2012

Using Agent-Based Modeling to Simulate the Foreclosure Contagion Effect

Andrew J. Collins
Old Dominion University

Michael J. Seiler
Old Dominion University

Original Publication Citation

Collins, A. J., & Seiler, M. J. (2012). *Using agent based modeling to simulate the foreclosure contagion effect.* The 2012 Southeastern INFORMS Conference, October 4-5, 2012, Myrtle Beach, South Carolina.

USING AGENT-BASED MODELING TO SIMULATE THE FORECLOSURE CONTAGION EFFECT

Andrew J. Collins, VMASC, Old Dominion University, Suffolk, VA 23435
Michael J. Seiler, Department of Finance, Old Dominion University, Norfolk, VA 23529

ABSTRACT

A foreclosed property can have a negative impact on the prices of other properties within its neighborhood and these reduced property prices can lead to further foreclosures within the neighborhood; this is known as the foreclosure contagion effect. This effect has been demonstrated, within the real estate literature, to occur. Traditionally, real estate research have used statistical regression to analysis this issues. The application of Agent-based Modeling and Simulation (ABMS) has risen in the last 15 years and has successfully been used to model complexity situations, e.g., the real estate market. ABMS offers a way to explore the impact of different factors on the real estate market without having to experiment on real-world systems. This paper looks at application of ABMS to investigate the foreclosure contagion effect.

INTRODUCTION

There were over 2.8 million properties given foreclosure notices in the United States (U.S.) in 2009 (Pollack et al., 2010) making the current real estate crisis is the worst the U.S. since the Great Depression. Through understanding the causes of the foreclosure, it might be possible to development governmental policies that help mitigate these causes and thus help decrease the number of foreclosures appearing on the market. One suggested cause of foreclosure spread has been labeled the "foreclosure contagion effect."

The foreclosure contagion effect is the negative impact on prices experienced by properties that are within the neighborhood of a foreclosed property. A property with a declining value has more of a chance of going into foreclosure and in doing so would decrease the value of the surrounding properties even further. This chain reaction of foreclosures could lead to a complete collapse of the property market. The traditional approach to researching this phenomenon is statistical regression have been employed by real estate academics (Rogers and Winter 2009); however, a recent Nature article has suggested that Agent-based Modeling and Simulation (ABMS) should be used instead (Farmer and Foley, 2009).

This paper reports the results gained from constructing an ABMS to investigate what impact foreclosures have on the surrounding property market. This is achieved by constructing a property market of 2,500 houses which is run for a 83 years at a monthly time-steps to determine the impact of various model parameters, i.e., local foreclosure appraisal discount and disposition time. This paper is divided into five sections. The first two sections give an introduction and background to the problem; the third section gives a brief description of the model and the final two sections present the results and conclusions.

BACKGROUND

The real estate market has a significant role in the nation's financial system which was made evident in the recent recession of 2007 through the present. Former lending practices allowed high risk individuals to obtain subprime mortgages. These subprime mortgages inundated the market which eventually produced a surge of foreclosures as subprime homeowners defaulted. The increase in foreclosures caused instability within the financial system which caused financial investment losses, high unemployment, and even more foreclosures. This positive feedback loop created one of the worse recessions in the history of the United States. It is clear that the real estate market is a critical element to the health of the nation's financial system.

Foreclosures within the real estate market occur when the borrower can no longer fulfill the mortgage contract and eventually defaults. A legal process then begins which allows the creditor, typically a bank, to gain possession of the property and then sell it to a third party. The money received from the sale is applied to the remaining balance on the original loan. The foreclosure process is extremely detrimental for all entities involved. Lin et al (2009) finds that foreclosure costs are estimated anywhere from $7,200 to $58,759, while Rogers and Winter (2009) defines this window between $27,000 and $30,000.

Foreclosed properties usually experience gross neglected, abandonment, and vandalism which lowers the value and visual attractiveness of the property. It has been suggested that this decline in maintenance of a foreclosed property, and subsequence devaluation, are contributing factors to the contingent effect (Harding et al., 2009). Foreclosed properties are eventually listed for sale along with the other properties that are listed in the traditional fashion. Therefore, foreclosures add to the supply of properties that are contending for buyers; as a result, the excess supply can cause neighboring property values to decline.

