ELES-Model Based Housing Affordability Comparative Research of Urban Households in Beijing Between 2004 and 2014

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Abstract In this paper, we apply the model of the extended linear expenditure system to measure housing affordability of urban households in Beijing, and calculate the affordable housing areas of urban households which are on different income levels in Beijing in 2014 and 2004. In this study, we find that, the household disposable incomes of urban households in Beijing increase along with the development of economy, all income levels of urban households in Beijing can cover the expenditures of their basic life needs, and housing affordability of urban households of different income levels in Beijing is increasing as well. The increasing disposable incomes enhanced the housing affordability of urban households in Beijing from the year 2004 to the year 2014, and all income levels of urban households in Beijing have improved their housing conditions. However, from the view of the affordable housing squares, their housing conditions depend on the housing price closely. If the growth of house price is faster than the growth of housing affordability, the affordable housing squares will decrease, and the housing condition of urban households in Beijing will be worse from 2004 to 2014. And the comparison between 2013 and 2014 shows the housing affordability problem has been relieved.

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1 Introduction

Housing is one of the basic necessities. For most people, house is not just a building, but a home like a warm haven that can give people a sense of security. China has a large population. Along with urbanization and population growth, a large number of people come into cities, which brings a lot of demands for housing. Besides, with income increasing, urban residents need to improve living conditions, which also brings housing demands. Although there is such a large demand for housing, not many urban residents can afford a house in big cities. However, there is a noticeable phenomenon in some cities in China, ghost towns, where have a high house vacancy rate in urban cities. This is very strange, one side is the high demands for houses, and another side is high house vacancy rate. Are the incomes of urban households too low or the house prices too high? Perhaps, there are other reasons that account for housing problem. Housing problem relates to the stability of society, it's meaningful for us to find out the reason why some urban households cannot afford a proper house in urban cities.

Foreign scholars and domestic scholars proposed a number of the concept of housing affordability [1–3]. After considering the various concepts of housing affordability, we define housing affordability as the ability to pay money when urban households get a house from real estate market [4]. There are many methods of studying housing affordability, such as price-income ratio [5, 6], housing affordability index [7–9], and so on. These methods have some advantages, such as easy to understand and calculate, but still have some disadvantages, like unable to measure housing affordability accurately, and so on. The model we use in this paper is the extended linear expenditure system (ELSE) [10]. The extended linear expenditure system is on the basis of the linear expenditure system [11]. There are extensive researches based on ELES in foreign and domestic [12–16], ELES is a more sophisticated model. Li [17] had used ELES-model to calculate housing affordability of urban households in Beijing in 2004, and had proved the applicability of this model in the study of housing affordability. Li [18] had used this model to do comparative studies of the same city in different years. In this paper, we get the latest data of urban households in Beijing, measure and compare housing affordability of urban households on different income levels in Beijing in 2014 and 2004, and find out the changes of housing affordability in Beijing between 2004 and 2014, and make some comparisons between 2013 and 2014.

In this paper, our goal is to find out the reason for housing problem and come up with the solutions to housing problem. This article consists of four sections, the first section is introduction, and the second part is the model. Empirical Research and conclusion are in the third and the fourth section. We measure the housing purchasing power of urban residents in Beijing in 2014 and 2004 based on the extended linear expenditure system, analyze the changes of the housing affordability of urban residents in Beijing between 2004, 2013 and 2014.

2 Model

Based on the linear expenditure system [11], Lluch C [10] took into account the savings and proposed the extended linear expenditure system model [17]. The expression of the extended linear expenditure system model is as follows:

$$V_i = P_i r_i + \beta_i (Y - \sum_{i=1}^n P_i r_i) \quad (1)$$

Here, V_i is the annual expenditure of a household spending on goods or services of i -th. $V = \sum_{i=1}^n V_i$, V is the total annual expenditure that the household spends on the total goods and services, P_i is the price of goods or services of i -th. r_i is the annual basic amount of goods or services of i -th in the household. $P_i r_i$ is the annual expenditure that the household spends on the basic amount of goods or services of i -th. Y is the income of the household. β_i is the marginal share of the budget of goods or services i -th, the proportion of income used on savings is β_{n+1} . $\sum_{i=1}^n \beta_i < 1$, and $\sum_{i=1}^{n+1} \beta_i = 1$.

Let

$$P_i r_i - \beta_i \sum_{i=1}^n P_i r_i = b_i \quad (2)$$

Then, the expression of the extended linear expenditure model is as follow:

$$V_i = b_i + \beta_i Y \quad (3)$$

First, we use the cross-sectional data to run a regression, then we can get the estimated values of b_i and β_i . Second, we calculate the annual expenditure that the household spends on the basic need of each consumer item and the total annual expenditure that the household spends on the total basic needs. Finally we estimate housing affordability of the household.

