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Group behavior decision of real estate investment in multi-information fusion for intelligent environment interaction

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Urban population migration is often accompanied by people's investment in real estate. The intelligent environment of human-computer interaction contains a massive amount of information, and the intelligent push of the platform always has an impact on investors' understanding of the market. At the same time, in the intelligent environment, the connection of the network changes the investment trend changes from individual to group investment behavior. Unlike previous studies, this work considers the characteristics of homebuyers' behavioral decision-making in an intelligent environment, focuses on the interaction mechanism between homebuyers' cognitive bias and behavioral decision-making, and uses the catastrophe theory to construct a group investment behavioral decision-making model under population migration. The research results show that the just-in-need investors are the driving force of the real estate market demand. Under the optimistic market expectation, when the initial proportion of people without houses is 50%, the increase of investment intention is significantly weaker than the interactive increase when 80% of people are without houses. However, although the rapid decline in house prices will encourage the just-in-need investors to buy a first home, it will not increase the probability of speculators buying a home. In addition, price changes have a lag for population migration and changes in the proportion of homebuyers.

Keywords: Behavior decision; Intelligent environment; Catastrophe model; Cognitive bias

1. INTRODUCTION

Population migration is the inevitable result of industrial agglomeration and social change, and its emergence further drives economic development and industrial upgrading. Population migration exhibits two main trends: the job opportunities in cities attract a large influx of migrant workers; and industrial agglomeration has increased the migration of people between cities [1]. This has led to increasingly frequent and active migration across regions, with increasing scale and scope.

However, population migration inevitably places pressure on urban resources, especially the highly influential real estate market. The continuous increase of housing prices in cities and the proportion of housing prices to income [2], not only affect population migration, but also bring more uncertainty to residents' investment. Although the net inflow of population is important for urban development, it also leads to an imbalance between supply and demand in the real estate market, continually increasing the prices of urban housing. Therefore, the population flow brought by population migration will determine real estate investment behavior, leading to the rise of housing prices in certain areas. However, when house prices are too high, the migrant population will find it difficult to relocate, resist the move,

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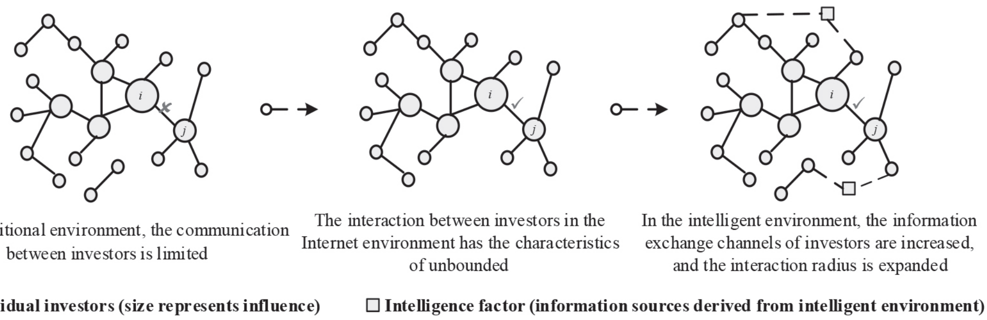


Figure 1 The unbounded nature of investor interaction and the expansion of interaction scope in intelligent environment.

and move out of the city, thus affecting the sustainable development of the city [3].

Due to population migration, residents are gradually increasing their demand for investment in real estate. However, the decision-making process for investment in real estate is very complicated due to the influence of internal and external factors. Hence, when residents make decisions as investors, their investment cognition is affected not only by individual personality traits, but also by external factors [4,5]. What is different from the past is that in the current intelligent environment facilitated by smart devices and access to massive amount of real-time information, the cognitive changes of investors show nonlinear and non-continuous characteristics, resulting in sudden changes in their investment behavior when making decisions.

Moreover, when investors interact with the outside world, they will also have an impact on the investment behavior of surrounding investors and groups. In the Internet environment, The boundaries of trust interaction among individuals and the thresholds of physical distance emerge and disappear., but there are still limitations such as insufficient interaction scope, and information filtering and pushing are difficult to be intelligent. However, in an intelligent environment, these limitations will no longer exist, as shown in Figure 1 [6]. In other words, investors in an intelligent environment are able to interact with connected individuals as they do in the traditional Internet environment, but they can also expand their information interaction; this gives them greater opportunities for interaction, so that groups such as real estate investors are more prone to polarization and reversal than in the past.

This study focuses on the influence of an intelligent environment on individual decision-making behavior in the real estate investment field, and the group polarization and reversal it causes in the context of population migration. In this paper, mutation theory and system dynamics are used to analyze the evolution mechanism of real estate investment decision-making behavior, and the influence of various factors on investment behavior decisions is observed through simulation experiments. Finally, on this basis, several intervention measures and control strategies in terms of population migration are proposed for the real estate field. This study addresses the following research questions: what is the mechanism driving sudden changes in real estate investment decisions caused by internal and external influences of investors? How does the behavior of real estate investors evolve as a result of various influencing factors? How should the government department intervene and control the real estate market and guide rational investment behavior?

To address these research questions, the rest of this paper is organized as follows: In the next section, we summarize the factors affecting individual real estate investment behavior and the evolution law of group behavior during the early period of population migration. In the third section, based on the mutation theory, we establish the individual investment decision model in an intelligent environment and explore the interaction characteristics of the group. In section 4, the simulation model is used to dynamically study the influence of interest rate, housing price, market expectation and other conditions on residents' real estate investment behavior, as well as the evolving interaction between the urban population and housing prices. In the last section, we draw conclusions and discuss potential directions for future research.

2. LITERATURE REVIEW

2.1 Influencing Factors of Real Estate Price

Previous researchers have conducted quantitative analyses of real estate prices in terms of multiple variables, and have also focused on investors and market changes to explain the impact of investment behavior on prices.

In their quantitative analysis of real estate prices from the perspective of supply and demand, Mankiw and Weil [7] used American data to analyze the impact of the baby boom and baby shortage on real estate prices and found that birth rate affects real estate demand. Eerola and Määttänen [8] found through the theoretical model that tight credit policy worsened the liquidity of the real estate market, which led to the difference in real estate prices. However, starting from the fundamental information of the real estate market, the fluctuation of the real estate price can be explained only to a certain extent. In particular, when real estate prices rise sharply, this phenomenon cannot be explained with fundamental information.

Previous research has extensively explored and analyzed the impact of investors on real estate prices. From the perspective of investors' income, McQuinn and O'Reilly [9] analyzed the impact of income and interest rate on real estate demand through a theoretical model of real estate pricing, and found that the income level of buyers and the interest rate level of economic environment determine the loan ability of buyers, and subsequently affect the real estate demand and price. Using the real estate price data of 33 cities in China, Zhang et al. [10] found that irrational expectation is an important factor that causes real estate price bubbles. Shiller [11] pointed out that the increase of real estate prices was due mainly to people's irrational trading and investment behavior. Their extrapolated expectations, pessimistic or optimistic market sentiment, herd psychology, the dissemination of information via social media, and effect of people's positive feedback on market information are all important factors influencing real estate demand and pricing. In regard to investment demand, Zheng et al. [12] applied fundamental and technical analysis methods to investigate the evolution of the supply and demand relationship in the real estate market and found that the investment demand of buyers was the main reason for the bubble in the real estate market. Bao and Hommes [13] believe that the investment demand of home buyers will increase the risk of market bubble and market collapse, but the endogeneity of real estate supply will prevent a market bubble.

