by car, and a 0.066% decrease in housing size. The commuting time by car is more elastic with respect to housing affordability than is commuting time by public transit, possibly because public transit involves more fixed time cost, such as time spent on transfers and walking.

Moreover, we use the regression result in columns (1) and (2) of Table 5 to impute the welfare loss due to the increase of housing expenditure-to-income ratio based on a back-of-the-envelope calculation. Here we only focus on the time cost, assuming that the marginal direct transportation fee is zero. The welfare loss for the average wage earner is simply the change in commuting time multiplied by hourly pay (shown in Eq. (6)). As presented in Table 6, if the housing expenditure-to-income ratio increases by one standard deviation, the annual welfare loss is approximately 1923.72 yuan per wage earner (or 0.042 standard deviation of annual wage) if the elasticity is calculated based on commuting time using public transit, or 1551.13 yuan (or 0.034 standard deviation of annual wage) if the elasticity is based on commuting time using cars.

$$\begin{aligned} \textit{Annual Welfare loss} = {} & \textit{One stardard deveiation increase in HETI} \times \textit{Estimated elasticity} \times \textit{Average travel time (hour)} \times \textit{Average hourly pay} \\ & \times 2\ \textit{Commutes per day} \times \textit{Number of working days per year (250 days)} \end{aligned} \tag{6}$$

Considering such a substantial negative welfare effect, as introduced above, the Chinese government has been devoting a large volume of financial resources to the public housing sector during recent years. However, it seems that the resource allocation still requires further improvement. While this topic is well beyond the scope of the current paper, in Appendix Fig. C4 we provide the suggestive evidence based on the statistics in 2013, the only year in which the city-level statistics on government expenditure on public housing is available. The horizontal axis depicts the city-level repayment-to-income ratio in 2012 based on the extended panel, while the vertical axis depicts the per capita public housing expenditure in 2013. The plots suggest a negative (although weak) correlation; that is, the cities with worse affordability problems at least did not spend more on public housing. Admittedly, we cannot conclude in any causality here, but it at least suggests that the public housing expenditures need to better fit the condition and consequences of housing affordability problems in various cities.

6. Conclusion

In this study, we document the overall housing affordability level in Chinese cities, the serious housing unaffordability problem in

[22] A relevant research along this line is by Linn, Wang, and Xie (2018), who found that in 2010, Beijing residents who received subsidized housing prior to the 1998 housing reform lived and worked much closer to the city center than the control group, had much shorter commuting distances, and were much less likely to use automobiles to commute.

Table 4
Definitions and descriptive statistics of variables.

Variable	Explanation	Obs.	Mean	Std. dev.	Min	Max
bus_dur	Travel time by public transit; in hours	10,442	1.58	0.90	0.23	10.36
car_dur	Driving time; in hours	10,548	0.58	0.48	0.01	12.96
area	Unit size; in square meters	10,550	86.86	27.20	25.29	346.60
HETI	Housing expenditure-to-income ratio	10,550	1.29	0.84	0.13	6.09
income	Pre-tax income; in yuan	10,550	6185	3810	300	79,244
hp	Transaction price; in 10,000 yuan	10,550	116.21	57.72	13.50	886.05
female	Whether the individual is female; 1 = yes, 0 = no	10,550	0.49	0.50	0	1
age	Age; in years	10,550	32.22	5.61	21	59
local	Whether the individual is a local resident; 1 = yes, 0 = no	10,550	0.41	0.49	0	1

Table 5
Impact of deteriorating housing affordability on commuting time.

	(1)	(2)	(3)
Variables	ln(bus_dur)	ln(car_dur)	ln(area)
ln(HETI)	0.097***	0.214***	−0.066***
	(0.010)	(0.014)	(0.004)
ln(income)	−0.036***	−0.018	−0.036***
	(0.010)	(0.014)	(0.005)
Local	−0.038***	−0.058***	0.053***
	(0.012)	(0.017)	(0.006)
Female	−0.058***	−0.087***	−0.005
	(0.011)	(0.016)	(0.005)
Age	−0.013	−0.029**	0.035***
	(0.010)	(0.014)	(0.004)
Age^2	0.000	0.000*	−0.000***
	(0.000)	(0.000)	(0.000)
ln(hp)	−0.047***	−0.037*	0.300***
	(0.013)	(0.019)	(0.007)
Year FE	Yes	Yes	Yes
Observations	10,442	10,548	10,550
R-squared	0.022	0.039	0.226

Robust standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 6
Welfare analysis based on columns (1)–(2) in Table 5.