According to Beijing Statistical Yearbook 2014 [18], we know the basic needs of a household consist of eight consumer items, they are food (item-1), clothing (item-2), household appliances and service (item-3), health care and medical services (item-4), transport and communications (item-5), education, cultural and recreation services (item-6), housing (item-7), miscellaneous goods and services (item-8). From formula (2), we can get

$$\begin{pmatrix} 1 - \beta_1 - \beta_1 & \cdots & -\beta_1 \\ -\beta_2 & 1 - \beta_2 & \cdots & -\beta_2 \\ \vdots & \vdots & \ddots & \vdots \\ -\beta_8 & -\beta_8 & \cdots & 1 - \beta_8 \end{pmatrix} \times \begin{pmatrix} P_1 r_1 \\ P_2 r_2 \\ \vdots \\ P_8 r_8 \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_8 \end{pmatrix} \quad (4)$$

Then, we get

$$\begin{pmatrix} P_1 r_1 \\ P_2 r_2 \\ \vdots \\ P_8 r_8 \end{pmatrix} = \begin{pmatrix} 1 - \beta_1 & -\beta_1 & \cdots & -\beta_1 \\ -\beta_2 & 1 - \beta_2 & \cdots & -\beta_2 \\ \vdots & \vdots & \ddots & \vdots \\ -\beta_8 & -\beta_8 & \cdots & 1 - \beta_8 \end{pmatrix}^{-1} \times \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_8 \end{pmatrix} \quad (5)$$

Let Y_j is the annual disposable income of a household on the income level of j , the monthly affordable repayment of the household on the income level of j is

$$w_j m_j = (Y_j - \sum_{i=1}^8 P_i r_i) \times \frac{1}{12} \quad (6)$$

m_j is the monthly disposable income of the household on the income level of j , w_j is the proportion that the household on the income level of j uses on the repayment for house, n is the loan period, r is the annual loan interest rate, P is the house price, and x is the down payment ratio.

Let $\Omega_1 = \{1, 2\}$, where 1, 2 respectively represent the new commercial housing and second-hand housing. Let $\Omega_2 = \{1, 2, 3, 4, 5, 6\}$, where 1, 2, 3, 4, 5, 6 represent the average-income household, low-income household, medium-low-income household, medium-income household, medium-high-income household, and high-income household respectively. According to the formula equal repayment of housing loans, we can get

$$(1 - x) \times P \times (1 + \frac{r}{12})^{12n} = w_j m_j \times \frac{(1 + \frac{r}{12})^{12n} - 1}{\frac{r}{12}} \quad j \in \Omega_2 \quad (7)$$

Housing affordability of the household on the income level of j is

$$P_j = w_j m_j \times \frac{(1 + \frac{r}{12})^{12n} - 1}{\frac{r}{12}} \times \frac{1}{(1 - x) \times (1 + \frac{r}{12})^{12n}} \quad j \in \Omega_2 \quad (8)$$

Then we can measure housing affordability of the urban household on the income level of j in Beijing by (8).

We calculate the affordable housing squares of the urban household on the income level of j in Beijing can buy from new commercial real estate market and second-hand real estate market,

$$S_i = \frac{P_j}{p_i}, i \in \Omega_1, j \in \Omega_2 \quad (9)$$

Here, S_i is the affordable housing square of the urban households in Beijing on the income level of j can buy, p_i is the house price.

The flow path of how to use ELES model to calculate housing affordability is as follow (Fig. 1).

Fig. 1 Flow path of ELES-model for housing affordability

3 Empirical researches

By Statistical Information Network of Beijing [19] and Beijing Statistical Yearbook 2005 [20], we can obtain the data about urban households in Beijing, as shown in Tables 1 and 2.

Running linear regressions, then we can get the estimated values of b_i and β_i .

Using the estimated values of b_i and β_i in Table 3, we can calculate the basic life consumer demand of urban residents in Beijing in 2014 and 2004, shown in Table 4.

According to the formula (5), we can measure the monthly affordable money that urban households in Beijing can pay for housing in 2014 and 2004, as shown in Table 5.