Previous Studies

Previous research efforts to explore the foreclosure contagion effect within the real estate market use a hedonic regression methodology. Hedonic models decompose complex, incomparable entities into smaller, comparable constituents for analysis. Once decomposed, the constituents are evaluated to determine their contribution to the state of the original entity. In the case of foreclosure contagion, relationships between foreclosures and neighboring property sale prices are explored by decomposing sales prices with two of the constituents being the number and distances of foreclosures within the proximity of the selling property. This approach has been used to identify and quantify relationships between foreclosures and property values from datasets that contain real estate sale prices and foreclosure events (Immergluck and Smith 2006; Harding et al. 2009; Lin et al. 2009; and Rogers and Winter 2009).

The reason for using regression models when analyzing foreclosure effects is partially historical and partially due to the availability of techniques (Lancaster, 1966). Due to developments in computer technology over the last 20 years, analysis techniques like simulation have come more accessible and useful within the research community and thus might be more applicable to researching foreclosure.

Appraisal Foreclosure Discount

Various studies have been conducted to quantify the impact of foreclosures on the surrounding property values. For instance, Immergluck and Smith (2006) showed the impact from foreclosed property was about 1% of the property values within eighth of a mile. In contrast, Lin et al (2009) suggested the effect was 8.7% on property values up to 10 blocks away for 5 years. The differences in the results can be attributed to differences in the data sets used even though the data sets are somewhat similar. For instance, both papers draw the data from the Chicago region and both papers used regression based models. A separate study of data in the St. Louis County, Missouri by Rogers and Winter (2009) showed similar results to Immergluck and Smith's outcomes, and also used a log linear regression based model for its hedonic price model. Although the literature offers different values for the quantifying the contagion effect, they agree that the effect is local and that it is a function of time and distance.

Disposition Time

The process by which a foreclosure gets resolved is a function of the state in which the property is located (Pence 2003; 2006). Judicial foreclosure states require the courts to get involved which substantially slows down the process. Alternatively, power-of-sale states allow the bank to sell the property without the court's supervision. To further compound the problem, states with a Statutory Right of Redemption indirectly delay the resolution of a foreclosure by effectively limiting the demand pool that is willing to step forward to buy a foreclosed property. The reason is that this law allows a foreclosed upon property owner to regain ownership of the foreclosed property for a fixed period (up to 1 year), even after it has been sold to someone else.

The previously cited literature acknowledges that having unresolved foreclosed properties in a neighborhood causes a magnification of the foreclosure contagion problem. Empirically, the question is, “To what extent does the added time on the market cause an increase in the likelihood of a market collapse?” We seek to address this question by allowing both the magnitude of the foreclosure impact to vary as well as the foreclosure time on the market, called disposition time. We select a minimum value of 1 month and a maximum value of 14 to provide a sufficient range to see varying results.

Agent-based Modeling and Simulation

ABMS is a simulation technique that has been recently advocated for use within economic modeling (Farmer and Foley 2009). Formally, ABMS is defined as a computational method that enables a researcher to create, analyze and experiment with models composed of agents that interact within an environment (Gilbert 2007; North and Macal 2007). The agents can be anything that can act autonomously and the environment is where the agents can act. ABMS has been applied to very diverse areas, from Electricity companies interacting within the energy markets (Bagnall and Smith 2005) to eggplant growth (Qu et al. 2010).

Real estate has a long history with agent-based modeling, Schelling invented ABMS when he constructed a model of housing segregation (Schelling, 1971). Schelling developed the model in an attempt to explain racial segregation within American cities. The model used a grid pattern as its environment and the agents were individual households. If an agent was surrounded by more than the tolerated numbers of other racial groups, then they would move. What was interesting about Schelling’s work was that even with relatively high levels of racial tolerance among the general model population, segregation (or clustering of households) would still occur.

