Understanding cyclical pattern of Taiwan's housing market: a system dynamics approach

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ABSTRACT

The housing market of Taiwan thrived in the years of 1973, 1980, and 1987 respectively, and the rises of every seven years in housing price have brought numerous social and economic problems. In order to understand the micro-structure of the housing market, we developed a system dynamics model of the market's multi-sector, in which landowners, construction companies, house buyers and house speculators are included. The interactions among decisions of various sectors formulate the micro-structure of the model. Through computer simulation, the cyclical fluctuations are generated and some macro-behaviors of the housing market model are explained.

INTRODUCTION

Similar to the seven- year- cycle of Taiwan's housing market, there is a fifteen to twenty-year-cycle in the United States (Bakken, 1990). In Taiwan, housing price has risen and fallen for several times. The excessive housing demand turned out to be a surplus most of time. The fluctuation consequently exerted negative influence on the society and the economy. It is appropriate to utilize the system dynamics approach to deal with this dynamics and counter-intuitive behavior in the housing market. As Wang and Young (1990) found in their public housing policy study.

To such cyclical fluctuation of behavior pattern , the System Dynamics National Model Project (Forrester, 1989; Graham, 1984) shows that physical, institutional, and decision-marking structure can cause economic instability of different wave lengths and amplitudes of the pattern. The National Model divided fluctuations into long (40-70 years), medium (15-20 years) and short (3-8 years) lengths (Forrester, 1990).

As a result , there must be an underlying structure behind the behavior pattern of cyclical fluctuation. From the perspective of micro-structure, this paper applies the system dynamics approach to build a model and further explain the macro-behavior of the housing market. The model of micro-structure has four major sectors of housing market: the landowner sector, the construction company sector, the house buyer sector, and the house speculator sector. The interactions of decisions made by the four sectors will be used to simulate the fluctuation of behavior pattern. The decisions of landowner sector influence mostly on the supply of land and its price. The decisions of construction companies influence on the demand of land, the supply of house , and the house price. While the decisions of house buyer and speculator sectors exert influence on the sales of houses, which influence the prices and construction decisions of construction companies. In general, the purpose of this paper is to build a preliminary system dynamics model to explain the cyclical pattern generated by the underlying interactive micro-structure of multi-sector.

MODEL DESCRIPTION

Sectors of the model

The four major sectors in the model are the landowner sector, the construction company sector, the house buyer sector, and the house speculator sector. The imbalance of housing demand and supply causes the fluctuation of housing prices and encourages housing speculation. As a consequence, there are plenty of empty houses left in the market.

The relationships among these four sectors are shown in Figure 1. On one hand, landowners are the major suppliers of the land, and construction companies are the major demanders of the land. On the other hand, construction companies are the major providers of houses, while house buyers are the major demanders of houses. The house speculators transfer house from construction companies to house buyers.

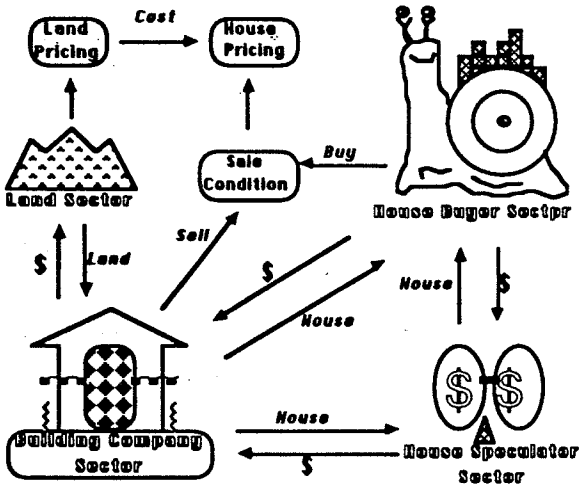


Figure 1. The relationships among the four sectors of the housing market

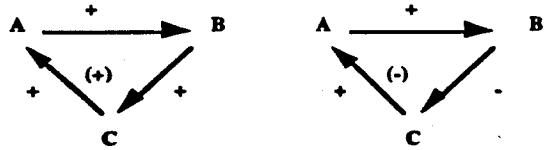
Apart from the four major sectors , two key behaviors are concerned, and they are land price and house price . In contrast to formulate the house price with the total market supply and the total market demand, however, in this paper, in order to reflect the bounded rationality of the construction company and the features of monopolistic competition of the real estate market, the house price is mainly determined by costs and sales perceived by construction company. The land cost is decided by the current demand and the trend of past demand, while sale ratio is determined by the number of sold houses and the number of houses on sale. Since it reflects the bounded rationality of landowner and the features of monopolistic competition in the housing market, .