It is evident that the studies cited above were concerned with more than a simple analysis of the impact of fundamental information on real estate prices; they went beyond the assumption of rational expectations to a certain extent, and attempted to explain the huge fluctuations and periodic movements in the real estate market. However, they did not consider the heterogeneity of the real estate market in general. In fact, a large number of empirical studies [14,15] show that there is strong heterogeneity among traders in the market. In the real estate market, owner-occupied buyers focus mainly on the natural attributes of real estate, while investment buyers pay more attention to the value attributes of real estate. Due to this heterogeneity, the various entities in the real estate market react differently to the economic environment, market state and government policy regulation, etc., which makes the evolution of real estate prices become a dynamic, evolutionary and game process. In recent years, an increasing number of scholars have begun to pay more attention to the impact of heterogeneity on the real estate market. Silos [16] explained the cyclical changes of the real estate market from the perspective of heterogeneous agents. Burnside et al. [17] explained the fluctuations of the real estate market from the perspective of buyers' heterogeneous beliefs through the heterogeneous agent model of belief change.

2.2 Population Migration and Real Estate Demand

In the past, studies on housing demand of population migration were mainly divided into two streams. The first is from the perspective of cross-regional population migration, focusing on the choice of population migration and the growth of housing demand after migration, the imbalance between supply and demand, and the characteristics of buyers. Population migration can affect the real estate market in two ways: one is the increase in urgent housing demand caused by the increase in urban population; the other is the speculative housing demand caused by the affluent urban population benefiting from urbanization [18]. Despite the increasing demand for housing driven by the rapid growth of income and the rapid expansion of new urban population, the release of supply lags behind, resulting in the short supply of housing in China's urban real estate market [19]. This produces an imbalance between supply and demand. The relatively higher income of well-educated immigrants in the population is more likely to generate effective housing demand, thus affecting local housing prices to a greater extent [20].

The second stream of studies focuses on the concentration of population, examining the impact on the balance of housing supply and demand of population movement to cities. In terms of equilibrium, when the housing supply in the market is not elastic, the population inflow will have a significant impact on the housing prices. However, the elasticity of housing supply will increase with the growth of urban population [21] and eventually achieve equilibrium. Furthermore, when Zhou Da analyzed the housing demand of urban immigrants, he also found that the increase of urban migrant population led to the rapid growth of housing demand, and the lack of elastic housing supply in the short term led to the rapid rise of housing prices [22]. The supply elasticity of urban real estate market will also have a reverse impact on urban population flow. If the supply elasticity of urban housing is small, the growth of urban housing price tends to be faster, and the growth of urban labor supply and population will be inhibited [23]. Moreover, from the perspective of space, housing price is also the reason for the change of spatial distribution of permanent population [24]. Jeanty et al. [25] used the Michigan census data to explain the spatial relationship between population changes and real estate prices.

The influx of population brings new housing demand, resulting in short supply and rising housing prices, and high housing prices will reduce residents' housing demand, thus negatively impacting housing prices [26]. Other studies have examined the one-way impact of population and housing prices. Many studies have confirmed that population inflow will increase housing prices [27,28], while some have concluded that population migration has little impact on the increase of housing prices. Further, Sá's study of the United Kingdom found that immigration has a negative impact on housing prices, and the influx of population makes local residents tend to migrate to the surrounding areas, thus reducing regional housing prices [29]. The empirical results of studies in China basically support the positive impact of population inflow on housing prices [30]. The high-quality resources in big cities are very attractive, resulting in the spatial heterogeneity of housing prices [31]. In terms of inhibiting population inflow, high housing prices will increase the cost of population migration [32] and reduce the population's willingness to migrate and buy houses. There are also studies on purchase restriction policies from the perspective of supply and demand, which found that investment demand is an important factor driving up housing prices, and the effect of expanding supply is insufficient. Moreover, it has been found that purchase restriction policies have no significant negative impact on housing prices in cities with purchase restrictions [33].

2.3 Catastrophe Theory and Social Dynamics

The decision-making behavior of investors is often nonlinear and discontinuous due to internal and external interactions, and the catastrophe theory is a methodology applied in many fields to study how small continuous changes of independent variables in the system lead to catastrophe of dependent variables with discontinuity [34].

In the field of finance, Ma Xiaomeng et al. used the cusp catastrophe model to analyze investor behavior decision-making in an intelligent environment, and summarized the mutation mechanism and control strategy [35]. Dou and Ghose used catastrophe dynamics to study customers' purchasing behaviors in e-commerce [36]. In the field of psychological behavior, Flay points out that abrupt behavior is a phenomenon shared by animals and humans. Hence, in the field of psychology, traditional mathematical modeling methods, such as stationary and continuous change, as well as monotonous step functions and threshold methods, do not solve the problem well. In sociological studies, Weidlich and Huebner regarded the change of people's views as being nonlinear. After establishing the dynamic model of the evolution of a group's views, they analyzed the evolution process over time and found that the change in the number of people holding discrete views in different environments had the characteristics of cusp catastrophe [37].

To date, a series of achievements have been made in the improvement and application of the classical catastrophe theory. For example, in the management of organizations, Xu Yan et al. studied competition and cooperation behavior in enterprise alliances by using the random catastrophe theory [38]. In the field of individual cognitive behavior, Lv et al. studied the rule of individual cognitive flexibility based on catastrophe theory and proved that the elasticity model based on cusp catastrophe can be used to analyze changes in individual cognitive flexibility [39]. Zhu et al. analyzed the autonomy of individual behavior by using the catastrophe theory and proposed corresponding control strategies and measures [40]. To sum up, it can be seen that the integration of catastrophe theory and other theories can transform the qualitative data generated by the catastrophe behavior of individuals in the network into quantitative research, through which the original and mature quantitative and inferential methods can be used to study the cognition and selection behavior of individuals in the network organization, reveal the nonlinear mutation of behavior, and discover the corresponding rules.

At the same time, social dynamics can often reveal the mechanism of abrupt characteristics of individual decision-making behavior on the evolution of group behavior, and multi-agent modeling and complex network are commonly-used modeling methods [41]. It is also typical practice in social dynamics to model and embed the psychological change process of individuals into the system to observe the macroscopic evolution law therein [42]. Because it is difficult for previous empirical studies to obtain dynamic data on such problems, the multi-agent model can be used to display dynamic interactions among individuals and emergent behaviors such as group reversal and polarization from top to bottom [43].

To sum up, how to break through the limitations of traditional empirical research and accurately and quantitatively reflect the dynamic mechanism and behavioral evolution of investors in real estate in the context of population migration has become an urgent problem to be solved. Based on the classical theories of behavioral decision-making and social psychology, this paper attempts to construct a mathematical model of the evolution mechanism of the cognitive bias within an intelligent environment. Then, the catastrophe theory and system dynamics are used to analyze this mechanism quantitatively, and the influence of various factors on investment behavior decision-making is observed through simulation experiments. Finally, on this basis, several intervention measures and control strategies are proposed for real estate entities dealing with population migration.

