**Leir Center For Financial Bubble Research**

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A Simple Cobweb Model of Speculative Housing Bubbles

P. Ben Chou

[pchou@njit.edu](mailto:pchou@njit.edu)

New Jersey Institute of Technology

Newark, NJ 07102-1982

**Abstract:** This research develops a simple Cobweb model that characterizes how a housing bubble forms and bursts. In particular, the model shows that the combination of the entry of a sufficiently large number of speculators and their expected price increase can reinforce each other and sustain a housing bubble at a new steady state in the short run as a self-fulfilling prophecy. The entry of speculators can also lower the fluctuations of the housing price, while the exit of the speculators will increase the volatility of the housing price. After the bubble bursts, it will be the re-entry of non-speculators that stabilizes the housing price. However the time frame for re-entry may be lengthy because potential homebuyers may be expecting price to fall even further. In addition, if banks are reluctant to begin lending again, government support as a lender of last resort may be required to speed up the process.

**JEL Classification:** D001,R21, R31

**Keywords:** Adaptive rationality, Bounded rationality, Cobweb model, Housing bubble, Speculation.

**1. Introduction**

In recent years, the rise and fall of the housing prices have attracted the attentions of general public and researchers. Before 2004 or 2005, many researchers, such as Labonte (2003) and Himmelberg *et al.* (2005), argued that the rising housing prices could be well explained by the economic fundamentals, and there was little strong evidence to support the occurrence of a housing bubble in the U.S. However, after the dramatic fall of housing prices in 2008, more researchers, such as Mikhed and Zemčík (2009) and Coleman *et al.* (2008), started to share a similar conclusion that in the U.S., some housing bubble had occurred between 2003 and 2004, and also between 2006 and 2007, although it varied from one metropolitan area to another. Therefore, similar to business cycles, it is difficult to be absolutely certain about the beginning of a (housing) bubble when or before it occurs. This is also why the Fed used to focus on cleaning up the mess after bubbles burst instead of trying to identify and burst a bubble when or before it occurs. At the same time, this is an indication of why it is important to gain a better understanding of bubbles, particularly when one has developed and where one is in the process of its evolution.

As discussed by Kaizoji (2009), the root causes of the recent U.S. housing bubble from 2000 to 2006 may include (i) non-elastic housing supply in (some) metropolitan areas, (ii) declines in the mortgage loan rate and the housing premium due to the massive mortgage credit expansion, and (iii) policy changes from the government***~~s~~*** and the Fed. At the same time, there are also other factors that can contribute to the formation of the bubble, such as the speculative behavior of buyers, which is the focus of this paper.

**Home Price Indices** (as of March 30, 2010)

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| http://www.standardandpoors.com/spf/January2010Chart.jpg |

Source: <http://www.standardandpoors.com/indices/sp-case-shiller-home-price-indices/en/us/?indexId=spusa-cashpidff--p-us---->

**Figure 1**-The Housing Bubble and Crash in the U.S.

There are also different kinds of speculators. Some of them may be more rational than others. However, it is unlikely that all or most of the speculators have rational expectations and can foresee the housing prices in the future. In fact, bounded rationality or even irrationality is not uncommon among speculators. As discussed by Baddeley (2005), “in a world of uncertainty, imperfect information, and irreversible decision-making, speculation and information acquisition will generate bubble, herding, and frenzies in housing demand.” Shiller (2009) argues that “people tend to confuse price levels with rates of price change.” He also mentions that “Karl Case and I asked random home buyers in the U.S. cities undergoing bubbles how much they think the price of their homes will rise each year on average over the next ten years. The medium answer was sometimes 10% a year.” Such bubbles “were made by widespread misunderstandings of the factors influencing prices”, or simply by the bounded rationality or irrationality of the speculators. Consistently, the Cobweb model in this research will show that it is the behavior of the speculators with bounded or adaptive rationality that causes and sustains abubble in the housing market.