Causal Diagram

The causal diagram of this model is shown in Figure 2. In the causal diagram, there are six feedback loops.[1]

Loop1 (land order --- land price --- house price --- profit mutiplier --- house planned to construct --- land order) is a cost-derived house price loop, and it is positive. The land price soars up when the land order increases, so that house price is pushed up. The higher the house price is, the bigger the profits are expected. Therefore, construction companies build more houses when expected profits are high. In the housing market, demand is quite insensitive to price whereas supply is very price sensitive (Bakken, 1998). Consequently, the land order and house price soar up. Therefore, the house price becomes higher and higher in this positive feedback loop.

[1]Feedback loop has two major patterns: positive feedback loop and negative feedback loop, as shown below. The variables in a positive feedback loop have a self-reinforcing growth or decay, while the variables in a negative feedback loop have a goal-seeking feature.



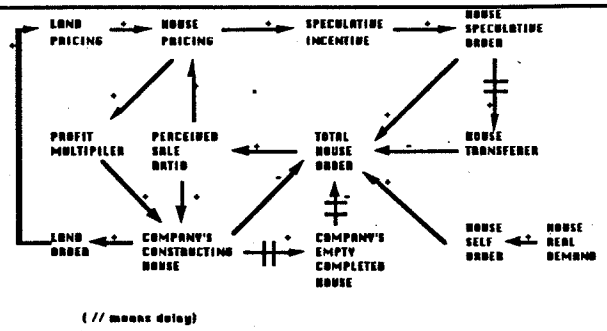


Figure 2. The causal diagram of the housing market

Loop 2 (house price --- speculative incentive --- speculative house order --- total house order --- perceiced sale ratio --- house price) is a speculative house demand loop, and it is a positive loop too. When house price rises, house speculators increase their speculation. The house demand grows, then the sale ratio perceived by construction company increases, which makes the construction companies sell their houses at higher price than before. Therefore, this positive feedback loop makes the house price become higher and higher.

Loop 3 (land order --- land price --- house price --- speculative incentive --- speculative house order --- total house order --- perceiced sale ratio --- house planned to construct --- land order) just likes loop 2, is also a positive feedback loop. We name it speculative house demand loop. The house price is no longer pulled by sales side, but derived by cost side. When the land order increases, land price soars up so that house price is pushed up. When house price rises, house speculators increase their speculation. The houses demand grows, and the sale ratio perceived by construction company increases. The rise of sales ratio indicates the increasing demand of houses. Construction companies then build more houses. Consequently, the land order and house price soar up. This positive feedback loop makes the house price become higher and higher.

Loop 4 (house planned to construct --- total house order --- perceiced sale ratio --- house planned to construct) is a house supply loop, but it is a negative loop. The rise of sales ratio indicates the increasing demand of houses. Construction companies then build more houses. On the contrary, the augmentation of supply lead to a lower house order and a lower sales ratio. As a result, construction companies curtails their supply. This loop is a self-adjusting feedback loop.

Loop 5 (perceived sale ratio --- house planned to construct --- empty house --- total house order --- perceiced sale ratio) is an empty house effect loop, which is a negative feedback loop. When construction companies supply more houses, completed empty houses will increase after some two years. However, after a period of time, these houses will be sold. Fewer house buyers order new houses, therefore, the sale ratio lowers down. And then the supply of houses will be reduced. This is a self-adjusting feedback loop.

Loop 6 (speculative house order --- house transfer --- total house order --- perceiced sale ratio --- house price --- speculative incentive --- speculative house order) is an house-transfered effect loop, which is a negative feedback loop. When house speculators buy more houses, however, after a period of time, the houses will be transferred from speculators to house buyers. Fewer house buyers order the new houses, therefore, the sales ratio lowers down. And then the speculative incentive will be reduced. This is a self-adjusting feedback loop.

In the housing market, demand is quite insensitive to price (Bakken, 1990). It is assumed that the real house demand is an external variable, and the land supply is unlimited in the model. As the simulation results show, although the land supply is unlimited, this simple structure also generate a cyclical behavioral pattern.