Schelling’s result is an example of what is called as emergent behavior which can occur within ABMS. This is when micro-level details (i.e., the agent’s racial tolerance levels), have macro-level effects (i.e., segregation of a population). This emergent behavior is one key benefit to using ABMS and is sometimes called a bottom-up approach to modeling. Emergent Behavior could occur due to the overwhelming complexity of a model, and as such, agent-based modelers try to keep the agent’s rules as simple as possible to avoid this.

MODEL

The agents in our foreclosure ABM are the individual real estate properties. A number of variables are used to represent these heterogeneous properties within the model, i.e. geographical location, current market value, loan type, resident type, and purchase price. Once a property-agent is sold within the simulation, the agent is refreshed with the new owner’s details and financial situation. The simulation contains 2,500 property agents that are equally spaced in a torus grid, as shown in Figure 1.

The purpose of this simulation was to explore the effects of foreclosures on the average property value and if these effects induced a complete market crash. A brief description of the model’s mechanics is given here; a complete description of the model, including the mathematical formulae, is given in Gangel et al (2012a). To the best of our knowledge, there is no previous study using ABMS for foreclosure modeling, thus we have attempted to make the model as simple as possible for this initial application of the ABMS methodology. To maintain simplicity, at each time-step each agent considers only a limited number of factors when trying to mimic reality.

The simulation runs were for 1,000 months (83 years) with a time-step of one month. During each time-step, the property agents performed a series of different tasks. These tasks included updating the properties loan information; performing a pricing appraisal of the property; determining if the property would go into foreclosure, based on characteristics like if the property was underwater or if it was a rental property; and determining if the property would be listed for sale using a probability based on the property's Return on Investment (ROI). The simulation was implemented in Repast Simphony (version 1.2), an open-source ABMS software developer's kit (North et al, 2006). Repast Simphony was selected due to its superior computing speed and programming flexibility to other ABMS software. All simulations were run on desktop computer with a quad-core 2.33Mhz Intel processor and 4GB RAM.

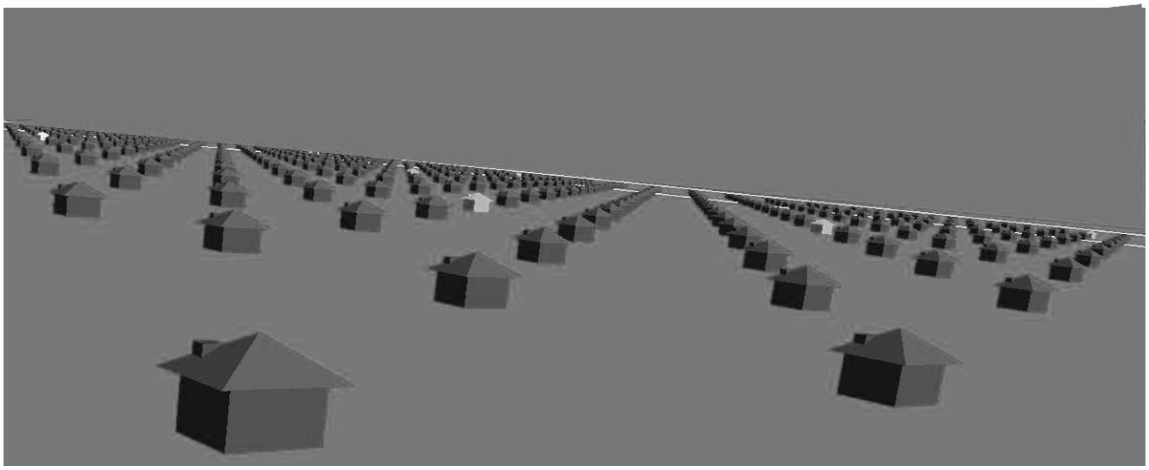

Figure 1: Screen from the Repast Simphony software of the foreclosure model implementation

Each simulation run was repeated 30 times for statistical significance and we only focus on the results relating to foreclosure discount factor and disposition time in this paper. Real interest rates from the last 30 years were used within the model. The model was validated through face validation of a Subject Matter Expert (SME) and sensitivity analysis was conducted using Latin Hypercube Sampling; details of the sensitivity analysis can be found in Gangel et al. (2012b).

