Forecasting Failure: a Systems Perspective on the Fall of Countrywide Financial

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To my amazing family and friends for all the love, support, and laughs throughout the years. I could not have done it without you. Thank you.

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Abstract

Countrywide Financial was acquired by Bank of America on January 11th, 2008 for $4.1B after losing $1.3B in 2007. Not only was it losing money, its financial prospects at the time looked bleak due to their large stake in subprime mortgages. This effective failure of Countrywide Financial set off a chain of events that eventually ended up almost crippling the global economy in late 2008 into early 2009. It will be shown that the financial crisis hit the housing market hard in 2007-2009 due to low mortgage standards in the preceding few years and an oscillating federal funds rate. Using publically available data from Countrywide Financial, prices of individual mortgage backed securities will be calculated using the standard pricing models and an author-developed simple pricing model that utilizes actual default rates at the time. Using these mortgage backed securities' prices along with a stakeholder value network analysis and system dynamics, it will be shown that Countrywide Financial could have been predicted to fail in the 2007-2008 time period. Suggestions for architecting a new housing market are then given after reviewing what was learned.

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Chapter 1: Introduction and Literature Review

> *"Like all systems, the complex system is an interlocking structure of feedback loops... This loop structure surrounds all decisions public or private, conscious or unconscious. The processes of man and nature, or psychology and physics, of medicine and engineering all fall within this structure."*
>
> *- Jay W. Forrester, Urban Dynamics (1969), p.107*

In hindsight, the collapse of the complex financial system in the 2007-2009 time period was brought about by economic actors acting in their own self-interest due to the rules of the financial system. It will be shown in this thesis that the rules, along with the actors, and the dynamics of the system led to the collapse of certain firms- such as Countrywide Financial Corporation- that created a domino effect that rippled throughout the market. The tools that will be used to show this are stakeholder value networks, system dynamics, mortgage backed securities pricing. Network analysis will be briefly discussed. In addition, JavaScript will be used to visualize the Countrywide Financial's Mortgage Backed Security (MBS) portfolio over the course of about a decade. With these theoretical and practical tools it could have been forecasted that Countrywide Financial would fail in about the same timeframe as it did. Therefore, if it could have been forecasted to fail, it possibly could have been prevented if the right steps were taken in time, as will be described in the conclusion.

But before that, debt – and money – will be discussed to more thoroughly understand the financial instruments of the housing crisis. Why does discussion of debt and money matter for the thesis? Mortgages are a specific type of debt instrument, so their underlying assumptions should be examined theoretically and historically. In addition, the typical American house is the biggest asset that most people own (Intuit 2015). Home ownership rates normally hover around two thirds of American households, as shown in Figure 1.1, so it is very important for all of society (Swift 2015). This also implies that the associated mortgage tied to their house is their biggest liability, or debt, and can take up more than 50% of one's income typically taking up one third of their income for homeowners with severely burdened housing-costs (Schwartz and Wilson 2012). Therefore, the topic of mortgages is extremely important not only to the economy, but also to the average American citizen, even if they may not realize it. The book "Debt: The First 5000 Years" is a great resource for thinking more deeply about this problem. In it we find numerous quotes to help us understand the core issues of debt and money. We discover that these two concepts are deeply intertwined. This being said, we will take a look at money independently first and then move on to debt.

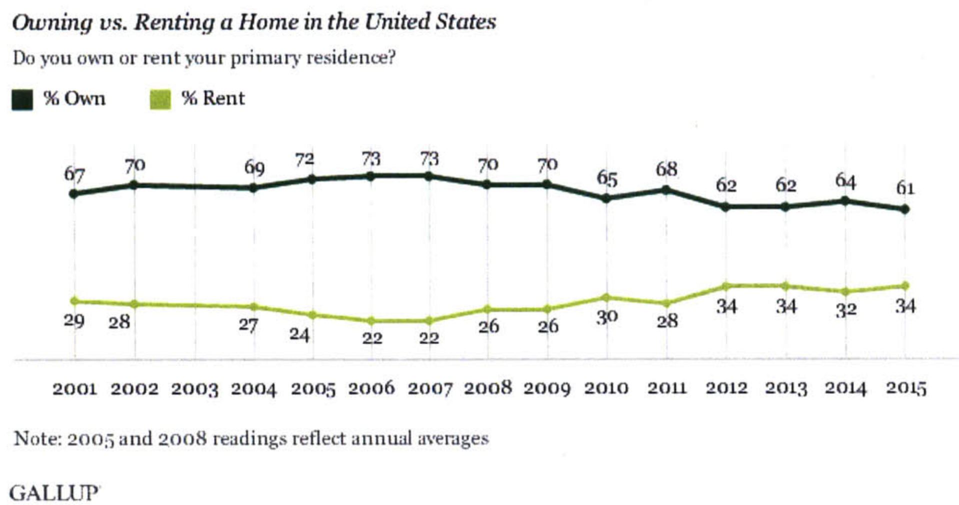

Figure 1.1- Home ownership rates from 2001-2015 (Swift 2015)

To analyze debt, let's first take a look at what money is, at its core. From "Debt: The First 5000 Years", we see that one school of thought is that "... money is just a commodity, chosen to facilitate exchange, and which we use to measure the value of other commodities." (Graeber 2011, 44). Another way of thinking about money is, "Credit Theorists insisted that money is not a commodity but an accounting tool... The obvious next question is: If money is just a yardstick, what then does it measure? The answer is simple: debt. A coin is, effectively, an IOU." (Graeber 2011, 46). Furthermore, "Credit Theorists argued that a banknote is simply the promise to pay *something* of the same value as an ounce of gold. But that's all that money ever is... A gold coin is a promise to pay something else of equivalent value to a gold coin. After all, a gold coin is not actually useful in itself. One only accepts it because one assumes other people will." (Graeber 2011, 46-47). Therefore, we see that money can be considered *both* a commodity and an accounting tool. Also, it is interesting to note that, "In this sense, the value of a unit of currency is not the measure of the value of an object, but the measure of one's trust in other human beings." (Graeber 2011, 47) It will be apparent throughout this thesis that trust across society was seriously affected by the 2007-2009 financial crisis.

What are some qualities of money? From "Debt: The First 5000 Years", we get that money needs to be accepted as a form of payment to governments, and "It makes no real difference whether it's pure silver, debased silver, leather tokens, or dried cod – provided the state is willing to accept it in payment of taxes. Because whatever the state was willing to accept, for that reason, became currency." (Graeber 2011, 48). In addition, the stability of currency measurement is essential, "What matters is that there is a uniform system for measuring credits and debts, and this system remains stable over time." (Graeber 2011, 48). Therefore, overall, money needs to be acceptable to the government, needs to have a stable and uniform credit and debit measurement system, and needs to be trusted by members of society. By meeting these requirements, it can be considered as a highly fungible commodity while simultaneously being a debt device: "Thus money is almost always something hovering between a commodity and a debt-token. This is probably why coins – pieces of silver or gold that are already valuable commodities in themselves, but that being stamped with the emblem of a local political authority, became even more valuable – still sit in our heads as the quintessential form of money. They most perfectly straddle the divide that defines what money is in the first place." (Graeber 2011, 75).

So now that we have discussed what money is and its qualities, one may wonder how money comes into existence. It should be rather obvious in hindsight that its essential component, debt, can be created by anyone, since it is just a way of debt accounting. For a more in depth description of this idea, we again turn to "Debt: The First 5000 Years" and see that, "Money is credit, it can be brought into being by private contractual agreements (loans for instance). The state merely enforces the agreement and dictates legal terms. Hence Keynes' next dramatic assertion that banks create money, and that there is no intrinsic limit to their ability to do so: since however much they lend, the borrower will have no choice but to put the money back into some bank again, and thus, from the perspective of the banking system as a whole, the total number of debits and credits will always cancel out." (Graeber 2011, 54). So while anyone can create a debt, banks, specifically the Federal Reserve Banks for the USA, have the power of creating money, the accountable debt.

Now we'll turn to epistemology of debt and the closely related topic of obligations. So what is the difference between a debt and an obligation? From "Debt: The First 5000 Years", we get the following text:

> *"On one level the difference between an obligation and a debt is simple and obvious. A debt is the obligation to pay a certain sum of money. As a result, a debt, unlike any other form of obligation, can be precisely quantified. This allows debts to become simple, cold and impersonal – which, in turn, allows them to be transferable. If one owes a favor, or one's life, to another human being – it is owed to that person specifically. But if one owes forty thousand dollars at 12-percent interest, it doesn't really matter who the creditor is; neither does either of the two parties have to think much about what the other party needs, wants, is capable of doing – as they certainly would if what was owed was a favor, or respect, or gratitude. One does not need to calculate the human effects; one need only calculate principle, balances, penalties, and rates of interest. If you end up having to abandon your home and wander in other provinces, if your daughter ends up in a mining camp working as a prostitute, well, that's unfortunate, but incidental to the creditor. Money is money, and a deal's a deal."* (Graeber 2011, 13-14).

This concept plays a huge role in the financial crisis; this is because debts can be quantified, fragmented, bundled, traded, and/or sold, whereas obligations cannot since they are personal and non-transferable. "The difference between a 'debt' and a mere moral obligation is not the presence or absence of men with weapons who can enforce that obligation by seizing the debtor's possessions or threatening to break his legs. It is simply that a creditor has the means to specify, numerically, exactly how much the debtor owes." (Graeber 2011, 14) Therefore, "A debt is, by definition, a record, as well as a relation of trust." (Graeber 2011, 213)

So how does the concept of debt relate to the issue here in the housing market? Debt and its derivatives are used as the financial instruments to create the unsustainable dynamic in financial system. This all stems from the fact that debt is not an obligation, and can ultimately be bought and sold since it is quantifiable by the creditor. This is good and bad; it is good since it is transferrable and other investors can invest in your debt other than the direct people (your 1st connections) you know, but it is also bad for the same reason. It is impersonal, and major deviations from its original intentions can be created, and the common person – and even some investors – don't understand these financial debt innovations. From (Graeber 2011) we read that, "For years, everyone had been hearing of a whole host of new, ultra-sophisticated financial innovations: credit and commodity derivatives, collateralized mortgage obligation derivatives, hybrid securities, debt swaps, and so on. These new derivative markets were so incredibly sophisticated, that – according to one persistent story- a prominent investment house had to employ astrophysicists to run trading program so complex that even the financier couldn't begin to understand them." (Graeber 2011, 15) How did these new instruments affect the average household? How did investors stand to gain with these new instruments? "They consisted of operations like selling poor families mortgages crafted in such a way as to make eventual default inevitable; taking bets on how long it would take the holders to default; packaging mortgage and bet together and selling them to institutional investors (representing, perhaps, the mortgage-holders' retirement accounts) claiming that it would make money no matter what happened, and allow said investors to pass such packages around as if they were money; turning over responsibility for paying off the bet to a giant insurance conglomerate that, were it to sink beneath the weight of its resultant debt (which certainly would happen), would then have to be bailed out by taxpayers (as such conglomerates were indeed bailed out (Graeber 2011, 15-16) This scheme will be analyzed in detail in the chapters to follow and will show that the financial dynamic was not sustainable and could have been forecasted ahead of time by anyone with these available tools.

The economy is sustained by transactions of debt between one person and the next either with money or various debt instruments. If this were to all come to a stop the economy, by definition, would collapse. This actually happened to a certain extent in the housing crisis in 2008; the number of houses that were sold plummeted and the housing market part of the economy collapsed. This collapse will be analyzed from many different angles and use numerous tools to do so. Some of the questions that will be addressed are the following: Where do the rules need to be changed so that agents are incentivized properly? Are they at the bank level, origination level, investor level, investment banking level, or federal level? How does supply and demand influence the system? What are the dynamics between building and selling houses and their financial transactions? In reality, there are two separate but intimately related systems: the financial system and the physical system behind it, both of which will be related through the system dynamics model that follows. Also, how does the pricing, building more units, and the "fear of missing out" (FOMO) affect the outcome of the system? How do each of the incentives for agents or entities in the system affect the system's dynamics?

These questions about the system and resulting financial market collapse will be analyzed through the lens of Countrywide Financial because they were a very large part of the overall housing market, there is a plethora of data available for analysis, and the mortgages are not completely concentrated in one region, and therefore more representative of the whole US. This thesis will examine the background behind the crisis, the incentives of all stakeholders in the system, create a system dynamics housing model, a MBS pricing model, and put it all together as it relates to Countrywide Financial and their failure.

Chapter 2 will concentrate on the financial housing market system description, including the system boundaries for the analysis. It will also define the stakeholders and agents and their role in the system and see which incentives each type of agent had. This list and incentive structure will be used to construct a stakeholder value network (SVN) model. The SVN model will be analyzed to find conclusions and take aways that will be used in developing the system dynamics model in Chapter 5.

Chapter 3 will deal with MBS portfolio data provided by the Countrywide Financial Corporation at www.mortgageinvestorcountrywide.com. This chapter will show how the data was gathered, what type of data is available, and what data was utilized in the analysis.

Chapter 4 talks about the commercial and developed tools that will be used for the analysis in Chapters 5, 6 and 7. Some of the tools used were Vensim for system dynamics, Excel and MATLAB for the MBS pricing model, a developed MBS time lapse tool that is available online, and a developed MBS analysis tool that is also available online.

Chapter 5 will develop and discuss the system dynamics model for the housing market. This model will be instrumental in showing how the crash could have been forecasted before it occurred. It will make use of the concept of feedback, and the law of large numbers that is inherent in the assumptions behind all system dynamical models.

Chapter 6 will specifically introduce and elaborate on the existing MBS pricing models and their implications for all agents in the system. The models being used are the Public Securities Association (PSA) and standard default assumption (SDA) models. The author also created a very simple model for pricing securities using existing prepayment and default rates. The chapter will describe how the models came about and its usefulness in our context.

In Chapter 7 is where all of the concepts are brought together; the stakeholder value network is used to show the players and general flows that can be modeled, the system dynamics model is used to show housing market dynamics and the MBS pricing model is used to price the Countrywide Financial portfolio. Using these two models and other tools in concert will allow the presentation of market mispricings and extreme overvaluations.

In the last chapter, Chapter 8, conclusions are determined and recommendations are drawn. The current automobile market will also be briefly discussed due to being in a very similar situation to the 2007-2009 financial crisis in the housing market. Suggestions about architecting a better financial system are given along with potential future research topics.

Chapter 2: The Financial System for the Housing Market

"The credit boom began to unravel in early 2007 when problems surfaced with subprime mortgages--mortgages offered to less-creditworthy borrowers--and house prices in parts of the country began to fall. Mortgage delinquencies and defaults rose, and the downturn in house prices intensified, trends that continue today. Investors, stunned by losses on assets they had believed to be safe, began to pull back from a wide range of credit markets, and financial institutions--reeling from severe losses on mortgages and other loans--cut back their lending. The crisis deepened last September, when the failure or near-failure of several major financial firms caused many financial and credit markets to freeze up. Stock prices fell sharply as investors lost confidence in the financial sector and became gloomy about economic prospects. Declining stock values, a teetering financial system, and difficulties in obtaining credit triggered a remarkably rapid and deep contraction in global economic activity and employment, a contraction that has persisted through the first months of 2009."

-Ben Bernanke, Federal Reserve Bank Chairman Ben Bernanke, Morehouse College, Atlanta, Georgia, April 14, 2009 (Bernanke 2009)

In this chapter we will do two essential things: define the scope of the financial system being analyzed in this thesis and define the key stakeholders within the scope. Defining the system boundary is essential in all systems-level analyses and should be performed at the initial stage of examination and can be repeated if new elements are needed to be added to the system. We define the system boundary in order to lower the degrees of freedom required to understand the central issues at hand. Before defining the system boundary, the elements inside the system should be understood and defined. In our case, the stakeholders and players in the housing market and financial industry will be defined and examples given on how they interact with the system. These are shown below in Table 2.1, only some of which will be considered inside the system's boundary and analyzed.