More importantly, Case and Shiller (2003) argue that “the mere fact of rapid price increase is not in itself conclusive evidence of a bubble. The basic questions that still must be answered are whether expectations of large future price increase are sustaining the market, whether these expectations are salient enough to generate anxieties among potential homebuyers, and whether there is sufficient confidence in such expectations to motivate action” (pp. 299-300). From a theoretical perspective, speculation is usually thought of as a demand side phenomenon, and the market demand is the aggregation of all the individual’s demands. One speculator with bounded rationality may not be able to raise the housing price, but large numbers of speculators with bounded rationality can cause the housing bubble to occur. Therefore, the focus of this paper is to develop a theoretical model to characterize the formation process of a housing bubble caused by the herding behaviors of speculators with bounded rationality. One important contribution of this paper is the derivation of the condition that sustains a housing bubble based on the combination of the numbers of speculators and the expected *real* housing price increase (adjusted by the GDP deflator or CPI).

There are four additional sections in this paper. Section 2 is a brief literature review. In Section 3, the Cobweb model is developed based on the individuals’ demand functions of non-speculators and speculators in a housing market. The combination of sufficiently large numbers speculators that enter the market and their expected future price increase not only drives up the housing price a new steady state, but also drives the non-speculators out of the market. Section 4 includes further discussions and lists some directions of extending this paper for future research. Section 5 concludes the paper.

**2. Brief Literature Review**

Many researchers have applied the Cobweb models to address different issues in different contexts. There are authors who have investigated the dynamics of a Cobweb model with heterogeneous beliefs, and/or those who conduct experiments to test the Cobweb model, such as Chen and Yeh (1996), Goeree and Hommes (2000), Sonnemans *et al.* (2004), Hommes (2005), Lasselle *et al.* (2005), Branch and McGough (2007), and Waters (2009). However, most of these models do not focus on the housing market, and more importantly, are too mathematical for general readers. In contrast, there are also many other researchers that apply econometric techniques to test the housing bubble/price, such as Englund and Ioannides (1997), Riddel (1999), Foley (2001), Labonte (2003), Green *et al.* (2005), Coleman *et al.* (2008), Goodman and Thibodeau (2008), Lai *et al.* (2009), and Mikhed and Zemčík (2009). However, these models are usually not based on the Cobweb models. Therefore, there exist knowledge gaps between these approaches, and the goal of this paper is to narrow some of these knowledge gaps in the context of the housing bubble.

There are also researchers that have applied Cobweb model to the housing market, and at the same time, tested the models using econometric techniques, such as Ferguson (1960), and more recently, Malpezzi and Wachter (2005), and Leung *et al.* (2007). However, there are still knowledge gaps between different approaches. Also, as the focus of this paper is to characterize how a housing bubble can form and burst, the empirical part of testing the model can be explored in future research. Therefore, based on the horizontal aggregation of the individual demands of speculators with bounded rationality, this research applies a simple Cobweb model to the housing bubble and derives the condition that can sustain the existence of a bubble as a self-fulfilling prophecy, at least for a short period of time.

**3. A Simple Cobweb Model for the Housing Bubble**

*3.1 The Basics*

There are (*m*+*x*) buyers and *n* sellers in the housing market, with *m* > 0, *n* > 0, and. The *m* buyers are non-speculators, while *x* buyers are the speculators. There are four stages in the game. In the first stage, only *m* non-speculators and *n* sellers enter the market. In the second stage, *x* speculators enter the market. In the third stage, the housing price is too high for the non-speculators to stay in the market. Only *x* speculators remain in the market. In the fourth stage, *m* speculators re-enter the market with *x* speculators in the market, with, i.e., if there are any speculators left. In addition, any buyer or seller in any period can exit the market by refusing to buy or sell the houses. Hence, the number of speculators, *x*, is not fixed, neither is *m* or *n*.

