Credit-Network Model of the US Housing Market*

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Abstract

In this paper, we implement a Heterogeneous Interacting Agents (HIA) model in an attempt to model a credit network of the US housing market. We draw on a financial fragility model by Delli Gatti et al. (2005, 2008) and adapt it for capture the salient features of the US housing market. Although our model is very simple, it does a good job in replicating qualitatively the short-run fluctuations of credit creation and credit defaults observed in the US housing market. We propose further directions to expand the model including the capability for endogenous price determination, and an additional layer by including a complex commercial banking network.

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Introduction

Beginning in late 2007, the mortgage industry has been in the news very often, as home prices in the US moved downward (Figure 1). As a result of this downward movement of home prices, those who borrowed heavily expecting the opposite began to become delinquent on their loans and then ultimately lost their homes. The high number of foreclosures started a chain reaction, affecting some of the mortgage business and Wall Street, and the rest is now history. What started as an issue for a specific niche of the mortgage market (namely, the subprime market) became a “mainstream” problem as borrowers with good credit histories began to succumb to the same pressure. We were motivated by this fluctuation in the market, and we sought to develop a model that explores the salient dynamics of the crisis.

Overview of the Housing Credit Industry

The mortgage industry has evolved into a complicated entity in the US, with many players. This growth and transformation have been made possible by the practice of securitizing and marketing loans backed by real estate, and lowering interest rates. Until recently, mortgage origination and issuance of mortgage-backed securities was limited to prime borrows. A steady reduction of interest rates encouraged more and more lending in what was considered non-prime markets, also called subprimes. Today’s market has eight primary actors: mortgagor (or the borrower), originator, arranger (or the issuer), warehouse lender, credit rating agency, asset manager, investor,

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5 Ashcraft, Adam B. & Schuermann, Til, 2008, Understanding the Securitization of Subprime Mortgage Credit, *Federal Reserve Bank of New York Staff Reports*
and servicer. A firm may take on multiple roles. For instance, a firm may be the originator, the issuer, and the servicer.

**Mortgagor:** Individual or household borrower, who applies for a mortgage to either purchase property or refinance existing property.

**Originator:** Entity that initially funds and services the loans.

**Arranger:** Institution that purchases pool(s) of mortgage loans. Performs initial due diligence on the originator and is responsible for bringing together all the elements to close the deal. Specifically, the arranger creates a trust that purchases the loans, hires a credit rating agency to finalize the deal structure, makes filings with the SEC, and underwrites the issuance of mortgage backed securities.

**Warehouse Lender:** The arranger is responsible for funding the loans until the securitization deal is final, and if the arranger requires funding during this period, a third-party lender is found and the loans are kept in the “warehouse.” Such a third-party lender is called a warehouse lender.

**Asset Manager:** A buyer of mortgage-backed securities, the asset manager is an agent for the ultimate investor.

**Credit Rating Agency:** Entity which assigns credit rating to the mortgage-backed securities.

**Investor:** Individual or institutions who buy mortgage-backed securities, typically through an asset manager.

**Servicer:** Entity responsible for collection and remittance of loan payments, making advances of unpaid interest, accounting for principal and interest, customer service to the mortgagor, managing escrow accounts, administering taxes and insurance payments,
contacting delinquent borrowers, and otherwise ensuring that the loan is current, and at some point, initiating foreclosures.

Model

We draw on Delli Gatti et al. (2005) to implement a simple credit network model with heterogeneous interacting agents. The fundamental premise of that model is aimed to capture is the emergence of credit cycles of boom and bust due to idiosyncratic shocks of households probability of defaulting on their mortgage debt. The interconnections of households’ mortgage payment defaults may cascade in such a way that produces the banking system to fail.

We proceed to describe our simple sequential economy composed of two types of interacting agents: households and banks.