	Public transit	Driving
(1) One standard deviation of housing expenditure-to-income ratio (normalized by the average housing expenditure-to-income ratio)	65.1%	65.1%
(2) Estimated elasticity on commuting time	0.097	0.214
(3) Average commuting time (h)	1.576	0.576
(4) Number of commutes per day	2	2
(5) = (1)*(2)*(3)*(4) Increase in daily commuting time (h)	0.199	0.160
(6) Average hourly pay (yuan)	38.660	38.660
(7) Working days per year	250	250
(8) = (5)*(6)*(7) Annual welfare loss (yuan)	1923.72	1551.13

the superstar cities, as well as the potential consequences of housing unaffordability. Our results suggest that the overall level of housing affordability in Chinese cities remained relatively stable or even improved during the sample period between 2014 and 2018. However, we identify a few “superstar cities”, such as Beijing, Shanghai, Shenzhen, and Xiamen, which are associated with serious housing affordability problem. Such problem results from both a shortage of supply in the housing space market and a potential

mispricing in the asset market, and may generate spillover effect to the surrounding cities due to the home purchase restrictions in these superstar cities. Last but not least, the micro-level analysis suggests that the housing affordability problem is associated with longer commuting time of the residents within these superstar cities, and lower housing space consumption to control their housing expenditures.

To alleviate housing affordability issues especially in big cities, some policies have been implemented or are set to be implemented in Chinese cities. In particular, besides the conventional policies such as the provision of public housing and HPF, the central and local governments started several new policy schemes in recent years. For example, the provision of shared ownership housing was piloted in a few cities in China from 2007, including Huai'an, a small city in Jiangsu Province, and Shanghai, and was implemented in Beijing in 2018. The shared ownership housing scheme in China allows the sharing of home ownership between a homebuyer and the government. Therefore, the housing price afforded by the homebuyer is 30–50% lower than the market price. Besides, the development of the rental market has become a priority in first- and second-tier cities in China since late 2016. In August 2017, a pilot program was introduced in 12 major cities in China, in which tenants of rental properties will enjoy the same access to public services as property owners. Therefore, evaluation of the effectiveness of such policies is important and awaits future research.

Appendix A: Gap between listing price and transaction price

In order to investigate the potential effect of the gap between listing prices and transaction prices on our results, we collect micro-level housing resale transaction data from a leading brokerage company in China. This dataset covers all resale units sold by this brokerage company between 2014 and 2018 in 21 major cities, namely, Beijing, Changsha, Chengdu, Chongqing, Dalian, Dongguan, Foshan, Guangzhou, Hangzhou, Hefei, Jinan, Langfang, Nanjing, Qingdao, Shanghai, Shenyang, Shenzhen, Suzhou, Wuhan, Xiamen, and Yantai. For each transaction, we calculate the ratio between the transaction price and the listing price. For all the 763,049 observations, the average ratio is 0.97; that is, on average the transaction price is 3% lower than the listing price. It is more important to note that, as shown in Fig. A1, the variation in the average ratio between these city-years is actually small. Therefore, using listing price, instead of transaction price, might slightly affect the level of affordability indicator calculated, but it would not affect the analysis on the temporal pattern or the city variations.