Key variables and equations

Land price determination function

Mass (1974) asserts that the business-land-price change (BLPC) is formulated as the product of the business-land-price (BLP) and the business-land-fractioal-price change (BLFPC). Change of land price occurs when supply and demand are imbalanced. For example, an excessive land demand in a city will gradually cause the bidding up of land price. To simulate the "bidding" apparatus of land market, the fractional price change has been modeled as a function of the ratio of the business land demand (BLD) to the business land supply (BLS). Thus, in order to reflect the bounded rationality of landowner and the features of monopolistic competition of the real estate market, the land price is decided by the current demand and the trend of past demand, that is, the land price is controlled by land order fraction. This model deduces the determination of land price as follows:

LPC= LP *LPCF (eq.1)
LPCF= f1(ORDER-F) (eq.2)
ORDERF=ORDER/ORDERN, (eq.3)
where
LPC: Land Price Change (N.T.$/month)
LP: Land Price (N.T.$)
LPCF: Land Price Change Fraction (1/month)
ORDERF: Land Order Fraction (1/month)
ORDER: Land Order, which reflects the demand condition (unit)
ORDERN: Normal Land Order , which reflects the trend of past demand (unit)
f1: a nonlinear increasing function

House price determination function

In contrast to formulate the house price with the total market supply and the total market demand, however, in this paper, the house price is determined by costs and sales perceived by the construction company. Cost mainly refers to the cost of land, while sales means sale ratio which is conditioned by the sales number and the number of houses on sale, as follows:

HPC=HP*((1+HPCF1)*(1+HPCF2)-1) (eq.4)
HPCF1=1.2*LPCF (eq.5)
HPCF2=f2(Sr-smooth), (eq.6)
where
HPC: House Price Change (N.T.$/month)
HP: House Price (N.T.$)
HPCF1: House Price Change First Fraction (1/month)
HPCF2: House Price Change Second Fraction (1/month)
Sr-smooth: Sale ratio smooth (dimensionless)
f2: a nonlinear increasing function

Speculative incentives

Mass (1974) indicates that the uprising of house price encourages speculation. Therefore, the speculative incentives of housing price are as follows:

SHI=f3(HP TREND), (eq.7)
where
SHI: Speculative House Incentive (dimensionless)
HP TREND: House Price Trend (dimensionless)
f3: a nonlinear increasing function

House sale ratio determination function

The computation of house sale ratio can be demonstrated by the following example. If we sell 500 units out of 1000 units in the first month and sell 250 units out of the left 500 units in the second month, then the sale ratio = (250+500)/(1000+500)= 0.5. So the sale ratio can be demonstrated by the following formulation:

SR=(ORDER1+ORDER2)/((H-for-sale-1)+(H-for-sale-2)), (eq.8)
where
SR: Sale Ratio (dimensionless)
ORDER1: house order in the first month (house unit)
ORDER2: house order in the second month (house unit)
H-for-sale-1: house for sale in the first month (house unit)
H-for-sale-2: house for sale in the second month (house unit)

Profit multiplier

Profit multiplier refers to the housing supply influenced by the housing price trend. The relationship between the tendency of housing price and profit multiplier can be displayed by the following formula:

PM= f4(HP TREND), (eq.9)
where
PM: Profit Multiplier (dimensionless)
HP TREND: Housing Price Trend (dimensionless)
f4: a nonlinear increasing function

SIMULATION

Base run

This model purports to sketch a cyclical behavior pattern of the housing market. The chosen indexes of behavior pattern and variable in the model are as follows: the land price (l-price), the house price (h-price), the speculative house demand (h-specu-demand), the sale ratio (sale-ratio), and the unsold empty house (h-comple-unsale).

As shown in the causal diagram of Figure 2, if the actual demand of houses does not change, the four major feedback loops will remain steady and no fluctuation will occur. The simulation of this model first takes one month as the simulation time unit. Time for simulation is 180 months (15 years). Suppose the real house demand remains the same as follows :

HRD=1500 (eq.10)
where
HRD: real house demand (house units)

The outcomes of the simulation are shown in Figures 3 and 4.