3. A DYNAMIC MODEL OF REAL ESTATE INVESTOR GROUP DECISION-MAKING BEHAVIOR

3.1 The Catastrophe Analysis and Modeling of Investor Behavior Decision

When real estate investors need to make decisions, they are driven mainly by potential psychological cognition and affected by cognitive bias arising from the external environment [44]. Due to the influence of cognitive bias, their investment behavior will change suddenly. In the cusp catastrophe model, the potential function representing this behavior is as follows:

$$v(f, u, v) = \frac{1}{4}f^4 + \frac{1}{2}uf^2 + vf \tag{1}$$

where f is the behavior state variable, which will change linearly and nonlinear between the two states with the change of u and v. The internal variable u controls the time when the behavior catastrophe occurs, and the external variable v controls the degree of the behavior catastrophe. By differentiating the equilibrium point of formula (1), formula (2), the behavior surface equation of f, can be obtained.

$$\frac{\partial V(f, u, v)}{\partial f} = f^3 + uf + v = 0 \tag{2}$$

By continuing to differentiate formula (2), we obtain formula (3).

$$3f^3 + u = 0 \tag{3}$$

By applying formula (2) and (3) simultaneously, we can obtain the set of branch cuts, as shown in formula (4).

$$\delta = 4u^3 + 27v^2 = 0 \tag{4}$$

Figure 2 is a diagram of the discrete changes of the equilibrium point of the behavior decision (i.e., Formula 4) with the continuous change of parameters. The surface of the upper half is the behavior equilibrium surface f of the system, where the upper half surface and the lower half surface respectively represent the two steady states of the behavior f, and the fold region in the middle is the unreachable region of the behavior f. The lower part is the control plane formed by the control variables u and v, and the triangular region is the singularity set, which is also the projection of the fold region of the upper part on the control plane. When the values of

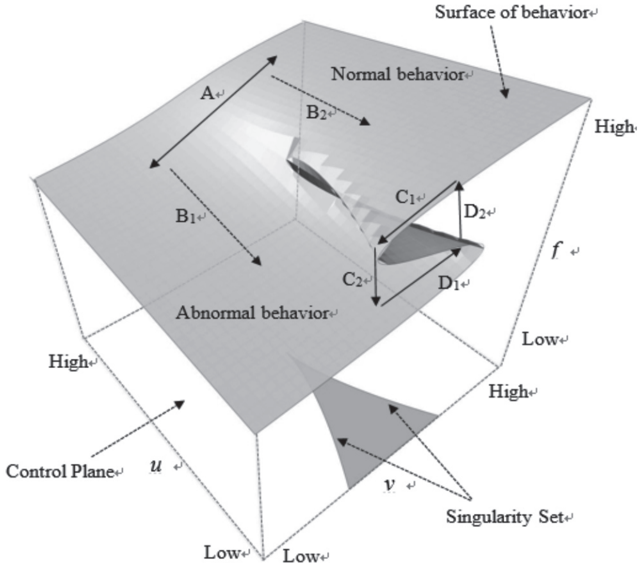


Figure 2 The graph of cusp catastrophe model.

u and v reach both sides of this triangle, a sudden change in behavior occurs. The C2 and D2 paths indicate that a person's behavior can suddenly jump from one stable state to another.

In this work, investor behavior decision f has two states, namely investment and non-investment. We set u as the internal decision influencing factor of home buyers, determined by their own living demand and purchase cost. v is set as an environmental influencing factor, determined by market expectations in the group.

According to Cobb's study, the function of internal variable u and external variable v can be set to:

$$\begin{cases} u = \alpha_0 + \alpha_1' x_1 + \alpha_2' x_2 \\ u = \beta_0 + \beta_1' y_1 + \beta_2' y_2 \end{cases} \tag{5}$$

Meanwhile, according to the algorithm proposed by Cobb, formula (5) can be simplified as follows:

$$\begin{cases} u = \alpha_0 + \alpha_1' x_1 \\ u = \beta_0 + \beta_1' y_1 \end{cases} \tag{6}$$

where α_0 represents the initial constant of the internal decision factor, α_1 represents the coefficient of the individual affected by the internal decision factor, which is related to the personality characteristics of the individual, and x_1 represents the degree of funds surplus of the individual. β_0 represents the initial constant of external environmental factors, β_1 represents the coefficient of an individual affected by external variables, which is related to the intelligent environment and network structure of an individual, and y_1 represents the deviation of investment demand generated by individual investor i influenced by market expectations and public opinion.

The degree of individual capital surplus is often affected by income, housing price, community environment and other factors. Therefore, we use I_l^t to represent the wage income of individual investor i at time t, $\bar{P}_t$ to represent the average level of housing price at time t, and ω_E to represent the weight of environmental factors of the house, which can be reflected in the housing price. $\omega_E \epsilon [-0.5.0.5]$, if $\omega_E > 0$, means that the environmental factors of the house are higher than the average level, and the housing price is also higher than the average level. Therefore, the price of the house at time t, $P_t = P_t(1 + \omega_E)$, A_t is the area of the house, r is the annual interest rate of the loan, R is the monthly interest rate of the loan, $R = r/12$, N is the number of loan terms, and formula (7) can be obtained.

$$x_1 = I_l^t - \bar{P}_t(1 + \omega_E)' A_t' \frac{(1+R)^N \cdot R}{(1+R)^N - 1} \tag{7}$$

With the changes of population flow and supply and demand, the average house price fluctuates as shown in formula (8).

$$\bar{P}_t = \bar{P_{t-1}} + \varphi \Delta S_t + \rho \Delta H_t + \sigma \Delta L P_t \tag{8}$$

where $\bar{P}_t$ is the average housing price at moment t, and $\bar{P_{t-1}}$ is the average housing price at moment $t - 1$. ΔS_t indicates the number change at time t; ΔH_t indicates the change of high-tech talents at time t; ΔLP_t is the change of land price at time t.

y_1 represents the investment demand deviation of individual investors affected by market expectations and public opinion. When facing decision-making, investors often exhibit irrational investment behavior because of external disruption. This external factor is due to the influence of the surrounding investors and the massive influential push in the intelligent environment, which will cause a deviation in investors' demands and investment behavior.

3.2 Behavioral Decision Evolution Model of Investor Group

Given the heterogeneity of individuals, we divided the investors in the group into two types: conservative and active. Based on the viewpoint dynamics, we established the

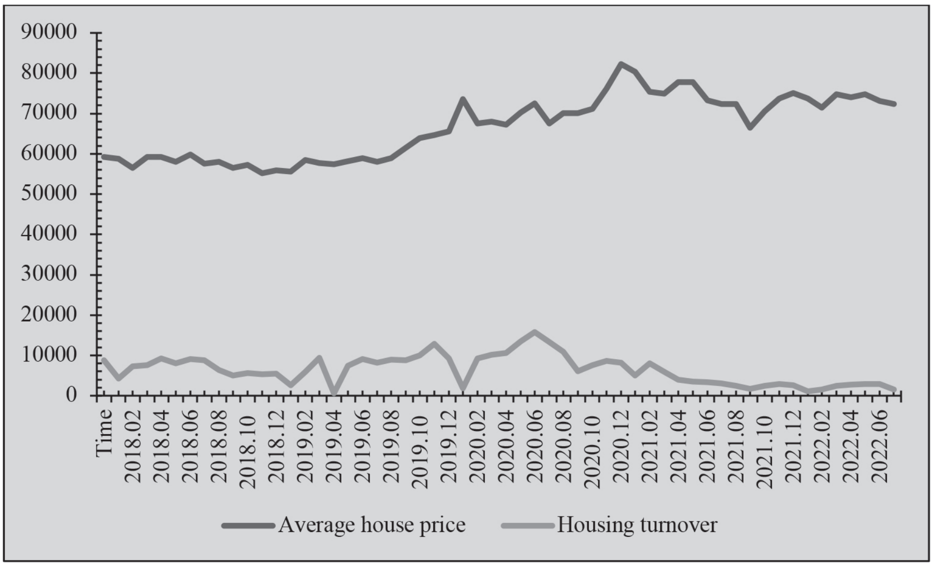


Figure 3 Housing price trend in Shenzhen from 2018 to 2022.

evolution model of the group's house purchase decision so as to dynamically study the behavioral evolution law of the group investors. Conservative investors are not susceptible to the influence of others, representing the just-in-need buyers, and the purpose of buying a house is often to obtain the residential attributes of real estate. Active investors are susceptible to the influence of others and represent speculative home buyers who purchase a property in order to acquire the investment attributes of real estate.