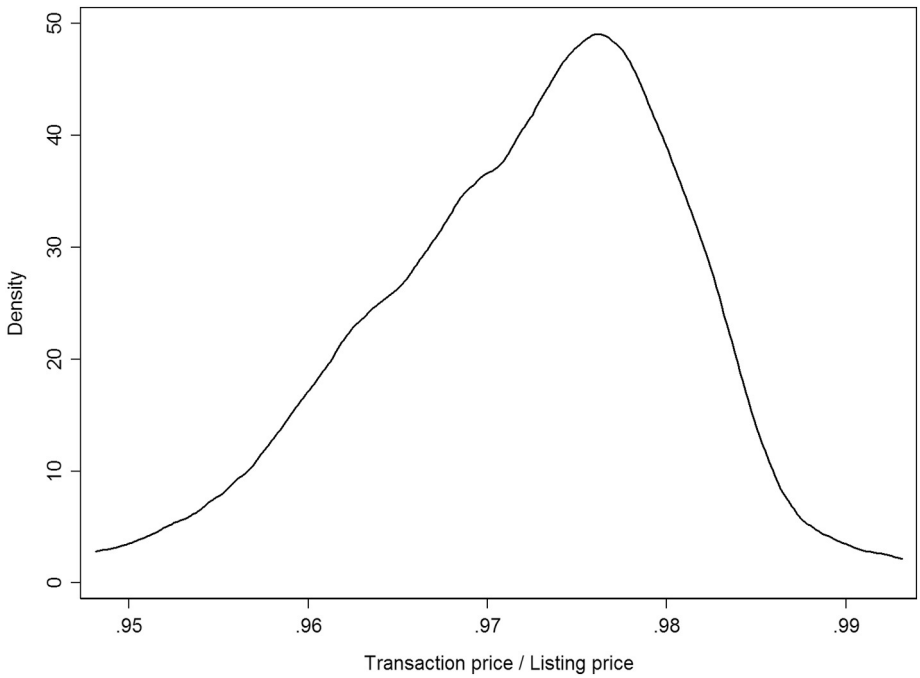

Fig. A1. Kernel density of transaction-listing price ratio in 21 major cities from 2014 to 2018.

Appendix B: Housing affordability in all Chinese cities from 1999 to 2018

Besides the city-level analysis between 2014 and 2018, we also extend the annual series to 1999, in order to investigate the housing affordability for homeowners in all Chinese cities from a longer horizon. As for the housing price series, we extend the annual series based on the annual growth rates of average transaction prices of newly-built housing units between 2000 and 2014, assuming that the resale housing prices and newly built housing price share very similar dynamic patterns. On the other hand, the source of the income data remains consistent.

In order to test the above assumption, we introduce the panel dataset covering 89 major Chinese cities between Jan, 2015 and Dec, 2017. For each city-month, we calculate the year-on-year growth rates for both the average resale housing prices and newly-built housing prices. The resale housing prices are calculated based on the online housing listing information as described in Wang, Li, and Wu (2018), while the newly-built housing prices are collected from the local housing authorities. As shown in Column 1 of Table B1, the correlation coefficient between resale housing price growth rates and newly-built housing price growth rates is 0.963, and it is statistically significant. In Column 2, we further introduce the year fixed effect and city fixed effect to calculate the conditional correlation coefficient, and the results remain consistent. Accordingly, it is reasonable to assume that resale housing prices and newly-built housing price share very similar dynamic patterns in the long run.

Based on the extended dataset, we plot the repayment-to-income ratio at different percentiles in our sample cities in Fig. B1. The figure shows a similar pattern as in Section 4.1. The median value of the repayment-to-income ratio kept within the range of 0.22–0.42 during the sample period, with mild fluctuations. We also provides four snapshots on spatial distribution of housing affordability in all the 275 cities in our sample in 2001, 2006, 2011 and 2016. As shown in Fig. B2, the cities with the worst housing affordability conditions, including Beijing, Shanghai, Shenzhen and Xiamen, remained almost unchanged during the sample period.

Table B1
Correlation between the average price growth rate of resale units and newly-built units in 89 major cities from 2015 to 2017.

	(1)	(2)
Variables	hpg_resale	hpg_resale
hpg_newly	0.963***	0.716***
	(0.110)	(0.198)
Year FE	No	Yes
City FE	No	Yes
Observations	266	266
R-squared	0.312	0.574

Robust standard errors in parentheses.
*** $p < .01$.