Stakeholder or Player	Description	Relation to Housing Market
Homeowners	Agents that own homes or buy homes	These are the agents that have the underlying need for housing
Real estate agents	Agents that facilitate the sale of homes	These agents are instrumental in being the intermediary between the buyer and seller of the house
Local, regional, and national banks	Entities that finance the construction or sale of a home. Assume that these banks only originate the home loans and do not securitize them	These entities finance the purchase of the houses by the homeowners
MBS investors	Entities that invest in MBSs	The MBS investors take the MBS off the banks' balance sheets and take on the risk of default or prepayment
Insurance companies	Entities that insure the potential for losses in the MBS market on some level	The insurance companies insure the banks against losses due to prepayments and defaults
Ratings agencies	Entities that assign a rating to each MBS or pool or portfolio of assets/liabilities	The ratings agencies assign levels of risk of default or prepayment for MBSs
Investment banks	Entities that sell pools of assets or securities, including MBSs	The investment banks are charged with selling the MBSs to other investors
Hedge funds	Entities that make bets on the directionality of markets, companies, and assets	Hedge funds are some of the entities that could purchase MBS or other financial instruments related to the housing market
Home builder companies	Entities that build houses with materials given by their suppliers and funded by homeowners (typically through banks)	These entities build the raw stock of houses
Homebuilder suppliers	Entities that supply various types of materials required	These entities supply material to the home

	to build houses	builders to build the houses
Federal Reserve Bank	This set of banks sets the rates of interest between their banks and other banks	Cheap money regimes given by the Federal Reserve Bank allowed homeowners to finance their house purchase cheaply or get a larger house than normally available
Government Sponsored Enterprises (Ginnie Mae, Fannie Mae and Freddy Mac)	Federal entities charged with supporting the housing market using federal money	Entities that buy and securitize mortgages

Table 2.1- Stakeholder, description, and relation to housing market

Now that the stakeholders and players have been identified, we shall discuss each one of them in depth to understand their perspectives and incentives in regards to the housing market. The reason this is important is twofold: it allows for the reader to understand underlying needs and incentives for the players and then ultimately for the SVN to be created. The SVN is an extremely useful tool that allows a high-level picture of the incentive structure inside the system boundaries. The incentive structure between agents and entities in the system is what causes transactions to occur, and therefore the system dynamics. If one can understand the dynamics at a high level, prediction is possible, which is the goal of this thesis.

There are three players that are in the housing market that are related due to the fact that they deal with the physical housing stock- the homeowner, the home builder, and the home builder suppliers. The rest of the market outside the physical system related to housing is the financial system related to housing and will be covered subsequently. The first obvious stakeholder in the physical system is the homeowner. The homeowner is at the center of the housing market since people have the primitive need for shelter; this allows this market to exist in the first place. At a basic level, people who are housed are either in an apartment or in a house. If they are in a house, many of them elect to mortgage their house since they do not have the funds to pay for it with cash. For this particular analysis renters will not be considered explicitly except in determining the overall percentage of homeowners. From here on out in this thesis, we will call the potential homeowner or homeowner one in the same, except as otherwise noted. Also, the homeowner will be agent who is either looking to purchase an existing home available in the market, or a brand new house not yet created. In addition, we will not explicitly distinguish between a true homeowner and a house "flipper", or an investor that is looking to purchase existing physical housing stock, upgrade it, and sell it at a premium. We will assume that the percentage of flippers is much smaller than the number of true homeowners. House flippers do add to homeowner liquidity, since they are both buyers and sellers but do not appreciably affect the dynamics assuming enough buyers and sellers are in the market.

The next stakeholder is the home builder. They are intimately related to the number of homeowners. If there are a positive amount of people who desire to be homeowners who are fundable by a bank, houses will be built by the home builder. Also, old housing stock is occasionally knocked down and a new house is built in its place. This net number of houses built will be considered for the analysis and will not be further broken down into its constituents. The home builder will take the materials from the materials suppliers and with the home builders' labor, will create the stock of houses represented in the US data. Also for the analysis, any subcontractors that are used to build houses will be combined with the homebuilder to be considered as one entity.

In terms of the physical materials needed for the housing market, we have the material suppliers representing this. They supply all of the materials that are needed to make any type of house. Any item that will eventually be paid for during the transaction with the homeowner through the home builder will be considered by this set of agents or entities. Some example material suppliers would be the timber, stone, shingle, concrete, electrical, and pipe suppliers. We will not consider any other effects past these suppliers, like how they make or process their materials, or even where they get them from. These are all unquestionably outside the system boundary since their effects would only be felt through the supply chain on short time scales.

The last group of players that are related to the physical transaction of the house with the homeowner and the previous homeowners are the middlemen, the real estate agents. They are important to reduce the 'friction' of the housing market. There are buy-side real estate agents, and sell-side real estate agents, usually called buyer agents and listing agents (Caruthers 2014). The buy-side agents are there to help the homeowner-to-be find a suitable house, and the sell-side agents are there to find buyers for their clients, the current house's homeowner. The two agents typically split the fee in some fashion at the conclusion of the transaction, and is normally 5-8% of the overall transaction cost. (Pollock 2013) These agents are important to keep the number of transactions growing and the housing market liquid; in this analysis we will assume that the market is sufficiently supplied with real estate agents to enable a liquid market.

Now we will move on to the non-physical related financial players in the housing market. Their jobs are to take on risks and move around money in space and time to the players that need it. Let's start with the entities who lend the money to the homeowner to be able to purchase the house in the first place, the banks. These are typically local, regional, and national banks that originate the loans. This essentially means that they have the cash on their balance sheet and can obligate this cash towards home acquisitions (either built or purchase existing housing stock). In exchange for this cash obligation to the homeowner, the bank creates a mortgage, which is a debt instrument specifically associated with the house. "In simple terms, a mortgage is a loan in which your house functions as the collateral. The bank or mortgage lender loans you a large chunk of money (typically 80 percent of the price of the home), which you must pay back -- with interest -- over a set period of time. If you fail to pay back the loan, the lender can take your home through a legal process known as foreclosure." (Obringer and Roos 2015). This mortgage deed is given to the homeowner along with the cash for the house. A diagram depicting the transaction with another homeowner can be seen in Figure 2.1, and it looks essentially the same in the case of a home builder, where the home builder would take the place of the seller. It will be assumed that these banks have the mortgages on their balance sheets until they are securitized inside a separate sub-company and sold to the sub-company or the mortgages themselves are sold directly. The lowered standards of these mortgages will also be scrutinized further in Chapter 3.

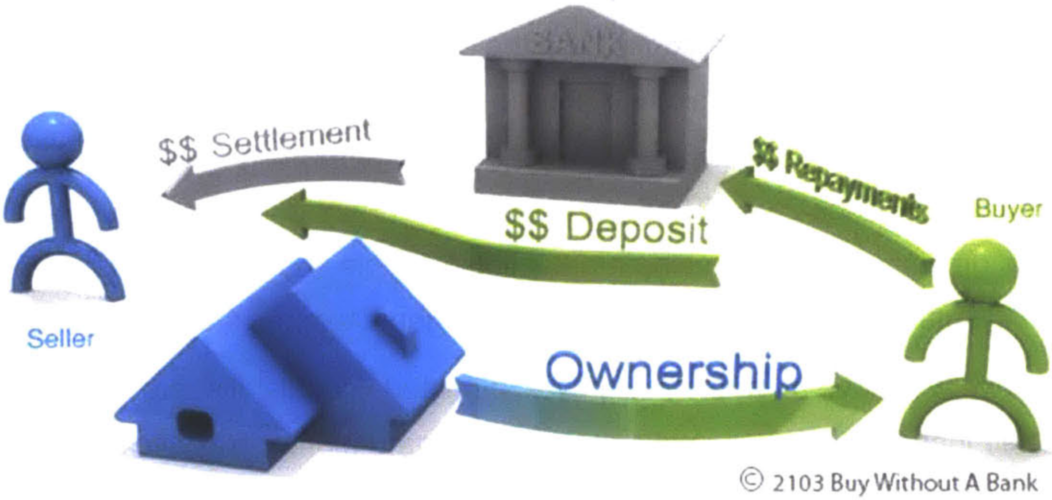

Figure 2.1- How mortgages work (Page 2015)

The next strictly financial players in the housing market are the investment banks. They are very important to making the market for MBSs; they are in constant discussion with various investors who are looking for different levels risk for their portfolios. On the other side of this trade are the banks, including our bank under scrutiny, Countrywide Financial. Some examples of investment banks that were MBS market makers during this time are Goldman Sachs, Morgan Stanley, and Lehman Brothers. (Tradeweb 2002) These banks gets lots of attention, but as we will see they don't play as big of a role in the system as many people believe, as they just connect the buyers-investors- and sellers- banks or mortgage originators- of the MBSs.

Another group of strictly financial players in the housing market are the MBS investors. These entities can be anyone and can range from individuals to boutique financial firms and hedge funds. To get an idea of how much money is required to invest in these mortgage pools, we see from (FINRA 2015) that the minimum investment is typically $10,000. This is out of the range of many in the general public, but within the range of wealthy individuals, banks, hedge funds, and many others in the financial sector. We will consider all of these types of entities as MBS investors without getting into much detail on the breakout or individual makeup of various investors.

One specific type of MBS investors, namely hedge funds, were important in buying many of the financial products created by the banks and insurance companies, like pass through MBSs, CMOs, and CDOs. They wanted very specific slivers of the risk spectrum and this is where investment banks came in to find out specific requirements and help the hedge funds and others financially engineer their portfolios. They also got deeply into the contracts behind the MBSs to make sure they were getting the ROI they desired, along with their perceived risks.

Another instrumental entity type were the ratings agencies which gave their stamp of approval to rating the MBSs and other types of asset classes. Subsequently they were found to be fudging the ratings in order to have a higher throughput of assets that were rated (White 2010). This is all because there were perverse incentives: the rating agencies were paid upon rating. The more ratings that were done, the more throughput there was. Therefore, the ratings agencies were calling up the banks and giving them a better rating than they might have deserved to induce them to do business with them. This would allow the banks to unload the MBSs easier, since many funds could only invest in top rated securities. This caused mispricings in the market in addition to higher volume of MBS deals. This will be essential to include in our system dynamics model later in Chapter 5.

Yet another type of entity from the table above are the insurance comThe insurance companies were being used by sophisticated investors and hedge funds in order to hedge their bets on MBS losses. Many of the insurance companies didn't really even look at their insurance contracts they were writing to see if they made financial sense. Because of their mismanagement, the insurance companies didn't have the capability of paying their contracts if losses were seen in the housing market. This means that they would be forced to default, which would be disastrous for the rest of the financial system even outside the housing market. In the case of American International Group (AIG)- a trillion dollar asset company- since the rating agencies didn't see this issue until after the fact, they gave all of the insurance instruments AAA credit ratings because they were backed by AIG as a whole (Moore 2008). We will see later that these entities are important for taking the default risks off the MBS in order for the other investors to purchase the remainder of the MBS. This allowed other players to leverage up even further due to the reduction the perceived risk.

The last stakeholder entity from Table 2.1 Federal Reserve Bank (FRB). This bank determines the rate of interest charged between the Federal Reserve Bank system and other banks, also known as the discount rate. “The discount rate is the interest rate charged to commercial banks and other depository institutions on loans they receive from their regional Federal Reserve Bank's lending facility--the discount window.” (FRB 2015). In this time period, the rate of interest was set very low in order to stimulate growth in the economy. This permitted more and bigger houses to be built than were possible in times with higher interest rates, which created a period of higher growth in the housing market. One could say that in general the lower interest rates triggered the housing boom in the past, as shown in Figure 2.2. Therefore the FRB determines the interest rate which drives real decisions to buy houses, whether they are built or exchanged between homeowners.

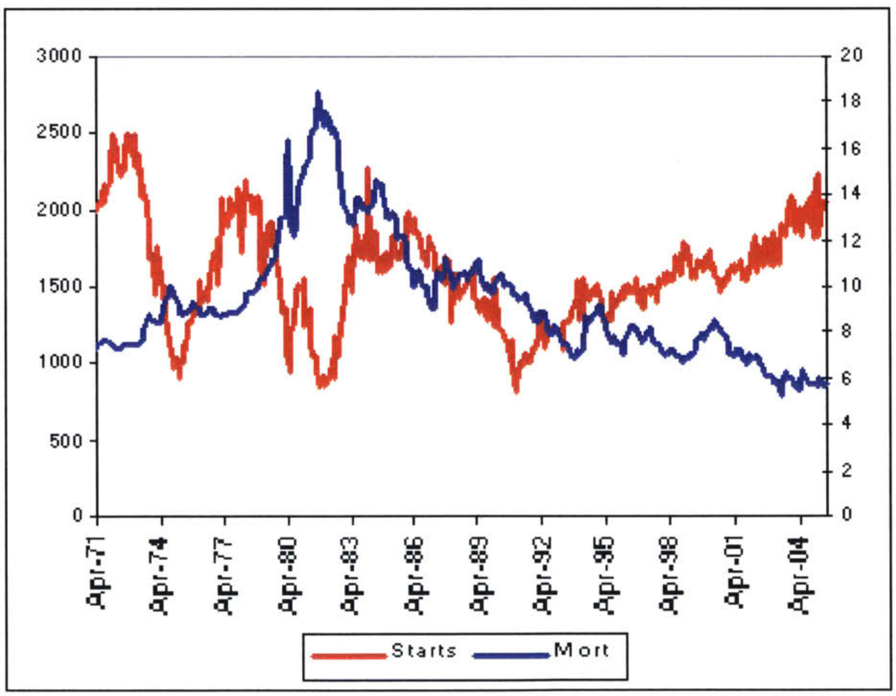

Figure 2.2- Housing starts vs. mortgage rates, housing starts on the left axis, interest rate % on the right axis (Thoma 2005)

After identifying the stakeholders and players in the system, let’s discuss what will be included in the system, and therefore the system boundary. Many times it is more instructive to show what *is not* in the system at first in order to make clear what *is* in the system. We will do that in this case. For our system, we will not consider the broader economy nor the part of the financial system not directly related to housing. Even though many things are connected in the true economic and financial network, it is a good first order approximation to assume that some things are not inside our system's boundaries. For instance, there is no clear relation between the electronics industry and housing, and therefore the electronics industry is excluded from the analysis. This does not mean that in actuality that there is no connection – such as with a new house and its HVAC system that contains electronics – it just means that the correlations are not high and the effects are not large. Therefore with this assumption in mind, the system boundary along with key stakeholders is shown below in Figure 2.3. Also, a few players that at first glance could be considered inside the system boundary but are not, are shown outside the dashed line. Although potentially debatable, we will assume that any effects that come from outside the system boundary are small and can be assumed to play a negligible role in the analysis and outcome. From the boundary in the figure below, we see that the entities such as other financial firms not involved with the housing market, other construction companies, and other material suppliers are not included in this analysis. Also, other countries' financial systems are not used in this analysis, as only the US housing market will be examined.

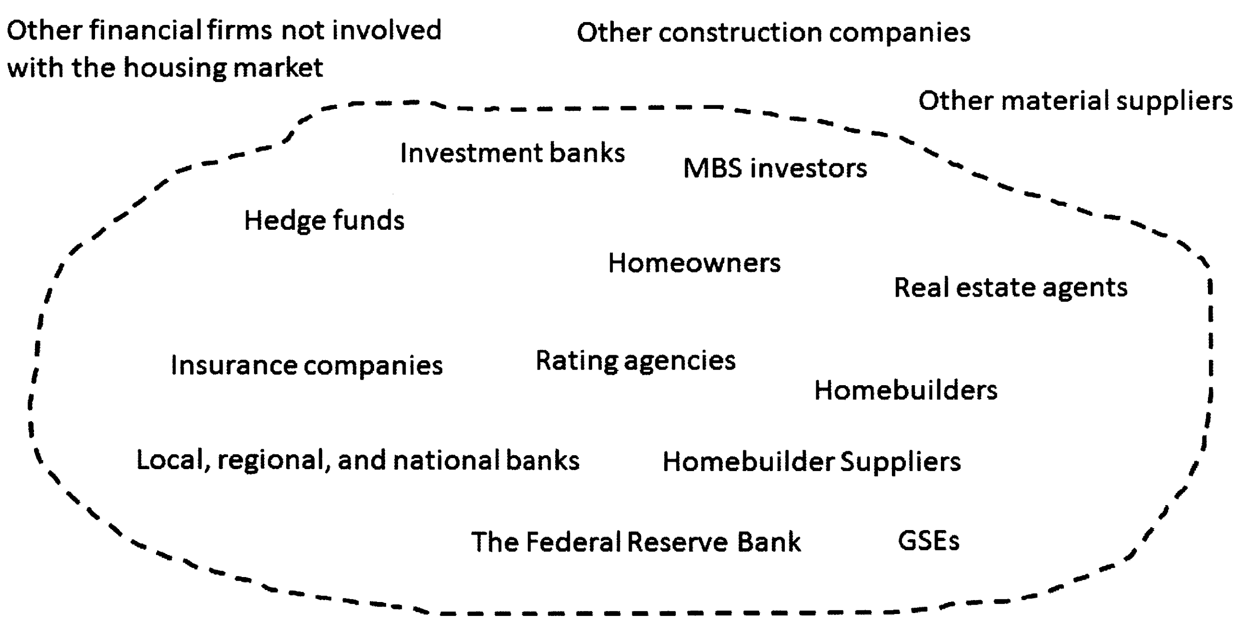

Figure 2.3- System boundary used for analysis

An analysis of the incentive structure for each of the agents in the system is required to see how the dynamics will play out over the long term. We will now examine each actor and their needs in depth. The table below shows the stakeholder or player, their underlying need, and the potential incentives that influence the stakeholder. Many of the needs are monetary, like wages or commission, or high return on investments (ROI) that investors desire. The only true player besides the Federal Reserve Bank with an explicit non-monetary need is the homeowner; this is true since the homeowner needs a physical place to live, whereas the other players are in it to make a living, an investment, or to hedge bets. The Federal Reserve Bank needs to make a return, but additionally has the rest of the financial system to be concerned with.

