Evolutionary Game Analysis of Stable Development of the Real Estate Market

Ning Zheng, Guoshun Ma

Abstract— **The mathematical model of two kinds of consumers in real estate market is set up by using evolutionary game theory , and by replicating the dynamic equation and evolutionary game model to analyze the behavior strategy of the main body.The results show that as long as there is a phenomenon of real estate speculation, the real estate market can not develop stably, and government intervention is needed at this time. The government's punishment for speculators is an important guarantee for the stable development of the real estate market.**

Index Terms— **government,consumers, evolutionary game, replicated dynamic equation, CLC F224 Document ID A**.

I. INTRODUCTION

In recent years, the rise in housing prices has made consumers who have a rigid demand for housing deterred. Behind the rapid rise in house prices, there are both internal factors such as insufficient supply and speculation by investors, as well as external factors such as rapid economic growth and excess liquidity in the population. The fundamental issue is still the tight relationship between supply and demand. The more tense resources are, the more buyers are, the higher house price will be, and the phenomenon of real estate speculation will intensify. In the report of the 19th National Congress of the People's Republic of China, the "supposing that the houses were used to live, not for speculation" was used to locate the new housing system so that all people could live . At present, there are mainly two types of consumers in the real estate market: one is the consumer group that has a rigid demand for real estate, and the other is the consumer group that mainly gains income or is called the real estate speculations. The existence of a large number of consumers with a rigid demand for housing promotes the emergence of the speculators group in order to make great profits, and the emergence of speculators group makes the consumers who have rigid demand for housing prohibitive.The simultaneous appearance of the two consumer groups makes the real estate market resource-intensive but not be fully and effectively utilized. Under such circumstances, It is necessary to consider how to effectively curb this phenomenon and make the "everyone has the housing right" housing system be effectively implemented .

Since then, there have been many experts and scholars in the real estate market have conducted in-depth studies on various issues [1-7] that have emerged . Wang Zhenpo [1] and others put forward several important problems in the real estate industry today. First, house prices have been rising and regional differentiation has become worse. Second, excessive administrative intervention products "regulatory policy bubble". and it has been proposed in the article that "everyone has the housing right" is the development trend of China's real estate. Yang Qiong [2] analyzed the current situation of real estate in china and used game theory to analyze and obtain the game strategy among various subjects in the real estate market as an important factor affecting real estate prices. As real estate prices have been rising in recent years, the government has proposed to establish public rental housing to ensure the stability of people's livelihood. Xu Si [3] through the evolutionary game method, concluded that the government has increased penalties and developers have increased technological research and tenants have chosen industrialized public rental housing in favor of achieving tripartite sharing win. By studying the relationship between central government and local government,Zhou Jianjun [4] and others established a game model to obtain a game equilibrium between them. Wang Jing [5] uses the Prisoner's dilemma model to analyze the behavior of developers in the real estate market. Research shows that the profits from cooperation between real estate developers are better than under the competition model. The developers in the game are in " Prisoner's dilemma " , the article finally proposes reasonable suggestions to real estate managers on this issue. Deng Jianlan [6] and others through the game between real estate developers and consumers, concluded that developers should increase credibility and propaganda efforts to convey truthful information to consumers, consumers make correct judgments, thus promoting the benign development of the real estate market. From the perspective of supply and demand, Jin Ling [7] conducted game analysis on the decision-making behavior of real estate developers and consumers, explored the reasons of continued high housing prices, and made prediction of the development of the real estate market on this basis, and provided some reference opinions for the government to reduce housing prices.

The above literature discusses the current situation of the real estate market n china, and discusses the game between central government and local government;the game between developers; the game between government and developers; the game between government and consumers from different game perspectives; However, with the emergence of speculators, there are also games between consumers. From the perspective of the consumer in the real estate market, this

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article explores the use of an evolutionary game model to analyze the game behavior between two types of consumers under the conditions of no-government intervention and government intervention. The real estate market is an effective proposal for stable development.