From Table 5, we can find that, for the urban households on the low income level in Beijing in 2004, their household disposable incomes were less than the basic consumer expenditure, these household needed the government's support to maintain the expenditure of the basic living needs, and they were unable to purchase houses in 2004. In 2014, for all income levels of urban households in Beijing, the monthly affordable payments for housing are more than 0, which means that all income levels of urban households in Beijing can cover their basic life consumer expenditure, so they had the remaining income available for purchasing houses. Comparing the monthly affordable payments for housing of the urban households in 2004 and 2014, we can find

Table 1 Consumption expenditure and disposable incomes of urban households in Beijing 2014

Income level	Item-1	Item-2	Item-3	Item-4	Item-5	Item-6	Item-7	Item-8	Income
Average	22,271	7490	5529	4804	11,370	10,759	5681	4360	113,288
Low	18,543	4767	3816	3405	6288	6681	4626	2106	63,540
Medium-low	21,022	6174	4742	4814	8770	8059	4356	3141	91,385
Medium	20,288	6603	4410	5022	11,188	9710	4663	2985	97,752
Medium-high	23,787	7371	5601	5095	10,818	12,664	5552	5113	122,545
High	26,079	11,204	8292	5303	17,169	14,496	8535	7417	168,537

Unit (Yuan)

Table 2 Consumption expenditure and disposable income of urban households in Beijing 2004

Income level	Item-1	Item-2	Item-3	Item-4	Item-5	Item-6	Item-7	Item-8	Income
Average	11,384	3081	2389	3430	4530	6136	3090	1340	45,350
Low	9174	1616	1369	2138	2648	4051	2047	622	23,683
Medium-low	11,188	2632	1774	3361	3453	5345	2301	974	33,978
Medium	11,667	3090	1750	3171	3490	5582	2352	1132	41,311
Medium-high	12,461	3761	2711	4603	4707	7157	3298	1631	53,518
High	13,752	4707	4630	4336	8874	9298	5809	2512	80,013

Unit (Yuan)

Table 3 The estimated coefficients of the extended linear expenditure system model

Years	<i>i</i>	1	2	3	4	5	6	7	8
2014	b_i	13,903.8	659.1	663.0	3078.4	102.9	1734.9	1165.4	−1634.0
	β_i	0.074	0.060	0.043	0.015	0.099	0.079	0.040	0.053
2004	b_i	8186.8	722.7	−317.2	1770.9	−531.3	1980.0	−60.4	−194.7
	β_i	0.074	0.052	0.059	0.037	0.111	0.092	0.069	0.034

Table 4 The basic expenditure of urban residents in Beijing

Years	Consumer items	Item-1	Item-2	Item-3	Item-4	Item-5	Item-6	Item-7	Item-8	Total
2014	Basic expenditure (Yuan)	16,617.1	2874.4	2250.2	3635.6	3733.4	4637.7	2641.4	317.3	36,707.2
2004	Basic expenditure (Yuan)	9999	1996	1127	2677	2187	4233	1629	638	24,485

Table 5 The monthly affordable payment of urban households for housing

Years	Income level	Average	Low	Medium-low	Medium	Medium-high	High
2014	The monthly affordable payment (Yuan)	6382	2236	4556	5087	7153	10,986
2004	The monthly affordable payment (Yuan)	1739	−67	791	1402	2419	4627

Table 6 Housing affordability of urban households in Beijing

Years	Income level	Average	Low	Medium-low	Medium	Medium-high	High
2014	Housing affordability (million Yuan)	160	56	115	128	180	276
2004	Housing affordability (million Yuan)	44	−2	20	35	61	116

that, after ten years of development, the monthly affordable payments for housing of the urban households in Beijing had been significantly improved, in this way we can conclude the capabilities of the urban households in Beijing to pay for housing are enhanced.

Set the annual loan interest rate $r = 5.51\%$, the down payment ratio is 30% , $n = 30$ years [20] is the loan period. And according to Eq. (8), we measure housing affordability of the urban households on different income levels in Beijing, the results are shown in Table 6.

Comparing housing affordability of the urban households on different income levels in Beijing in 2004 and 2014, it shows that, housing affordability of the urban households in Beijing had improved. In 2014, the housing affordability of the urban households in Beijing range from 56 million Yuan to 276 million Yuan.

According to the website of Soufang [21], in 2014 the average price of new commercial housing in eight districts of Beijing was 32,711 Yuan/m², the average price of Second-hand housing in eight districts of Beijing is 38,454 Yuan/m²; According to Real Estate Market Conditions of Beijing in 2005 [22], we can know the average price of new commercial houses in Beijing in 2004 was 5642 Yuan/m², the average price of Second-hand housing in Beijing in 2004 was 3921 Yuan/m². Then we can measure the affordable housing squares that the urban households on different income levels in Beijing can buy via Eq. (9). We refer the affordable housing squares that the urban households on different income levels in Beijing and house prices in 2013 to Li [18]. The results are shown in Table 7.

