Postprint: A Study on the Evolutionary Characteristics of Housing Affordability in Major Chinese Cities

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Abstract

Using methods such as the housing price-to-income ratio, moving T-test, and Sen's slope estimator, this study investigates the evolution characteristics of residents' housing affordability in 27 large and medium-sized Chinese cities from 2001 to 2019, and analyzes the correlation between the evolution characteristics of urban residents' housing affordability and China's real estate regulation policies. The results indicate that: (1) The housing affordability of residents in major Chinese cities showed a generally significant weakening trend during the study period, with the phenomena of "continuous decline" and "skip-level decline" in housing affordability grades being relatively common, and the proportion of cities exhibiting an "accelerated decline" evolution characteristic in housing affordability reaching 18.52%. (2) Significant differences exist among different cities across three dimensions: evolution characteristics of residents' housing affordability grades, evolution stages of the housing price-to-income ratio, and stage-specific evolution trends. (3) Overall, the evolution stages of urban residents' housing affordability show strong correlation with the timing of major adjustments to China's real estate regulation policies and the introduction of important local real estate regulation policies, and the stage-specific evolution trends of housing affordability are consistent with the development situation of China's real estate market. The study calls for the establishment and improvement of an evaluation and monitoring system for urban residents' housing affordability, to timely grasp the housing affordability and its evolution patterns in major cities. It advocates adhering to the general positioning of "housing is for living, not for speculation" and "stabilizing housing prices," scientifically and rationally formulating a "package" of real estate regulation policies, and advancing the urban residents' housing affordability improvement project by region and category.

Full Text

Evolution Characteristics of Housing Affordability in Major Chinese Cities

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Abstract: This study examines the evolution of housing affordability in 27 large- and medium-sized Chinese cities from 2001 to 2019 using the house price-to-income ratio, moving T-test, and Sen' s slope estimator. The relationships between urban housing affordability evolution and China' s real estate regulation policies are also analyzed. The results indicate: (1) Housing affordability in major Chinese cities showed a significant weakening trend during the study period, with widespread "persistent decline" and "leapfrog decline" in affordability ratings. Cities exhibiting "accelerated decline" in housing affordability accounted for 18.52% of the sample. (2) Significant differences exist among cities across three dimensions: the evolution characteristics of affordability ratings, the stages of house price-to-income ratio evolution, and the corresponding stage-specific trends. (3) The evolution stages of housing affordability are strongly correlated with the timing of major adjustments to China' s real estate regulation policies and the introduction of important local housing control measures. The stage-specific evolution trends of housing affordability align with China's real estate market development. The study calls for establishing a sound assessment and monitoring system for urban housing affordability to track its status and evolution patterns in major cities. It advocates adhering to the overarching principles of "housing for living, not speculation" and "stable housing prices," and formulating scientifically sound and comprehensive "policy packages" for real estate regulation to promote housing affordability improvement programs tailored to different regions and categories.

Keywords: housing affordability; evolution; house price-to-income ratio; moving T-test; Sen' s slope estimator; China

1 Data and Methods

1.1 Data Sources

This study selected 27 major Chinese cities as the research area. Considering data availability, Beijing, Shanghai, Guangzhou, and 24 other large- and medium-sized cities were ultimately chosen to evaluate housing affordability and its evolution from 2001 to 2019. Required data on annual per capita disposable income of urban residents, average unit selling price of commercial residential

housing, and per capita residential building area in urban areas were obtained from the *China Statistical Yearbook*, *China Urban Statistical Yearbook*, and the statistical yearbooks and *National Economic and Social Development Statistical Bulletins* of each city for corresponding years.

1.2 Methods

1.2.1 House Price-to-income Ratio The house price-to-income ratio (PIR) is a common method for measuring urban housing affordability. It uses the ratio of the price of a standard housing unit to household income to reflect affordability. Since median house prices and household incomes are difficult to obtain widely, the ratio of average values is typically used in practice. Drawing on existing research, this study sets the reasonable range for China' s PIR at 4.39–6.78 and classifies housing affordability into five categories: strong (PIR $<$ 4.39), relatively strong (4.39 $\leq$ PIR $<$ 5.5), moderate (5.5 $\leq$ PIR $<$ 6.78), relatively weak (6.78 $\leq$ PIR $<$ 7.9), weak (7.9 $\leq$ PIR $<$ 9), and extremely weak (PIR $\geq$ 9).