Stakeholder or Player	**Underlying Need**	**Potential Incentives Influencing Stakeholder/ Business Model**
Homeowners	Desire for a place to live that they can call their own	Cheaper house, better financing, better subjective qualities in a house
Real estate agents	Make a living, help people find a house they like	Commission per transaction
Local, regional, and national banks	Make a good ROI on the money that was invested with them	Interest on loans while keeping risk low; more loans, more money
MBS investors	Make a good ROI on money for investors	Depends on investor and type of risk taken in MBS, but typically very similar to a loan with interest
Insurance companies	Make money by charging a premium to risks spread out to many policy holders	Many policies, more profit/ push as many policies as possible
Ratings agencies	Make a living by selling ratings for money	Sales based on # of transactions (throughput)
Investment banks	Make a living by charging for connecting buyers (investors) and sellers (banks) of MBSs	Sales based on # of transactions
Hedge funds	Make a good ROI on money for investors while (typically) taking least risk (hedging)	Depends, but typically take on options on MBSs, or potentially risky portions of MBSs
Home builder companies	Make a living by marketing and selling house for a profit	Sales based on # of houses built and sold

Homebuilder suppliers	Make a living by transforming raw materials into building supply materials and selling to home builders	Sales based on # of materials transactions
Federal Reserve Bank	"...maximum employment, stable prices and moderate long-term interest rates." (FRB- Chicago 2015)	Make money while keeping markets and economy stable
Government Sponsored Enterprises (Ginnie Mae, Fannie Mae and Freddy Mac)	Finance mortgages for the American public, including low to medium income people	"The initial annual goal for low-income and moderate-income mortgage purchases for each GSE was 30% of the total number of dwelling units financed by mortgage purchases and increased to 55% by 2007" (Wallison 2012)

Table 2.2- Underlying needs and incentives or business models

Now that we have discussed the entities that will and will not be included in the system we can move on to the SVN. The purpose of the SVN is to determine the network between the entities in the system and what flows between them. There are many different types of flows such as money, knowledge and information, financial instrument contracts such as mortgages or insurance contracts, building materials, labor, homes, policies, and completed homes. We will merge all of these flows into 3 main types of flows: information, money, and material. In addition, they are labeled with the more specific tag, as discussed above. The other legend gives the type of entity, whether it is the homeowner, a physical goods entity, financial entity, or a government/other type of entity. These flows between the entities and the type of entity are shown in the legends in the figure below.

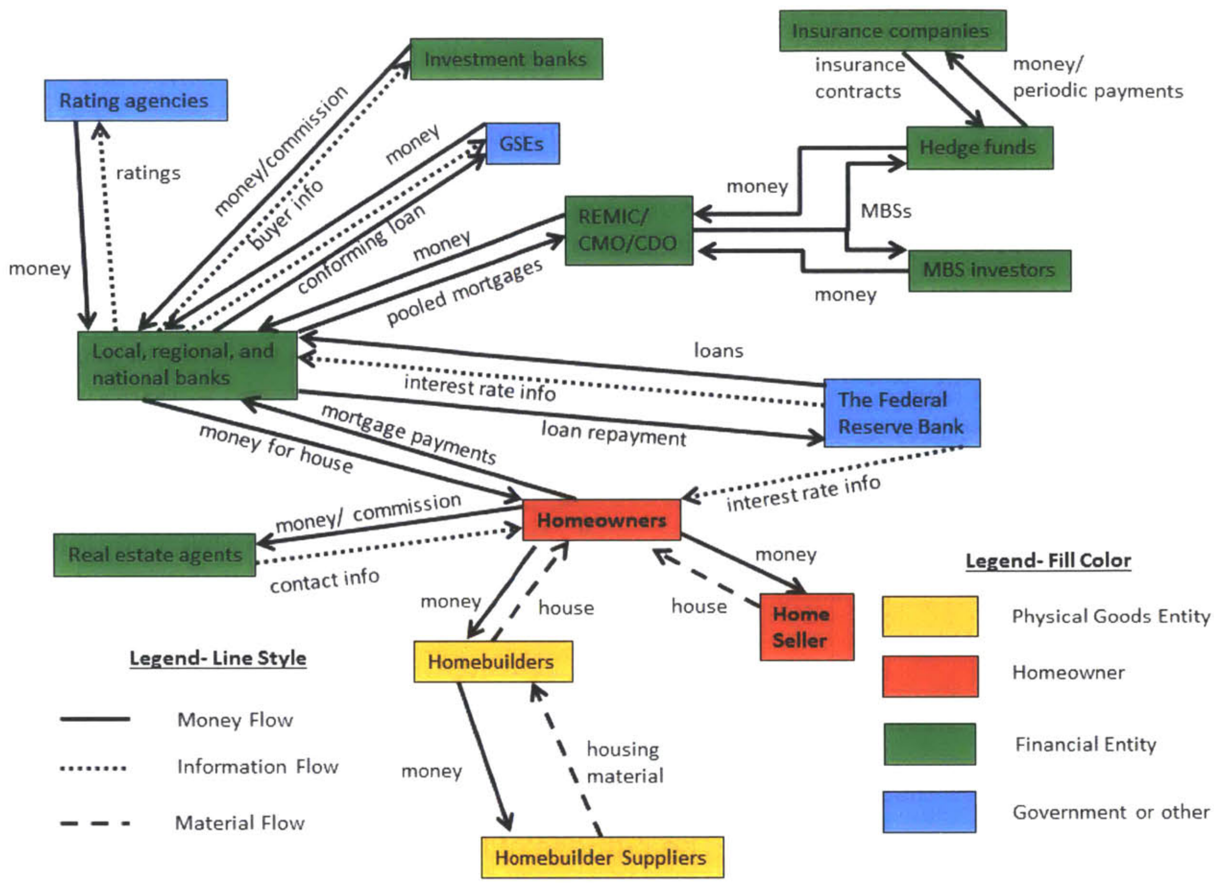

Figure 2.4- Stakeholder value network (SVN) model

After examining the SVN above one can see that there are many flows between the players, many of them being money and various types of information flows. From the figure, we can see that the housing market is relatively cluttered, but not too hard to comprehend at the stakeholder level. Let's first understand the coloring for the type of stakeholder. Then we can go through each of the arrows to understand their meaning. With these two types of information being conveyed, namely the type of entity, and type of flow, we can start to create a framework for what should be included in a stock and flow diagram, which will be discussed in Chapter 5.

The color on the diagram indicates what type of entity the box represents, with orange being entities exchanging physical goods, red meaning the new homeowner or the home seller, green being any type of financial-only entity, and finally light blue representing the government or any other type of entity. The arrow type indicates what type of flow is occurring between the entities and has a more descriptive tag attached to each arrow. There are only two material flows in the diagram: one from the material suppliers to the home builders, and the other from the home builders to the homeowner. For existing homes, a third material flow can be considered going from the home seller to the home buyer, or homeowner, in the diagram. One observation that can be made from the diagram is that financial entities only deal with exchanges of money or information. The monetary exchanges can be exchanges over time, like loans, or can be exchanges to get information from other entities, like investment banks receiving a commission from banks to find sellers of their loan portfolios. Clearly, the physical goods entities only deal with home building materials and money. The two pseudo-government entities, the GSEs and the Federal Reserve Bank, both have informational flows and monetary flows. The GSEs collect loan information from the bank regarding conforming mortgages that were made. It should be noted that the US government regulated the GSEs and there was an implicit guarantee for MBSs bought and securitized by these entities. So in the event of a default, the taxpayer would have to fund these entities directly with flows of money from outside our system's boundaries. If they decide to buy them for securitization, the banks will get paid. As for the Federal Reserve Bank, it sends out monetary policy and interest rate signals to the market, which are heard by everyone, but in particular the homeowner and banks are most interested. The Federal Reserve Bank also originates low interest rate loans, or debt, with banks. The last entities in light blue are the ratings agencies which rate securities and assets in return for a payment.

Now let's move on to understanding a typical MBS deal that was done. In understanding the players in this deal, we can better understand the issues for modeling later on. Figure 2.5 shows how the players are linked in the deal, along with how the typical MBS was broken into tranches of Senior- AAA, Subordinate, and the Residual.

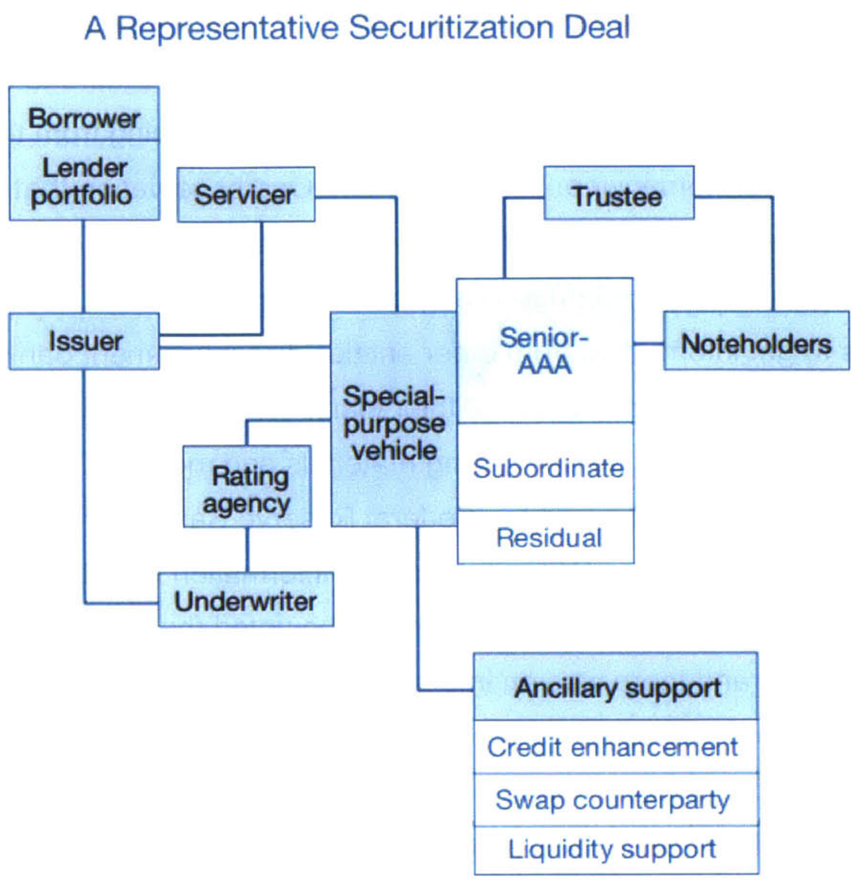

Figure 2.5- A representative securitization deal, as described by the FRB (Cetorelli, and Peristiani 2012)

So who are all of these players? There are 6 key roles in creating a MBS: the issuer, servicer, trustee, rating agency, underwriter, and noteholders, and the principal Special Purpose Vehicle (SPV) entity. These 6 roles are essential to keeping all parties at "arm's length" with one another. Instead of doing these 6 roles injustices, we will refer to the New York Federal Reserve Bank's exceptionally through description of these roles:

> *"The issuer (sometimes referred to as sponsor or originator) brings together the collateral assets for the asset-backed security. Issuers are often the loan originators of the portfolio of securitized assets because structured finance offers a convenient outlet for financial firms like banks, finance companies, and mortgage companies to sell their assets.*

In the basic example of securitization represented in the exhibit, all of these assets are pooled together and sold to an external legal entity, often referred to as a special-purpose vehicle. The SPV buys the assets from the issuer with funds raised from the buyers of the security tranches issued by the SPV. The transfer of the assets to the SPV has the legal implication of obtaining a true sale opinion that removes issuer ownership and insulates asset-backed investors in the event of an issuer bankruptcy. The SPV often transfers the assets to another special-purpose entity—typically a trust. This second entity actually issues the security shares backed by those assets under GAAP sale rules outlined in the Financial Accounting Standards Board's Statement No. 125.

Another important role in the securitization process is performed by the servicer, the party responsible for processing payments and interacting with borrowers, implementing the collection measures prescribed by the pooling and servicing agreements and, if needed, liquidating the collateral in the event of default. In cases in which the issuer is also the lender of the underlying assets, there is a greater likelihood that the issuer would retain these servicing rights.

In addition to managing payment flows, servicers are expected to provide administrative help to the trustee. The trustee is an independent firm with the fiduciary responsibility for managing the SPV/trust and representing the rights of the investors (that is, the noteholders). The primary role of the trustee is to disperse payments to investors and to oversee the security on behalf of the investors by collecting information from the servicer and issuer while validating the performance of the underlying collateral.

The role of underwriters in structured finance is similar to that in other methods of securities issuance. Asset-backed security underwriters fulfill traditional arranger roles of representing the issuer (here, the SPV or trust). The primary job of the underwriter is to analyze investor demand and design the structure of the security tranches accordingly…

Working closely with the rating agencies, the underwriter helps design the *tranche structure of the SPV to accommodate investors' risk preferences. Under the guidance of rating agencies, the expected cash flows from securitized assets are redirected by the underwriter into multiple tranches. The rating agencies played a critical role in the rapid growth of structured finance in the United States over the past two decades. Rating agencies provide certification services to investors who need to carry out a due-diligence investigation of the underlying assets and evaluate the structure of the security. Ratings are necessary because many large institutional investors and regulated financial firms are required to hold mostly investment-grade assets."* (Cetorelli, and Peristiani 2012).

Chapter 3: Countrywide Financial and Corresponding MBS Data

"Errors using inadequate data are much less than those using no data at all."

-Charles Babbage, father of the computer (BrainyQuote 2015).

"Without big data, you are blind and deaf in the middle of a freeway."

-Geoffrey Moore, author of Crossing the Chasm (AZQuotes 2015).

"Information is the oil of the 21st century, and analytics is the combustion engine."

-Peter Sondergaard, Gartner Research (Pettey 2011)

In this chapter, we will discuss the state of Countrywide Financial leading up to the 2007-2009 financial crisis along with associated relevant firms and their interactions. We will then identify the main players in the market and discuss money flows across the housing market in relation to Countrywide Financial. Then we will incorporate large amounts of data into the discussion that is available through the Countrywide Financial investor website, www.mortgageinvestorcountrywide.com. We will also show what type of data is available on the website, what data was gathered, how the data was gathered, and the process behind transforming the data to something useable for our purposes.

So where does the Countrywide Financial story start? We can say that it officially started in 1968 with the first guarantee of a pass through security by Ginnie Mae (US 106 Stat. 3941 1992). In addition, "...In 1971 Freddie Mac issued its first mortgage passthrough, called a participation certificate, composed primarily of private mortgages." (US 106 Stat. 3941 1992). Also, "In 1981, Fannie Mae issued its first mortgage passthrough and called it a mortgage-backed security." (US 106 Stat. 3941 1992). So by 1981, all three major GSEs were set up and issuing MBSs. In 1992, the Housing and Community Development Act was passed with the intent to "... have an affirmative obligation to facilitate the financing of affordable housing for low- and moderate-income families in a manner consistent with their overall public purposes, while maintaining a strong financial condition and a reasonable economic return." (US 106 Stat. 3941 1992). Furthermore, "The initial annual goal for low-income and moderate-income mortgage purchases for each GSE was 30% of the total number of dwelling units financed by mortgage purchases and increased to 55% by 2007." (US 106 Stat. 3941 1992). This meant that now the GSEs were required by law to spend 30-55% of their budget on low to moderate income families instead of the lower risk, upper class mortgages. Moreover, "...In 1999, Fannie Mae came under pressure from the Clinton administration to expand mortgage loans to low and moderate income borrowers by increasing the ratios of their loan portfolios in distressed inner city areas designated [originally] in the Community Reinvestment Act (CRA) of 1977. Additionally, institutions in the primary mortgage market pressed Fannie Mae to ease credit requirements on the mortgages it was willing to purchase, enabling them to make loans to subprime borrowers at interest rates higher than conventional loans." (US 106 Stat. 3941 1992). This increase in loans made to low and moderate homeowners and the easing of loan requirements enabled a boom in the subprime mortgage market. "In 2000, because of a re-assessment of the housing market by HUD, anti-predatory lending rules were put into place that disallowed risky, high-cost loans from being credited toward affordable housing goals. In 2004, these rules were dropped and high-risk loans were again counted toward affordable housing goals." (US 106 Stat. 3941 1992). Once these rules were dropped, this opened the floodgates for the GSEs to once again make numerous loans to underqualified, ignorant borrowers.

