



# Analysis on Housing Affordability of Urban Residents in Mainland China Based on Multiple Indexes: Taking 35 Cities as Examples

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## Abstract

Over the last 10 years, the soaring housing prices have raised concerns over ‘affordability’ in Chinese housing market, although it is still not enshrined in agreed standards, partly because of different opinions about how it should be measured. To overcome the inadequacy of a single index, we examine the housing affordability of 35 large and medium cities in China from 2009 to 2016 using price-to-income ratio (PIR), monthly payment-income ratio (MIR) and the residual income approach (RI). With consideration of the characteristics of China’s real estate market, we have re-discussed the reasonable range of the indexes. The comparison of single index between cities shows significant periodicity and multi-index clustering analysis reveals regional characteristics, which help us to further the understanding of housing affordability. In the end, policy recommendations on reforming Chinese urban housing system are suggested according to the differences and changing laws of housing affordability among cities.

**Keywords** Price-to-income ratio · Monthly payment-income ratio · Residual income · Housing affordability

## 1 Introduction

Over the last 10 years, the massive rise in house prices surpassed the increase in disposable income of residents, which has spurred the issue of housing affordability for most urban residents to be one of the top social concerns in China. There is clear evidence that the poverty and wealth have become more polarized due to high prices on Chinese housing market [1]. Taking account of this, many scholars have studied

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the owner's housing affordability with theoretical and empirical researches done from different perspectives.

There has been a long-running but not fully resolved debate between different approaches when measuring affordability and setting standards: 'affordability ratios' versus 'residual income'. Within recent literature one can see that there are three main types of measures—"expenditure on housing to income ratio", "residual income approach", and "house price to income ratio", of which the last one is more frequent [2–4]. Weicher proposed using the ratio of the median price of new homes actually sold to the median of household's income (per year) to examine the housing affordability [5], which is the broadest index available in developed countries. However, the ratio of average income and the average housing price is preferred in the domestic market due to the availability of data. Zhang thought that the investigation of the "house price–income ratio" aimed to reflect the payment capacity of residents and the state of market operation. This measure uses the average actual-trading areas and the average total family income [6].

As for the reasonable intervals, Bertrand Renaud, chief economist of the World Bank China, argued that "house price–income ratio" in fast urbanized countries (developing countries) is often ranging from 4 to 6 [7], which is used by many researchers as international experience data. However, Gan suggested that "4–6 times" for the reasonable interval may not apply to every country [8]. Considering that China's residential market is dominated by newly-built residential buildings, the great difference between old and new residential prices, and the special situation that residents may receive parents' assistance when purchasing housing, Ding revised the empirical data, give "3.5–6.9" for the reasonable interval in China [9]. According to the loan interest rate and other factors, China's reasonable interval of PIR calculated by Liu is 2.85 and 9.21 [10]. Another problem is that whether in developed or underdeveloped economies, incomes do not grow more than 10% per year. This means that *any* period of a sharp rise in prices will be characterized by an increase in price to income ratio, therefore, the ratio cannot distinguish periods where prices increase caused by structural or non-sustainable factors.

In addition to PIR, M.E. Stone argues that the residual income method is more reasonable in measuring housing affordability of families with different income levels [11]. Stephen measured the housing affordability of families having housing and that of rented families with a monthly payment-income ratio and rent-income ratio respectively [12]. Oliner outlined an approach to constructing a Dynamic Housing Affordability Index (DHAI) that is grounded in the user cost theory and influenced by variations in the price of housing, mortgage interest and property tax rates, property insurance, transaction costs, and depreciation and maintenance, which reflects the anticipated cost of owner-occupied housing and performs well in tracking changes in the demand for homeownership [13]. Li and Su proposed a flexible evaluation strategy of affordable public housing price based on extended linear expenditure system (ELES), comparing the affordable public housing price with the housing affordability and analyzing whether they are matched [14]. Yang and Yi applied residual income for Beijing households and revealed that middle and low-income families in Beijing cannot afford a standard unit [15]. Zhang and Feng put forward a new method of measurement with combination of the house prices and income consumption level

regional development level by supplying structure of the housing market credit level and other factors and making an empirical study of residential housing purchasing power of 35 major cities of mainland China in 2009 [16]. Yang and Wang studied the housing affordability of residents in Changsha using residual income method and gave suggestions in the end [17].