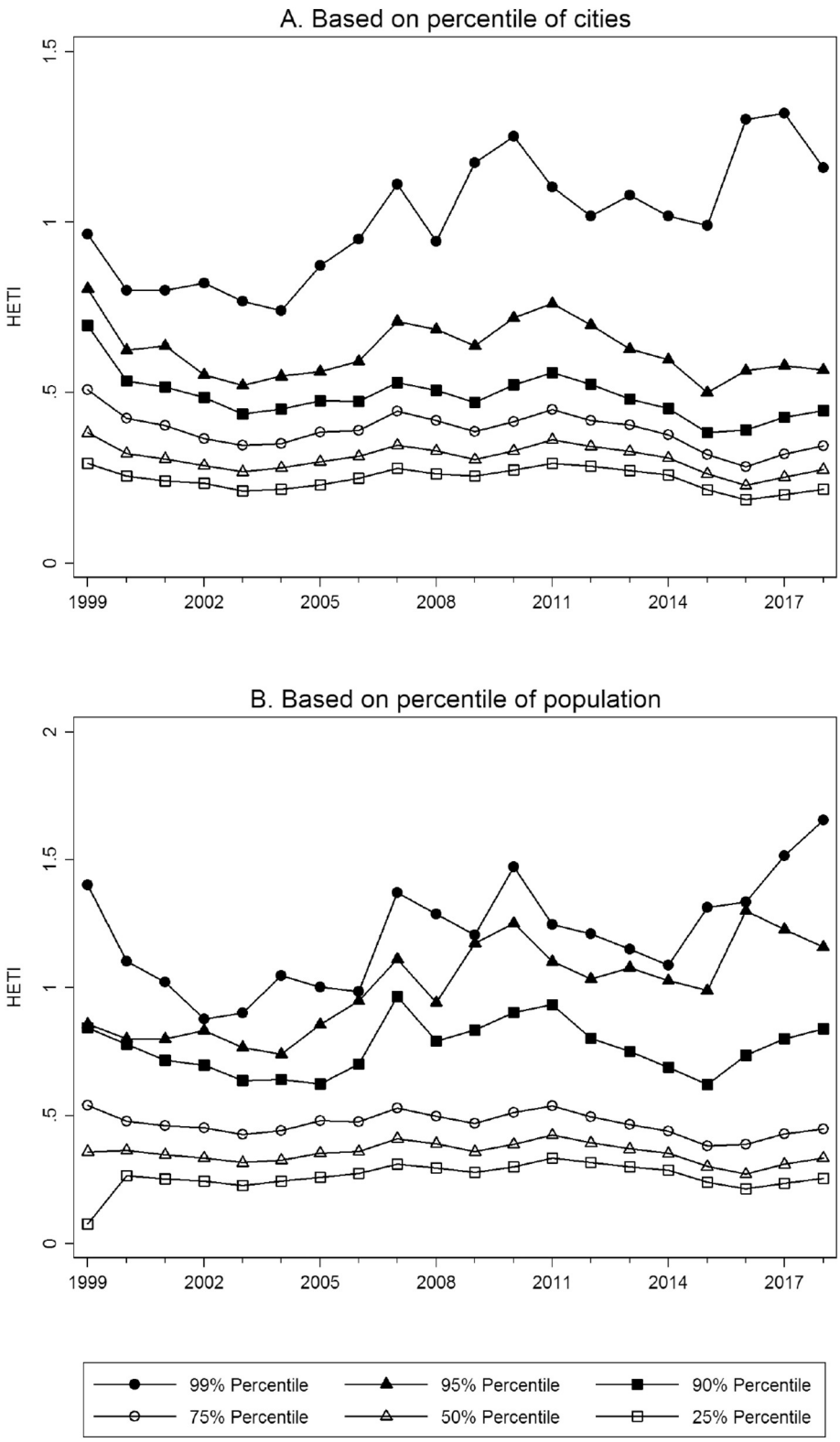

Fig. B1. Changes of housing affordability in different percentiles of cities between 1999 and 2018.
Notes: See Subsections 3.1 for details on the method of calculating the housing expenditure-to-income ratio.