Why was all of this talk about mortgage securitization and GSEs important? It was important since for the first time, the banks that originated the home loans to the homeowner could now rid themselves of loans on their balance sheets, making room to make more transactions. This allowed for the banks to, for the first time, create a positive feedback cycle in the mortgage market. What this means is that since the banks used to originate the loans and keep them for the life of them, they couldn't make new loans unless they had additional invested capital or reinvested profits, which was a relatively slow process. With this new dynamic, the local, regional, and large national banks could sell these assets to investors through MBSs thereby allowing them to originate more loans and continue the cycle. Over many years, this growth in pass-through securities (Figure 3.1 below) would alter the housing market dynamic. Also, their incentives changed since they no longer had to hold onto the mortgages. They could now take on whatever mortgages the investors would invest in, including subprime borrowers, without worrying they would be stuck with a defaulting homeowner. This incentivized them to make as many loans as possible. After the loan was made, it could then be sold to a GSE to finance its next loan origination.

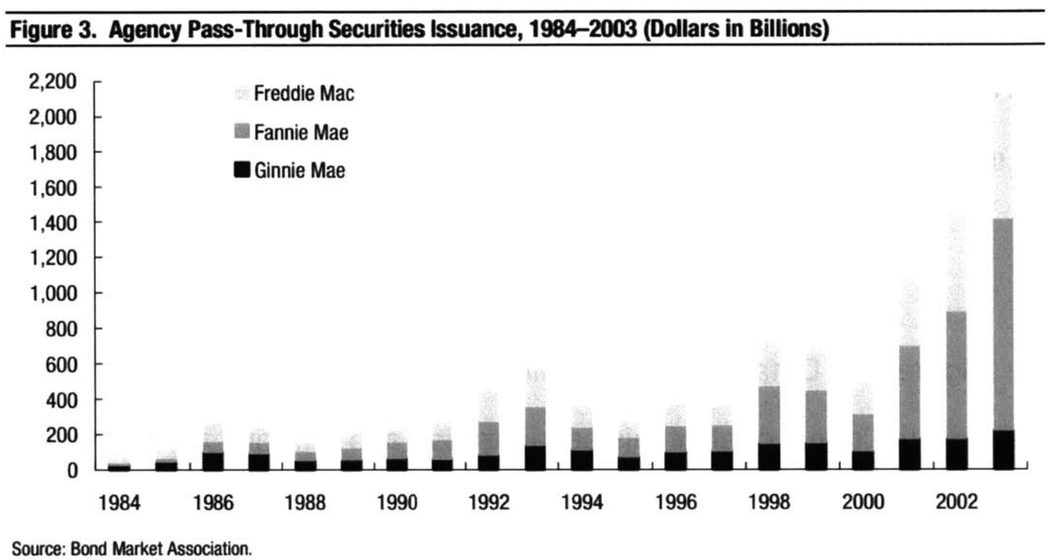

Figure 3.1- Growth of pass through securities (Hayre and Young 2004).

How about the laws and regulations changing? This had a huge impact on who could obtain a mortgage. Due to the fact that the government would take on more mortgages from low income and bad credit people, the standards from the banks were lowered systematically over the years. The creation of the GSEs to absorb any qualifying mortgages allowed the banks to originate many more subprime loans than usual even knowing that they had a high default probability. To add to the problem, not only could you now get a loan with lower required credit scores, but in 2006-2007 you could even get a loan with no money down payment! (Robertson 2015). Basically you could get a loan "as long as you had a heartbeat (and sometimes that was optional) there was a mortgage program available for you..." (McCall 2009). Because the standards were lowered and the amount of down payment that was required plummeted, there was a much higher risk of default. Default was not typically a large part of any MBS model at the time, as prepayments dominated these models, as shown in a Citigroup model below.

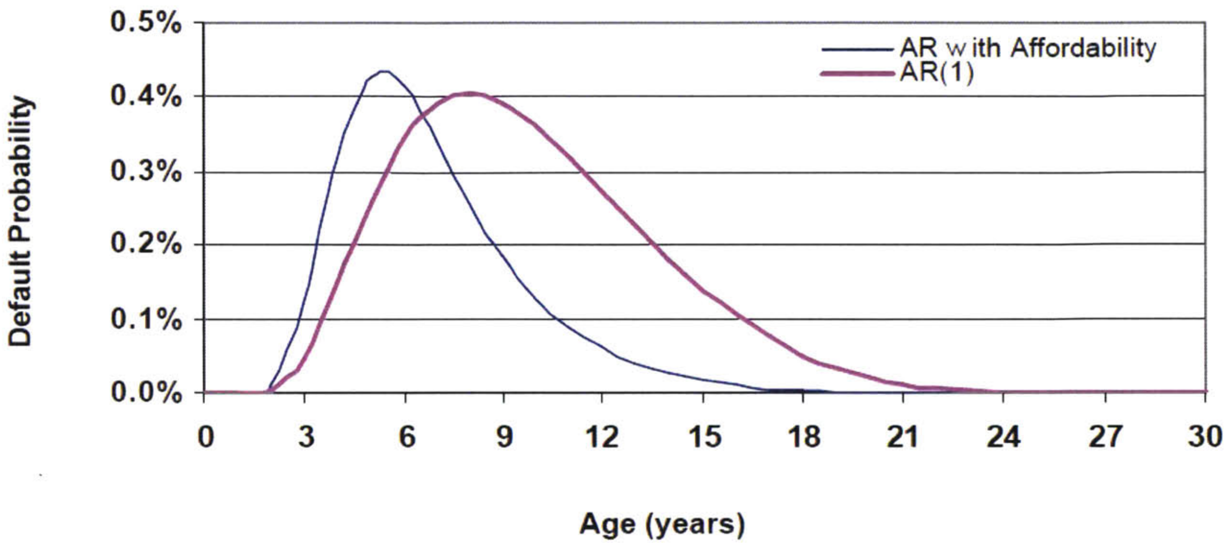

Figure 3.2- Default model for Citigroup circa 2006 (Hayre 2006)

What was the result of all of this securitization and lowering the mortgage standards? One measure is the number of transactions for new homes and amount of money available for borrowers skyrocketed. This can be seen in Figure 3.3 below. Just the number of new houses purchased about doubled from 676k in 1988 to 1.283M in 2005. The amount of money that went towards this new housing stock went from $93.49B in 1988 to $381.05B in 2005 (US Census Bureau 2015).

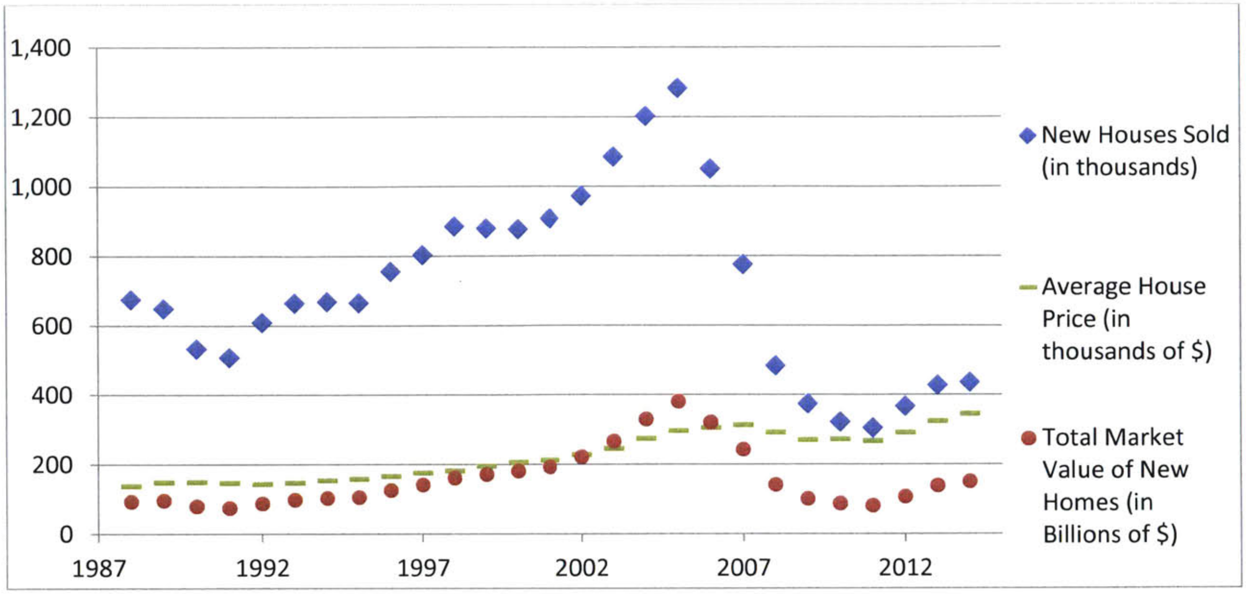

Figure 3.3- Number and market value of new home purchases

Now that we have established the history of the financing for the housing market, we can turn to the company at hand, Countrywide Financial. Why was this particular company representative and important to the system? "Countrywide, which was purchased by Bank of America in mid-2008, still managed to sell $86 billion in mortgages to Fannie that year... Fannie Mae purchased a total of $631 billion in mortgages from all of its seller/servicers in 2008..." (Robertson 2009). Quickly doing the math, we see that Countrywide Financial sold 13.6% of all Fannie Mae purchased mortgages in 2008. As you can see, this is an enormous sum of money and a large percentage of mortgages in the securitization market. Therefore, we can make the assumption that Countrywide Financial can be used as a fairly decent proxy for the overall market given their size and breadth of mortgages in their portfolio, which will be shown shortly.

Luckily, through the www.mortgageinvestorcountrywide.com website, we can peak behind the data curtain to see some of the types of mortgages that were included in these MBSs every year since 1998. The next step is to briefly go through how to use the website to collect the MBS housing data. We will also see what types of data are available and what was gathered. Then we will show how the data was transformed to something usable in this thesis. We will conclude with a synopsis of the data used in the analysis in Chapter 7.

In order to examine any data on the website, sign up is required. After signing up on the website, one can see deals that were done and all of the data behind them. The whole deal book for all of the Countrywide Financial deals can be found on the website. A snapshot of the first few deals in the deal book is shown below in Figure 3.4. In this figure, it shows the tranche, the ID of the deal, the type of collateral, and the underwriter. Even as far back as 1998-2001 period, many of the asset backed securities being sold were subprime. Since there are numerous large and well known underwriters, we can assume that many entities had explicit knowledge of the housing market and were vying to get a piece of the securitization pie. In terms of the data that will be used in this thesis, the period from 2006-2007 will be the focal point. This is due to the fact that before this time, many of the mortgages and MBS that were originated at Countrywide Financial or purchased by Countrywide Financial were more than likely securitized or sold to other investors. It is only during this period of 2006-2007 where the mortgages start accumulating on the balance sheet and eventually in August 2007 the MBS secondary market becomes illiquid and the assets are not able to be sold. Therefore only deals from 2006 and 2007 will be downloaded, analyzed, and conclusions using them, synthesized.

Series / Tranche	ID	Collateral	Underwriter
Countrywide ABS 1998-2	CWL 1998-2	Subprime	Prudential
Countrywide ABS 1998-3	CWL 1998-3	Subprime	Prudential
Countrywide ABS 1999-01	CWL 1999-1	Subprime	Prudential
Countrywide ABS 1999-02	CWL 1999-2	Subprime	Lehman Brothers
Countrywide ABS 1999-03	CWL 1999-3	Subprime	Lehman Brothers
Countrywide ABS 1999-04	CWL 1999-4	Subprime	RBS
Countrywide ABS 2000-01	CWL 2000-1	Subprime	Countrywide Home Loans
Countrywide ABS 2000-02	CWL 2000-2	Subprime	Bear Stearns & Co. Inc.
Countrywide ABS 2000-04	CWL 2000-4	Subprime	RBS
Countrywide ABS 2001-01	CWL 2001-1	Subprime	Countrywide Home Loans
Countrywide ABS 2001-02	CWL 2001-2	Subprime	Countrywide Home Loans, J.P. Morgan Chase
Countrywide ABS 2001-03	CWL 2001-3	Subprime	Countrywide Home Loans
Countrywide ABS 2001-04	CWL 2001-4	Subprime	Bank of America
Countrywide ABS 2001-BC1	CWL 2001-BC1	Subprime	Countrywide Home Loans
Countrywide ABS 2001-BC2	CWL 2001-BC2	Subprime	J.P. Morgan Chase, Countrywide Home Loans
Countrywide ABS 2001-BC3	CWL 2001-BC3	Subprime	RBS

Figure 3.4- Snapshot of Countrywide Financial Deal Book

Chapter 4: Tools Utilized

"I think it's fair to say that personal computers have become the most empowering tool we've ever created. They're tools of communication, they're tools of creativity, and they can be shaped by their user."

-Bill Gates, (BrainyQuote 2015)

"Technology is nothing. What's important is that you have a faith in people, that they're basically good and smart, and if you give them tools, they'll do wonderful things with them."

-Steve Jobs, (BrainyQuote 2015)

In this brief chapter we will discuss tools that will be used in the analysis in the coming chapters. For system dynamics we have Vensim, for the MBS pricing model we are using MATLAB, and for visualization we will be using Javascript/HTML/CSS. These tools all existed during the financial crash of 2007-2009, so they would have been available to use towards this thesis. Why are these tools being used and not other similar tools? For Vensim, an alternative is MATLAB, but Vensim was specifically created to help solve system dynamics problems such as this one; it is very simple to put down stocks and flows and visualize the results in just a few clicks. Also, it is simple to explicitly leave all other variables outside of the system boundaries by using a "cloud" icon. Lastly, there are pages between different parts of the model so that they can be switched between effortlessly. So, while it is possible to achieve the same functionality with MATLAB, Vensim makes the system dynamics modelling process much easier.

For the MBS pricing model, we will be using MATLAB. An alternative is Excel, but the scripting is not as simple or natural as with MATLAB. Another reason for choosing MATLAB is that the author has used MATLAB extensively and is very comfortable with creating new models from scratch using this tool.

As for the online data visualization, the tools of choice are Javascript and HyperText Markup Language (HTML). Javascript is the 8th most popular scripting language (TIOBE 2015). HTML is the language used by many websites on the internet.

Cascading Style Sheets (CSS) is a programming language used for formatting the look of the website and will also be used as needed.

More specific information on the tools is shown in the table below.

Concept	**Tool Chosen**	**Alternative(s)**	**Reason Why Chosen**	**Version Number used**
System Dynamics Model	Vensim	MATLAB	Easy to create stock and flow diagrams	6.3
MBS Pricing	MATLAB	MS Excel, C++	MATLAB scripting is simple, author is comfortable with MATLAB	R2014b
Online Big Data Visualization	Javascript/ HTML/CSS	Ruby, Python, many others	Javascript/HTML are the premiere scripting and visualization languages of the web	1.8.2
System Architecture	Opcat	SysML	Universal system architecture language	4.0

Table 4.1- Major tools and alternatives used in various capacities

Chapter 5: Housing Market System Dynamics Model

"The behavior of a system arises from its structure. That structure consists of the feedback loops, stocks and flows, and nonlinearities created by the interaction of the physical and institutional structure of the system with the decision-making processes of the agents acting within it."

– John Sterman, (Sterman 2000, 107)

One might ask- What is system dynamics? "System dynamics is an approach to understanding the nonlinear behaviour of complex systems over time using stocks and flows, internal feedback loops and time delays." (Wikipedia 2015). How do system dynamics models work? System dynamics works by using differential equations and their integral counterparts in addition to the law of large numbers to give accurate models of past happenings and future predictions. The "flows" in a stock and flow diagram are the derivatives of the "stock" variables. For instance, the number of home purchases per year would be considered a flow while the number of houses in existence would be a stock. A stock can typically be observed whereas a flow cannot since it is a flow of stock per unit of time. In equation 1 below, the typical form of a system dynamics model equation is shown in integral form. The law of large numbers is also required because this is an aggregation modeling method where the averages, and not individual agents or entities are considered. The law of large numbers is shown in equation 2 below.

$$Stock = \int_0^t (Input - Output)\, dt \qquad (1)$$

$$\bar{X}_n \rightarrow \mu \quad for \quad n \rightarrow \infty \qquad (2)$$

This chapter will aim to fully describe and augment the system dynamics model mentioned earlier. At first a simple system dynamics model with players and type of business model will be presented to show incentive structure before and after the creation of MBSs. This will help elucidate the reason for which the market boomed exponentially for a number of years before crashing. These simple system dynamics models are typically called causal loop diagrams (CLDs) and are useful for determining feedback loops and causalities in complex systems, such as the one being studied here. Once a simple CLD is created, a more complex, formal system dynamics model can be created using the steps shown in Figure 5.1 below, taken from (Sterman 2000). This consists of articulating the problem clearly, forming a dynamic hypothesis, forming a simulation model, testing the model, and finally designing policy around the model. The details for this process can be found in (Sterman 2000).