Based on the RA model, the interaction rule between investor i and investor j is shown in Formula (9).

$$\begin{cases} u_{i,t+1} = u_{i,t} + \alpha_1 \cdot (u_{i,t} - u_{j,t}) \\ v_{i,t+1} = v_{i,t} + \beta_1 \cdot (v_{i,t} - v_{j,t}) \end{cases} \tag{9}$$

In the intelligent environment, investors will receive a massive amount of information (push). We introduce parameter d_i to represent the intensity of information domination by investor i. The greater the value, the greater the impact on investor i. The interaction rule is shown in formula (10).

$$\begin{cases} u_{i,t+1} &= u_{i,t} + \alpha_1 \cdot d_i \cdot (u_{i,t} - u_{j,t}) \\ v_{i,t+1} &= v_{i,t} + \beta_1 \cdot d_i \cdot (v_{i,t} - v_{j,t}) \end{cases} \tag{10}$$

where d_i represents the interaction intensity in the group, which not only includes the influence of investor i from surrounding investors, but also includes investment expectations and information push in the group.

4. MODEL SETTING AND EXPERIMENTAL RESULTS

We used Anylogic 8.5 to build a multi-agent simulation model, and carried out the initial value setting and model correction of the model based on the data of Shenzhen City, Guangdong Province, China.

We obtained the transaction prices and volume data of five major intermediary websites in Shenzhen from 2018 to 2022, as shown in Figure 3. Due to the synchronization of the platform data, the volume data lags behind the price data; also, disrupting factors such as holidays and epidemics are excluded. Comprehensive analysis shows that when the price trend is stable, the trading volume will oscillate slightly but remain in a stable state. When the price starts to increase, so does the volume. However, when the price escalates, the volume begins to decline due to the impact of the cost of purchasing.

4.1 Borderless Networks for Investor Decision Making in an Intelligent Environment

In the model, the investors' investment decision and behavior are influenced by two factors: one is the internal decision-making process, which is determined by their own housing demand and house purchase cost; the other is the intensity of investors' investment demand, which is influenced by market expectations and public opinion. The influence of this factor is due mainly to the information push of the intelligent environment, where the group structure conforms to the scale-free network structure. Therefore, we used a scale-free network structure to construct the interaction structure between investors, as shown in Figure 4. In addition, the network structure is different from the traditional word-of-mouth recommendation, which is influenced by frequent communication and has no boundary; hence, for simulation, we set the network structure parameter M to 10.

4.2 Initial Simulation Results of Group House Purchase Decision Evolution Model

The initial model settings are shown in Table 1.

We explain the setting of the initial data as follows:

The number of investors is set to 5000 because the simulation model is built based on Anylogic. We compared

(1) Scale-free $M = 1$ (2) Scale-free $M = 5$ (3) Scale-free $M = 10$

Figure 4 The influence of the number of node connections in the network structure.

Table 1 Model initialization settings.

Variable	Value	Describe
population	5000	Number of investors
r	4.9%	Annual interest rate
R	0.41%	Monthly interest rate, $R = r/12$
N	240	Number of loan terms, calculated over 20 years
$\bar{P}_t$	60000	Average initial house selling price
ω_E	Random $(-0.5, 0.5)$	The environmental value weight of the house
A_t	50	House area
I	Triangular (6000, 50000, 15000)	Initial wage
$N_{house} = 0$	80%	Proportion of people without housing
Network structure	Scale-free	The network structure is scale-free network
M	10	The number of connections per node is 10

the convergence speed and efficiency of models with the number of investors of 2000, 3000, 4000, 5000 and 6000, and found that there was no significant difference in convergence speed and efficiency when the number of investors was greater than 3000. Therefore, in order to ensure the stability of the results and the running speed of the model, the number of investors is set to 5000.

The annual interest rate of the loan r=4.9% is based on the requirements of China's financial policy. Under the premise of no preferential policies and upward floating policies, the annual interest rate of the loan for more than 5 years is 4.9%.

The monthly interest rate R=0.41% is calculated based on the annual interest rate of 4.9%.

The number of loan terms N=240 is taken into account since China's housing price is relatively high and the gap between housing price and income is large. Based on relevant statistics, the average length of mortgage loans is 20–30 years. Given the high wealth and salary level of the population in Shenzhen, the initial loan period is set at 20 years, with the number of loan terms being monthly. Therefore, the maturity of the loan is 20 years *12 months =240 maturity.

The average initial house price $\bar{P}_t$ is set as 60000 yuan based on the second-hand house transaction data we collected in Shenzhen in recent years. The average house price in Shenzhen is 60000 yuan.

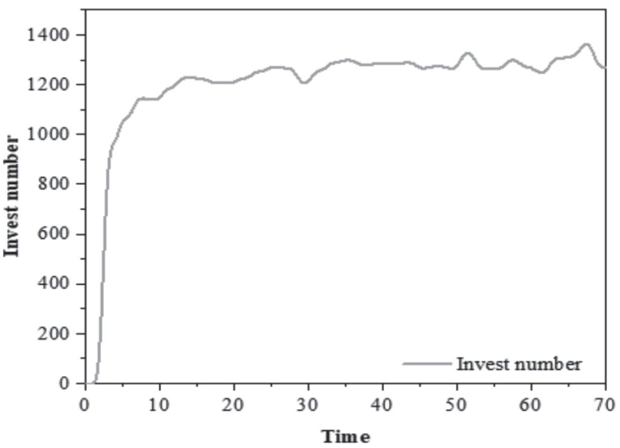
The environmental value weight of the house is a random distribution of $(-0.5, 0.5)$, and the average selling price of the house is set at 60,000 yuan. However, house viewing is a random process, with some houses in good condition and others in relatively poor condition. Therefore, the weight adopts a random distribution to reflect the house selling price of the individual purchase decision.

The housing area of 50 is set based on the data of Shenzhen Municipal Bureau of Statistics; the per capita residential area is 47.9, so it is rounded to 50.

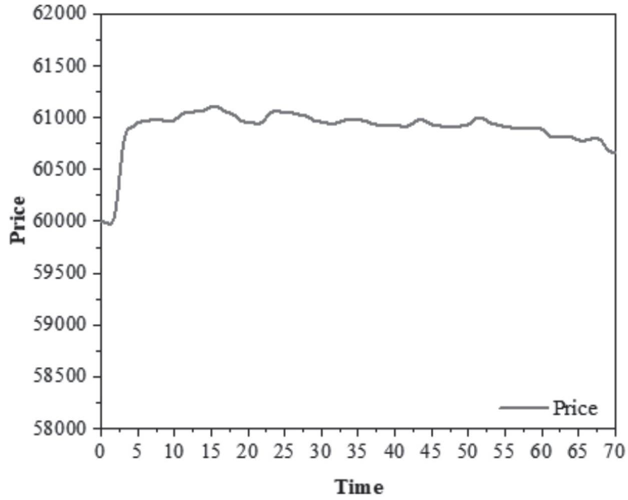
The initial wage is set according to the wage guide price published by Shenzhen Human Resources and Social Security Bureau.