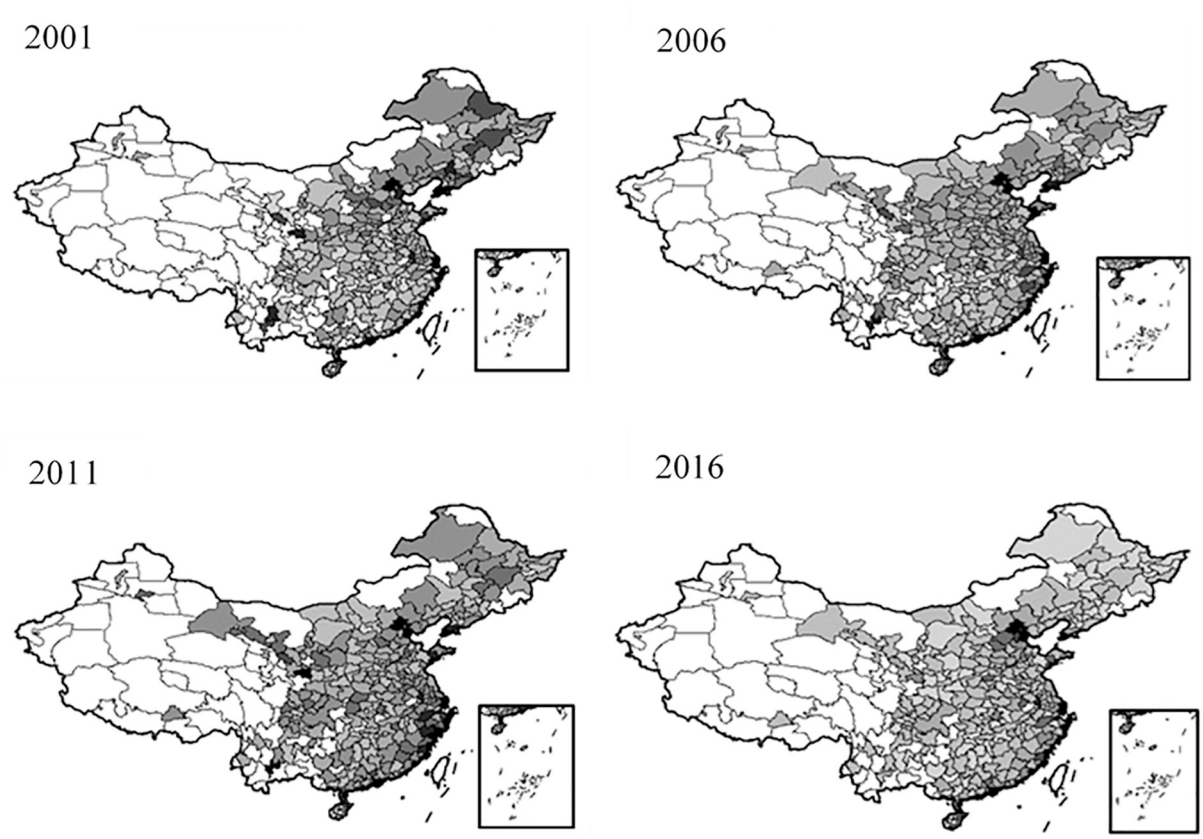

Fig. B2. Spatial distribution of repayment-to-income ratio of all cities in four representative years.
Notes: See Subsections 3.1 for details on the method of calculating the housing expenditure-to-income ratio.