The PIR is calculated as:

$$\mathrm{PIR} = \frac{\mathrm{HP}}{\mathrm{AR} \times \mathrm{AF}}$$

where HP is the average selling price of commercial residential housing in the study unit, AR is the average annual disposable income per urban household, and AF is the average urban household size. A larger PIR value indicates weaker housing affordability, and vice versa.

1.2.2 Moving T-test The moving T-test detects mutations in time series data by examining whether the means of two consecutive subsequences of equal length are significantly different. The procedure for identifying mutation points and dividing evolution stages for each city' s housing affordability time series is as follows: First, set the subsequence length (n*), then slide sequentially through the time series data (total length L) from year n* to time point L-n*, calculating the t-statistic for each point. Second, identify mutation points based on the t-statistic and critical value t* at a given significance level. If |t| $>$ t*, a mutation occurred at that time point. Finally, divide the evolution stages based on identified mutation points.

The t-statistic is calculated as:

$$t = \frac{\overline{x}_1 - \overline{x}_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where $\overline{x}_1$ and $\overline{x}_2$ are the means of the two subsequences, s_p is the pooled standard deviation, and n_1 and n_2 are the lengths of the two subsequences.

1.2.3 Sen' s Slope Estimation This study uses Sen' s slope estimator to measure the evolution trend of housing affordability within different stages for each city. Sen' s slope estimator detects trends in time series data using the median slope between all possible pairs of points. For a city' s housing affordability time series x of length M, the slope between time points j and k (S_{ij}) and the median slope (S_{med}) for the stage are calculated as:

$$S_{ij} = \frac{x_j - x_k}{j - k}, \quad j = 1, 2, \ldots, M-1; \quad k = i+1, i+2, \ldots, M$$

$$S_{med} = \begin{cases} S_{[(N+1)/2]} & \text{if } N \text{ is odd} \\ \frac{S_{[N/2]} + S_{[N/2+1]}}{2} & \text{if } N \text{ is even} \end{cases}$$

where x_j and x_k are data values at time points j and k, and N is the total number of slopes between any two points in the time series ($N = M(M-1)/2$). The median slope reflects the evolution rate of the time series: a positive S_{med} indicates an increasing trend (weakening affordability), while a negative value indicates a decreasing trend (improving affordability). Larger absolute values indicate faster evolution.

The significance of the trend is tested using Kendall' s Z-statistic (Z_p). If $|Z_p|$ exceeds the critical value at a given significance level, the time series exhibits a significant evolution trend.

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2 Results and Analysis

2.1 Overall Characteristics of Housing Affordability and Its Evolution

From a temporal perspective, housing affordability in the 27 cities showed a clear weakening trend during 2001–2019. In 2001, housing affordability was relatively strong overall, with 25 cities rated as "strong" or "relatively strong" and only 2 cities rated as "relatively weak." However, the number of cities with "strong" and "relatively strong" ratings generally decreased over time, while the proportion of cities with "relatively weak," "weak," and "extremely weak" ratings increased. Notably, the proportion of cities with "extremely weak" housing affordability grew significantly. These findings indicate an overall weakening of housing affordability across major Chinese cities during the study period.

[Figure 1: see original paper]

In terms of evolution patterns, 55.56% of the 27 cities exhibited a persistent weakening trend in housing affordability ratings. Beijing' s housing affordability declined gradually from "moderate" to "extremely weak," while Xi' an' s dropped from "moderate" to "weak." Chongqing' s affordability fell from "strong" to "relatively weak." During the study period, Shenzhen, Hangzhou, and Hefei

experienced "leapfrog declines" in housing affordability. Hangzhou' s rating dropped from "moderate" to "relatively weak," while Shenzhen and Hefei fell from "relatively strong" to "weak." Shanghai, Changchun, and 12 other cities showed fluctuating patterns, with affordability ratings shifting repeatedly across categories. In contrast, Yinchuan, Hohhot, and Shenyang maintained relatively stable affordability ratings without significant major changes.