II. Evolutionary Game Analysis Among Consumers Without Government Intervention

2.1 Model assumptions

The research subject of this model is two types of consumer groups in the real estate market when there is no-government participation, one is the consumption group with rigid demand for housing (participant 1), and the other is the consumption group whose purpose is to obtain income (participation 2). Because participant 2 has a variety of ways to obtain benefits ,this paper only studies participant 1 and participant 2 are directly involved in the consumption approach. Two types of participants are bounded rational. Assume that participant 1 has two consumption strategies: purchase and not purchase; participant 2 has two consumption strategies:speculation and non-speculation.

Define parameters for the benefits, losses and costs of both parties. Assume that the participant's1 purchase income is a_1, participant's 2 speculate income is a_2.
Participant 2 gains the extra income of speculation is e When participant 1 chooses to purchase,Simultaneously,the additional loss of participant 1 is b ,and the participant 2 psychological loss of non-speculation is d .When participant 1 chooses to non-purchase , participant's 1 loss is p if participant 2 chooses to speculate, for example, the potential loss caused by rising house prices result in the price increase to participant 1; When participant 1 chooses to non-purchase , participant's 1 social income is f if participant 2 choose to non-speculation. All parameters are greater than zero. If the probability that the participant 1 purchases is x , then the probability that non-purchases is $1 - x$,if the probability that the participant 2 chooses to speculate is y ,then the probability that chooses to non-speculation is $1 - y$.

2.2 Model establishment

Based on the above assumptions, the payment matrix of participant 1 and participant 2 are shown in the following table:
(1)Evolutionary strategy analysis of participant 1
Assuming that the purchase income of participant 1 is W_1, non-purchase income is W_2, the average income is $\overline{W}$

$$W_1 = y(a_1 - b) + (1-y)a_1 = a_1 - by$$

$$W_2 = y(-p) + (1-y)f = -py + f - fy$$

$$\overline{W} = xW_1 + (1-x)W_2$$
$$= x(a_1 - by) + (1-x)(-py + f - fy)$$

Replicated dynamic equation of Participant 1

$$f(x) = \frac{dx}{dt} = x(W_1 - \overline{W})$$
$$= x(1-x)[(a_1 - f) - (b - p - f)y] \quad (2.1)$$

According to (2.1), we get the possible stability points for the system

$$x_1 = 0, x_2 = 1, y^* = \frac{a_1 - f}{b - f - p}$$

(I) when $y = y^*$,there is $f(x) = 0$, at this time, this point isn't stable point.

(II) when $y \neq y^*$,because $0 \le y^* = \frac{a_1 - f}{b - f - p} \le 1$,

Let $\mathrm{H} = a_1 - b + p$,It shows that when the participant 2 real estate, the total income of the participants 1 purchases minus non-purchases, Find the derivative of $f(x)$

Participant1 Participant 2	Speculation (y)	Non-speculation $(1-y)$
Purchase (x)	$a_1 - b, a_2 + e$	$a_1, -d$
Non-purchase $(1-x)$	$-p, a_2 - c$	$f, 0$

$$\frac{df(x)}{dt} = (1-2x)[(a_1 - f) - (b - p - f)y]$$

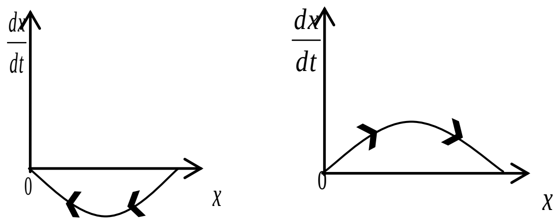
Evolutionary stability strategy (ESS) requires $\frac{df(x)}{dt} < 0$, there are two situations at this time, The first case
When $\mathrm{H} = a_1 - b + p < 0$, there were

$$0 < a_1 - f \le b - f - p$$

① when $y > y^*$, $\left.\frac{df(x)}{dt}\right|_{x=0} < 0$, $\left.\frac{df(x)}{dt}\right|_{x=1} > 0$,
$f(x) < 0$, $x = 0$ is a balance point.