TABLE 3-1
Steps of the modeling process

1. **Problem Articulation (Boundary Selection)**
   - **Theme selection:** What is the problem? Why is it a problem?
   - **Key variables:** What are the key variables and concepts we must consider?
   - **Time horizon:** How far in the future should we consider? How far back in the past lie the roots of the problem?
   - **Dynamic problem definition (reference modes):** What is the historical behavior of the key concepts and variables? What might their behavior be in the future?
2. **Formulation of Dynamic Hypothesis**
   - **Initial hypothesis generation:** What are current theories of the problematic behavior?
   - **Endogenous focus:** Formulate a dynamic hypothesis that explains the dynamics as endogenous consequences of the feedback structure.
   - **Mapping:** Develop maps of causal structure based on initial hypotheses, key variables, reference modes, and other available data, using tools such as
     - Model boundary diagrams,
     - Subsystem diagrams,
     - Causal loop diagrams,
     - Stock and flow maps,
     - Policy structure diagrams,
     - Other facilitation tools.
3. **Formulation of a Simulation Model**
   - **Specification** of structure, decision rules.
   - **Estimation** of parameters, behavioral relationships, and initial conditions.
   - **Tests** for consistency with the purpose and boundary.
4. **Testing**
   - **Comparison to reference modes:** Does the model reproduce the problem behavior adequately for your purpose?
   - **Robustness under extreme conditions:** Does the model behave realistically when stressed by extreme conditions?
   - **Sensitivity:** How does the model behave given uncertainty in parameters, initial conditions, model boundary, and aggregation?
   - . . . **Many other tests** (see chapter 21).
5. **Policy Design and Evaluation**
   - **Scenario specification:** What environmental conditions might arise?
   - **Policy design:** What new decision rules, strategies, and structures might be tried in the real world? How can they be represented in the model?
   - **"What if . . ."** analysis: What are the effects of the policies?
   - **Sensitivity analysis:** How robust are the policy recommendations under different scenarios and given uncertainties?
   - **Interactions of policies:** Do the policies interact? Are there synergies or compensatory responses?

Figure 5.1- System dynamics modeling (Sterman 2000, 86)

So where do we start with this very complex problem? Figure 5.2 below gives a good model of how to start to think about modeling problems like these (Sterman 2000). Modeling involves iterating between the real world and the system model. Information from the real world should be used to create the model and mental model. From the mental model, the strategy, decision rules, and the system structure can be ascertained and used to create a model. Finally, mini experiments should be run to see if the model in some way approximates the real world through the lens being examined. For this thesis, we will start with a very simple model of the housing market and work our way up in complexity from there. Some of the entities discussed in earlier chapters will be discovered to be secondary effects in the model and will be left off the final model.

FIGURE 3-2
Modeling is embedded in the dynamics of the system.
Effective modeling involves constant iteration between experiments and learning in the virtual world and experiments and learning in the real world.

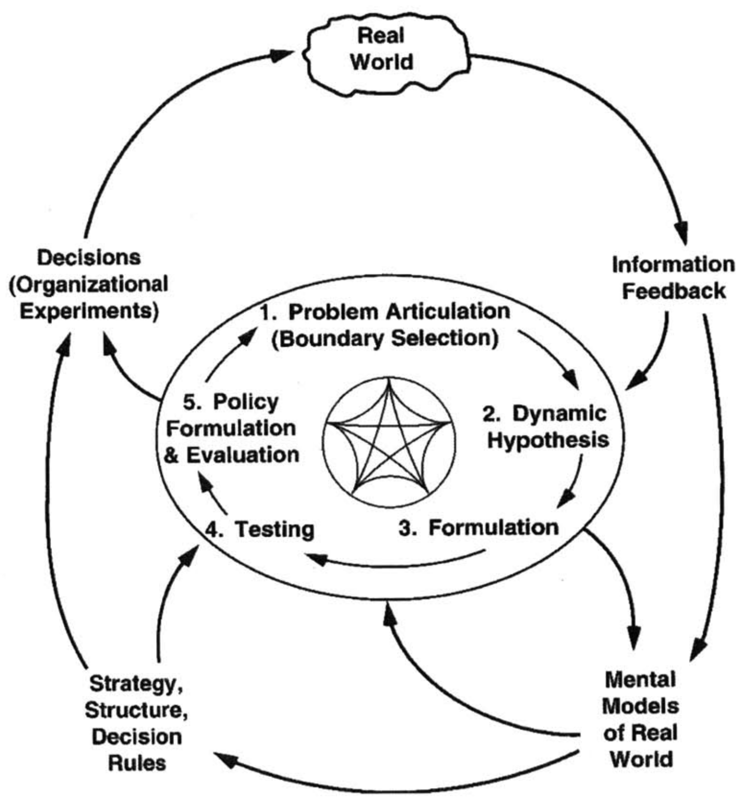

Figure 5.2- Model of system dynamics modeling (Sterman 2000, 89)

The most basic system dynamics model of the housing market as a causal loop diagram is shown in Figure 5.3 below. In this model we see one feedback loop and two inputs. Inputs will always be assumed to be outside the system boundaries, and should be taken as a given. These are called exogenous variables. The two inputs are the population of the US, and the desired people per household. Population is self-explanatory and desired people per household is an input that changes slowly over time that indicates the optimal amount of people per household, as determined by comfort levels, perception of birth and death rates, and other constraints (e.g.- economic means). If there are more people per household, on average more houses will be built, as per the diagram. If more houses are built, there will be more housing available. If there is more housing available, the amount of people per household goes down, thus completing the balancing (B) feedback loop below. A balancing, or negative, feedback loop is one that self corrects; when the variable in question goes above some value, it decreases, and vice versa. This works because some concepts involved in the loop in question are balanced with other concepts to have the system come to an equilibrium. Polarities of arrows are also assigned to show the viewer if the concept where the arrow comes from positively or inversely influences the concept where the arrow points to. These are indicated by the + and – signs which indicate positive and inverse affecting, respectively. The number of negatives in feedback loop can be tallied to determine if the loop is balancing or reinforcing; if the number of negatives is odd, then the loop is a balancing loop. If it is even, it is a reinforcing (or positive) feedback loop.

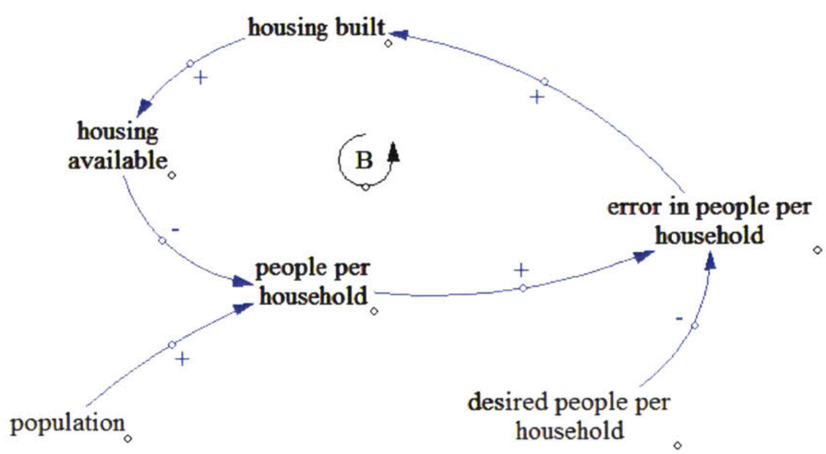

Figure 5.3- Simplest system dynamics CLD model of housing market

Similarly, there is a second balancing feedback loop added in Figure 5.4 below that reflects the change in interest rates. As there are more houses built, there is a better economy which leads to higher interest rates and then mortgages become more costly which ends up reducing the number of houses being built.

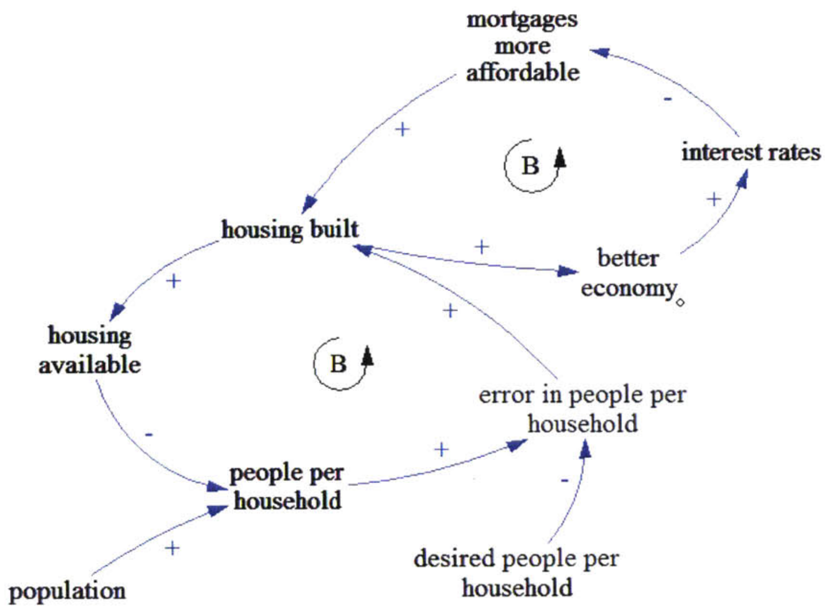

Figure 5.4- Balancing feedback loop on interest rates added to CLD

Another loop that should be added is a loop related to the securitization of the MBSs. We will capture that by the following line of reasoning: as there are more houses built, there is more investor interest in the market. With more investor interest comes more securitization and risk spreading which in turn leads to mortgages being more affordable and finally with more houses being built. This is all shown in Figure 5.5. One can see that this is not the same as the previous two loops that brought things into balancing, aka a balancing loop; this loop is a reinforcing loop that extenuates the perturbation in the same direction. This also works in the negative direction, meaning that if fewer houses are being built, this causes investors to be less interested in the space, which reduces the securitization and risk spreading, which makes mortgages less affordable, and finally drives down the rate of houses being built.

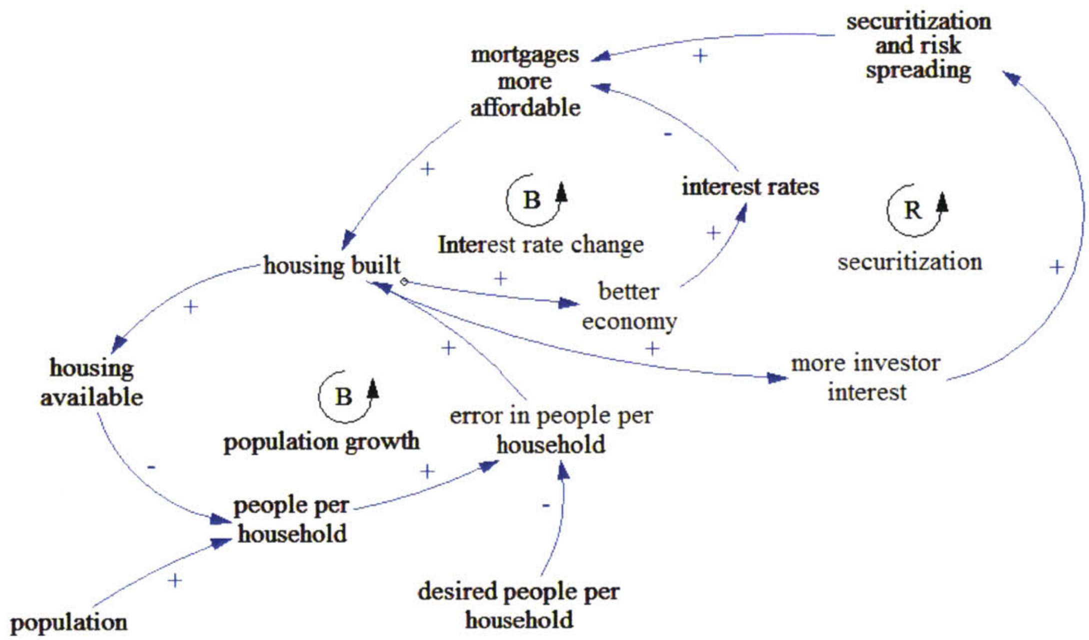

Figure 5.5- Securitization (reinforcing loop) added to CLD

The next thing that will be added to the model is an exogenous variable, namely the mortgage standards. This affects the system in 2 ways: as the standards go down, the mortgages are more affordable, and also as the standards go down, the number of defaults go up, leading to lower investor ROI and finally to the reduction of investor interest in the space. This is shown in Figure 5.6. This particular exogenous variable is very important to the operation of the system as we will see later, but its loop will eventually be closed and made an endogenous variable in the stock and flow diagram to follow.

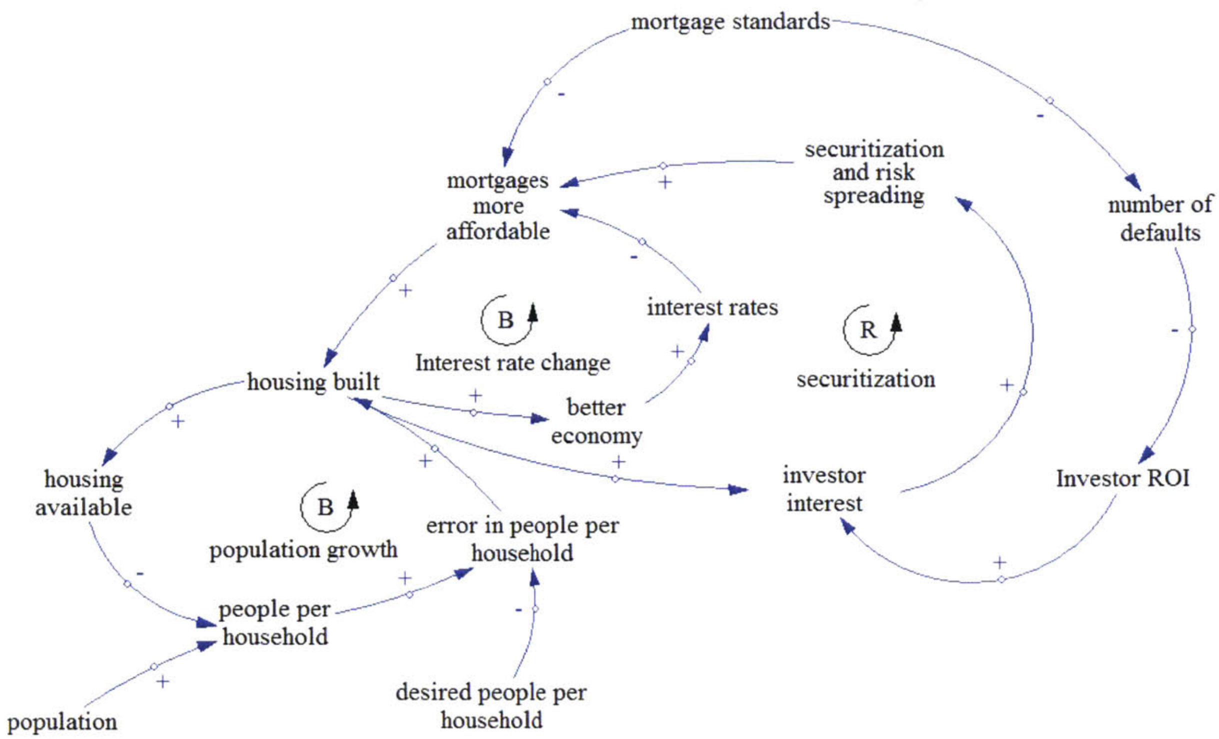

Figure 5.6- Mortgage standards are added to the CLD model

Now another loop that should be added to our model is the investment bank selling loop. This loop describes the feedback loop between the investment bank's behavior and the rest of the system. When there is more securitization and risk spreading desired, the investment bank gets more business and makes a higher commission, which will cause the bank to want to drum up more investor interest by pitching more investors. When more investors are pitched, more investors are likely to become interested. This leads to an overall reinforcing loop for the system, as shown below in Figure 5.7.