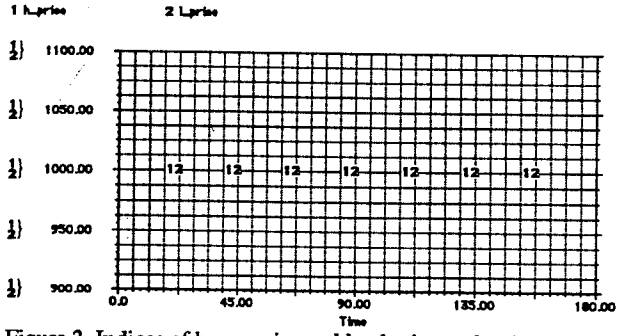


Figure 3. Indices of house price and land price under the real house demand unchange condition
Note: h-prce: house price; l-prise: land price

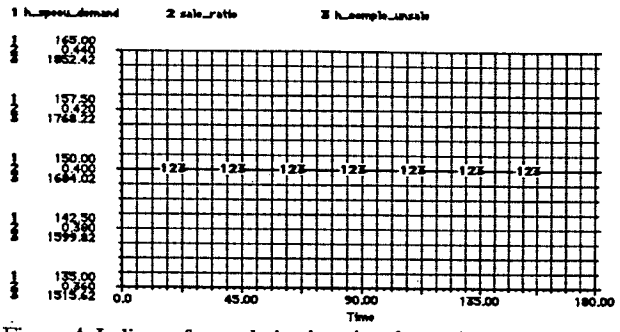


Figure 4. Indices of speculative housing demand, sale ratio, and unsold completed house under the real house demand unchange condition

Note: h-specu-demand: speculative house demand; sale-ratio: sale ratio;
h-comple-unsale: unsold completed house

Test runs

We will change the real house demand to some extent and see the pattern of simulated outcome.

Test 1.

If the real house demand of the first year remains steady, and it then increases by 10% from the second year.

HRD= if time >= 12 then 1500*(1+10%) else 1500 (eq.11)

As the simulation results show, the chosen cycle index will extend from time 12 to time 90; that is, about 6 to 7 years and then gradually become steady (Figures 5, 6, 7, and 8).

Figure 5 exhibits the fluctuation of the house price and the land price. As shown in the figure, the simulated house price will increase sharply from 1000 up to 1635(the increment is about 63%) in 2 or 3 years, and then gradually falls down to 1566 at time 90 (the decrement is about 1% to 2%). On the other hand, the simulated land price will increase sharply from 1000 to 1416 in 2 or 3 years (the increment is about 41%), and then gradually falls down to 1395 at time 90 (the decrement is about 4% to 5%). Due to the little 10% increment in real house demand, the land price and house price will increase by more than 10%.

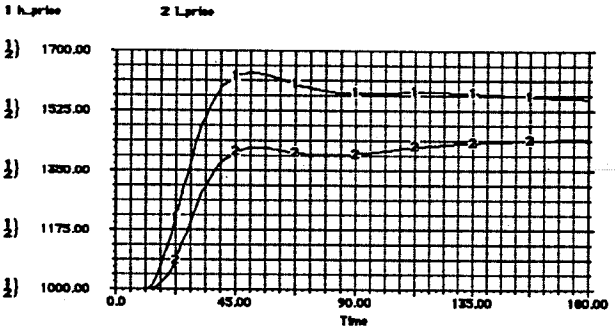


Figure 5. Indices of house price and land price under the real house demand step change condition

Note: h-prce: house price; l-prise: land price

Figure 6 exhibits the fluctuation of speculative house demand. As shown in the figure, the effect of speculative incentive is more sensitive than that of house price or land price, the simulated speculative house demand increases sharply in about 1.5 years, then it falls deeper than the level of house price or land price.

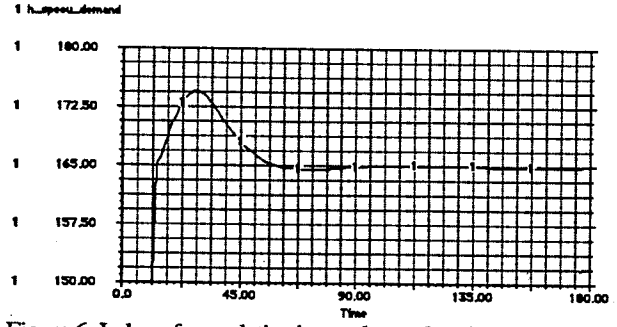


Figure 6. Index of speculative house demand under the real house demand step change condition
Note: h-specu-demand: speculative house demand

Figure 7 exhibits the fluctuation of sale ratio. As shown in the figure, the sale ratio reaches its peak in 1.5 to 2 years, and it then comes to the blue time.