Appendix C: Other appendix figures

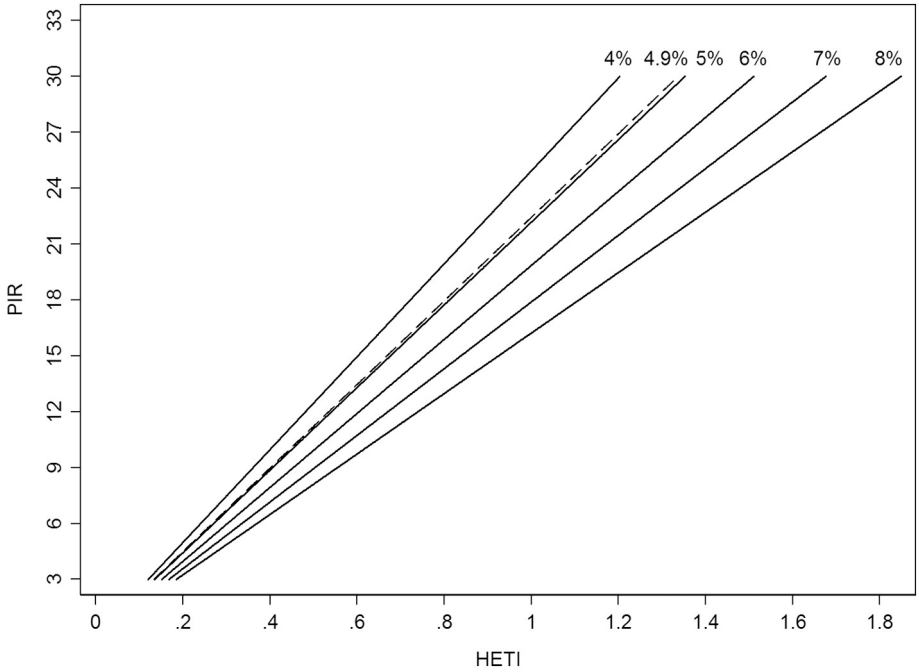

Fig. C1. Indifferent curves between repayment-to-income ratio and PIR.

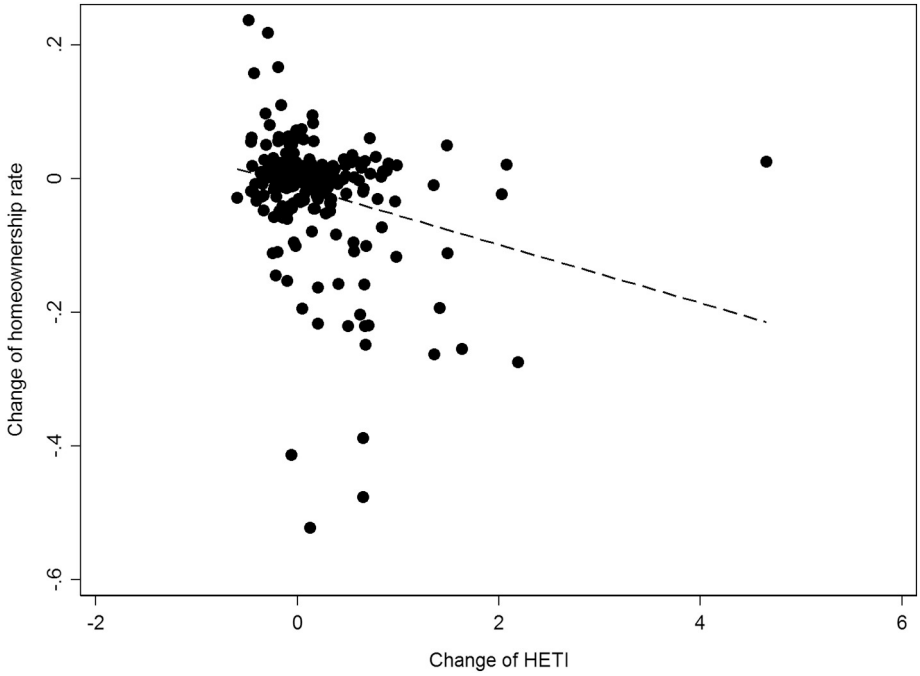

Fig. C2. City-level change of homeownership rate and change of repayment-to-income ratio between 2000 and 2010.
Notes: Change of homeownership rate is calculated based on the 5th and 6th population censuses in 2000 and 2010, respectively. The repayment-to-income ratio is calculated by the authors. The dashed lines are linear fit.