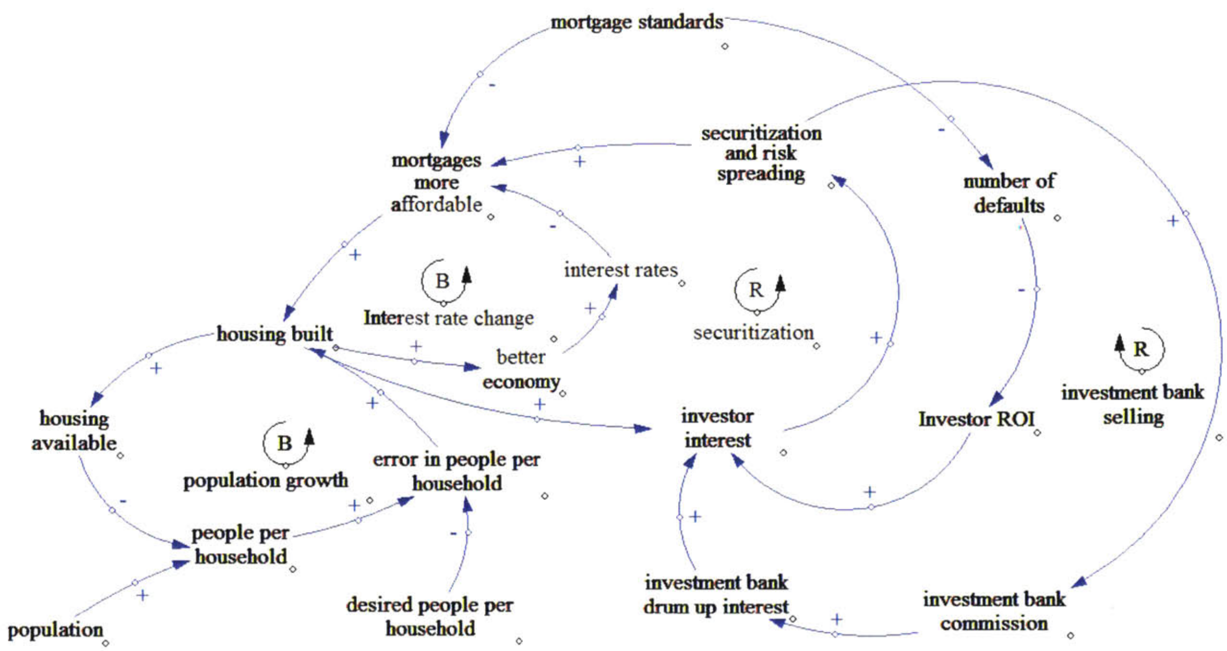

Figure 5.7- Investment banks loop added to CLD

Two more loops will be added to the CLD with the first one being the loan volume loop and the second one being the MBS ratings loop. The loan volume loop is a reinforcing loop since when there are more loans originated, there can be more securitization and risk spreading. This is given in Figure 5.8 below. This process of adding loops can be continued on indefinitely, but we will take the learning from these CLDs and apply it directly to the stock and flow diagram.

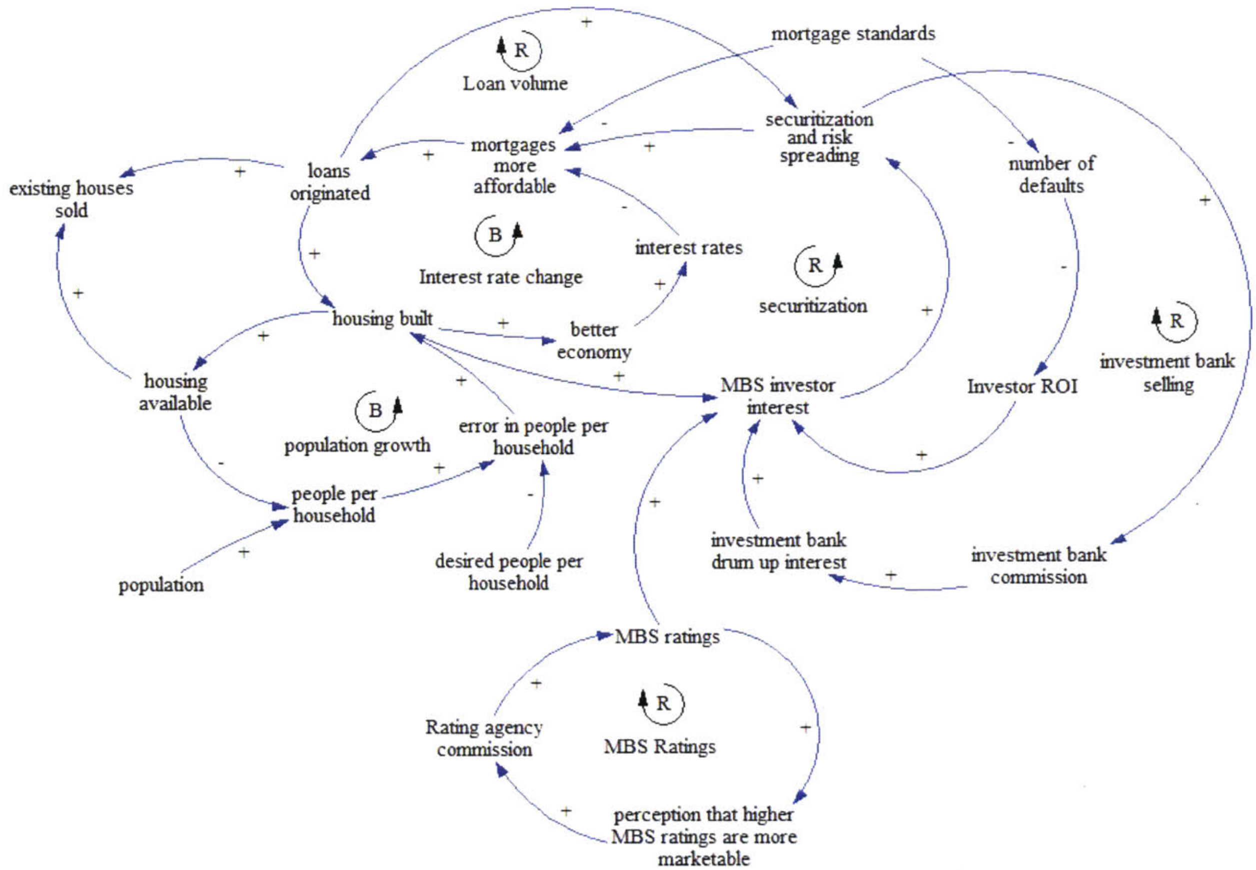

Figure 5.8- Loan volume (R) and MBS ratings (R) loops added to CLD

Now that the general CLD has been created, the actual stock and flow diagram that can quantify the housing market dynamics will need to be modeled very formally. The CLD that was created previously will be used in the construction of this new system model. If one can quantify broad trends in the housing market, information flows, business models, and mental models, the overall system's trends can be identified. Again we will turn to Vensim to create this model and actually run the simulation to yield quantitative results.

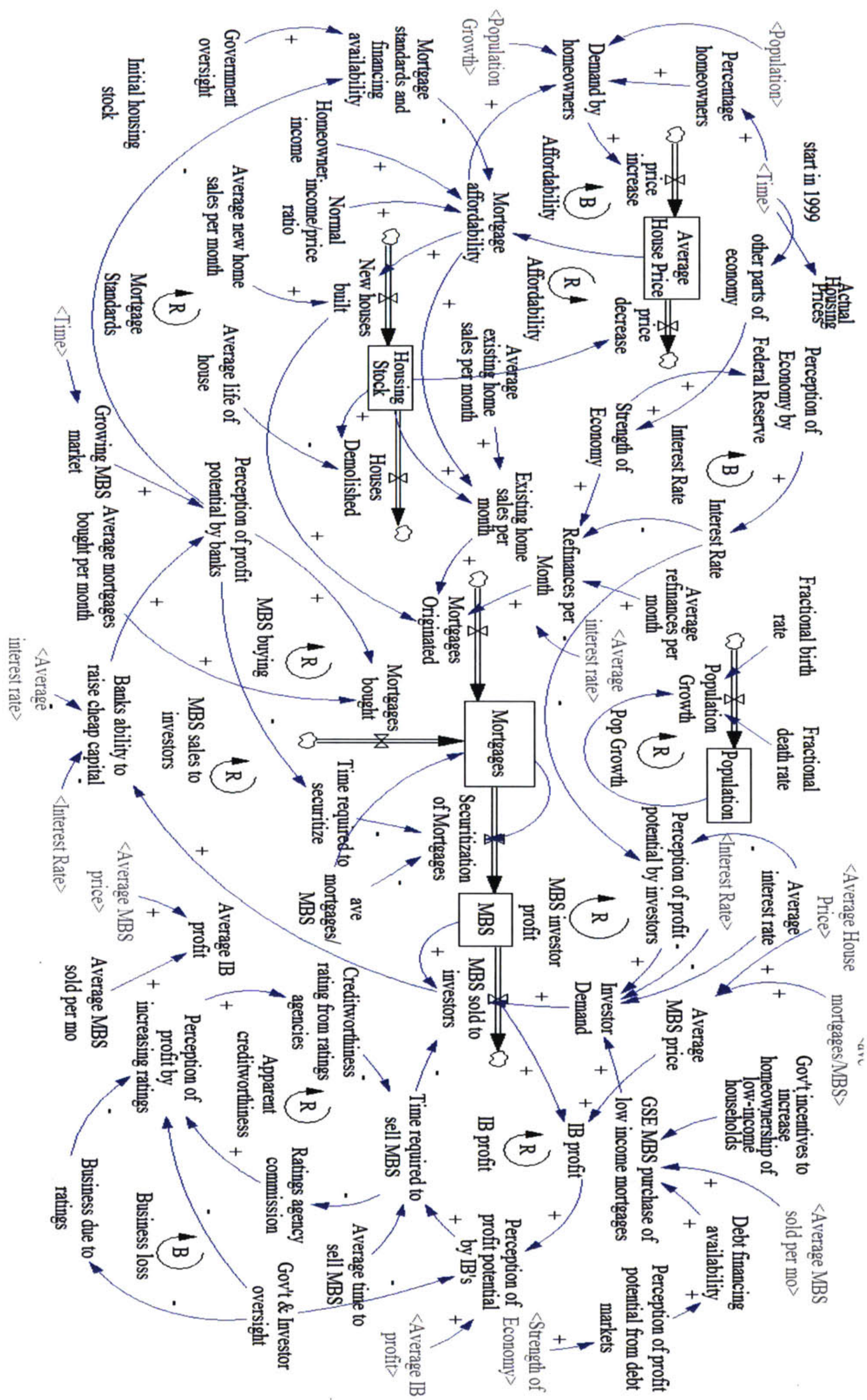

Figure 5.9- The system dynamics model for the housing market

The stock and flow diagram of the housing market system can be seen in Figure 5.9 above. There are 5 main stocks that are included in the diagram. The first is the housing stock. Without this stock, there would be no market. Intimately related is the average home price stock which can go up or down depending on the supply and demand of the market. Next we have the overall population. This represents the total population in the US over this time period. Lastly we have the mortgages and the related MBSs. This is the financial coupling between the actual housing stock and the financial markets.

The housing stock has a flow of "New houses built" into the stock and a flow of "Houses Demolished" out of the stock. Flows into the stocks typically increase the stock whereas flows out of the stock reduce the stock. The "Average House Price" is the stock that represents the market's collective mental model, and consists of price increases and price decreases that alter its value. Another stock that is important over longer term models such as this one, is the population. The population is transformed by the fractional birth and death rates; when there are more births than deaths, the population increases, as would be expected.

The last two stocks- the number of mortgages and MBSs- are arguably the most important for the dynamics of the system. When there are many MBSs sold, this allows for the returned capital to be reused for more mortgages. The main processes for the mortgage stock are the origination of mortgages, purchase of mortgages, and securitization of the mortgages. The output of the mortgage stock is the number of securitized MBS per month which is the input flow to the MBS stock. The outflow from this stock is the number of MBS sold to investors every month.

There are many other variables in Figure 5.9. These are either constants or auxiliary variables. The main loops that drive the dynamics are the investment bank profit, the apparent creditworthiness, the MBS investor profit, the mortgage buying, the affordability, and finally the mortgage standards and financing ability loops. It is left to the scrupulous reader to analyze the whole system dynamics program that was used in the analysis on their own. The full code is available in Appendix C.

Chapter 6: MBS Pricing Model

"The global financial crisis - missed by most analysts - shows that most forecasters are poor at pricing in economic/financial risks…"

-Nouriel Roubini, (BrainyQuote 2015)

"When the government gets involved in pricing, I don't think it's the right way to look at a business."

-Jamie Dimon, (BrainyQuote 2015)

This chapter will elaborate on the models that will be used to evaluate the mortgage backed securities created by Countrywide Financial. There are two major components to pricing any MBS: the default rate, the prepayment rate. Up until the financial crisis it had been assumed that the amount of defaults that would occur for any MBS portfolio were minimal and therefore most of the effort for pricing was put into modeling the prepayments, as will be shown below. As for the default rate, it was typically modelled as an increase and then a drop to near zero.

It is important to note that in agency-backed MBS, prepayment risk is borne by the MBS holder, whereas the default risk is taken on by the agency (Fannie May, Freddy Mac, etc.). With private labeled MBSs, the default risk is taken on by the MBS holder, which is a key difference when modeling the MBS payments. We shall assume that all of the MBSs that are priced were private and therefore the default risk was accepted by the MBS holder.

There was one main model for pricing the prepayments of mortgages by homeowners and it is called the PSA (Public Securities Association) prepayment model. The model takes the fact that the mortgage borrowers typically don't relocate to a new home or refinance their mortgages as much in the first 30 months. It models it as a linear increase in the conditional prepayment rate (CPR) and then a complete leveling off of this rate after the 30 months. The actual model goes as follows:

> "The standard model (also called "100% PSA") works as follows: Starting with an annualized full prepayment rate of 0.2% in month 1, the rate increases by 0.2% each month, until it reaches 6% in month 30. From the 30th month onward,

the model assumes an annualized prepayment rate of 6% of the remaining balance." (Hayre 2001,24)

This indicates that if the homeowners are repaying their mortgages at double this conditional prepayment rate, this would be labeled as "200% PSA" and if half, "50% PSA". These exact scenarios are shown in Figure 6.1 below. Therefore we can take all of the previous information and boil it down into one simple equation for modeling the single month mortality (SMM) prepayment rate:

$$SMM = 1 - (1 - CPR)^{\frac{1}{12}}, \qquad where\ CPR\ is\ given\ by:$$

$$CPR = \begin{cases} (0.2 * m * PSA)\%, & 0 \le m \le 30 \\ (6 * PSA)\%, & m > 30 \end{cases}, \qquad where\ m = month\ \#$$

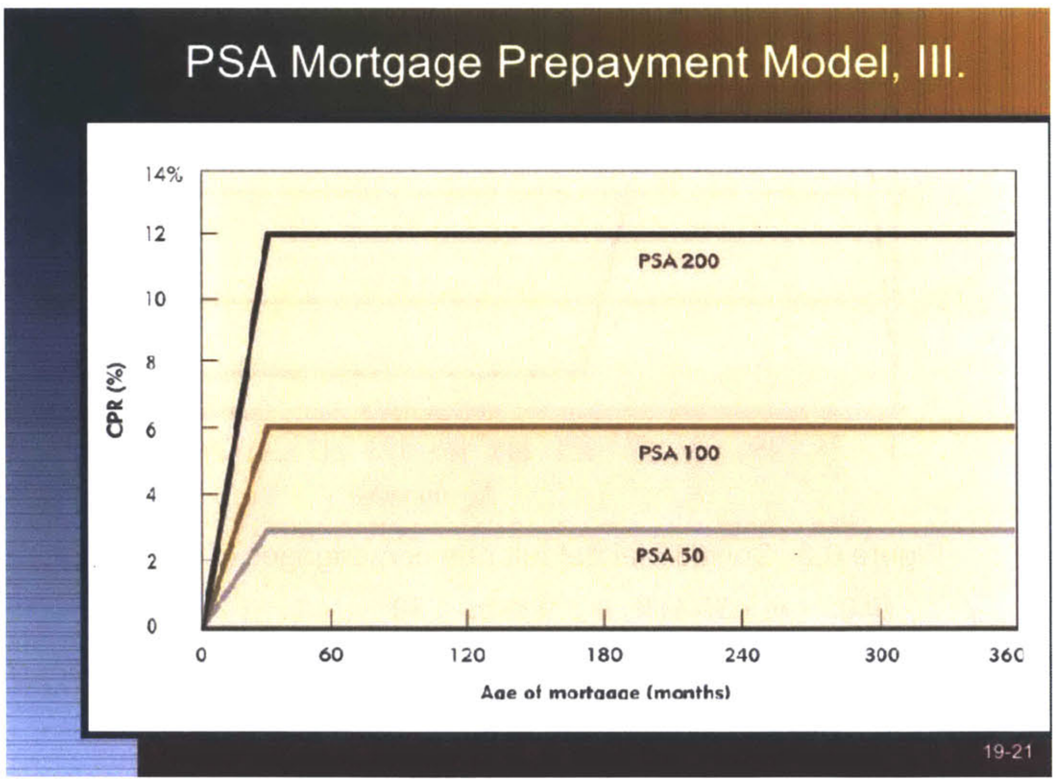

Figure 6.1- The plot of the PSA prepayment model (Corrado and Jordan 2004)

Now let's turn our attention to the default model. There are two types of defaults: voluntary defaults and involuntary defaults. Voluntary defaults are where the homeowner defaults on their mortgage but the value of the house is greater than the purchase price. An involuntary default is one where the default occurs and the value of the house is less than the purchase price. This is commonly referred as the homeowner being underwater. These two defaults can be combined to create the single month mortality (SMM) for defaults. The annualized version of this is called the conditional default rate, or CDR. The standard model for modeling the percentage of defaults is shown in Figure 6.2 below.

