Who Creates the Housing Bubble? An Agent-Based Study

Jiaqi Ge

Iowa State University

Abstract

This paper develops an agent-based spatial model of the housing market. Real estate is many families’ single biggest asset. It is also widely held by financial institutions, in the form of mortgage based securities. As a result, avoiding extreme housing price volatility is crucial for maintaining financial stability of the nation. The housing market is very unique: it is thin, highly regulated, highly leveraged, involves speculative behaviors, and exhibits spatial correlations. To this day, there are few housing market models that take into account all of these complications. In this paper, we propose an agent-based spatial model of the U.S. housing market. The exploratory work in this paper will enable us to better understand the housing market, make policy advice, and eventually prevent another damaging housing bubble.

1 Introduction

More than five years have passed since the sub-prime crises in the U.S. housing market and the financial crises it has triggered. Till this day, America is still seeing its consequences. About four and half million American families have lost their homes to foreclosures or were on the edge of going foreclosure. Nearly 11 trillion in household wealth has vanished, with retirement accounts and life savings swept away. In fact, housing bubble is a global phenomenon. Japan experienced the property price bubble in the late 1980s. The bubble burst in the early 1990s, followed by an economy slow down in the years after. In Europe, housing bubbles occur in Norway, Spain and Ireland. Emerging economies such as South Korea, then Russia, China, India, and Brazil have also witnessed big housing bubbles. For many families, the house is their single biggest asset. For banks and financial institutions, real estate has become an increasingly important component in

1We want to thank Tom Randall Real Estate Team, Hunziker & Associates, and an anonymous realtor for their generous help and useful inputs. Any mistakes are ours.
their portfolios, in the form of mortgage backed securities. Hence, extreme volatility in the housing market, like a housing bubble, will not only hurt homeowners, but also disturb the economy on a large scale.

The housing market is very unique: it is thin, highly regulated, highly leveraged, involves speculative behaviors, and exhibits spatial correlations. To this day, there are few housing market models that take into account all of these complications. This paper proposes an agent-based spatial model of the housing market. Our model setup is based on interviews with real estate personnel, in order to replicate important aspects of the business. The model will provide us with a more comprehensive understanding of the housing market and the housing bubble. Our research questions include: What are the major contributors of a housing bubble? In particular, what is the role of investors in the market? What is the role of the bank’s lending criteria? Is there any spatial patterns in the housing price movements?

2 Review of Literature

There are mainly three groups of papers in the housing literature. The first group focuses on speculative behavior in the housing market. Examples are Shiller[10] and Riddel [9]. The second group of papers, mostly done after the U.S. housing crises, look at the relationship between the housing market and sub-prime lending. Examples are Goetzmann et al. [4] and [1]. The third group studies land use choice and housing supply elasticities. Examples are Goodman et al. [6] and Glaeser et al [2].

As far as agent-based modeling goes, Goldstein [5] and Markose et al. [8] devised agent-based models for the interaction between the housing market and financial securities, such as residential mortgage based security, collateralized debt obligations, and credit default swaps. Torrens [11] developed an three-leveled agent based model to simulate individual housing choices. However, some important aspects such as the market price formation and price expectation are largely omitted. Moreover, the model does not have a financial sector. The agent-based housing market model proposed by Geanakoplos et al [3] does have a sophisticated financial sector, but the model is non-spatial.

According to a recent review by Mayer [7], the current literature is not satisfying in explaining and predicting a housing bubble. Some important aspects of the housing market are still to be explored. For instance, few papers have looked at intra-city differences. Few have modeled the negotiation process and the difference between the listing and final prices. In terms of future price expectation, most studies only consider past prices, but few consider prices in neighboring areas. In short, we feel that much more can be done in this area, and our paper could fill the gap.
3 The Housing Market: Model Logic and UML Presentation

Our housing market sits on a two dimensional landscape that contains multiple regions. A region can have as many houses as its maximum capacity allows. Two regions are neighbors if they share a common border. Each region has exogenous attributes such as nature quality, and endogenous attributes such as neighborhood quality. Neighborhood quality measures the attractiveness of a region’s neighborhood environment, such as safety, public service, or school qualities. It is endogenous because it depends on who lives in the region, which is endogenously determined in the system. The nature quality, on the other hand, captures anything that is exogenously determined, such as weather, distance to the beach, or cultural heritage.

Our model has five types of market participants: the real estate agent, the developer, buyers, homeowners, and the bank. We further distinguish buyers and homeowners as investors and non-investors. Investors buy a property in hope of profiting from housing price appreciation. Their purchase decisions are based on their expectation of future housing price. Regular buyers, on the other hand, obtain utility from living in the house. Hence, their purchase decisions depend on the house’s attributes: its listing price, neighborhood quality, and nature quality. We need to distinguish investor buyers/homeowners from regular ones because the two types have very different objectives and behavioral rules. Figure 1 is a class diagram of the model. It outlines the model’s class structure and demonstrates relationships between different types of agents.