Housholds

The household (HH) sector represents both the production and consumption side of the economy. Households’ income is a function of the output they produce. Income is spent in household consumption, investment and credit (mortgage) repayment. Income for each household is stochastic through price fluctuations around the equilibrium price.

We derive the HH net income for HH ‘i’ at period ‘t’ ($\pi_{it}$):

\[
\pi_{it} = u_{it} Y_{it} - gr_{it} K_{it} = (u_{it} \phi - gr_{it} )K_{it}
\]

where,

\[Y_{it} : \text{Output of HH } i \text{ at time } t\]

\[K_{it} : \text{Borrowed capital for HH } i \text{ at time } t\]

\[u_{it} : \text{random variable with mean 1 and variance 1}\]

\[r_{it} : \text{rate of return on capital } i \text{ at time } t\]

\[\phi : \text{productivity of capital}\]

\[g : \text{constant to proxy for variable costs as a proportion of financing costs } (g>1)\]
HH use their net worth and may get credit to meet their expenses due to consumption and investment. The HH credit demand function is given by:

\[ L^d_{it} = \frac{\phi - gr_{it}}{c\phi gr_{it}} - \pi_{it-1} + \left( \frac{1 - 2gr_{it}}{2gr_{it}} \right) A_{it-1} \]

where,

- \( L^d_{it} \): Credit demand of HH i at time t
- \( A_{it} \): Net worth of HH i at time t
- \( \pi_{it} \): Net income of HH I at time t
- \( r_{it} \): Interest rate i at time t

The net worth of the HH is given by the following law of motion:

\[ A_{it} = A_{it-1} + \pi_{it} \]
Banks

The banking sector is the only source of credit in this simple economy. The banks’ balance sheet is $L^s_t = E_t + D_t$, where $L^s_t$ represents the total credit supply, $E_t$ the bank’s equity and $D_t$ deposits (a residual in this model). Banks work under fractional reserve banking system such that: $L^s_t = \frac{E_{t-1}}{v}$ where $v$ represents a risk coefficient constant. Credit supply is thus,

$$L^s_{it} = \lambda L^s_t \frac{K_{it-1}}{K_{t-1}} + (1 - \lambda) L^s_t \frac{A_{it-1}}{A_{t-1}}$$

(4)

$$K_{t-1} = \sum_{i=1}^{N_{i-1}} K_{it-1}$$

(5)

$$A_{t-1} = \sum_{i=1}^{N_{i-1}} A_{it-1}$$

(6)

where $0 < \lambda < 1$

Therefore each mortgage is proportional to the size of HH’s capital and HH’s net worth.

Bank’s profits are given by:

$$\pi^B = \sum_{i \in N_t} r_{it} L^s_{it} - \bar{r}_t \left[(1 - \omega)D_{t-1} + E_{t-1}\right]$$

(7)

where,

$r_{it}$: borrowing interest rate

$\bar{r}_t$: average lending interest rate

$\omega$: spread parameter on the interest rate
Finally, bank’s equity is given by:

\[ E_t = \pi_t^B + E_{t-1} - \sum_{\Omega_{t-1}} B_{it-1} \]  

(8)

where,

\[ B_{it} : \text{Bad debt of each HH in the defaulting HHs set } \Omega_t \]

**Credit Market Equilibrium**

The crucial element of the model lies in the determination of the equilibrium interest rate in the credit market. The market clearing interest rate is determined each period by equating credit supply and credit demand. Solving for the equilibrium interest rate we obtain:

\[ r_{it} = \frac{2 + A_{it-1}}{2cg\left(\frac{1}{\phi c} + \pi_{it-1} + A_{it-1}\right) + 2cgL_t^S[\lambda K_{it-1} + (1 - \lambda)A_{it-1}]} \]  

(9)

**Households’ Dynamics**

The process of acquisition and default of HH mortgages is modeled as a function of the prevailing interest rate at time in the last period.

The probability of entering into a new mortgage contract depends inversely on last period’s market interest rate \( r_{t-1} \).