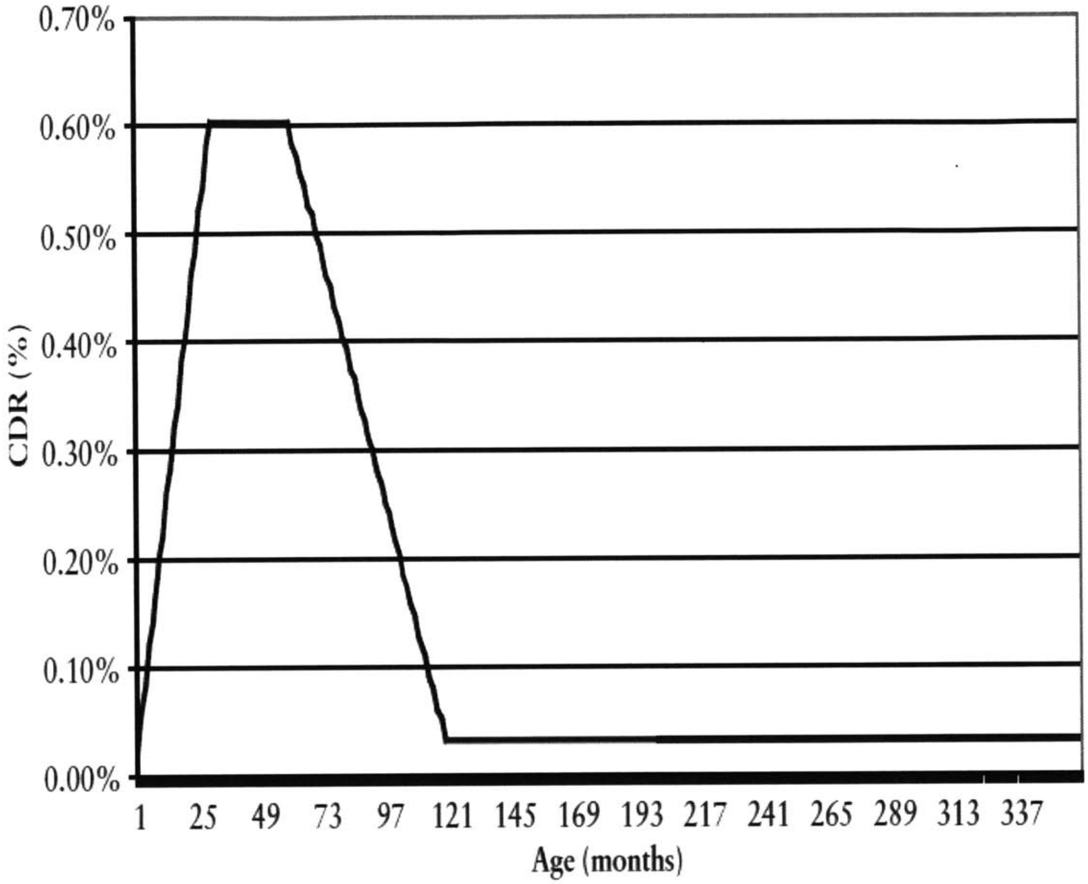

Figure 6.2- Conditional default rate of mortgages (Torous 2015)

$$CDR = \begin{cases} (0.02 * m * SDA)\%, & 0 \leq m < 30 \\ (0.6 * SDA)\%, & 30 \leq m < 60 \\ (0.6\% - 0.0095 * m\%) * SDA, & 60 \leq m < 120 \\ (0.03 * SDA)\%, & m > 120 \end{cases} \quad where\ m = month\ \#$$

This model is given in equation form above. One can see that for all months, the number of defaults are annualized default rate is much less than 1% and very close to 0% on a monthly basis. This is because the CDR can be solved for in the equation below using the single month mortality (SMM) for defaults. The SMM equation below is exactly the same equation as the CPR equation where the CDR is substituted for the CPR variable. Doing some simple math, the maximum of a 0.60% CDR yields a SMM of

0.05%, and the minimum of a 0.02% CDR gives a SMM of 0.0017%. To make this more computationally efficient and a more tractable problem to calculate, we will simplify the analysis using a constant monthly rate of default throughout the life of the MBS. A constant rate of default of 1% per month will be much more conservative than the 100% standard default assumption (100% SDA) described above. This will lead to an underpriced security compared to the 100% SDA model. To compute the MBS prices, values of 0%, 1%, 2% and 5% for annual default rates will used in the analysis. One can see that considering the very small percentage of defaults, the standard default model the rate of prepayment variable is the dominant driving force in the standard pricing models.

$$SMM = 1 - (1 - CDR)^{\frac{1}{12}}$$

The actual MATLAB code that was used will now be discussed and is given in the Appendix. In this code, there are a few key functions that need to be considered. The master script is priceMultipleMBS.m. In this script there are 3 main sub functions or scripts that are used to create pricing for a string of MBS files. The first one that can be seen going down from the top of the function is reading in all of the MBS data files to be analyzed. This function takes the listFileName string along with the range given and reads in the raw text of file names. This raw column of cells is converted into a column of strings called 'files'. From here a loop is run to price each MBS using various inputs. There are two loops that are run. One is looping through the CDRs and the other loops through the pricing of the same MBS i times. In the code that was run for this thesis i was 3; this means that the MBS was priced 3 times and averaged to get the final price. This was done for convenience in terms of computational time. If future users want a more accurate answer i should be much larger- say 10 or more. The reason why multiple runs need to be averaged is that a Monte Carlo simulation is run for each house in terms of its actual prepayment and default using average default rates. The last part of the loop does the averaging of the i MBS pricings and finally adds this MBS price to the MBS_price_total matrix. In this way each MBS can be priced multiple times, averaged, and output to the user.

The next layer down is the PriceMBS function which is the main- and most important- function of the MATLAB code. This function's goal is to take the input file given by ‘filename’ along with the average default rate being modeled and output a price for the MBS using the default algorithm developed by the user and the existing PSA and SDA models and corresponding algorithms. In addition, there are 3 switches to turn various parts of the function on and off to see where large portions of the valuation differences come from. These three switches are turning the prepay model on, the default model on, and finally turning the discounted cash flow model on. These were very useful in debugging and also in getting a general sense of the values of portions of the MBS cash flow.

This function contains 10 or so sub functions. From the top of the function we encounter the first bit of code which is the run getMBSData.m file. This file gets all of the data that is needed in analyzing the MBS and determining its price. In it the interest rate, the FICO score, the combined loan-to-value ratio, the loan value, the home value, the monthly principal and interest and the remaining term on the mortgage is grabbed from the Excel file that was input into the PriceMBS.m function from the master function’s loop.

The next file that is run is the default_data.m file. This file contains all of the default data that was obtained from the Federal Reserve Bank of Chicago (Amromin and Paulson 2010). This file contains the nationwide default averages for the 2004-2007 time period. In addition it contains a few explanatory variables to explain the differences in homeowner default rates such as the homeowner’s FICO score, their combined loan to value ratio, and the interest rate on their mortgage. These variables are the key variables explaining the difference between one homeowner and the next and will help explain differences in whole pools of mortgages in the MBS. Lastly, the file contains the average loan characteristics from 2004-2007 for these key explanatory variables.

The next portion of the code identifies each homeowner by whether they are subprime or not using their FICO score. The typical score that differentiates subprime and prime is 640 (Investopedia 2015). This is useful when trying to determine and visualize overall what percentage of each MBS is prime vs. subprime.

The subsequent piece of code that is run is the IR2PSAtable.m file. This file is a table that takes an interest rate and has an associated prepayment rate given by a PSA value. This will be used to determine the actual monthly prepayment rate further on down the function. The basic premise of this is that as the interest rates drop the PSA will go up dramatically since the homeowner will be incentivized to either refinance or find a new place to live.

The main loop of the PriceMBS function is next in the code. This loop uses the statistics given by all of the data described above- the actual default averages, default explanatory variables, and loan characteristics- to create a default probability using the defaultProbability function. This defaultProbability function takes in the FICO score, CLTV, and interest rate of the homeowner's mortgage and the average statistics to determine an average probability of defaulting. The actual calculated value is calculated using the Monte Carlo method and a random number generator. The next part of the loop gives the Monte Carlo calculation of the chance of each mortgage to prepay during that month. Finally, the discounted expected cash flow stream for each mortgage is calculated using the calculated default, calculated prepayment and homeowner's monthly payment. This discounted cash flow is reported back to the priceMultipleMBS main function as the MBS_price for that run. Again, this is run 3 times for each MBS and averaged to give a good estimate of the expected MBS price.

Chapter 7: Putting it All Together, Results

"When you combine ignorance and leverage, you get some pretty interesting results."

-Warren Buffett, (BrainyQuote 2015)

"You don't get any medal for trying something, you get medals for results."

-Bill Parcells, (BrainyQuote 2015)

The first thing that should be discussed in this chapter is the visualization of all of the data that is available from the Countrywide Financial website. The reason why this is important is because humans are typically very visual learners- they need to actually see what is going on to help understand problems. To that end, the author has created a visualization tool to help analyze the data from a few MBSs. The tool is available at http://web.mit.edu/friedl/www/project.html.

While not directly used in the analysis to follow, it is a good tool to visually understand the makeup of MBSs. The tool uses Google Maps to map out houses by zip code that are contained in various MBSs. The tool also has many metrics that are available on a house-by-house basis such as the latitude & longitude of the zip, the appraisal amount, the note rate, the maturity term, the CLTV, the property type, the owner type, and the type of documentation provided to get the mortgage. These data are available by double clicking on a colored circle once a MBS is loaded onto the screen. In order to get the visualization of a MBS one must select the MBS from the drop down menu on the bottom of the screen and hit the 'Start' button. Once one is loaded, any other can be loaded by selecting the MBS from the same list and then hitting the 'Get it!' button below the MBS list. A screenshot of the visualization is shown in Figure 7.1 below. The house information data tool is shown in Figure 7.2 below. One can see that there are numerous mortgages along the coasts of the US with a sprinkling of them in the eastern half of the country. This visualization tool can help a MBS purchaser decide if the particular MBS contains the right amount of state-level risk to take on. For instance, this MBS is heavily weighted to mortgages in California, Florida, and the central eastern coast.

In terms of the colors of the mortgages in the MBS pool, these indicate the combine loan to value ratio for each house. When the house is indicated as green this is a CLTV ratio of less than 20%, which is a very positive CLTV. If it is over 80% CLTV it is indicated as a bright red dot showing that it is a very high CLTV ratio. Moving on to the size of the dot, the smaller it is the less the loan taken out. The smallest dots are representing mortgages of less than $165k whereas the largest dots are for mortgages over $3.3M. In this way one can quickly see what types of mortgages are in an area and visually assess the situation.