② when $y < y^*$, $\left.\frac{df(x)}{dt}\right|_{x=0} > 0$, $\left.\frac{df(x)}{dt}\right|_{x=1} < 0$,
$f(x) > 0$, $x = 1$ is a balance point.

The phase diagram of the above two cases is as follows



$y > y^*$ $\qquad$ $y < y^*$

Figure 1: Phase diagram of $\mathrm{H} < 0$

The second case, when $\mathrm{H} = a_1 - b + p > 0$, there is

$$0 > a_1 - f \ge b - f - p$$

① when $y > y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} > 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} < 0$,

$f(x) > 0$, $x = 1$ is a balance point.

② when $y < y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} < 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} > 0$,

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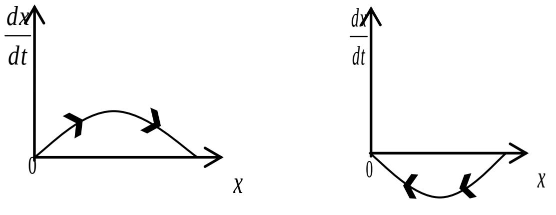


$y > y^*$ $\qquad$ $y < y^*$

Figure 2: Phase diagram of $\mathrm{H} > 0$

(2)Evolutionary strategy analysis of participant 2

Assuming that the speculation income of participant 2 is V_1 non-Speculation income is V_2 ,the average income is $\overline{V}$

$$V_1 = x(a_2 + e) + (1-x)(a_2 - c) = ex + cx + a_2 - c$$

$$V_2 = -dx$$

$$\begin{aligned}\overline{V} &= yV_1 + (1-y)V_2 \\ &= y(ex + cx + a_2 - c) + (1-y)(-dx)\end{aligned}$$

Replicated dynamic equation of Participant 2 speculation

$$\begin{aligned}f(y) &= y(V_1 + \overline{V}) \\ &= y(1-y)[(e+c+d)x - (c-a_2)] \qquad (2.2)\end{aligned}$$

According to（2.2）,we get the possible stability points for the system

$$y_1 = 0, y_2 = 1, x^* = \frac{c - a_2}{e + c + d}$$

(I)when $x = x^*$,there is $f(y) = 0$,this point isn't stable point, Participants 2 speculation or non-speculation has no effect on the equilibrium results when the probability of purchase is equal to $\dfrac{c-a_2}{e+c+d}$.

(II)when $x \neq x^*$,because $0 \le x^* = \dfrac{c-a_2}{e+c+d} \le 1$,as a result $c - a_2 > 0$, Let $\mathrm{I} = a_2 + e + d$, known by $\mathrm{I} = a_2 + e + d > 0$,It shows that the income of participant 2 speculation is greater than non-speculation when the participant 1 purchases .Find the derivative of $f(y)$

$$\frac{df(y)}{dt} = (1-2y)[(e+c+d)x - (c-a_2)]$$

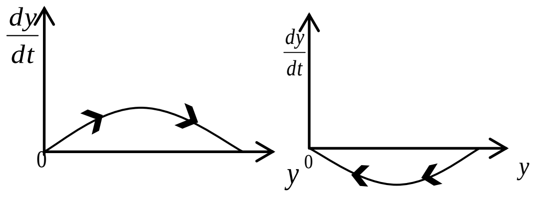
①when $x > x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} > 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} < 0$,

$f(y) > 0$, $y = 1$ is a balance point.

②when $x < x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} < 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} > 0$,

$f(y) < 0$, $y = 0$ is a balance point.