From the previous study, we could find the following problems: first, the indicators can reflect partial information of the residents housing affordability, but there is controversy about how to define the current indicators to be more reasonable; second, each indicator has their own advantages and disadvantages, so there may be a one-sidedness in the evaluation using a single indicator; third, the studies of regional characteristics are mostly from the static point of view, while ignoring the dynamic perspective of the temporal information; Fourth, the conventional study lacks of the regional characteristics of the residents and is on the subjective assessment of a researcher when finding the similarity. Therefore, we choose price-to-income ratio and monthly payment-income ratio from the supply and demand side respectively and pick residual income with consideration of nonhousing needs of households which the first two ignore. In order to find regional characteristics and changing laws of housing affordability in different cities, this paper will make dynamic comparison with a single index and clustering analysis with multiple indexes based on the re-designed standard.

## 2 Evaluation System Development

### 2.1 Price-to-Income Ratio (PIR)

#### 2.1.1 Initial House Price–Income Ratio

Given the characteristics of statistics in our country, we adopt the average house price of the city or the country to average family income as PIR, which can be written as:

$$PIR = \frac{p \times S \times N}{I \times N} = \frac{p \times S}{I} \quad (2-1)$$

where  $p$  represents the average price of the national or city's new commercial housing,  $I$  denotes the per capita income,  $S$  denotes per capita housing area of urban household, and  $N$  is the population of each family. The bigger the PIR is, the worse people's housing affordability.

#### 2.1.2 Reasonable Interval of PIR

In order to understand the precise meaning of the value of PIR, we need to determine the reasonable interval of PIR. Currently, the reasonable interval that is commonly used in the world is ranging from four to six. As different country faces unique national situation, the reasonable interval does as well. In this paper, we use the theoretical model of purchasing a house to examine the reasonable interval of PIR from 2009 to 2016.

In China, when house purchasers buy a house, they need to pay at least 20 or 30% of the total prices.<sup>1</sup> Assume the proportion of down payment is  $k$ , and the residual amount is borrowed from a bank that will be amortized. Mostly, housing loan is a medium and long-term loans. We suppose medium and long-term loan rate of bank (more than 5 years) is  $i$ , amortization period is  $n$ , and the ratio of loan payments every year to family income every year is  $m$ . Housing is:  $P = p \times S \times N$ , household disposable income is:  $W = I * N$ , here  $p, S, N$  and  $I$  have the same meaning with (2-1), so we have:

$$(1 - k) \times P = m \times W \times \frac{(1 + i)^n - 1}{i \times (1 + i)^n} \quad (2-2)$$

$$\frac{(1 - k) \times P}{W} = m \times \frac{(1 + i)^n - 1}{i \times (1 + i)^n} \quad (2-3)$$

That is:

$$PIR = \frac{m}{(1 - k)} \times \frac{(1 + i)^n - 1}{i \times (1 + i)^n} \quad (2-4)$$

When examining the reasonable interval of PIR in China,  $m$  is assumed to be 50%.<sup>2</sup> From 2009 to 2016, the medium and long-term loan rate has been adjusted 13 times<sup>3</sup> To get the annualized interest rate ( $i$ ), we compute the mathematics average for this rate with the weight of the duration.

As we know,  $k$  is 20 or 30% and amortization period ( $n$ ) is mostly between 5 and 30 years. When  $k$  is 30% and  $n$  is 30 years, the upper boundary of reasonable interval can be calculated by the above equation. Similarly, when  $k$  is 20% and  $n$  is 5 years, we can get the lower boundary of reasonable interval. As indicated in Table 1, the reasonable interval of China is about (2.6, 9.0). So the general experience vale is not very applicable to our country.

### 2.1.3 Revision of PIR

PIR is a relative value. For different reasonable intervals, there are different meanings to the same value. In this paper, we carry on comparative analysis of different years of house price to income ratio. While the medium and long-term loan interest rate change calls for the change of a reasonable interval of PIR, we need to combine the reasonable interval of PIR of every year to modify PIR. Since PIR is an indicator of reverse-type, we can make use of this correction to make it positive for principal component analysis.

<sup>1</sup> According to the "General Office of the State Council forwarded the Ministry of Construction and other departments on the adjustment of housing supply structure to stabilize the views of house prices notice" (State Council issued [2006] No. 37) Article 5.