![Figure 1: Class Diagram For The Housing Model](image)
Figure 2 is an activity diagram of the housing model. It illustrates how market participants interact with each other. In the activity diagram, an arrow in red represents an information flow, and an arrow in black represents an action flow.

In each period, new buyers enter the market in search of a house. At the same time, existing homeowners may decide to put their houses on the market for sale. The model works as follows, at the beginning of period $t$

**Step 1** **The Real Estate Agent**: given prices in each region in the previous period, announces new listing price for houses in each region.

**The Bank**: announces its mortgage rate and lending criteria.

**Step 2** **The Developer**: given new listing prices, builds new houses in each region.

**A Homeowner(Non-Investor)**: applies for refinance if appropriate. Given new listing prices and mortgage terms, decides whether to default. If chooses to default, the homeowner’s property goes into foreclosure. If chooses not to default, decides whether to sell the property. If chooses to sell, submits an asking price on the house. Otherwise, enter period $t + 1$.

**A Homeowner(Investor)**: applies for refinance if appropriate. Given new listing prices and mortgage terms, decides whether to default. If chooses to default, the homeowner’s property goes into foreclosure. If chooses not to default, decides whether to sell the property, according to the homeowner’s expectation of future return on the house, and her benchmark return. If chooses to sell, submits an asking price on the house. Otherwise, enter period $t + 1$.

**A Buyer(Non-Investor)**: searches each region, submits a bid on a house in the region that gives her the highest utility while affordable. The value of bid depends on the number of period the buyer has been on the market.

**A Buyer(Investor)**: searches each region, and picks the region that gives her the highest expected return while affordable. If the highest return from the particular region exceeds her bench market return, submits a bid on a house in that region.

**Step 3** **The Real Estate Agent**: collects all the bids and asks, and settles the final market price for each region.

**Step 4** **The Developer**: sells houses according to the market price. Unsold units become stock, and are put for sale in period $t + 1$.

**The Bank**: sells foreclosures according to the market price.

**A Homeowner**: sells her property and exits the market, if her asking price is lower than the market price. Otherwise, enters period $t + 1$ as a homeowner.

**A Buyer**: buys a house and enters period $t + 1$ as a homeowner, if her bidding price is higher
Figure 2: Activity Diagram For The Housing Model
than the market price.

Step 5 End of period $t$. Enter period $t + 1$.

4 Treatment Factors

One of the treatment factors in the model is Bank’s lending criteria. For example, a bank can adopt one of the three cases: normal, lenient, or strict lending. Each case is a package of four components: mortgage rate in the first two years, mortgage rate after the second year, minimum down payment, and maximum debt to income ratio. Here debt to income ratio is simply the ratio between monthly payment and monthly income, since we assume away any other forms of household debt. In the lenient lending case, homeowners enjoy a lower mortgage rate for the first two years of the loan duration. When the lower rate expires, homeowners have the opportunity to refinance. If refinance is approved, the lower rate will be in effective for another two years. Otherwise, the higher rate will be applied. Homeowners can get at most three refinance opportunities. In other words, lenient lending adopts an adjustable mortgage rate. Details of each case are listed in Table 1.

<table>
<thead>
<tr>
<th>component</th>
<th>Normal</th>
<th>Lenient</th>
<th>Strict</th>
</tr>
</thead>
<tbody>
<tr>
<td>mortgage rate (year 1 &amp; 2)</td>
<td>0.05</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>mortgage rate (year 3 &amp; more)</td>
<td>0.05</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>minimum down payment</td>
<td>0.05</td>
<td>0.00</td>
<td>0.20</td>
</tr>
<tr>
<td>maximum debt to income ratio</td>
<td>0.33</td>
<td>0.50</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Another important treatment factor is the number of investors, as opposed to the number of non-investor buyers. Will more investors lead to a larger housing price volatility, because they tend to follow trend? Or, on the contrary, more investors will lead to less housing price volatility because they try to seize investment opportunities and enter the market when the it is at the bottom. Our model would provide some insight.

5 Preliminary Results

Figure 3 shows the simulated mean housing price, mean number of foreclosures, and neighborhood inequality across all regions against time $t$ for 300 periods (300 months, or 25 years in real time) with the three lending case. (We eliminate 120 burn-out periods at the beginning of the simulation.) In
graph 3a through 3c, the solid line is the mean price across all regions; The blue/red line represents maximum/minimum price across all regions. From Figure 3, it is obvious that the bank’s lending

(a) Mean Price - Strict  (b) Mean Price - Normal  (c) Mean Price - Lenient

(d) Total Foreclosure - Strict  (e) Total Foreclosure - Normal  (f) Total Foreclosure - Lenient

Figure 3: Housing Market Simulation Results With No Income Shock

criteria has a substantial impact on the housing market. Lenient lending (see Table 1) is associated with higher housing prices, larger housing price volatility, and big number of foreclosures. Strict or tight lending, on the other hand, is associated with a lower housing price, smaller housing price volatility, and no foreclosure. The reason price is higher in the lenient lending case is that more people are qualified for a loan. The demand is higher in the lenient lending case, compared with the normal and strict ones. Because the majority of buyers are qualified for a loan from the bank, including even the riskiest lenders whose income is marginally higher than the minimum income required, and because no down payment is required, any price perturbation will induce loan default and foreclosures.