The demand function for a non-speculator in period *t* is a decreasing function of the market price (adjusted by inflation) in period *t*, i.e., = *a* – *b*, with *a* > 0 and *b* > 0. The demand function of a speculator in period *t* depends on the market price in period *t* as well as their reaction to the expected price increase from period *t* to period *t*+1, = *a* – *b*+, where is the reaction of an individual speculator *i* at time *t* to the expected future price change, or, similar to the perspective of Riddel (1999), the expectation of a real change in the housing price in the next and future periods. This also implies that = 0 for non-speculators in period *t*. Since the focus of this paper is on the herding behavior in the formation process of bubbles, for simplicity, we assume that = *c* > 0, for each speculator *i* in every period. In this case, *c* becomes an element in the trend of housing prices. It can also be interpreted as the mean of the expected price increase of speculators in the housing market. From the horizontal aggregation, the market demand curve in period *t* is = *ma* – *mb*+ *xa* – *xb* *+ xc*, if *x* > 0, and  = *ma* – *mb* if *x* = 0.

For the supply side, each seller of houses has the supply function =  +, with,, and . The supply function in period *t* includes the previous period price because of the time lag to construct a new house. The assumption that *h* is greater than zero means that the producers are willing to produce or construct more houses available for sale in period *t* if the housing price in period *t-*1 is higher. The coefficient  is usually negative because of the positive reservation price before the sellers are willing to sell the house. The coefficient  is usually positive because it is the slope of the supply function. Alternatively, there are also two other perspectives for market supply functions. First, the coefficient of  comes from the sellers that have rational expectation that can correctly anticipate the market price, while the coefficient of  comes from the sellers that have adaptive or naïve expectation. Second, the coefficient of  mainly comes from existing houses, while the coefficient of  mainly comes from the newly constructed houses that are built based on the expected price, which is the simplyas a result of naïve expectation.

Generally speaking, the housing prices should increase more in the areas where housing supplies tend to be more inelastic, while the areas with more elastic housing supply should have fewer and smaller bubbles, and with smaller price increases, as discussed by Glaeser *et al.* (2008). For our purposes, the focus of this paper is on the speculation from the demand side. Hence, we focus on the situation when the housing supply function is most (or perfectly) inelastic. For simplicity, we also assume that,, and . Therefore, from the horizontal aggregation, the market supply function in period *t* is = *n*.

In each stage, we assume the market clears such that =. The buyers of houses in period *t* buy the houses that have been produced in the previously period, *t* – 1. The total number of houses will change only if *n* or *h* changes.

In the first stage when *x* = 0, market equilibrium implies that *ma* – *mb*= *n*, which can be simplified as. In the second stage when the speculators enter the market, market equilibrium = implies that.

*3.2 The Four Stages of a Bubble*

*3.2.1 The First Stage – the Bench Mark*

When there are no speculators in the first stage,  is a first-order differen***tial*** equation. If the steady state exists where the steady state price = =, then =, which is positive because all the coefficients are positive. Because =, it also implies that  increases when *m* increases, and decreases when *n* increases. At the same time, =. Hence, will increase if either *m* or *n* increases.

If the market price is  at the beginning of stage 1, then the market price  can be transformed as follows:

= 

= 

= .

Given that,  over time will oscillate around. If , or equivalently, , the market price will converge to over time. If ,  will oscillate around with equal distance. Finally,  will diverge (explosively) if .

Furthermore, the stability condition, (*nh/mb*) < 1, means that, in terms of absolute values, the supply curve must have a larger slope (1/*nh*) than the slope of the demand curve, (1*/mb*), which is true when the supply curve is steeper than the demand curve, with *P* on the vertical axis.

*3.2.2 The Second Stage – The Entry of Speculators*

When speculators enter the market in the second stage, the market demand function will become = *ma* – *mb*+ *xa* – *xb* *+ xc*, while the market supply function is still = *n*. Market equilibrium implies that. Likewise, if a steady state exists, the***n*** = . Because,  will increase if *x* increases, and will decrease if *x* decreases. The original  without speculators is now just a special case when *x* = 0. In addition, at the steady state, *Q*\* =. When *x* increases, *Q\** will also increase.

Similarly,  can be transformed as follows:

= .

Because,  over time will oscillate around the new. If , the market price will converge to over time. If ,  will oscillate around with equal distance. And  will diverge (explosively) if .