<sup>2</sup> According to the "Guidelines for Risk Management of Commercial Banks' Real Estate Loans" issued by the CBRC in September 2014.

<sup>3</sup> Data source: WIND database.

**Table 1** Reasonable interval of PIR of China in 2009–2016

Year	2009	2010	2011	2012	2013	2014	2015	2016
Weighted average interest rate (%)	5.94	6.19	6.96	6.66	6.55	6.52	5.53	4.90
Upper boundary of interval	9.50	9.46	8.90	9.18	9.27	9.31	9.63	9.90
Lower boundary of interval	2.63	2.62	2.57	2.59	2.60	2.61	2.67	2.71
Interval length	6.87	6.84	6.33	6.59	6.67	6.70	6.96	7.19

For a given year  $y$ , the lower boundary of interval is  $A_y$ , the reasonable interval length is  $D_y$ , and PIR of city  $C$  in year  $y$  is  $PIR_{Cy}$ . Thus, the corrected PIR can be expressed as:

$$PIR'_{Cy} = \begin{cases} 100 + \frac{A_y - PIR_{Cy}}{D_y} \times 100 & PIR_{Cy} < A_y \\ 100 & PIR_{Cy} = A_y \\ 100 - \frac{PIR_{Cy} - A_y}{D_y} \times 100 & PIR_{Cy} > A_y \end{cases} \quad (2-5)$$

It is reasonable when  $PIR'_{Cy}$  is bigger than 100. And the bigger this value, the better the purchasing power of households.

**2.2 Monthly Payment-Income Ratio (MIR)**

Monthly payment-income ratio (MIR) is the ratio of the monthly mortgage expenditure of urban households to disposable income per month, it can be calculated as:

$$\begin{aligned} MIR &= \frac{\text{Monthly mortgage expenditure}}{\text{Family monthly disposable income}} \times 100\% \\ &= \frac{\text{Monthly mortgage expenditure}}{I \times N} \times 100\% \end{aligned} \quad (2-6)$$

The application conditions of MIR are buying houses on mortgage. According to the existing execution standard of first suite,<sup>①</sup> we choose the proportion of new house down payments  $k=30%$ , thus,

$$\begin{aligned} \text{Monthly mortgage expenditure} &= P \times (1 - k) \times \frac{i}{12} \times \frac{\left(1 + \frac{i}{12}\right)^{360}}{\left(1 + \frac{i}{12}\right)^{360} - 1} \\ &= p \times s \times N \times 0.7 \times \frac{i}{12} \times \frac{\left(1 + \frac{i}{12}\right)^{360}}{\left(1 + \frac{i}{12}\right)^{360} - 1} \end{aligned} \tag{2-7}$$

Here the meaning of  $p, s, N$  is the same with (2-1). Usually, when MIR is below 50%, residents have a certain ability to purchase.<sup>②</sup> The lower the MIR, the stronger the residents’ affordability.

### 2.3 Residual Income (RI)

Residual income (RI) refers to the gap between family disposable income per year and non-housing expenditure of households. It is considered as maximum affordability for housing. This measure is proposed for the deficiency of PIR and MIR with consideration of social standards of housing and consumption characteristics of households, which are often used in the study of purchasing ability of different income groups.

Set family expenditure per capita to  $c$ , which includes consumer spending, housing and construction spending, metastatic spending, property spending and social security spending. Housing and construction spending per capita ( $hc$ ) is regarded as housing expenditure. The spread between them is non-housing expenditure, which can be written as:

$$\text{Family non - housing expenditure per capita } \overline{hc} = c - hc \tag{2-8}$$

$$\text{Family residual income per year } RI = (I - \overline{hc}) \times N \tag{2-9}$$

At present, the standard housing for a family of three, adopted by most study on residual income measure, is 90 m<sup>2</sup> [18]. Meanwhile, in order to indicate the maximum payment capacity of households, we set the proportion of payment down to 30% and maturity of 30 years, thus:

$$\text{Loan repayments per year } A = P \times (1 - k) \times \frac{i \times (1 + i)^n}{(1 + i)^n - 1} = p \times 90 \times 0.7 \times \frac{i \times (1 + i)^{30}}{(1 + i)^{30} - 1} \tag{2-10}$$

$$RIGAP = RI - A \tag{2-11}$$

Here the  $p$  has the same meaning with the Eq. 2-1;  $k$  and  $i$  is the same with 2-2. RIGAP, that is the gap between family residual income and loan repayment per year. If  $RIGAP > 0$ , households have some ability to purchase a house and the opposite does not have. Theoretically, the bigger the gap, the stronger the affordability of households.