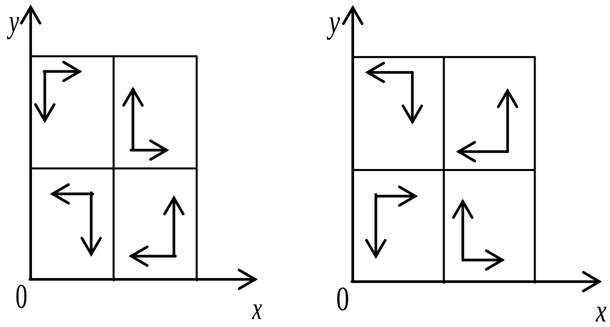
The phase diagram of the above two cases is as follows



$x > x^*$ $\qquad$ $x < x^*$

Figure 3: Phase Diagram of $\mathrm{I} > 0$

System evolution phase diagram



$\mathrm{H} > 0, \mathrm{I} > 0$ $\qquad$ $\mathrm{H} < 0, \mathrm{I} > 0$

Figure 4: System evolution phase diagram

2.3Evolutionary game analysis

Combine(2.1) and (2.2), we get 5 possible stability points, which are A（0.1）, B（1.0）, C（0.0）, D（1.1）, E（$\dfrac{c-a_2}{e+c+d}$, $\dfrac{a_1-f}{b-f-p}$）, Where E is Saddle point.We found out by analyzing the stability of various points in different situations.when $\mathrm{H} < 0, \mathrm{I} > 0$,there is no stable point;when $\mathrm{H} > 0, \mathrm{I} > 0$,there are stable points C(0.0) and D(1.1);which is $x < x^* = \dfrac{c-a_2}{e+c+d}$,

$y < y^* = \dfrac{a_1 - f}{b - f - p}$,the stability point is C(0.0),

Participant 1 chooses to non-purchase and participant 2 non-Speculation. Although the income of two types of consumers is stable, for the real estate market, there will be a large amount of idle resources which doesn't meet the concept of stable development of the real estate market. Participant 1 chooses to purchase and participant 2 non-Speculation When the stability point is D(1.1),which is

$x > x^* = \dfrac{c-a_2}{e+c+d}$, $y > y^* = \dfrac{a_1 - f}{b - f - p}$,The action strategies of the two types of consumers make the supply of resources insufficient and the house prices rise sharply isn't conducive to the development of the real estate market. That is , once there are speculators, the real estate market is difficult to form a stable development situation, and this requires government intervention.

III. EVOLUTIONARY GAME ANALYSIS AMONG CONSUMERS DURING GOVERNMENT INTERVENTION

3.1Model assumptions

The research subject of this model is the game situation of two kinds of consumer groups when the government intervention. Based on the model 1, it is assumed that the government only shows its intervention when it directly acts on two types of consumers.

Let E is the highest penalty for speculators, and F is the highest compensation income for participants 1 who chooses to purchase when participants 2 speculation.

Government punishment level for speculators is δ , $0 \le \delta \le 1$.

3.2 Model establishment

Based on the above assumptions, the payment matrix for participant 1 and participant 2 is shown in the table:

Participant1 1 Participant 2	Speculation (y)	Non-speculation $(1-y)$
Purchase (x)	$a_1 - b + \delta F$, $a_2 + e - \delta E$	a_1,$-d$
Non-Purchase $(1-x)$	$-p, a_2 - c$	f,0

(1) Evolutionary strategy analysis of participant 1

Assuming that the purchase income of participant 1 is W_1, non-purchase income is W_2, the average income is $\overline{W}$

$$W_1 = y(a_1 - b) + (1-y)a_1 = a_1 - by$$

$$W_2 = y(-p) + (1-y)f = -py + f - fy$$

$$\overline{W} = xW_1 + (1-x)W_2$$
$$= x(a_1 - by) + (1-x)(-py + f - fy)$$

Replicated dynamic equation of Participant 1

$$f(x) = \frac{dx}{dt} = x(W_1 - \overline{W})$$
$$= x(1-x)[(a_1 - f) - (b - p - f)y] \quad (3.1)$$

According to (3.1), we get the possible stability points for the system

$$x_1 = 0, x_2 = 1, y^* = \frac{a_1 - f}{b - f - p}$$

(I) when $y = y^*$,there is $f(x) = 0$, at this time, this point isn't stable point.