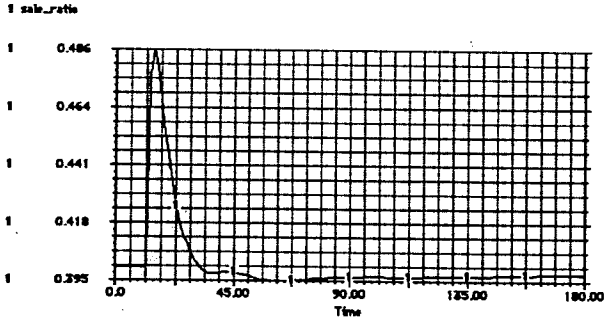


Figure 7. Index of sale ratio under the real house demand step change condition
Note: sale-ratio: sale ratio

Figure 8 exhibits the fluctuation of unsold empty house. As shown in the figure, there clearly comes the six-year to seven-year fluctuation. In the previous stage, due to the increase of speculative demand, the empty houses will be consumed much quickly than before. Then, because of the increase of sale ratio, the construction companies will build more houses than 10%. However, after a period of construction time, these houses will be completed and consequently the speculative demand slows down in the meantime, therefore, the quantity of empty house will increase.

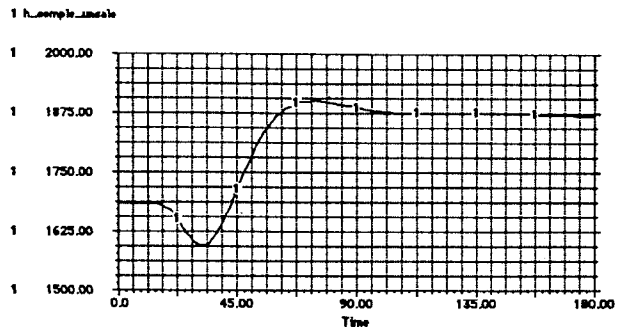


Figure 8. Index of unsold completed house under the real house demand step change condition
Note: h-comple-unsale: unsold completed house

In sum, the 10% increment of real house demand causes the sale ratio perceived by construction company increases, which makes the construction company price the house higher than before. Meanwhile, the order for land by construction companies increase too, which then push the land price and house price up. When the house price rises, the house speculators increase their speculation. The houses demand grows, empty houses will then be consumed quickly than before, and the sale ratio perceived by company increases again, which again makes the companies price their house higher than before. However, after some time, the unsold empty houses will increase and the houses transfered from speculators to house buyers will also increase. Because of the bounded rationality, construction companies cannot predict the empty house effect and house transfer effect precisely. Therefore, the construction companies will build more houses than 10%, and consequently the house price, the speculative demand and the sale ratio will still increase for a period of time, and then fall down.

Test 2

Test 2 is similar to test 1. If the real house demand remains 1500 units in the first year, then it increases randomly within the range of 10% (that is, from 1500 units to 1650 units) from the second year on.

HRD = if time>=12 then (1500+1500*10%*Random) else 1500. (eq.12)

The result of test 2 is similar to test 1. The chosen cycle index also extends from time 12 to time 90 (that is, about 6 to 7 years), however, the pattern of the amplitude will be gradually shorten. The results of the simulation are shown in Figures 9, 10, 11, and 12.

Because the fluctuation of speculative house demand is unregulated, we take an exponential smooth process to present it. It is called an HSD-cycle-index (see Figure 10). The sale ratio is also represented by the treatment of exponential smooth process, and we name it as Sr-cycle-index (see Figure 11).