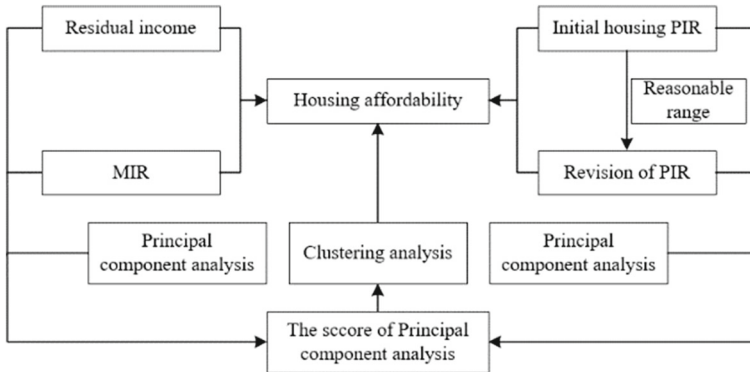


Fig. 1 The evaluation system

## 2.4 Construction of Evaluation System

There are advantages and disadvantages of each evaluation index. In consideration of the complementary of index and data availability, we choose PIR, MIR and RI to assess the affordability of households comprehensively. The evaluation system is illustrated in Fig. 1. Evaluation system consists of three parts: (a) single-index analysis: based on the analysis of three indicators of panel data; (b) multi-index comprehensive evaluation: reduce dimension of the three indicators of panel data by principal component analysis and analyze with the principal component scores and ranking of each city indices and ranking comprehensive analysis; (c) comparative evaluation: use cluster analysis based on the scores of three index from principal component analysis to get regional characteristics of households' housing affordability.

## 3 Empirical Analysis of Households' Housing Affordability

Now we examine PIR, MIR and RIGAP with single-index analysis, multi-index analysis and comparative evaluation in China's 35 large and medium cities including nationwide from 2009 to 2016.<sup>4</sup>

### 3.1 Single-Index Analysis

#### 3.1.1 Analysis Based on PIR and MIR

The PIR and MIR of 35 large and medium cities are presented in Figs. 2 and 3. From Fig. 2 we know that most cities' PIR are within the reasonable interval (2.6, 9.0). The PIR of Beijing, Shenzhen, Fuzhou, Hangzhou is larger than 9, which indicates

<sup>4</sup> Source: WIND database, cities' and national yearbook. In the calculation of RIGAP, some cities in the statistical yearbook published the total household expenditure only without the purchase and construction expenditure while the province where the city located published data completely. So we estimated the missing data according to the their corresponding relationship.