The entry of the speculators has two effects. First, it will increase the steady-state equilibrium price. The more the speculators are in the market, the higher the steady-state priceis. Second, when *x* increases, will become smaller, which will also increase the possibility of convergence as well as the speed of convergence. That is, the more speculators, the faster the market price will converge to the steady-state price, which will reinforce more quickly the expectation of speculators, and attract even more speculators to enter the market. Therefore, for the speculators, the bubble is formed as a self-fulfilling prophecy by the speculators. The more speculators that enter the market, the bigger the bubble that will be formed. And it is the *collective* herding behavior of the speculators that sustain the bubble. We will now derive the condition that sustains the bubble in the Section 3.2.3.

*3.2.3 The Third Stag-The Price and the Kink*

Because speculators have different individual demand functions, there are two components of the market demand curve, = *ma* – *mb*+ *xa* – *xb* *+ xc*, one from the aggregate of the demand functions of the *x* speculators, and the other one from the demand functions of the *m* non-speculators. The original demand curve (when *x* = 0) has an intercept of  on the *P*-axis, while the combined demand curve has an intercept , which is higher than because *c* > 0 and *x* > 0. Therefore, the market demand curve from horizontal aggregation is kinked. When the price is high enough, i.e.,, all the non-speculators will be driven out of the market by the high price (because of the linear demand curves). Then only the speculators will remain in the market.

When there are only speculators in the market, the market demand function will become = *xa* – *xb* *+ xc*, with the steady-state price =, which should also be higher than. The inequality >  can be simplified to *x* >, or, equivalently, , which is the condition to sustain a bubble. Therefore, the number of speculators and their expected price increase will reinforce each other. When there are enough speculators in the market with a high enough *expected* increase in the housing price, it is possible for the speculators to reach and sustain a steady-state price that is higher than the highest market price determined by the non-speculators and economic fundamentals.

Nevertheless, when the housing price continues to increase, the number of buyers will decrease because fewer and fewer buyers can afford to buy houses at such high prices. In the extreme case at the highest possible housing price on the demand curve, = 0, which implies that. That is, at , no speculators would be able to buy the houses any more. In addition, . When the number of speculators, *x*, increases, will become closer and closer to , for a given *c*. And the higher the *c*, the higher the  and . This ironically implies that the higher the *c*, the more frenzied the speculators are, and the less likely for the market to run out of the speculators to sustain the housing bubble as a self-fulfilling prophecy.” However, recall that to sustain the bubble, the inequality  must be satisfied. Hence, when *x* decreases, the bubble can still be sustained only if *c* is high enough. The speculators left in the market, however irrational they may be, must be optimistic or frenzied enough to believe in the continued or rebound increase of the housing price. While the more rational speculators exit the market, the rest of the speculators, including those that just entered the market, continue to sustain the bubble. However, when *x* starts to decrease*,* will decrease, which may also lead to the decrease in *c*. And when *xc* is too low to satisfy , the bubble will burst.

This is also the range of the demand curve where the greater fool theory applies. That is, when housing price increases, every homebuyer is looking for a fool to buy the house when the housing price increases in the future. And every fool that buys a house is looking for an even greater fool to buy the same house later when the price is even higher. Eventually, will be close to , and the market will be running out of fools. And when the bubble cannot be sustained by the number of speculators or their expected price increase, the bubble will burst.

There are also other causes that will burst a bubble in the long run. First, the quantity supplied for each builder or producer, i.e., *h*, may increase, which will lower the steady-state price. Second, more producers may enter the market in the long run such that *n* increases. As a result, the condition that *x* > may not hold in the long run. Third, “more” rational or “less” irrational speculators will enter the market as early as possible. While these speculators exit the market and earn their profits, other “less” rational or “more” irrational speculators are entering the market, and sustain or even increase the market price. However, eventually when the number of the speculators that exit the market will be higher than the number of speculators that enter the market, *x* will fall, and the steady-state price will also fall. This situation can be worsened if the market supply = *n* has increased based on the higher price in the previous period. In addition, if *n* or *h* has increased,  may not hold, which means there will be more volatility in market price which will not converge to the new steady-state price that is lower than the original bench-mark price because of increase in housing supply.