RESULTS

A sampling of results from the simulation runs is given in figure 2; these results focus on the impact of the foreclosure discount and disposition time on the average property values. These results were drawn from the same study presented in Gangel et al. (2012a, 2012b) though the discussion is unique to this paper. Figure 2 is composed on two key regions. The "lake" is the flat part at the bottom-right of the graph and it represents combinations of discount rate and time to foreclosure that cause the market to collapse, this is represented as an average house price of $10 within our model. Once a catastrophic crash occurs there is no recovery of the property market. The "mountain" in the graph conveys market declines (but not failures) for the remaining combinations. It is clear from this graph that the relationship between disposition time and foreclosure discount is non-linear. If it were, the side of the mountain would slope down to the lake in the shape of a plane and there would be no curvature at all.

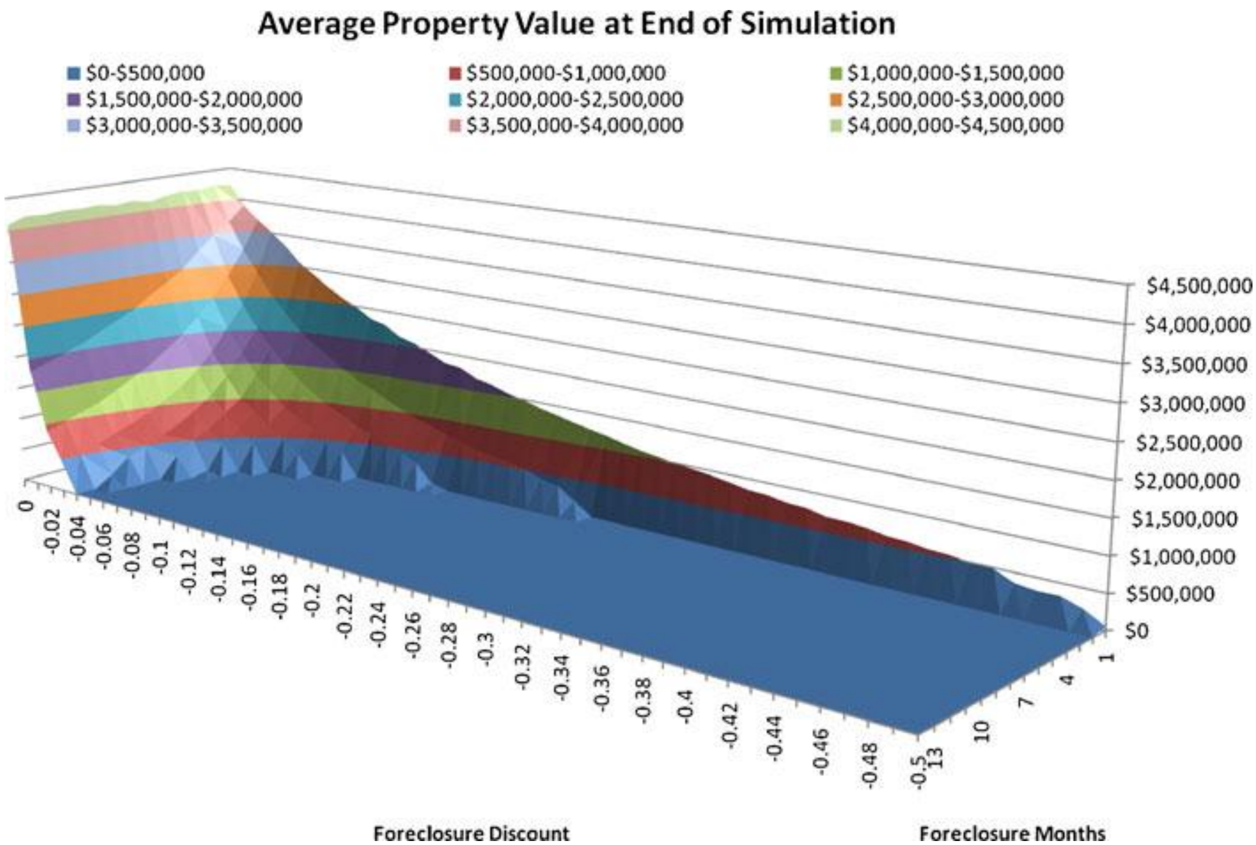

Figure 2: Graph depicting simulation results nicknamed the "mountain-lake graph"