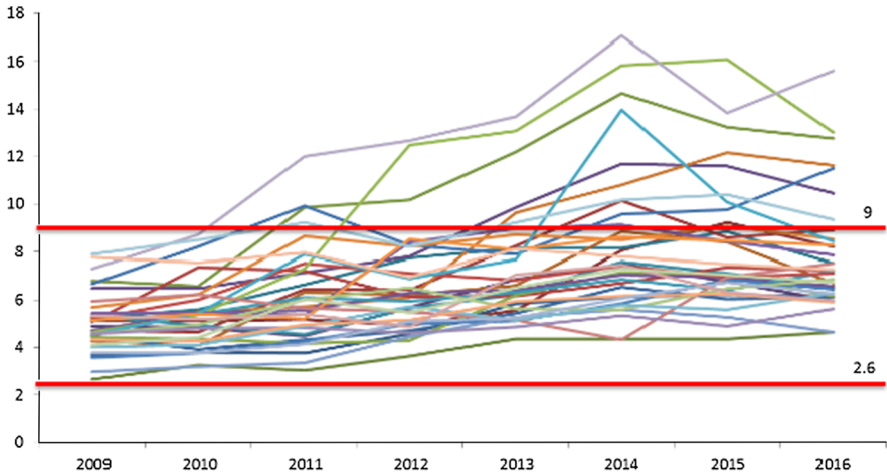


Fig. 2 The PIR of 35 cities from 2009 to 2016

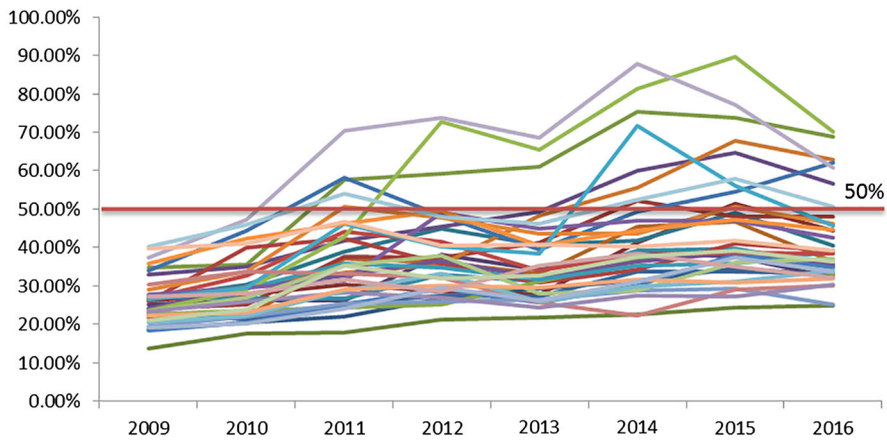
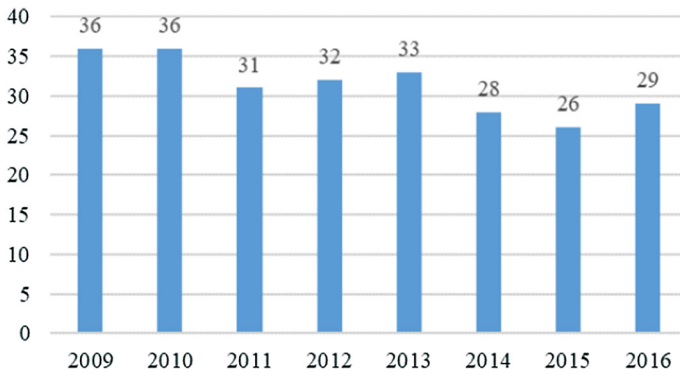


Fig. 3 The MIR of 35 cities from 2009 to 2016

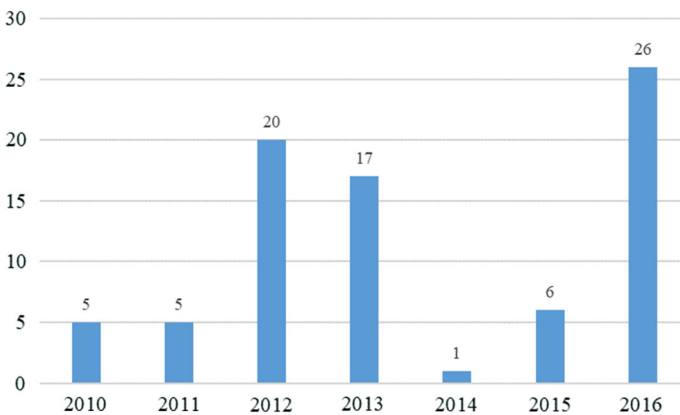
that most large and medium-sized cities' households of our country have ability to purchase while the purchasing power of second-tier cities' households is poor. The message from MIR in Fig. 3 is similar to PIR.

From Fig. 4 we know that from 2009 to 2010, all cities' and national PIR are in the reasonable intervals, which indicates better affordability. From 2011 to 2013, the number of cities whose PIR is in the reasonable intervals had declined but gone up again year by year as the result of the pressuring prices by the government during that period of time. Spanning from 2014 to 2016, the number of cities whose PIR was within a reasonable interval experienced a fluctuation, but the average purchasing power of households shrunk, compared with the previous two phases.





**Fig. 4** The number of cities with PIR in reasonable intervals from 2009 to 2016



**Fig. 5** The number of city with negative growth from 2010 to 2016

### 3.1.2 Analysis Based on RIGAP

As reviewed in 3.1.1, most cities' PIR and MIR performed well from 2009 to 2016. But in terms of RIGAP, all the RIGAP value is negative except Shenzhen in 2009 which explains that almost residual income of each city is not enough to pay the prevailing housing mortgage. Overall, it shows weak affordability of urban residents in our country.