From a game theory perspective, when more speculators enter the market, it will drive up the market price, which is a positive externality or even public good[[1]](#footnote-1) to all the players. However, when the price is high enough, it is similar to the multiple-player prisoners’ dilemma in which the dominant strategy of any player is to sell the house. But if too many people sell their houses, the house price will go down, and every player will be worse off, which is a negative externality or public bad to all the players. Therefore, there is an early-mover advantage to sell the houses. In this paper, we assume these early movers are the “more” rational or “less” irrational players among the speculators. The players that enter the market later to buy the houses simply “herd” to follow the early movers. Therefore, it is the herding behavior of sufficient large number of less rational or more irrational players that cause and sustain the bubble. It is also these players that cause the bubble to burst later on because of their herding behaviorto stop buying or sell.

*3.2.4 The Fourth Stage - The Re-entry of Non-speculators*

Eventually, the stability of the market price relies on the number of non-speculators, *m*, that re-enter the market. Despite the decreases of *x* and the increase of *n* or *h*, if *m* increases enough,  will hold again, and the market price will return to the new steady state, which is the fourth stage of a bubble. If *c* continues to decrease or even to reach zero and/or no speculators are left in the housing market, the steady state determined by the non-speculators will become a new bench mark for another bubble to begin in the future.

*3.3 The Crash*

Unfortunately, when *c* continues to decrease, it may also become negative if the speculators become pessimistic. This may also impact the non-speculators as well. Then from horizontal aggregation, there will be another kink of the demand curve, which leads to a lower price than the original benchmark price. It is possible that all the speculators have exited the market, not because they have sold their houses, but because they choose not to buy any more houses. Or they are simply trapped with the houses that they cannot sell. They can even face foreclosure problems if they have liquidity problems paying their mortgages. For non-speculators, they can also be waiting for the housing price to go even lower. This is why a crash usually follows a bubble due to the combination of increased supply and decrease in demand after a bubble bursts. Once again, if even *x* = 0, if *m* is large enough, the market price will become stable again, with probably a lower steady-state price than the original benchmark price in stage 1. Then the new steady-state housing price will become the new benchmark for anther bubble to begin in the future. Such a price movement can be observed in Figure 1 of this research. One additional problem, however, is that banks may not be willing to lend and/or can apply stricter standards for homebuyers to get a mortgage. Therefore, if lenders are reluctant to begin lending, government support as a lender of last resort may be required.

**4. Discussion and Extensions**

*4.1 Theoretical Extensions*

There are many ways to extend the simple model. From the theoretical perspective, the first extension is to include the possibility ~~that~~ that and, or at least, such that the market supply function will include the  term. In this case, when the speculators (can still) sell their houses, it will change the slope of the supply curve, thus further lowering the housing price.

Second, *c* in this paper is assumed be a parameter, although it can change over time, which is the subjective reaction of a speculator to the expected price change,. Hence, another extension of the model is to assume that the speculators have bounded rationality or naive expectation such that  =. That is, the expected increase or decrease in prices from period *t* to period *t*+1 should be the same as the price increase or decrease or percentage price increase or decrease[[2]](#footnote-2) (or acceleration or deceleration) from period *t-*1 to period *t*. Hence, = *r*, where *r* is the reaction coefficient to the price change. In this case, we can incorporate the past prices into the demand functions without the *c*.

Third, we can include the law of motion that describes how  changes over time. One extension, for example, is based on the adaptive or naïve expectation of the speculators. The law of motion can be. It means that the number of the speculators from period *t* to period *t+1* will increase if, and decrease if. The coefficient  shows how fast the number of speculators will change in response to the price change. However, by including such a law of motion for the number of speculators, the model will become a system of non-linear differential equations, which may be too mathematical for general readers.

*4.2 An Evolutionary Game Theory Perspective*

One important assumption under the evolutionary game theory is that players have bounded rationality, but can *learn* to be more rational. From an evolutionary game theory perspective, one extension of the model is to assume that there are two types of agents or speculators, one with rational expectation (type R) and the other one with naïve expectation (type N). There is a fixed cost that the agents have to *pay* to be able to have rational expectation, either through learning to be experts or paying the experts in order to obtain that knowledge. The agents with naïve expectations, the extreme form of the adaptive expectation, do not have any fixed cost.