The network structure is a scale-free network, the most important feature of which is its degree of node distribution that follows a power law distribution; that is, some nodes in the network have a very high connection (commonly known as "central node" or "hyperlink node"), while most nodes have a very low connection in both the large and small scales of the network.

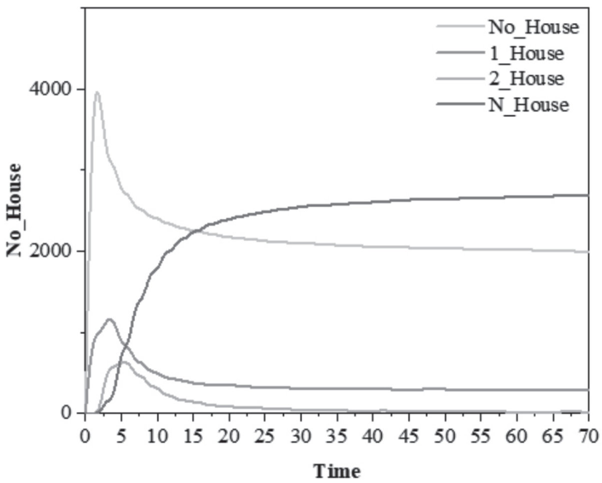
Here, the M represents the number of nodes in the existing network to be connected to each time a new node is added. Typically, scale-free networks grow by the constant addition of new nodes. Each time a node is added, it establishes a connection with several existing nodes in the network. New nodes tend to establish connections with those that already have more connections. This is known as the "rich get richer" or the "Matthew effect" and is a key mechanism that characterizes scale-free networks. Taking into account the usage habits and communication frequency of social platforms, we input "M=10", meaning that every time a new node is added to the network, it randomly selects and connects to the 10 nodes already in the network. This type of connection can cause some nodes (those that have multiple connections to begin with or acquire them early on) to accumulate more and more connections over time, forming a central or hub node in the network. This mechanism is the key to forming a power-law degree distribution, and is also a prominent feature of scale-free networks.



(a) Price change under initial condition



(b) Investor number under initial condition



(c) The number of four types of homebuyers changed

Figure 5 Simulation results under initial conditions.

The proportion of people without housing is set at 80% because of the large migrant population in Shenzhen, Shenzhen has an actual population of more than 21 million through mobile signaling data, and according to the grid registration data, Shenzhen's permanent population is more than 17 million, with more than 5 million people registered as having housing; hence, the proportion of people without housing is set at 80%.

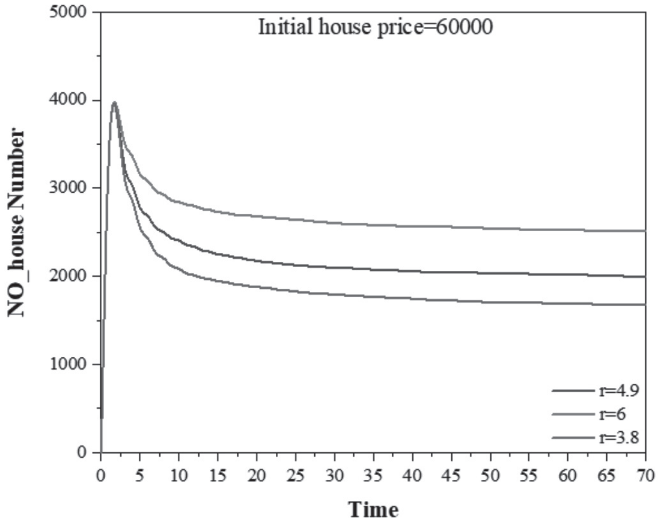
Simulation results with initial values are shown in Figure 5.

As can be seen from Figure 5, when the price is within a relatively stable range, the number of individuals making purchase decisions is also in a relatively stable state; when the price falls, the turnover increases. This is consistent with the trend in the actual data. Through the simulation of the number of homebuyers (just-in-need, speculators), we find that when the salary can afford the current price of the mortgage, most of the non-homeowners will choose to buy the first house. Nearly half of the people who own the first house choose to buy the second house. Because the price level has not changed greatly, people who own second homes have a great opportunity to become speculators. If the price continues to maintain a steady state, the number of the three tends to stabilize.

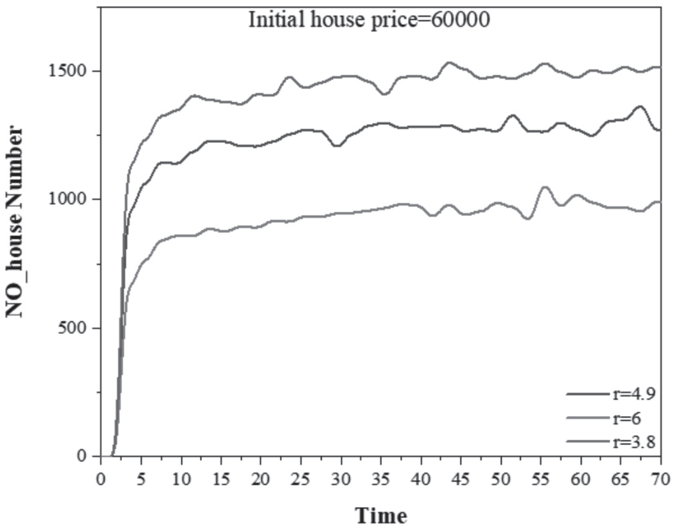
4.3 The Influence of Loan Interest Rate and Housing Price Changes on Investors' Purchase Decisions

Subsequently, we analyze the influence of loan interest rate on homebuyer behavior. We find that when wages can meet current home prices, more favorable mortgage rates encourage home buying. However, when the rising trend of housing prices is not obvious, a more favorable loan interest rate can promote the purchase decisions of only some just-in-need buyers, but has no significant impact on the purchase decisions of speculators. That is, a more favorable loan interest rate will not significantly increase the amount of investment, as shown in Figure 6.

Under the condition that the loan interest rate is unchanged, the influence of the housing price on the behavior of the buyers is analyzed. We find that the lower the price, the more likely it is to attract buyers to invest. When the price rises appropriately, the investment enthusiasm of speculators can increase. However, when the price exceeds the affordable range of buyers, the quantity of just-in-need buyers decreases



(a) Changes in the number of non-homeowners under different lending rates



(b) Changes in the number of homebuyers under different lending rates

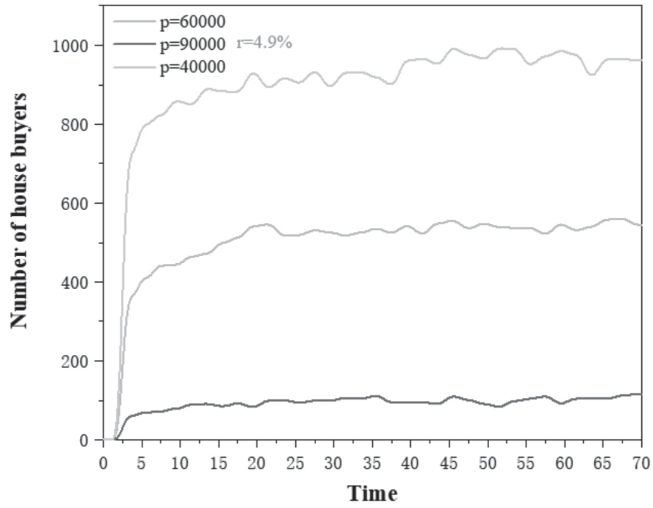
Figure 6 When the initial housing price is a certain value (x=60000), the influence of different loan interest rates on investment behavior.

and the transaction liquidity is insufficient, resulting in a sharp decrease in the number of transactions, as shown in Figure 7.