Further analysis reveals a general pattern of increasing housing affordability from southeast to northwest China. Cities with "persistent weakening" or "leapfrog decline" patterns are concentrated in southeastern coastal cities such as Beijing and Shenzhen. These cities experienced rapid population growth and strong housing demand, leading to heated real estate markets and rapid declines in affordability. In contrast, western cities like Yinchuan have relatively lower socioeconomic development and population growth, resulting in generally lower and more stable price-to-income ratios.

[Figure 2: see original paper]

2.2 Staged Characteristics of Housing Affordability Evolution

The moving T-test results of price-to-income ratio time series data reveal variations in mutation points and evolution stages across cities. First, the number of mutation points and evolution stages differs among cities. Nine cities, including Lanzhou, Shijiazhuang, and Hangzhou, had 4 mutation points and 5 evolution stages. Lanzhou, Shijiazhuang, Shenzhen, and 7 other cities had 3 mutation points and 4 stages. Wuhan, Nanchang, Shanghai, and 8 other cities had 2 mutation points and 3 stages. The remaining 3 cities had 1 mutation point and 2 stages.

Second, the number and timing of evolution stages vary significantly. The number of cities with increasing price-to-income ratios grew continuously, reaching 74.07% of the sample by 2019. This indicates that housing affordability declined persistently in most major Chinese cities during 2001–2019. Specifically, Wuhan, Nanchang, Chongqing, Fuzhou, Shanghai, and Qingdao showed significant increasing trends throughout the entire study period. Beijing, Qingdao, Shanghai, Guiyang, and Xi' an exhibited accelerating declines, with Sen' s slope values increasing across consecutive stages. However, Lanzhou, Ningbo, Xiamen, Wuhan, Nanchang, Chongqing, Fuzhou, and Jinan showed decreasing Sen's slope values across consecutive stages, indicating a slowdown in the rate of affordability decline. Shenzhen, Hohhot, Dalian, Changchun, Shenyang, Yinchuan, and Nanjing experienced negative Sen' s slope values in some stages, suggesting temporary improvements in affordability. Notably, after decreasing, Shenzhen, Hohhot, and Yinchuan showed "bottoming out" and rebounding trends, while Shenyang' s Sen' s slope values continued to increase across stages, indicating persistent decline.

Overall, first-tier cities like Beijing and Shanghai show significant declining trends, while second-tier cities like Changchun and Hohhot exhibit stage-

specific improvements, and third-tier cities like Lanzhou show weakening declines. These findings suggest that urban socioeconomic development levels are associated with housing affordability and its evolution patterns.

2.3 Correlation Between Housing Affordability Evolution and Real Estate Regulation

Analysis of the overall evolution characteristics of housing affordability in 27 cities and China' s real estate regulation policies reveals a strong correlation between regulation and affordability evolution. First, the "inflection points" in housing affordability evolution largely coincide with major policy adjustments. China' s real estate market underwent three major policy shifts during 2001–2019. The first occurred in 2002 when commercial state-owned land use rights transitioned from "negotiated transfer" to "public bidding," which significantly drove up land and housing prices and led to persistent declines in housing affordability. The second was the 2008 "four trillion stimulus package" in response to the global financial crisis, which lowered benchmark lending rates and down payment ratios and exempted business tax on personal housing sales. These policies, combined with previous regulation measures, propelled China' s real estate industry into a new phase of rapid development. The third was the 2016 Central Economic Work Conference, which established the principle that "houses are for living in, not for speculation," laying the foundation for subsequent regulation policies.

Second, the evolution characteristics of housing affordability align with real estate market development trends. Since 1998, China implemented commercial housing presale and land bidding systems. In 2003, the State Council designated real estate as a "pillar industry" of the national economy, leading to rapid market development and housing price growth. As urban housing prices generally grew faster than residents' incomes, housing affordability continued to decline. The study confirms this analysis, showing widespread mutation points in housing affordability around 2002 and 2008, with stage-specific trends correlating with market development.