What is most important about this analysis is the point at which the market turns from healthy to potentially unstable. If the research of Immergluck and Smith (2006) is to be believed, with a foreclosure impact factor of 1%, then we are not likely to see a complete property market collapse due to foreclosures. In contrast, Lin et al (2009) suggested the foreclosure effect was 8.7% on property values, which would mean that our results imply that there could be a complete market crash if disposition time was allowed to go above 10 months. Overall, our results show that letting foreclosed homes needlessly linger in the neighborhood causes an increasing foreclosure contagion problem—possibly to the point of market collapse.

Given the stochastic nature of the simulation and the number of properties involved, it was very surprising to us to observe such smooth results that are shown in figure 2. We behavior these smooth results give creditability to our results and are a demonstration of emergent behavior from the simulation.

CONCLUSIONS

This is the first study to apply agent-based modeling to the field of real estate and foreclosures. It began by building a simulation that reasonably tracks the intricate relationships that exist in the observable real world, which was validated by a SME. It was found that the greater the time a foreclosed property is allowed to remain on the market, the greater the probability the market will fail. Future research will incorporate social networks and the new phenomenon of “strategically defaulting.”

In summary, no matter the politics or economic view relating to this topic, we can all agree a better understanding of real estate markets is ideal. ABM can be used to gain additional insight beyond the ability of traditional tools used in the past.

REFERENCES

Bagnall A J and Smith G D (2005). A multiagent model of the UK market in electricity generation. IEEE transactions on evolutionary computation 9(5): 522-536.

Farmer J D and Foley D (2009). The economy needs agent-based modelling. Nature 460(7256): 685-686.

Gangel M, Seiler M J, and Collins A J (2012a). Exploring the foreclosure contagion effect using agent-based modelling. The Journal of Real Estate Finance and Economics, forthcoming.

Gangel M, Seiler M J, and Collins A J (2012b). Latin Hypercube Sampling and the Identification of the Foreclosure Contagion Threshold," Journal of Behavioral Finance, forthcoming.

Gilbert, N (2007). Agent-Based Models. Sage Publications: Thousand Oaks, CA.

Harding J P, Rosenblatt E and Yao V W (2009). The Contagion Effect of Foreclosed Properties. Journal of Urban Economics 66: 164-178.

Immergluck D and Smith G (2006). The External Costs of Foreclosure: The Impact of Single-Family Mortgage Foreclosures on Property Values. Housing Policy Debate 17(1): 57-79.

Lin Z, Rosenblatt E and Yao V W (2009). Spillover Effects of Foreclosures on Neighborhood Property Values. Journal of Real Estate Finance and Economics 38(4): 387-407.

Lancaster K J (1966). A New Approach to Consumer Theory. Journal of Political Economy 74(2): 132-157.

North M J, Collier N T and Vos J R (2006). Experiences Creating Three Implementations of the Repast Agent Modeling Toolkit. ACM Transactions on Modeling and Computer Simulation 16(1): 1-25.

North M J, and Macal C M (2007). Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation. New York: Oxford University Press.

Pence, K. M. (2003) "Foreclosing on Opportunity: State Laws and Mortgage Credit," Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series, 2003-16.

Pence, K. M. (2006). Foreclosing on opportunity: state laws and mortgage credit. Review of Economics and Statistics, 88(1), 177–182.

Pollack C E, Lynch J, Alley D E and Cannuscio C C (2010). Foreclosure and Health Status. Leonard Davis Institute of Health Economics 15(2): 1-4.

Qu H, Zhu Q, Fu H, and Lu Z (2010).Virtual EP: a Simulator of Multi-agents-based Virtual Plant Growth in Response to Environmental Heterogeneity. Journal of Simulation 4(3): 181–195.

Rogers W H and Winter W (2009). The Impact of Foreclosures on Neighboring Housing Sales. Journal of Real Estate Research 31(4): 455-480.

Schelling T C (1971). Dynamic Models of Segregation. Journal Of Mathematical Sociology 1(2): 143-186.