(II)when $y \neq y^*$ because $0 \le y^* = \dfrac{a_1 - f}{b - f - \delta F - p} \le 1$

Let $\mathrm{H}^* = a_1 - b + \delta F + p$,It shows that when the participant 2 speculation,the total income of the participants 1 purchases minus non-purchases,The first case when $\mathrm{H}^* = a_1 - b + \delta F + p < 0$,there is $0 < a_1 - f \le b - f - \delta F - p$,we can get conclusion $\delta < \dfrac{b - p - a_1}{F}$,at that time

① when $y > y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} < 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} > 0$, $f(x) < 0$, $x = 0$ is a balance point.

② when $y < y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} > 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} < 0$ $f(x) > 0$, $x = 1$ is a balance point.

The phase diagram of the above two cases is as follows

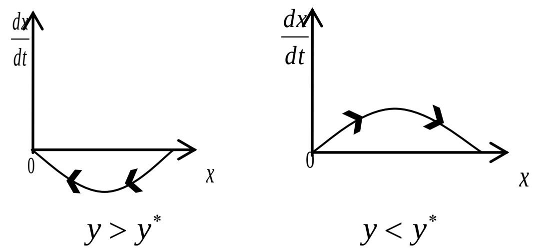


Figure 5: Phase Diagram of $\mathrm{H}^* < 0$

The second case, when $\mathrm{H}^* = a_1 - b + \delta F + p > 0$, there was $0 > a_1 - f \ge b - f - \delta F - p$,so $\delta > \dfrac{b - p - a_1}{F}$,at that time

①when $y > y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} > 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} < 0$, $f(x) > 0$, $x = 1$ is a balance point.

②when $y < y^*$, $\left.\dfrac{df(x)}{dt}\right|_{x=0} < 0$, $\left.\dfrac{df(x)}{dt}\right|_{x=1} > 0$, $f(x) < 0$, $x = 0$ is a balance point.

The phase diagram of the above two cases is as follows

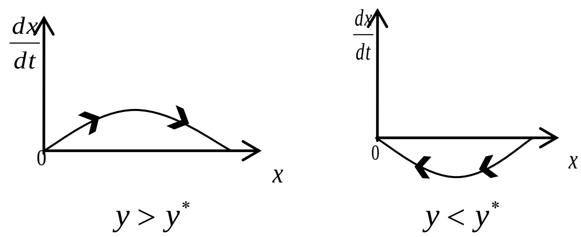


Figure 6: Phase diagram at time of $\mathrm{H}^* > 0$

(2) Evolutionary strategy analysis of participant 2

Assuming that the speculation income of participant 2 is V_1

non-Speculation income is V_2 ,the average income is $\overline{V}$

$$V_1 = x(a_2 + e - \delta E) + (1-x)(a_2 - c)$$
$$= ex + cx + a_2 - c - \delta Ex$$
$$V_2 = -dx$$
$$\overline{V} = yV_1 + (1-y)V_2$$
$$= y(ex + cx + a_2 - c - \delta E) + (1-y)(-dx)$$

Replicated dynamic equation of participant 2 speculation

$$f(y) = y(V_1 + \overline{V})$$
$$= y(1-y)\left[(e + c + d - \delta E)x - (c - a_2)\right] \quad (3.2)$$