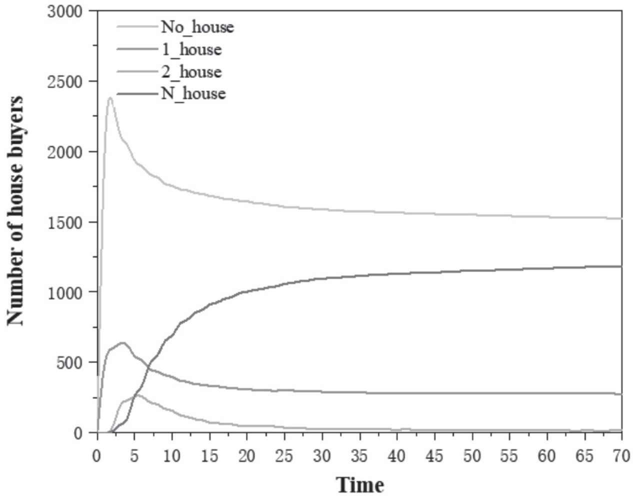
4.4 The Influence of Loan Interest Rate and Housing Price Change

As mentioned above, external factors such as public opinion are also important influencers of investment behavior. In order to further verify the investment intention model of investors under the dual influence of individual emotions and the market expectations that we built, we conducted comparative experiments with internal factors as dependent variables, as shown in Figure 8. Figure 8(a) shows that when investors interact only under the influence of market expectations, their willingness to invest is a gradual evolutionary process, which is not quite consistent with the current volume changes in the market. However, when we increase the dual influence of individual emotion and market expectation, there are mutations and reversals in the change of investment intention, which is more in line with the actual situation, as shown in Figure 8(b).

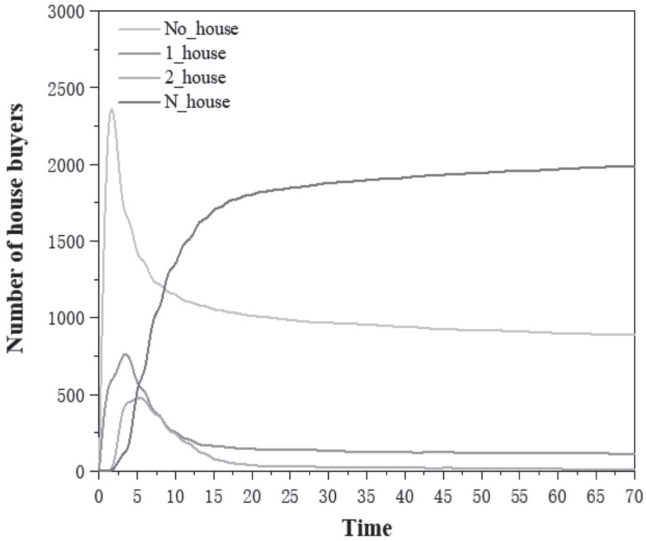
Similarly, the impact of the ratio of the amount of rigid demand in the market on the willingness to invest in the market, can often reflect the degree of optimism in the transaction. We use the change of the initial proportion of rigid demand to explore the impact on the investment willingness of rigid demand buyers and speculators. As can be seen from Figure 9(a), when the initial proportion of people without houses is 80%, there is an obvious upward trend along with the interaction process of views, leading the group's investment intention to evolve in a positive direction. However, Figure 9(b) shows that when the initial proportion of people without houses is 50%, the increase of investment intention is significantly weaker than that after interaction when the initial proportion of people without houses is 80%, as shown in the red box in Figure 9. It indicates that the greater the quantity of just demand, the greater the demand in the market, and in the case of optimistic market expectations, it is easier to guide the increase of market investment willingness.



(a) Changes in the number of buyers at different prices

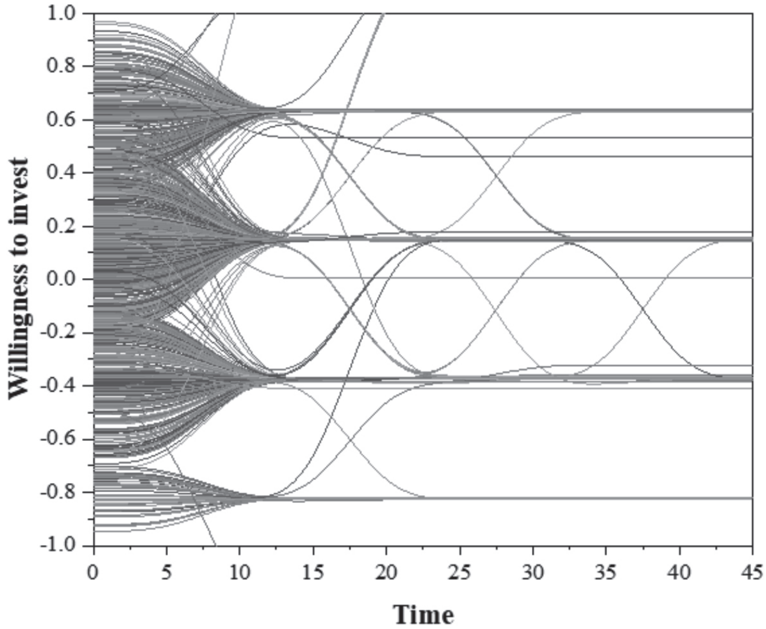


(b) Changes in the number of different types of buyers when prices are lower

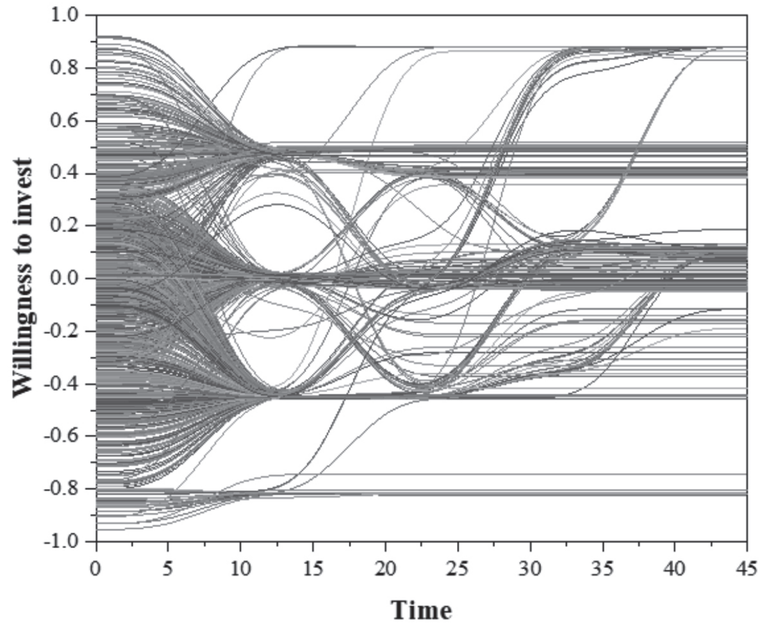


(c) Changes in the number of different types of buyers when prices are higher

Figure 7 The influence of different housing price levels on investment behavior when the loan interest rate is 4.9%.