From Table 7, it shows that, for the low-income urban households in Beijing, the affordable housing squares changed from negative to positive because of the increased household disposable income and the improved housing affordability, the low-income urban households improved their housing conditions, but these families could buy only a little of housing squares. In fact, there are some public policy to support the low-income household's housing and they can apply affordable house to live with a low payment in Beijing. For all income levels of urban households in Beijing, except the low-income level, they cost more money and get less housing squares in 2014 compared with 2004. For medium, medium-high and high income levels, they expend more money and get less housing squares from new commercial housing market; they cost more money and get more housing squares from second-hand housing market in 2014 compared with 2013.

We compare the house prices and the housing affordability of urban residents in Beijing in 2004, 2013, 2014, to find the relations between the growth rates of housing affordability and housing prices. We refer housing affordability and housing prices of 2013 to Li [18]. The results are shown in Table 8.

From Table 8, all income levels of urban households in Beijing, except the low-income urban households, the growth multiples of the housing affordability are less than the housing price comparing 2004 and 2014, no matter what new commercial housing or second-hand housing. So the affordable housing squares of the urban households of all income levels of urban households in Beijing, except the low-income urban households, are less. Comparing 2013 and 2014, for medium, medium-high and high income levels urban households in Beijing, the growth multiples of the housing affordability are more than the growth multiples of the housing price in second-hand housing market and less than the growth multiples of the housing price in new commercial housing market. So they can afford more housing squares in second-hand housing market and less in new commercial housing.

Table 7 Affordable housing squares of urban households at different income levels

Years	Income level	Average	Low	Medium-low	Medium	Medium-high	High	House prices (Yuan)
2014	New housing squares (m ²)	49.0	17.2	35.0	39.1	55.0	84.4	32,711
	Second-hand housing squares (m ²)	41.7	14.6	29.8	33.2	46.8	71.8	38,454
2013	New housing squares (m ²)	51.7	14.4	33.0	39.9	56.6	85.4	28,700
	Second-hand housing squares (m ²)	39.0	10.8	24.9	30.1	42.7	64.4	38,036
2004	New housing square (m ²)	77.5	−3.0	35.2	62.5	107.8	206.1	5642
	Second-hand housing areas (m ²)	111.4	−4.3	50.7	89.9	155.1	296.6	3921

Table 8 The housing prices and the housing affordability of urban residents in Beijing

Years	Housing price		Housing affordability with different income level					
	New commercial	Second-hand	Average	Low	Medium-low	Medium	Medium-high	High
2014	32,711	38,454	160	56	115	128	180	276
2013	28,700	38,036	148	41	95	115	162	245
2004	5642	3921	44	−2	20	35	61	116
The ratio of housing price in 2014 to that in 2004	4.798	8.807	2.670		4.759	2.628	1.957	1.374
The ratio of housing price in 2014 to that in 2013	0.140	0.011	0.081	0.362	0.208	0.116	0.106	0.127

According to the Ministry of Construction [23], the commercial residential squares in the real estate market were mainly 90–140 m², which is more than the affordable housing squares most urban households could purchase, made the problem of purchasing houses for urban households in Beijing even worse.

4 Conclusions

In this paper, we measure the housing affordability and the affordable housing squares of the urban households on different income levels in Beijing in 2014 and 2004 based on the extended linear expenditure system model. After ten years of development, the household disposable incomes of urban households in Beijing increase. They can afford the expenditure of basic needs and have more remaining disposable incomes to purchase houses. The housing affordability of urban households on different income levels in Beijing had enhanced. The increasing disposable incomes enhanced the hous-

ing affordability of urban households in Beijing, in this respect, all income levels of urban households in Beijing have improved their housing conditions. But from the view of the affordable housing squares, their housing conditions depend on the housing price deeply. If the growth of house price is faster than the growth of housing affordability, the affordable housing squares will decrease, and the housing condition of urban households in Beijing will be worse.

With the development of economy and with the support of financial housing loans, suppose that the annual interest rate of housing loan and the loan period unchanged, the more disposable income it is, the stronger housing affordability it is. To solve the problem of purchasing house for urban residents, the government would increase the disposable incomes of urban residents step by step. In addition, the government would control the reasonable growth of house price. What's more, real estate business providing housing should take housing affordability and the affordable housing squares of urban residents into account.

In this study, we study housing affordability from the micro level and consider factors such like the structure of expenditure, the household disposable income and the commercial housing loans. Comparing to dynamic methods, ELES-model is a static method. In future study, we should consider some dynamic methods and macroeconomic factors that affect housing affordability.

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