According to（3.2）,we get the possible stability points for the system

$$y_1 = 0, y_2 = 1, x^* = \frac{c - a_2}{e + c + d - \delta E}$$

(I)when $x = x^*$,there is $f(y) = 0$ this point isn't stable point

(II)when $x \neq x^*$,because $0 \le x^* = \dfrac{c - a_2}{e + c + d - \delta E} \le 1$

there is $0 < c - a_2 \le e + c + d - \delta E$ or $e + c + d - \delta E \le c - a_2 < 0$,Let $\mathrm{I} = a_2 + e - \delta E + d$,It shows that when the participant 1 purchases,the total income of the participants 2 speculation minus non-speculation,Let $f(y) = 0$,there are two stable points $y_1 = 0, y_2 = 1$,Find the derivative of $f(y)$

$$\frac{df(y)}{dt} = (1-2y)[(e + c + d - \delta E)x - (c - a_2)]$$

The first case, $\mathrm{I}^* = a_2 + e - \delta E + d > 0$, that is $0 < c - a_2$,at that time $\delta < \dfrac{a_2 + e + d}{E}$

①when $x > x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} > 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} < 0$,

$f(y) > 0$, $y_2 = 1$ is a balance point.

②when $x < x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} < 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} > 0$,

$f(y) < 0$, $y_1 = 0$ is a balance point.

The phase diagram of the above two cases is as follows

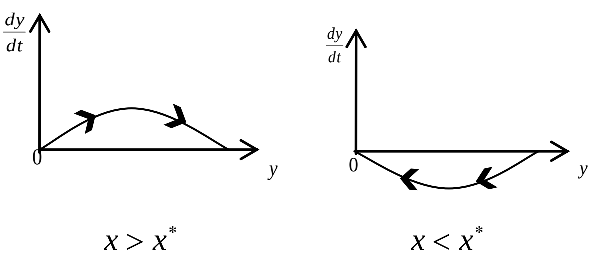


Figure 7: Phase Diagram of $\mathrm{I}^* > 0$

The second case, $\mathrm{I}^* = a_2 + e - \delta E + d < 0$, that is $0 > c - a_2$,at that time $\delta > \dfrac{a_2 + e + d}{E}$

①when $x > x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} < 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} > 0$,

$f(y) < 0$, $y_2 = 0$ is a balance point.

②when $x < x^*$, $\left.\dfrac{df(y)}{dt}\right|_{y=0} > 0$, $\left.\dfrac{df(y)}{dt}\right|_{y=1} < 0$,

$f(y) > 0$, $y_1 = 1$ is a balance point.

The phase diagram of the above two cases is as follows

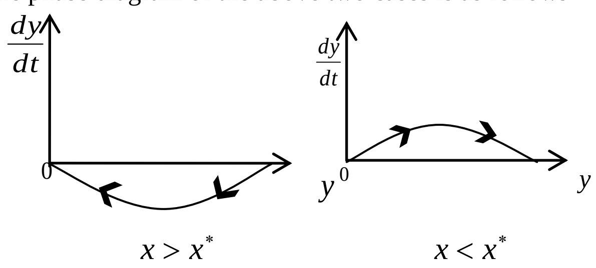


Figure 8: Phase Diagram of $\mathrm{I}^* < 0$

We have drawn the evolutionary phase diagram of $\mathrm{I}^* > 0, \mathrm{H}^* > 0$, $\mathrm{I}^* > 0, \mathrm{H}^* < 0$, $\mathrm{I}^* < 0, \mathrm{H}^* > 0$ and $\mathrm{I}^* < 0, \mathrm{H}^* < 0$