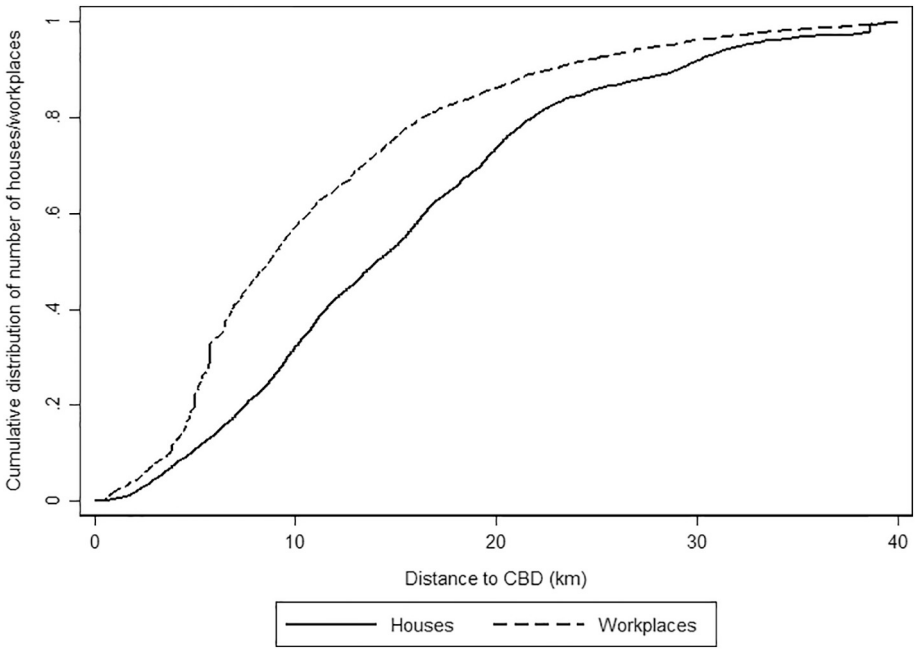

Fig. C3. Cumulative distribution of number of houses and workplaces.
Note: See Subsection 3.2 for details of the data source.

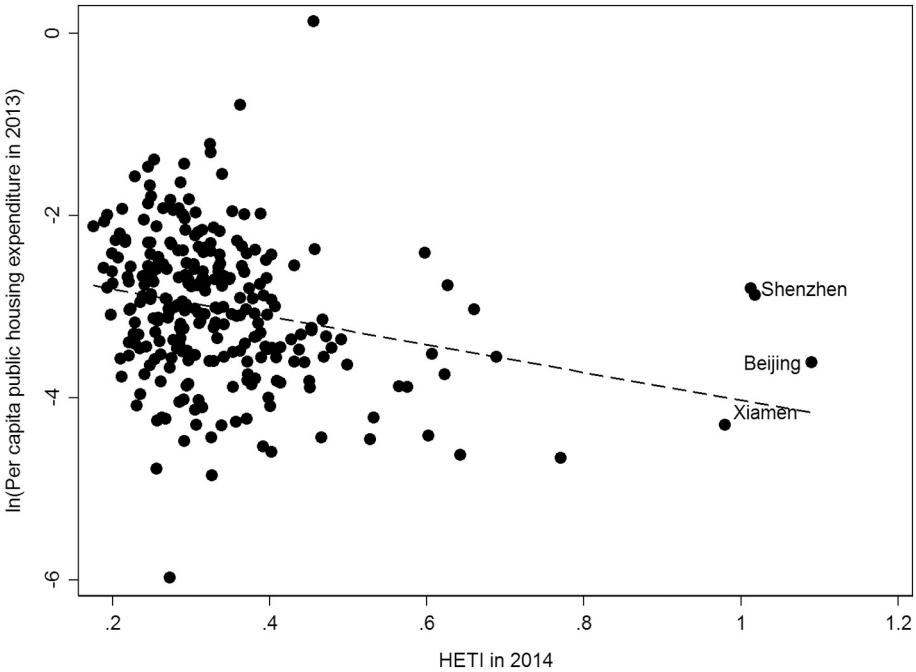

Fig. C4. Resource allocation of government expenditure on public housing.
Notes
1. The per capita public housing expenditure in 2013 is calculated based on the 6th nationwide population census and China Statistical Yearbook for Regional Economy. The indicators in two cities, including Nanning and Shanghai, are missing. The housing expenditure-to-income ratio is calculated by the authors.
2. The dashed lines are linear fit.

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