Almost all RIGAP are negative. From the point of growth rate, if the growth rate of RIGAP is negative, it indicates that the unaffordability of households is on the mend. In Fig. 5, the growth rate of 26 cities in 2016 is negative. As residual income per year grows and the gap declines, the affordability of households is getting better yet still lacking.

Besides, Fig. 5 shows similar characteristics of Fig. 4 and the housing affordability of households in large and medium-sized cities in China can be divided into three stages from 2009 to 2016. Urban residents' housing affordability was relatively good from 2009 to 2010; from 2011 to 2013, it showed a certain degree of decline; from 2014

to 2016, it fell again but improved within the interval. In addition to the periodicity of housing affordability of households, it also shows that regulation and control measures over China's real estate industry have some impact to improve the capacity.

### 3.2 Comparative Evaluation: Principal Component Analysis

Principal component analysis replaces high-dimensional space with lower-dimensional space, which supplies a projection of this object when viewed from its most informative viewpoint. It uses only the first few principal components so that the dimensionality of the transformed data is reduced as well as duplicate information between indicators. It becomes more difficult to research on the regional characteristics of households' housing affordability through cluster analysis as we use multiple indexes of panel data. With the help of principal component analysis, we can take advantage of component scores from simplified panel data to do cluster evaluation. In this paper, we do principal component analysis by using SPSS 21.0 with time as a variable, thus being able to retain the original temporal characteristic of data.

We do the principal component analysis for  $PIR'_{C_y}$ , MIR, RIGAP respectively. During the KMO and Bartlett test inspection, KMO value is 0.854, 0.854 and 0.847. All of them are greater than 0.5, showing that the samples are sufficient. The associated probability of Bartlett test Chi square value is 0.000, which indicates that the correlation matrix is not a unit matrix and three indicators are appropriate for principal component analysis. When extracting the common factors, two are extracted from each index which could explain 92.661, 92.109 and 94.622% of the variables respectively. Ending up with principal component score, the results are presented in Table 2.

It can be seen from Table 2 that the characteristics of corrected PIR score are similar to the MIR score. That is the city with more developed economy and better living environment has lower score. Beijing, Tianjin and Shenzhen are ranked in the latter position, but Shanghai and Guangzhou's top ranking. The ranking of RIGAP score of the city is distinct from PIR and MIR. The economically developed cities rank later obviously, as Beijing, Shanghai, Guangzhou, Shenzhen occupy the last row. The top cities ranked by the three indicators show some difference, but not much. At this point, three indicators show a commonality.

### 3.3 Comparative Analysis: Cluster Analysis

According to the main component score in Table 2, the cluster analysis results are shown in Fig. 6. In this case, 35 cities can be divided into four groups, the results of which are shown in Table 3.

From the above grouping situation, we can see the following characteristics:

First, the average level of the national town is highly representative. Although the average of the national is poor by the score ranking of  $PIR'_{C_y}$  and MIR, it is assigned to a group with most of the cities by the integrated three indicators which can be seen in a certain representation and learn from meaning.

Second, economically developed cities have similar housing affordability. In terms of ranking, the relatively developed cities rank behind. They have similar economic

**Table 2** 35 large and medium cities' scores of  $PIR'_{Cy}$ , MIR, RIGAP

City	$PIR'_{Cy}$	MIR	RIGAP	City	$PIR'_{Cy}$	MIR	RIGAP
Hohhot	1.49	2.57	1.19	Zhengzhou	0.16	-0.02	0.93
Guiyang	1.30	1.23	0.67	Kunming	0.08	0.29	0.70
Shijiazhuang	0.94	1.15	1.26	Nanjing	-0.02	-0.23	-0.15
Changsha	0.90	1.06	0.60	Chengdu	-0.12	-0.94	-0.25
Urumchi	0.89	1.02	0.63	Guangzhou	-0.14	-0.34	-2.04
Harbin	0.76	0.83	0.37	Dalian	-0.20	-0.44	-0.72
Xining	0.75	0.77	0.80	Nanchang	-0.20	-0.32	0.67
Lanzhou	0.71	0.82	0.36	Nanning	-0.21	-0.43	0.55
Jinan	0.68	0.72	0.68	Fuzhou	-0.32	-0.43	0.02
Yinchuan	0.66	0.67	0.28	Haikou	-0.33	-0.58	0.22
Chongqing	0.46	0.33	0.56	Wuhan	-0.62	-0.77	0.09
Shenyang	0.42	0.24	0.00	National	-0.85	-0.81	0.28
Xi'an	0.36	0.22	0.30	Ningbo	-0.91	-0.97	-0.60
Changchun	0.34	0.20	0.32	Shenzhen	-1.21	-0.98	-0.81
Hefei	0.33	0.21	0.30	Amoy	-1.26	-1.14	-1.47
Shanghai	0.28	0.17	-1.68	Tianjin	-1.43	-1.23	-0.43
Qingdao	0.25	0.06	0.19	Hangzhou	-1.62	-1.35	-1.67
Taiyuan	0.21	0.10	-0.07	Beijing	-2.54	-1.66	-2.07