Both types of agents can learn from each other. When one type of agent does better than the other type, say, in terms of profits, the number of one type of agents with higher profits will increase, while the number of the other type of agents will decrease. If the numbers of both types of agents follow a law of motion or replicator dynamics, it is possible to show that, as discussed, for example, by Goeree and Hommes (2000), among others, when the market price is high enough, all the agents will have only the naïve expectation. This result is similar to the situation when there are only speculators with bounded rationality that remain in the market. However, by using the approach of evolutionary game theory, the mathematics involved will become much more complicated than those presented in this paper, but this is one possible extension of the model.

*4.3. An Empirical Perspective and Test*

In terms of an empirical approach, the variables are usually in the natural log form. The  and  discussed in this paper will represents the natural log of the data. The advantage of doing so is that the coefficients estimated using OLS can be the proxies for the elasticities of the variables. In a consistent manner with our model, empirically, the supply curve in the housing market is usually (more) inelastic in the short run, and (more) elastic in the long run. And it varies across different metropolitan areas in the U.S. and countries, since different cities have different regulations and rules.

The market demand function in this paper has an intercept (*ma + xa+ xc*). Empirically, this intercept is a function of many variables. Because a log-linear demand function is usually assumed, the intercept becomes a sum of many other log variables. These variables, however, also vary over time, and are quite capable of generating price changes in the market. One difficulty of empirical testing is to separate the effects of these variables from the part of the market price changes that have been driven by the *aggregate* changes of individual expectations. And these variables can actually explain the variations in the market prices pretty well with a high R square. It is thus not surprising to see that some authors can show that there is a bubble forming in some areas while others disagree, particularly before 2003 in the US or other countries.

Another issue related to empirical testing is to that we need to determine what the long-run trend is before we can determine how much the price has deviated or increased from the long-run trend. For example, if the market price suddenly increases in one period, does that change the trend? It is not difficult to detect the formation of a bubble after a bubble has burst. But it is more difficult to detect the formation of a bubble, particularly in the early stages before it bursts. Therefore, one important extension is to integrate the empirical and theoretical studies or at least narrow the knowledge gaps between them. From the empirical and policy perspective, it is important to identify the variables that can explain the bubble in a statistically significant way, for example, through econometric analysis. In addition to the variables mentioned in the econometric studies, more efforts are needed to identify the number of speculators and the proxies of the aggregate expectation in the market. If we can determine these “indicators” of bubbles, it will be possible to better estimate how or when market price will reach the peak during the bubble as well as when the bubble will burst.

*4.4. Government Intervention*

The financial crisis that we experienced in recent years manifests the importance of the intervention of the government, especially, the Fed, as the lender of last resort. More importantly, instead of just cleaning up the aftermath of a financial crisis, today the Fed is moving toward a more pro-active supervising role to detect a bubble, as well as developing the policy instruments to limit the development of a bubble without damaging the economy. Therefore, how to include the intervention of the Fed or the government into the theoretical model would be another research topic to explore in the future.

**5. Conclusion**

The simple Cobweb model developed in this paper shows that the combination of the number of speculators and expected price increase will increase both the steady state price and the speed of convergence toward the steady state. The condition that sustains a bubble is also derived. When this condition is satisfied, the entry of larger numbers of speculators with high enough expected price increase can stabilize the housing price, and sustain the bubble as a self-fulfilling prophecy. However, when the housing price is high enough, it is possible that all the non-speculators can be driven out of the market. When the bubble bursts and the number of the speculators and expected price increase start to decrease, market price not only falls, but also becomes less stable or even unstable as the speculators rush to exit the market. A crash may also happen if people expect price to fall even further. At the end, it will be the return of non-speculators that stabilizes the market price, which is the benchmark for another bubble to begin in the future. However, if lenders are reluctant to begin lending, then government support as a lender of last resort may be needed to speed up the process.

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1. Public good (or bad) implies that there is no rivalry in consumption and no excludability to access. [↑](#footnote-ref-1)
2. If *Pt* is defined as the logarithm of the actual price at time *t*, then the difference between *Pt* and *Pt-1*will become a proxy for percentage change in housing prices. [↑](#footnote-ref-2)