Further analysis reveals that differences in evolution inflection points and trends are also associated with local regulation policies. For example, inflection points in 2015 in Shenzhen, Hefei, Chengdu, and Xiamen coincided with local policy adjustments such as lifting purchase restrictions and lowering down payment ratios. Improvements in affordability in Yinchuan, Shenyang, and Hohhot were linked to local policies like increasing housing provident fund loan limits and reducing down payment ratios. These cities, mostly in western and northeastern China, have less heated real estate markets. Under "stable housing price" oriented regulation, their housing affordability improved. However, Nanjing' s affordability declined after 2015 despite regulation efforts, due to effective price control measures including land supply restrictions, crackdowns on hoarding, expanded purchase restrictions, and sales limits.

3 Conclusions and Discussion

3.1 Conclusions

Based on evaluating housing affordability in 27 major Chinese cities including Beijing, Shanghai, and Guangzhou from 2001 to 2019, this study employed time series analysis methods including moving T-test and Sen' s slope estimator to examine evolution stages and trends. The main conclusions are:

(1) Housing affordability in major Chinese cities showed a significant weakening trend during the study period. In terms of affordability ratings, the number of cities with "weak,""relatively weak,"and "extremely weak"ratings increased over time. Among the 27 cities, 55.56% exhibited persistently weakening affordability ratings, with some experiencing "leapfrog declines." In terms of stage-specific evolution trends, 74.07% of cities showed persistent declines, while 18.52% exhibited accelerating declines. Only a few cities experienced slowed declines.

(2) The evolution characteristics of housing affordability in major Chinese cities show significant differences across three dimensions. First, in the dimension of rating evolution patterns, four types exist: "persistent weakening," "leapfrog decline," "fluctuating," and "relatively stable." Second, in the dimension of evolution stages, cities differ in the number and timing of stages. Third, in the dimension of stage-specific trends, multiple patterns exist including "persistent weakening," "accelerating decline," "decelerating decline," and "bottoming out and rebounding."

(3) Housing affordability evolution is strongly correlated with real estate regulation. The widespread mutation points in 2002 and 2008 coincide with major national policy adjustments. Local regulation policies also correlate with evolution patterns. For instance, inflection points in Shenzhen, Hefei, and other cities in 2015 corresponded with local policy adjustments such as lifting purchase restrictions. Improvements in Yinchuan and other cities related to policies increasing provident fund loan limits. Under "stable housing price" oriented regulation, these cities saw improved affordability. Nanjing' s effective "policy package" successfully curbed affordability decline through land supply, sales, and purchase restrictions.

3.2 Discussion

The study reveals that major Chinese cities still face risks of declining housing affordability. By examining the staged evolution characteristics of housing affordability from 2001 to 2019 and their correlation with regulation policies, this paper offers three policy insights:

First, adhering to the "housing for living, not speculation" principle and "stable housing prices" orientation, and formulating scientifically sound comprehensive

regulation policies, are effective means to curb excessive price growth and alleviate affordability decline. Under the current context of COVID-19 and market downturn, policies should aim for both "stable housing prices" and "sustainable development," preventing both rapid price increases and ensuring a "soft landing" for the market. Nanjing's multi-dimensional "policy package" targeting land transfer, sales, and purchases has achieved initial success in stabilizing prices and curbing affordability decline, providing a valuable reference.

Second, implementing "city-specific policies" to ensure housing prices align with income levels is key to improving affordability. Policies should be tailored to local socioeconomic and income conditions, combining "price stabilization," "market expansion (for both renting and buying)," and "income promotion" measures to form integrated policy packages. This "city-specific" approach should systematically promote housing affordability improvement programs across different regions and categories.

Third, strengthening "decision support" by establishing a robust housing affordability assessment and monitoring system is essential. Such a system would enable timely tracking of affordability status and evolution patterns in major cities, providing critical support for policy formulation. While this study identifies strong correlations between affordability and regulation policies through qualitative analysis, future research should quantitatively analyze evolution patterns and influencing factors across cities of different sizes when data becomes available, thereby advancing policy research on improving housing affordability.

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Note: Figure translations are in progress. See original paper for figures.