**Probability of entry (new credit)**

\[ \Pr(Entry) = \frac{1}{1 + e^{\beta(r_{t-1} - \bar{r})}} \]  

(10)
Where $d$ and $e$ are constants. The number of new mortgages per period is computed by multiplying a constant $\overline{N} > 0$ by the probability in (10). $N^{\text{entry}} = \overline{N} \cdot \Pr(\text{Entry})$.

**Exit condition (foreclosure)**

HHs are foreclosed in the event that they cannot honor their credit repayments. This condition is binding when the HH has negative net worth:

\[
A_{it} < 0
\]

\[
A_{it} = A_{it-1} + \pi_{it}
\]

(11)
Results

We discuss the preliminary results from simulating the model economy discussed in the previous section. Our credit market is initially populated with 1000 HHs and is simulated for 1000 periods.

Figure 1.

Figure 1 depicts growth rates of total output in the credit economy. In addition to the sharp fluctuations in aggregate economic activity, it is also readily observable volatility clustering in the time series. This latter feature is a stylized fact of financial time series.

Next we look at the interest rate time series. Figure 2 illustrates how the stochastic production of HHs affect the equilibrium interest rate. As a result the credit demand conditions fluctuate with the interest rate (Figure 3).
Figure 2.

Figure 3.
Figure 4 below shows the relative high frequency of the number of foreclosures due to HH’s inability to repay their debts. This in turn is reflected in the sharp fluctuations in profits of the banking sector (Figure 5).
The last graph below illustrates the asymmetry in the distribution of growth rates of the HH demographics. This skewness towards the left reflects the fact that banks’ uncertainty about the HH’s future income stream when allocating credit.
Conclusions

This paper implemented a simple credit network model to capture the salient features observed in the housing market. Namely, our model aimed to capture qualitatively the fluctuations of credit creation and destruction in the housing market. The driving factor of these dynamics are the idiosyncratic shocks to HHs income. HHs decision to undertake a new mortgage credit is myopic in that is based on the availability of cheap credit today and it does not take into account the future stream of debt repayments. Banks also suffer as they provide credit to HHs without accounting for the uncertainty associated with short-term default probabilities.

Overall the model illustrates how the sequence of interactions of heterogeneous economic agents can generate anomalous economic behavior such as the housing market bubble.

Due to time and resource constraints the model has several shortcomings which need to be addressed in the future. Several directions envisioned by the authors to improve the present model include: i) A layered banking sector with commercial banks and a central bank. In the spirit of Battiston et al. (2007) the model can be extended with a credit chain of commercial banks which at the same time provide inter-banking loans to each other to prevent failures in the banking sector. This could be further extended with the central bank main role in setting the discount interest rate in order to regulate the banking sector ‘thermostat’. ii) Endogenous price determination of housing price level. The main shortcoming of the present model is that it takes house prices as given. It is clear that the stylized fact in the current bubble is the boom and bust in house prices. In order to incorporate price determination the model has to be extended to a full scale general equilibrium model where house prices are determined by supply and demand for houses. iii) Policy analysis. The extensions suggested in i) and ii) are fundamental to study the implications of macroeconomic policy in the housing market model.
References


Appendix

The following are the structural parameters used to simulate the model:

For the HH:

• Productivity of capital, $\phi = 0.1$

• Equity-loan ratio, $\alpha = 0.08$

• Variable cost parameter, $g = 1.1$

For the bank:

• Spread parameter on the interest rate, $\omega = 0.002$

• Weight given by the bank to capital in allocating credit supply, $\lambda = 0.3$

Initial conditions for the model economy:

\[ K_{i0} = 100 \]
\[ A_{i0} = 20 \]
\[ L_{i0} = 80 \]
\[ \pi_{i0} = 0 \]
\[ B_{i0} = 0 \]
\[ \bar{N} = 180 \]
\[ T = 1000 \]