(a) Taking only market expectations into account

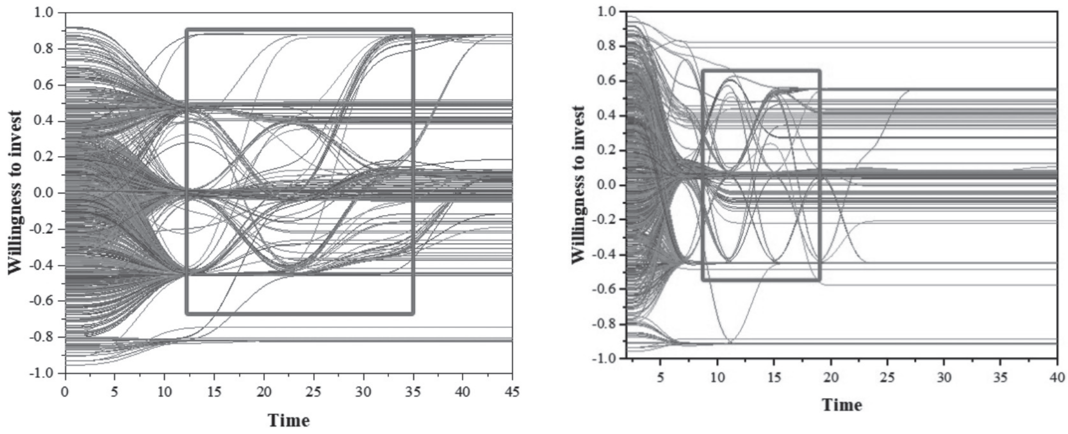


(b) Taking into account both individual sentiment and market expectations

Figure 8 Analysis of the change of investment intention.

Figure 10 shows the impact of different types of buyers on the group's investment intention when the initial proportion of people without houses is 80%. When both just-in-need buyers and speculators believe that the market expectation is good, the market investment intention will evolve in a positive direction, as shown in Figure 10(a). When both just-in-need buyers and speculators believe that market expectations are not good, in the steady state of evolution, most individuals will choose not to invest, although some speculators do not want to suffer losses and choose to invest, as shown in Figure 10(c). A comparison of Figure 10(b) and Figure 10(d) shows that speculators account for a minority in the market, and just-in-need buyers represent the real demand of the market. Therefore, when the just-in-need buyers think that the market expectation is not good, even if the speculators have been propagating that the market expectation is good, they still cannot prevent the investment intention from taking a negative direction, as shown in the red box in Figure 10(b). However, there is a clear jump when just-in-need buyers believe that the market is expected to improve, as shown in the red box in Figure 10(d).

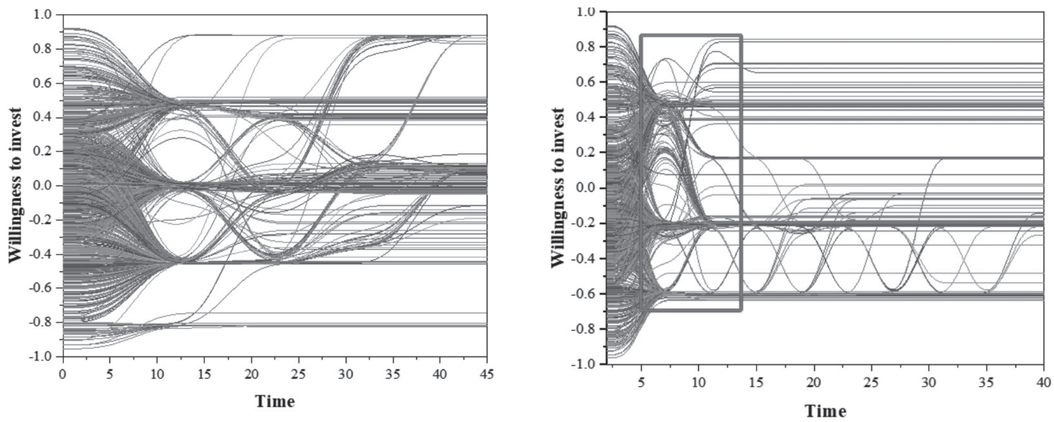
Figure 11 shows the changes in the buying behavior of just-in-need buyers and speculators when the market expectations are either optimistic or pessimistic. Similar to the change result of market public opinion, when the overall market is optimistic, it is the hottest time for real estate, and the number



(a) The proportion of people without housing under the initial conditions is 80%

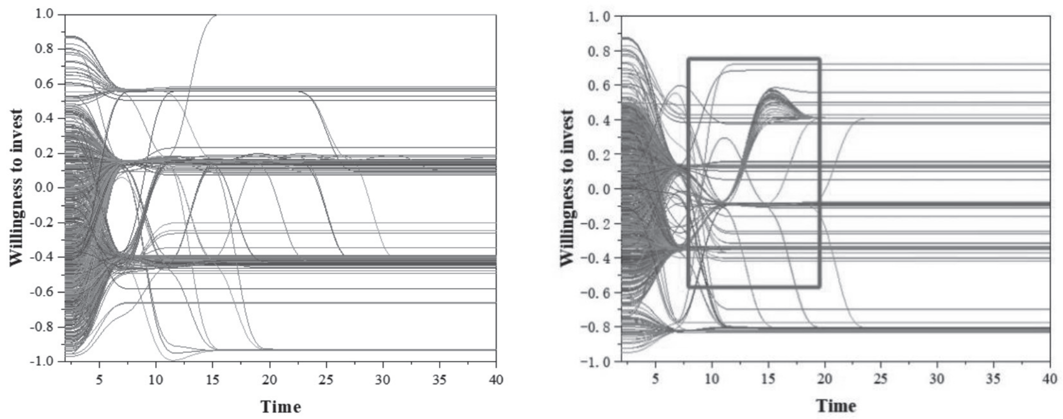
(b) The proportion of people without housing under the initial conditions is 50%

Figure 9 The influence of demand difference on investment intention under optimistic market expectation.



(a) Both just-in-need buyers and speculators believe that market expectations are positive

(b) Speculators believe that market expectations are positive, while just-in-need buyers believe that market expectations are negative



(c) Both just-in-need buyers and speculators believe that market expectations are negative

(d) Speculators believe that market expectations are negative, while just-in-need buyers believe that market expectations are positive

Figure 10 Different types of real estate buyers have different market expectations and the change of group investment intention.