characteristics such as more complete public infrastructure, more employment opportunities to attract foreign residence. However, the expansion of the population leads to the rising of house prices, and the fact that the rate of revenue growth can not keep up with the rate of rising house prices, resulting in poor purchasing capacity of residents.

Third, the housing affordability of households in the first-tier cities has both similarity and differences. We can see Beijing and Shenzhen are classified into a group while Shanghai and Guangzhou are in the same group. In view of  $PIR'_{Cy}$  and MIR, residents' housing affordability in Shanghai and Guangzhou is much better than that in Beijing. But from RIGAP, the four performed poorly with rankings in the bottom. On the one hand, the housing affordability of households in first-tier cities is weak. On the other hand, cities like Beijing and Shenzhen should learn from Shanghai and Guangzhou to improve the purchasing capacity of residents.

Fourth, the regional characteristics of housing affordability of residents in China's large and medium-sized cities in China are obvious. Overall, the housing affordability of residents in eastern China is similar to that of residents in southern China. The same is the case with the northern and southwestern regions. This kind of similarity is closely related to the living environment. The environment of the eastern coastal city and the southern city is better as well as the economy is more developed, thus attracting more and more people, which results in the increasing purchasing pressure of local citizens.

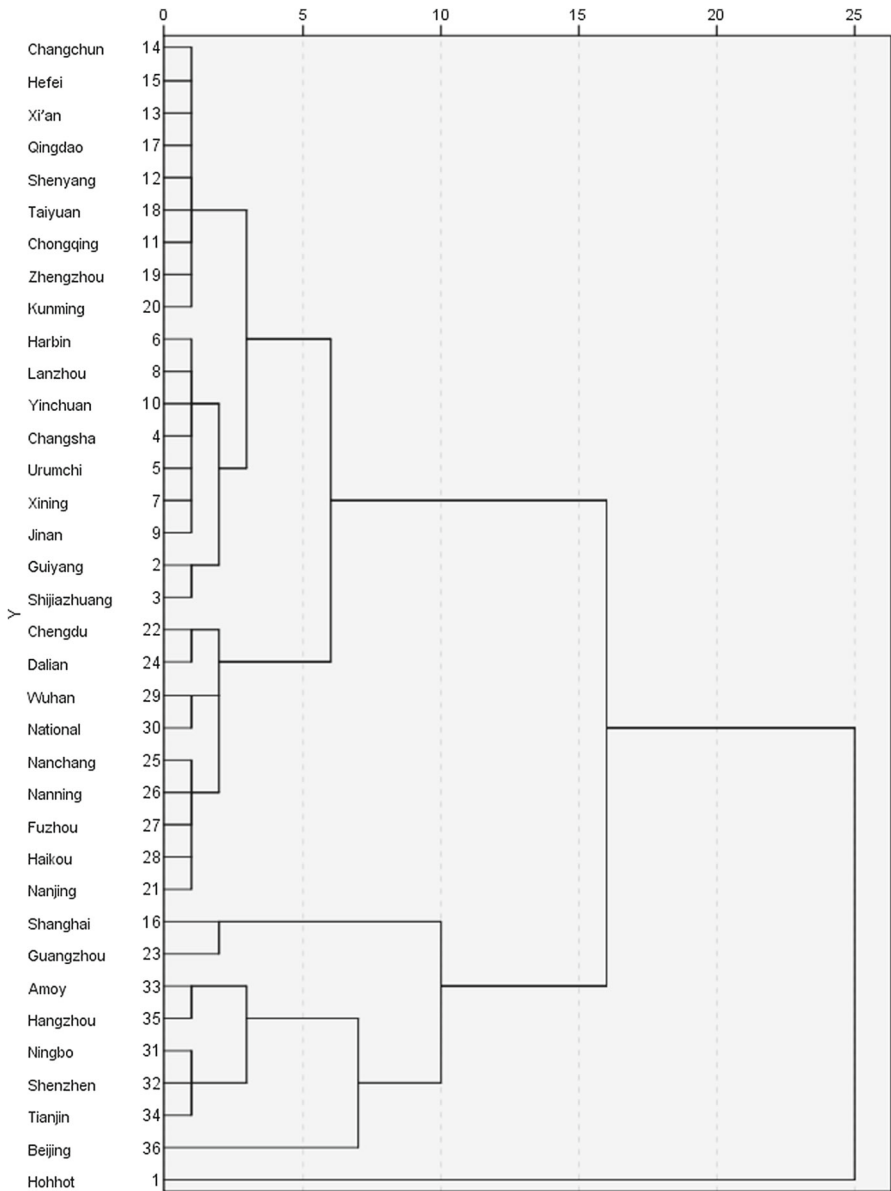


Fig. 6 Cluster tree using principal component scores of 35 cities

Fifth, housing affordability of households in large and medium-sized cities in China shows a ladder-type characteristics. As can be observed in the results of the grouping, the economically backward cities are divided into a group and the relatively developed cities are classified as a group. At the same time, the more developed the city's economy, the lower the housing affordability of households. Based on this point, when

**Table 3** The grouping of cluster analysis

Group	City and the rank of RIGAP	PIR ranking	MIR ranking
Group 1	Hohhot (2)	1	1
Group 2	Shanghai (34), Guangzhou (35)	16, 23	17, 23
Group 3	Tianjin (28), Shenzhen (31), Ningbo (29), Hangzhou (33), Amoy (32)	31–35	31–35
Group 4	Beijing (36)	36	36
Group 5	Nanjing, Haikou, Fuzhou, Nanning, Nanchang, National, Wuhan, Dalian, Chengdu		
Group 6	Shijiazhuang, Guiyang, Jinan, Xining, Urumchi, Changsha, Yinchuan, Lanzhou, Harbin, Kunming, Zhengzhou, Chongqing, Taiyuan, Shenyang, Qingdao, Xi'an, Changchun, Hefei		