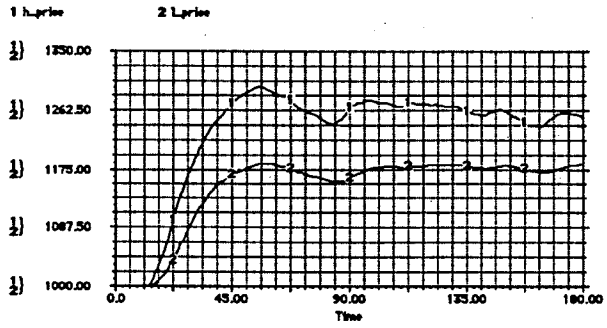


Figure 9. Indices of house price and land price under the real house demand random change condition
Note: h-prce: house price; l-prise: land price

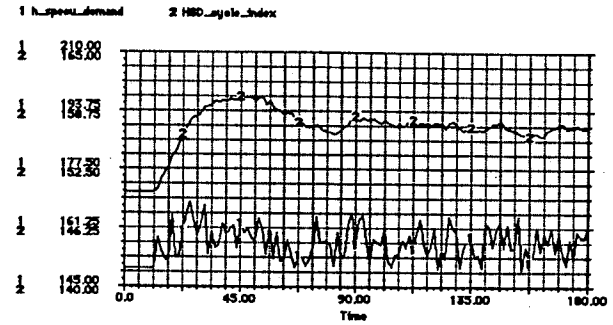


Figure 10. Indices of speculative house demand and HSD cycle under the real house demand random change condition

Note: h-specu-demand: speculative house demand
HSD-cycle-index: speculative house demand cycle index

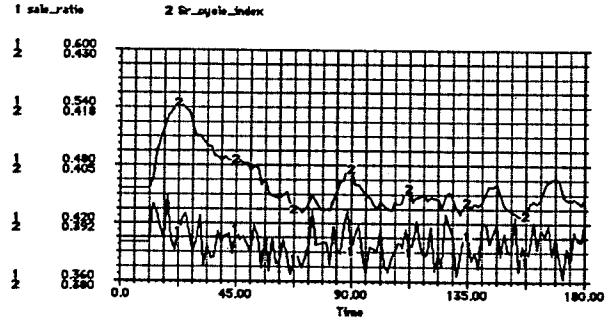


Figure 11. Indices of sale ratio and sale ratio cycle under the real house demand random change condition
Note: sale-ratio: sale ratio; Sr-cycle-index: sale ratio cycle index

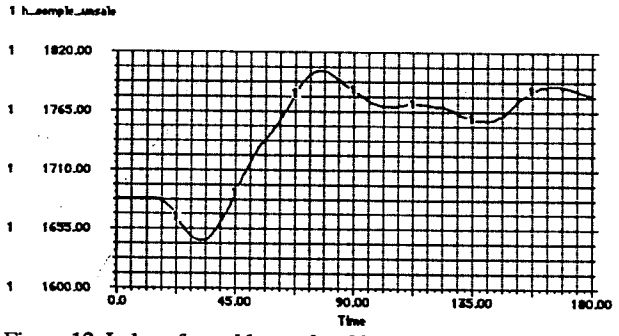


Figure 12. Index of unsold completed house under the real house demand random change condition
Note: h-comple-unsale: unsold completed house

DISCUSSIONS

The model shows us the complexity and dynamics of Taiwan's housing market. In the process of decision-making, the market displays an intensely fluctuation cycle. When the real house demand remains the same, the behavior pattern of the housing market will keep steady. If the real house demand jumped up by 10% and then stay there for the rest of time , the behavior pattern will fluctuate violently. After one cycle, it will then become steady slowly. However, if the real house demand increases randomly within 10%, the behavior pattern will pass through a cycle and become steady after a long time. The

results indicates that the cyclical behavior pattern is influenced by the structure of the housing market itself.

In the real world, the house demand is affected by some other social and economic events. However, as the simulation results indicate, these events are much like fuses, the cyclical behavior in the housing market is determined by the structure itself. In fact, the speculative mechanism also amplifies the amplitude and the period of the cyclical behavior. Even without the speculative mechanism, the cyclical behavior is expected due to the bounded rationality of the construction companies and the landowners.

In the model, it is assumed that land supply is unlimited. As the simulation results show, the simplified structure also generate a cyclical behavioral pattern. In the real world, the urban land is very limited. If the land scarcity is considered, the land price won't look like a cyclical pattern, but a step one. In fact, the land scarcity plays a fuse in the last housing boom in Taiwan.

Because of the bounded rationality of the construction companies, the landowners and the decision structures among sectors, the housing market generates the momentums of cyclical behavior itself. It seems to be a good direction for understanding the macro cyclical behavior through this micro-structure approach.

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