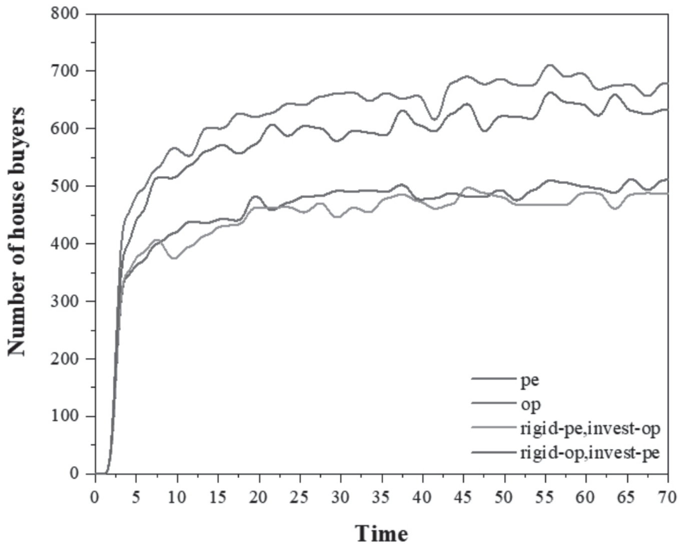


Figure 11 The influence of market expectations on investment behavior.

of transactions shows a steady upward trend, as shown by the blue line in Figure 11. When the market as a whole is pessimistic, the number of transactions is low. It is worth noting that the market expectations of just-in-need buyers have a greater impact on the overall market than the market expectations of speculators. When just-in-need buyers are pessimistic about the market, the amount of investment in the market drops significantly, as shown by the green line in Figure 11. Because just-in-need buyers are the source of market demand, when they are pessimistic about the market, they cannot drive the linkage effect of the capital chain without making purchase decisions. Only when just-in-need buyers are optimistic about the market can they drive the volume growth of the real estate market, as shown by the purple line in Figure 11. From the analysis results, it can be seen that speculators alone cannot maintain the positive operation of the real estate market.

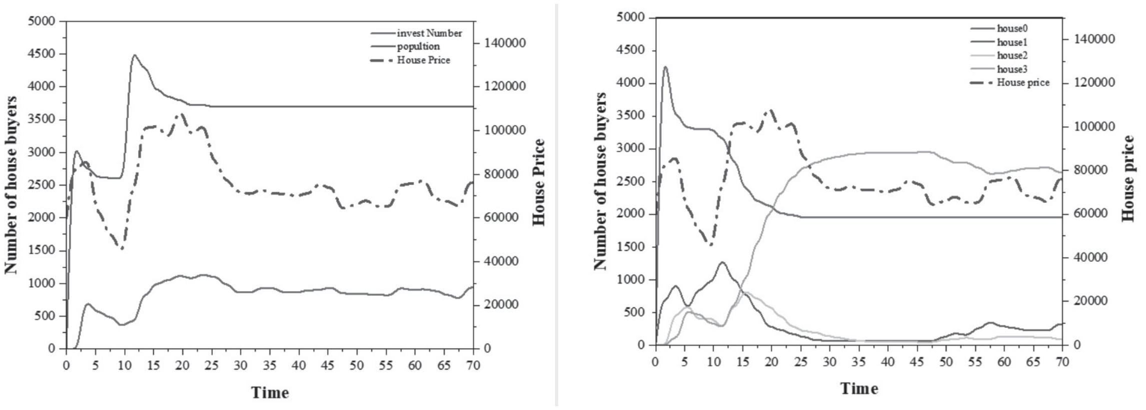
4.5 Simulation of the Dynamic Evolution Trend of Population Migration and Real Estate Prices

The change of urban population is a dynamic process. We further simulate the interaction between population and housing prices. We set the conditions of population inflow and outflow in the model. When residents do not have their own homes in the city and there is strong pressure to buy houses, they will choose to leave the city with a certain probability θ. When the ratio of average housing prices to average wages in a city is less than a given threshold ε, it attracts population inflows. As can be seen from Figure 12(a), in the early stage of the simulation, housing prices began to rise with the increase in the number of buyers, and then due to the greater pressure of house purchase, the urban population began to decline, resulting in less demand and a decrease in housing prices. Attracted by low housing prices and wages, a large number of people flow into the city, which increases the demand for housing, prompting a rapid rise in housing prices. Then some people, driven by high housing prices, choose to leave the city until the housing price level and population maintain a stable state.

Figure 12(b) shows the change in house prices and the changes in the number of people who own houses in the city. It can be seen from the figure that the rapid decline of house prices will accelerate the purchase of the first house by the non-homeowners. However, for speculators, the rapid decline in house prices does not increase their purchase probability, and speculators are attracted only when house prices start to rise, as shown by the green line in Figure 12(b). At the same time, the changes in population and the proportion of buyers caused by price changes have a lag. It can be shown from Figure 12(a) that, affected by the stagnant demand, the housing price starts to decline rapidly after a lag of 2 simulation times; after the housing price declines, the population starts to rise rapidly after a lag of 3 simulation times; after the population rises rapidly, the population increases rapidly. The increase of house prices also reflects the lag, showing overall the change of volume decline - price decline - demand rise - price rise - volume rise.

4.6 Implications

Population migration is often restricted and affected by urban resources, especially in regard to the real estate market. The population flow brought about by population migration will encourage investment in real estate, leading to the increase of housing prices in the area of migration. However, when the housing price is too high, it will increase the cost of localization of the migrating population and become an obstacle to population migration, thus affecting the sustainable development of the city. In this study, the mutation theory and system dynamics are used to analyze the evolution mechanism of residents' real estate investment behavior decision in large immigrant cities, and the influence of various factors on investment behavior decision is observed through simulation experiments. This study innovatively divides homebuyers into just-in-need homebuyers and speculative



（a）Changes in housing prices and population

(b) Changes in housing prices and the number of urban owner-occupancies

Figure 12 Analysis of linkage change between housing price and population.

homebuyers, and examines their decision-making differences caused by internal and external influences.

The research conclusion shows that just-in-demand buyers are the source of market demand. When specifying real estate policies, the respective government department should first accurately identify the needs of buyers. For example, it could specify an appropriate down payment percentage for first homebuyers, and should not reduce the down payment percentage for buyers of a second house. At the same time, market expectations play an important role in investors' purchase decisions, and government management departments should severely crack down on collusion between buyers and intermediaries, and build a public opinion guidance system to stabilize expectations. The collusion strategy between the buyers and the real estate agents is often an important incentive for the change of housing price expectation. Relevant departments should actively establish real estate data interconnection and build an online and offline public opinion guidance system: at the level of online new media, while stabilizing expectations through real data, severely crack down on the self-media and the capital behind inciting market sentiment to break collusion. Offline, it is necessary to resolutely promote the theoretical advocacy of traditional media and grass-roots managers, emphasize the risks of the real estate market, change people's mindset about the operation of the real estate market and the government's support, and explore long-term arrangements to guide public opinion.

5. CONCLUSIONS

Population migration is closely related to real estate investment behavior. Large-scale population migration usually leads to an increase of net population inflow, which influences real estate investment behavior, and leads to the rise of housing prices in areas experiencing a population increase. However, when the housing price is too high, it may also increase the cost of citizenship of the migrant population, and become an obstacle to population migration, resulting in population emigration.

(1) When wages can meet the current housing price level, a more favorable loan interest rate will encourage the purchase decision of only just-in need buyers, but has no significant impact on the purchase decision of speculators.

(2) The lower the real estate price, the more attractive it is for buyers to invest. When the price rises abruptly c, it can stimulate the investment enthusiasm of speculators. However, when the price exceeds the range that buyers can afford, the number of just-in-need buyers decreases, and the transaction liquidity is insufficient, resulting in a sharp decrease in the number of transactions.

(3) Just-in-need buyers are the source of market demand when: they are pessimistic about the market, will not make purchase decisions, and will not be able to drive the linkage effect of the capital chain. Only when people are optimistic about the market can they drive the growth of the real estate market.

(4) The rapid decline in house prices will accelerate the purchase of first homes by just-in-need buyers, but will not increase the probability of speculators buying homes. Only when house prices start to rise will speculators be attracted. At the same time, there is a lag between the change in the population and in the proportion of buyers caused by price changes.

6. ACKNOWLEDGMENTS

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