developing cities' economy grows to a higher level, they could learn lessons from economically developed cities in advance in order to solve the problem of poor housing affordability.

## 4 Conclusion

The core objective of housing policy is to improve the housing affordability of residents, although it is still not enshrined in agreed standards, partly because of different opinions about how to measure it and at what thresholds. In this paper, we start with various issues around the concept of housing affordability and bring out a new model with multiple indexes that complement each other. Applying the model to analyze housing-related data of 35 large and medium cities in China from 2009 to 2016, we find that the housing affordability of households is closely related to the level of the economic development, showing obvious regional characteristics—the housing affordability of households in eastern coastal areas and some southern cities is poor, while it performs well in northern and part of central regions. To sum up, we make the following recommendations:

From the results of cluster analysis, we know that the grouping of cities has a strong ladder-type characteristic, that is, the more developed urban residents are less

able to buy houses. As China's economic development accelerates, the gap between backward districts and forward will narrow, leading to the lower housing affordability. One possible explanation is the resource constraints caused by large-scale immigration. Therefore, if the development among regions is more balanced, the public pressure will be alleviated to a certain extent. It calls on the governments to establish the long-term mechanism of real estate to deal with the contradiction between urban development and resource constraints, for example, give preferential policies to increase financial input to the midwest and north-east regions.

In addition to the regional characteristics, there are also periodic patterns. The housing affordability of residents in large and medium-sized cities from 2009 to 2016 can be divided into three stages. 2009–2010 is a stage, the other two is 2011–2013 and 2014–2016. The latter two stages similarly show that the affordability has declined, comparing with the previous stage, but improved internally. However, whether there is a three-year period of the cycle remains further research. If there are cyclical characteristics exactly, it may provide the certain reference for governments to determine when is the best time to implement regulation policies to promote the development of a sound and healthy real estate market.

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