In the lower panel of Figure 3, we see that foreclosure does not exist in the strict (Figure 3d) or the normal (Figure 3e) lending cases. In the lenient lending case, however, even without any exogenous
shock foreclosures occur (Figure 3f). It’s part of the reason why price is also more volatile in the lenient lending case: since there is no down payment, even a relatively small drop in price may cause people to default, which will further drag the price down.

Next we introduce an exogenous income shock at t=100. At t=100, residents’ income shrunk from a mean of 2.8 (thousand) to 2.2 (thousand), an equivalent of a 21% drop. The shock lasts for 24 months. After 24 months, income goes back to the original level. We are curious to see how housing prices and number foreclosures respond in the three lending cases. The results with an income shock are shown in Figure 4.

Figure 4: Housing Market Simulation Results With Income Shock at t=100

Once again, in the lenient lending case, the system has the biggest price drop at the time of the income shock. Mean housing price plummets by nearly 70% in 24 months. Mean housing price in normal or strict lending case also decreases at the time of shock, but to a lesser extent. Tremendous number of foreclosures occur during the income shock in the lenient lending case. Around 15% of
all houses (1500 out of 10,000) go into foreclosures during the sock. Moreover, in all cases, price rebounds after the shock and when income goes back to the original level. It’s not surprising that in the short post-shock period when income has recovered from the shock, but housing price has not, buyers enter the market and make a purchase. Demand is high in that post-shock period, especially for investors because the price is rising quickly from the bottom. Consequently, housing price rebounds to a higher level than pre-shock average.

As for number of investors, each period we create a certain number of investors. However, the number of investors in the market is endogenously determined by the system. Investors have heterogeneous expectation about future housing price. An investor will enter the market and purchase a house if she thinks it is profitable to do so. Similar, an investor will sell a house if she believes it’s no longer a good investment. In short, we do not control the number of investors who make a purchase or sale in the market. We only control the number of investors newly created in each period to search for profitable opportunities. Figure 5 shows the mean prices in lenient lending, with a shock at t=100, when we have less (200 per period) and more (600 per period) new investors created per period to start the search.

![Figure 5: Housing Market Simulation Results With Less or More Investors](image)

In Figure 5, we see that the shapes of the two curves are really similar. The difference lies in discrepancy between the minimum and maximum prices during the shock period. It seems like having more investors do not interfere with the mean price movement, but during the shock period, investors tend to invest more in high-end neighborhood than in other neighborhoods. In other words, the introduction of more investors does not shift the mean price, but widens the price differences between neighborhoods during the after-shock period. As a result, high-end neighborhoods
are quicker to recover from a shock than low-end neighborhoods.

6 Conclusions

This paper develops an agent-based spatial model of the housing market. We try to incorporate some important aspects of the housing market that are largely ignored in the existing housing literature, such as the negotiation process of buyers and seller, buyer’s choice between different areas, and the role of the bank and the real estate agent. Our research questions include: who creates the housing bubble? What is the role of the bank’s lending criteria? What is the role of investors? Are there any spatial correlations?

The preliminary results are very promising. We have generated sensible aggregate results from individual buyer and seller interactions in the market. From the preliminary results, we can already conclude that one of our treatments: bank’s lending criteria, does have a substantial impact on the housing market. A lenient lending case, like the one we have experienced during the recent U.S. housing bubble, does lead to more foreclosures, higher housing prices, and higher price volatility.

When an exogenous income shock is imposed on the system, housing price drops in all three cases, but it drops by the biggest amount in a lenient lending case. In all three cases, prices rebounds after income goes back to the original level, and it rebounds by the biggest amount in the lenient lending case. One thing that is different in our experiment than in reality is that, in the experiment, the bank always remains lenient lending criteria during and after the shock; while in reality, banks tighten lending. We test what if the bank tightens its lending and shift to normal lending case during and after the shock. We found that post-shock housing price still rebounds, but by a lesser extent.

Investors also play a role in the housing bubbles. Our model results show that investor do not interfere with mean housing price as some might expect. However, they are responsible for widening regional housing price differences during the period when housing prices move dramatically. Investors are more likely to invest in high-end neighborhoods. As a consequence, prices in high-end neighborhoods recover more quickly from a shock than those in low-end neighborhoods.

To sum up, we have looked at a global phenomenon that affects household wealth, the financial market, and the economy on a large scale. By talking to numerous real estate agents, we have set up a model that captures important aspects of the market. The preliminary results we have got so far show that the model is able to generate sensible aggregated outcomes and stylized facts from the bottom up. Further exploration of the model is still needed. The exploratory work in this
paper will lay the foundation for follow-up studies that will eventually enable us to predict and prevent another damaging housing bubble.

References