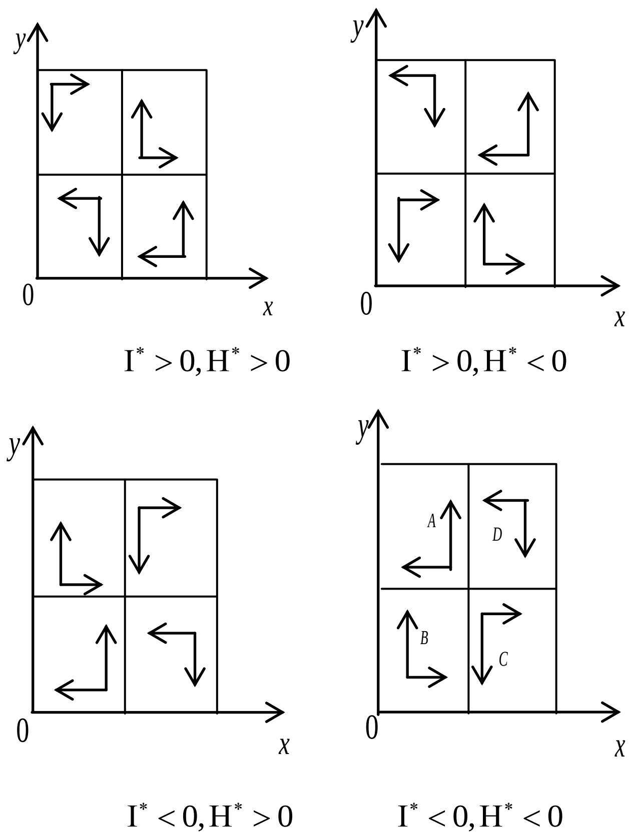


Figure 9: Phase diagram of system evolution under government intervention

3.3 Model Analysis

Combine (3.1) and (3.2), we get 5 possible stability points, which are A（0.1）,B（1.0）, C（0.0）, D（1.1）, E($\dfrac{c-a_2}{e+c+d-\delta E}$, $\dfrac{a_1-f}{b-f-\delta F-p}$),Where E is Saddle point.We found out by analyzing the stability of various points in different situations. $I^*>0, H^*>0$ was similar to model 2.1 we don't detailed discussion here;when $I^*<0, H^*>0$, $I^*>0, H^*<0$,There is no stable point in the system;when $I^*<0, H^*<0$,The system has a stable point A（0.1）and B（1.0）;Participant 1 chooses to purchase and participant 2 chooses to non-Speculation When the stable point is B（1.0）,. At this time, $\delta>\dfrac{a_2+e+d}{E}$ and $\delta<\dfrac{b-p-a_1}{F}$,In other words, the government's punishment level is between $\dfrac{a_2+e+d}{E}<\delta<\dfrac{b-p-a_1}{F}$,the real estate market can achieve real stability. This conclusion is also more consistent with the "over-administrative interventions result in "regulatory policy bubbles" .because $\dfrac{a_2+e+d}{E}<\delta<\dfrac{b-p-a_1}{F}$,it can be known by analysis that the appropriate intervention of the government will make the participants 2 speculation income less than non-speculation, so more participants in the group of participant 2 will choose to non-speculation ; More participants in the group of participant 1will be choose to purchase strategies,When the stable point is A (0.1),Because f, c, d, p doesn't affect the acreage of the enlarged area C, it is not considered for the time being. According to the analysis,When a_1 increases (increases the income of purchasers), a_2 reduce (reduce the income of Speculators) or increase the maximum punishment E for speculators can increase the area of C,This stable point A (0.1) toward B (1.0).

IV. Conclusions and Suggestions

This paper combines the current situation of the real estate market and establishes an asymmetric game model between two types of consumer groups. Using the evolutionary game model to analyze the different strategies of the two types of consumers, it is concluded that the evolutionary stability strategy when there is no government intervention and the impact of the punishment level on the stability strategy when there is government intervention.

In summary, combined with the analysis,the following conclusions are drawn: (1) When there are consumers for the purpose of extracting profits, the real estate market will be difficult to form a stable development. (2) The government's punishment level for speculators determine whether the real estate market is developing in stable direction. According to the analysis of Model 2,when $\dfrac{a_2+e+d}{E}<\delta<\dfrac{b-p-a_1}{F}$,That is , when the participant 1 chooses to purchase , if the government's punishment level of the participant 2 is greater than the ratio of the sum of the speculation gains and the non-speculation gains with the maximum punishment level when the government non-intervene, the real estate market will develop to (purchase,non-speculation).

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