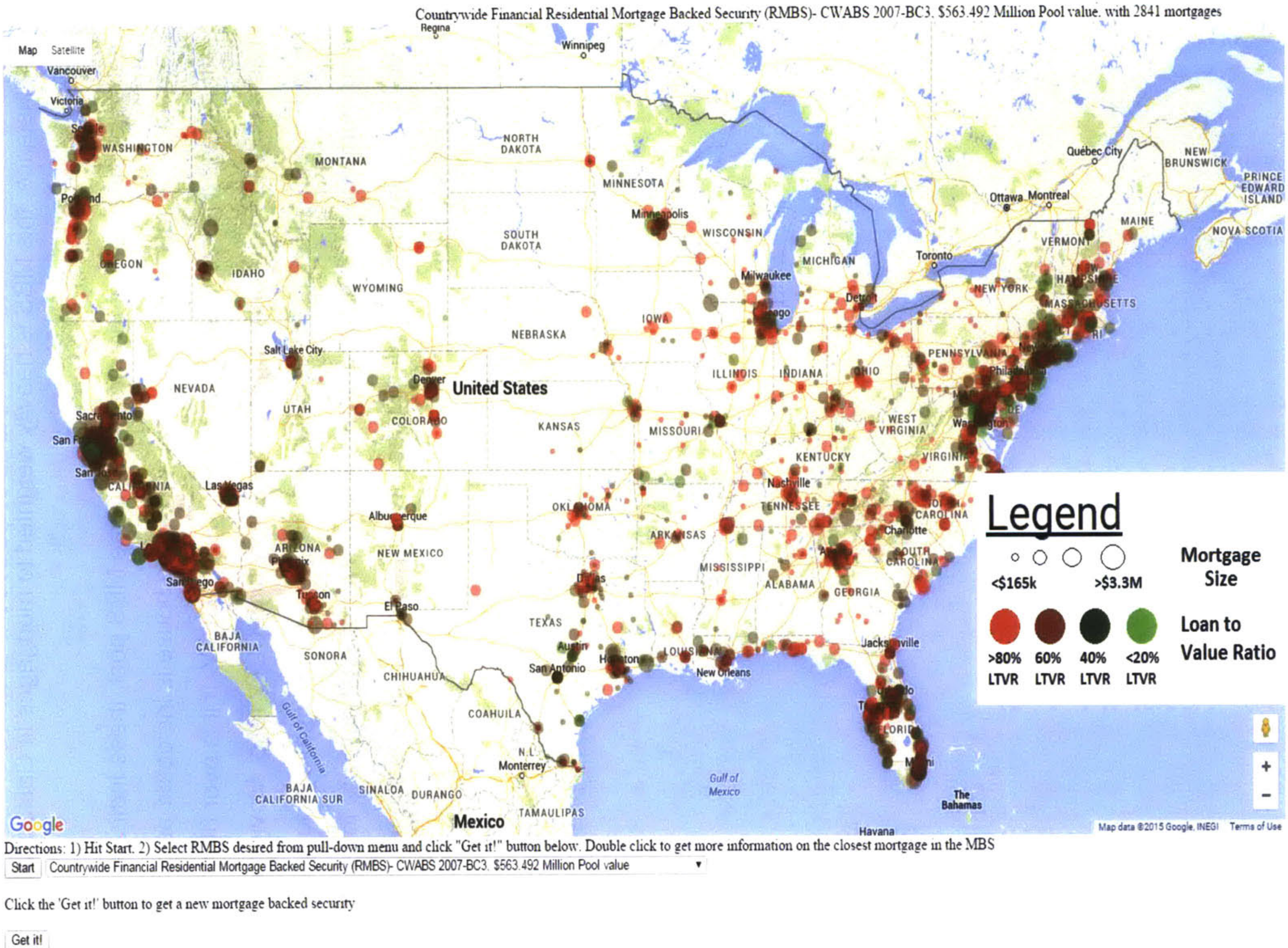

Figure 7.1- Visualization of a 2007 MBS issued by Countrywide Financial

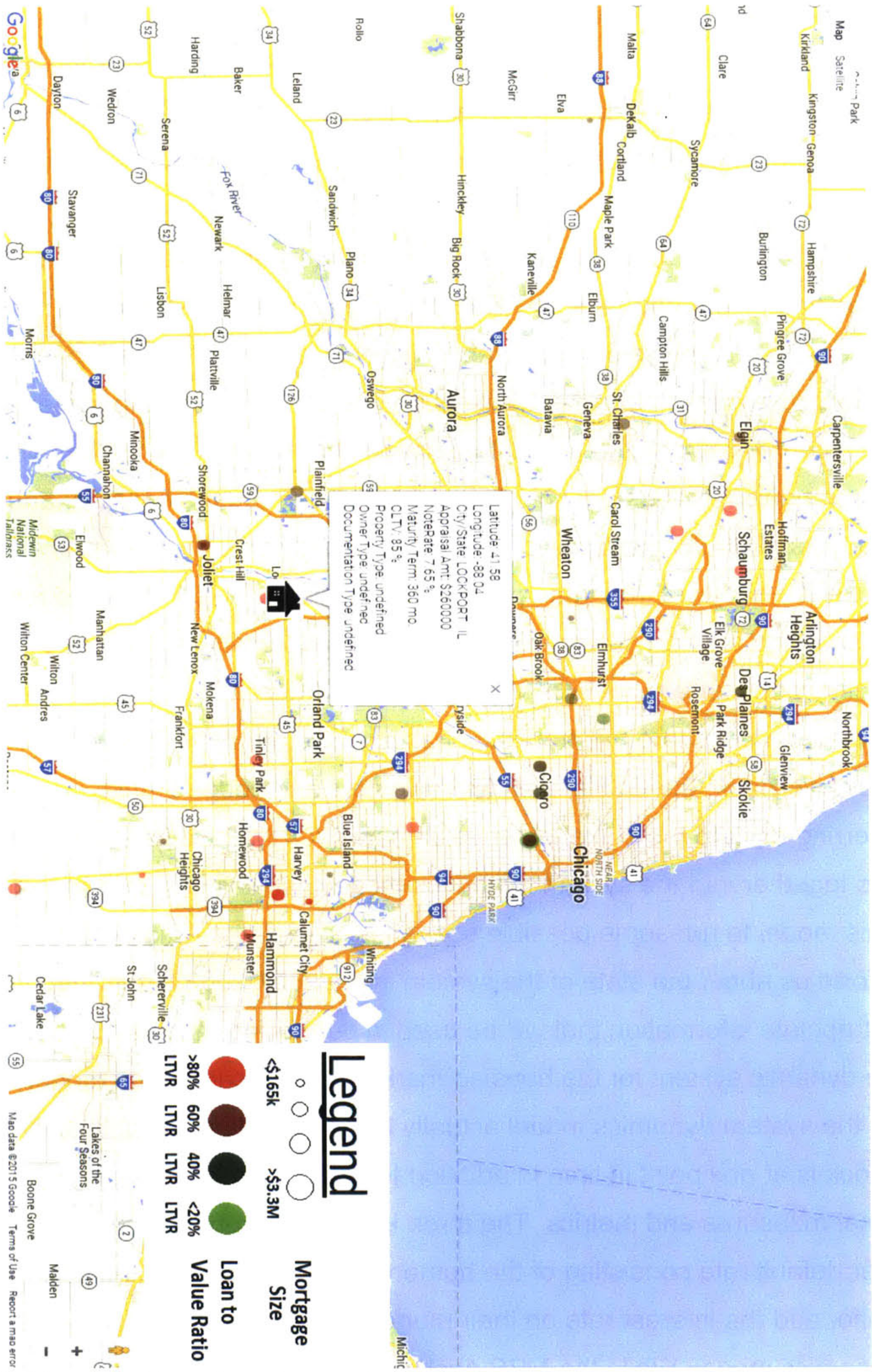

Figure 7.2- Visualization of mortgage data on a specific house in Lockport, IL

Now that the MBSs can be visualized, let's get to the crux of this thesis and determine if it was possible to predict the failure of Countrywide Financial. To do so all of the tools, methods, and models thus far described will be utilized. It will be shown that the system dynamics indicated that there was an overpricing in the housing market, loan to value standards were decreased, acceptable FICO scores were lowered, and applicable mortgage interest rates were increased. All of these factors played a role in the mispricing of the MBSs.

The first thing that needs to be discussed is the incentives that were in the market at the time. Referring back to Table 2.2, one can see that there are many different incentives in the system from various agents. One of the most common incentives is a commission, or a per-transaction fee. The agents in the system that have this type of incentive include the real estate agents, banks that securitize their loans, insurance companies, ratings agencies, investment banks, home builders, and home builder suppliers. With this commission type of incentive in the system, numerous agents desire the highest throughput per period of time possible in order to maximize profit, all else being equal. This is also shown in Figure 5.9 where it shows that there are reinforcing loops for a number of various types of transactions. The only agents in the system that do not share this transactional incentive are the homeowners, the Federal Reserve Bank, the GSEs, the MBS investors and hedge funds.

Referring back to the stakeholder value network (SVN) we can now pull all of these flows together into the system dynamics model that was described in Chapter 5 and use this model to run some possible scenarios. These simulation runs will then be used to inform us about the state of the system in the 2007-2008 timeframe. From this we can extrapolate information that will be used in our pricing models.

The dynamic system for the housing market was described and modeled but what does the system dynamics model actually tell us? It tells us what the state of the housing stock is at any point in time in addition to national housing pricing and informational measures and metrics. The three key explanatory variables for the homeowner default rate consisting of the homeowner's FICO score, their combined loan to value ratio, and the interest rate on their mortgage are also the key variables in this system dynamics model. While the MBS pricing algorithm deals with actual data from individual homes, the system dynamics model deals with very large trends across the broader housing market.

Below is a selection of the possible results that can be discussed. The first graph shows the predicted housing prices versus the actual housing prices across the US. This and the general interest rate trends were used to calibrate the rest of the model. In Figure 7.3 below, one can see that with the system dynamics model that was created in Chapter 5, one can get fairly close to the actual housing prices. The interest rates are endogenous to the model and match the data fairly well, although it doesn't go as low as the actual interest rate in the period from 2002-2004. The interest rates, displayed in Figure 7.4, are largely driven by the macro economy and the stimulating and tempering of the economy by the Federal Reserve.

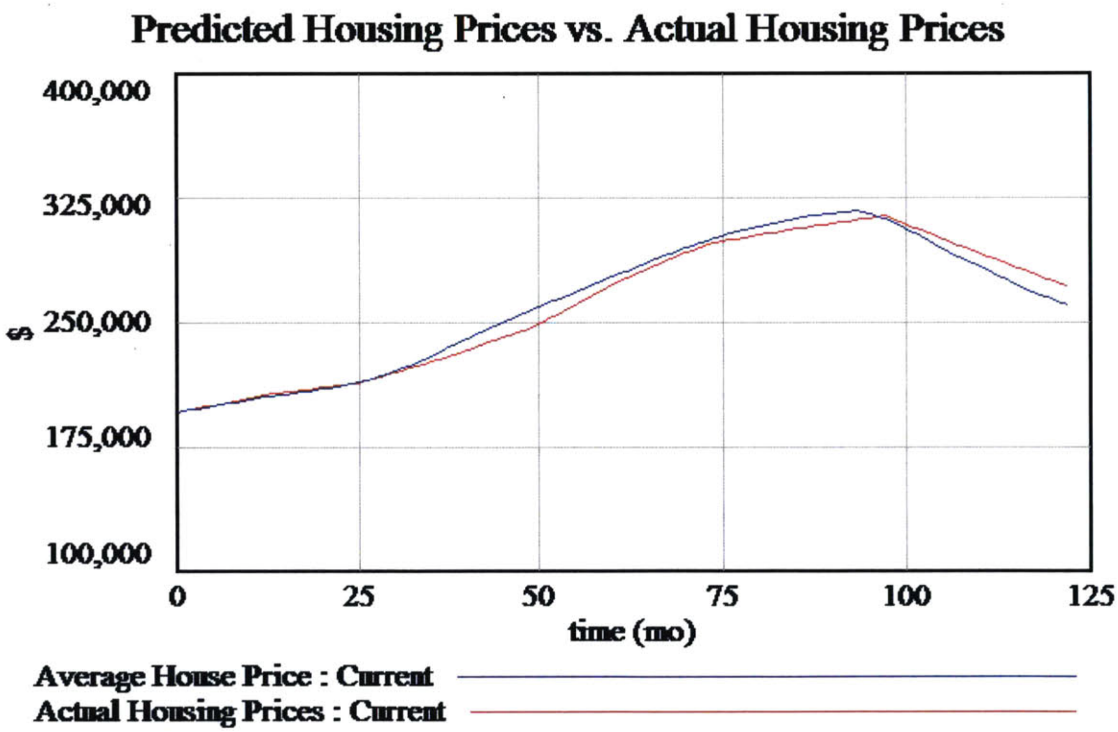

Figure 7.3- The predicted housing prices using SD versus actual housing prices, month 0 is Jan. 1999 and month 120 is Jan. 2009

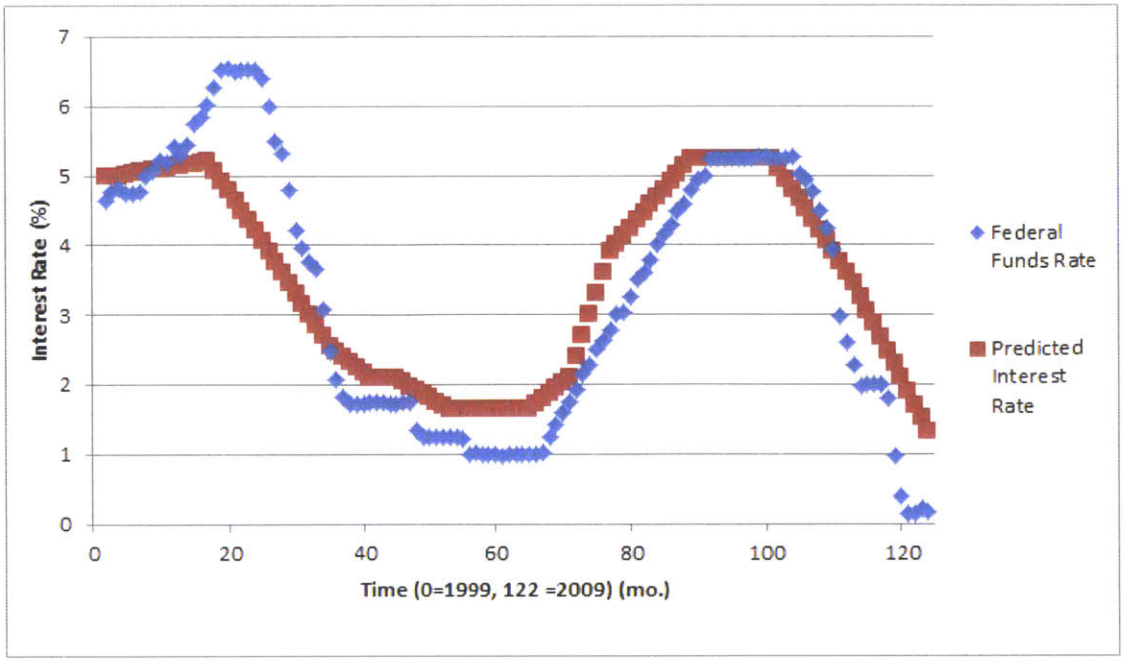

Figure 7.4- The predicted interest rates using SD versus actual interest rates

The next figure, Figure 7.5, shows that the simulated total market price of all mortgages originated in the US matches the long term trend, although can't . A higher fidelity system dynamics model would be needed to capture these faster dynamics. This is ok since the goal is to capture long term trends that can be predicted. In our case, the fact that there was going to be a large slowdown could have been predicted well in advance of the actual slowdown- possibly as early as 2006, but certainly by 2007 as shown in the figure. A higher sampling rate would be needed from the data to make a more precise prediction. In the last figure in the system dynamics modeling portion of this chapter, Figure 7.6, the number of new houses created in the economy could have been predicted fairly well from 1999 through 2003. In 2004 through 2006 there is a large deviation from the actual data. It is hypothesized by the author that this could have been fueled by additional speculation in the market, not by the underlying demand for housing. This possible speculation is not captured explicitly in the system dynamics model. Nonetheless, the general trend of a large reduction in new housing built could have been predicted with a good degree of certainty in the 2006-2007 timeframe.

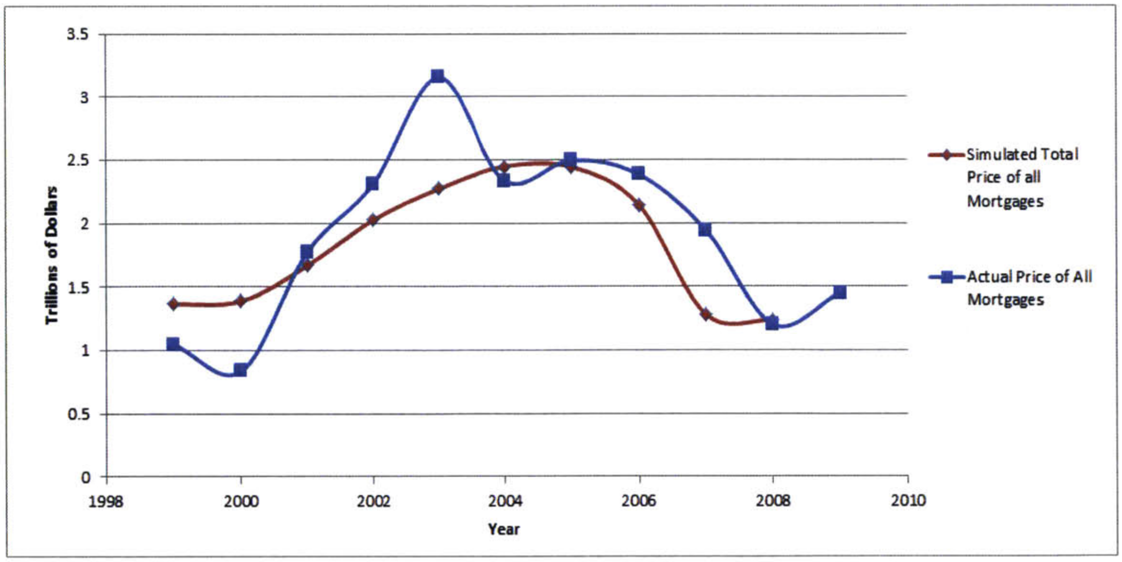

Figure 7.5- Total mortgages originated in the US per year, in trillions of $

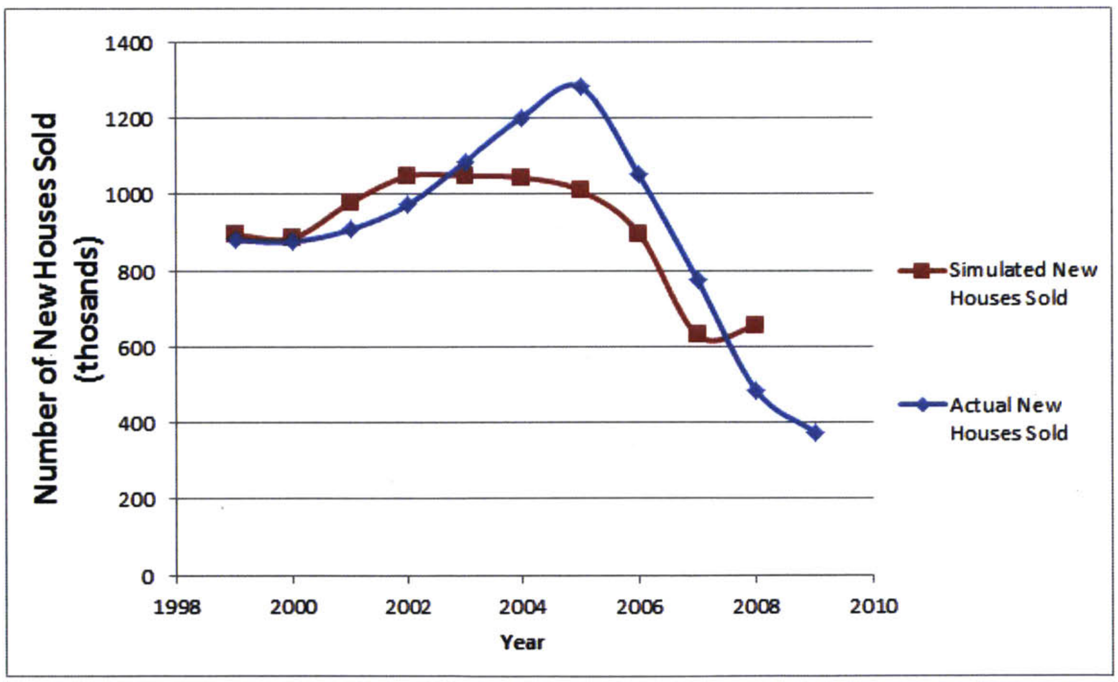

Figure 7.6- The predicted new house sales versus actual house sales

Now that we have discussed the broader housing market we can turn our attention to the actual data that is available from Countrywide Financial. Using the algorithms discussed in Chapter 6 and the data from the Countrywide Financial website we can now confidently give approximate prices to the individual MBSs. These prices are in the form of what the current state of the default and prepayment models were, and what they should have been, as shown by the author's very simplified algorithm that takes the actual averaged national homeowner default data into account to better inform the pricing model.

The first plot shown in Figure 7.7 below gives the ratio of the actual return versus the expected return for the 51 'prime' collateralized MBSs. A ratio of one indicates that for every dollar that was expected- or the price using the SDA and PSA models- there was one dollar actually returned, as calculated by the author's simple default algorithm. This also means that the asset manager correctly predicted the rate of defaults and prepayments so that the actual rates were equal to the expected or predicted rates. So if the original standard model was used with a 5% default rate, many of the prime MBSs would actually return around 150-180% of their money versus what was expected. Therefore if the asset manager estimated a 5% default rate and expected to get back X dollars, they would actually get back 1.5X – 1.8X. A 0% expected default rate gives actual returns that are less than one meaning that the asset manager underestimated the number of defaults. A value of about 0.6% defaults per year gives the best fit to the data, as shown by the red square in Figure 7.7. It should also be noted that there is a slight down trend in the data indicating that MBS returns from the beginning of 2006 to the end of 2007 are going down.

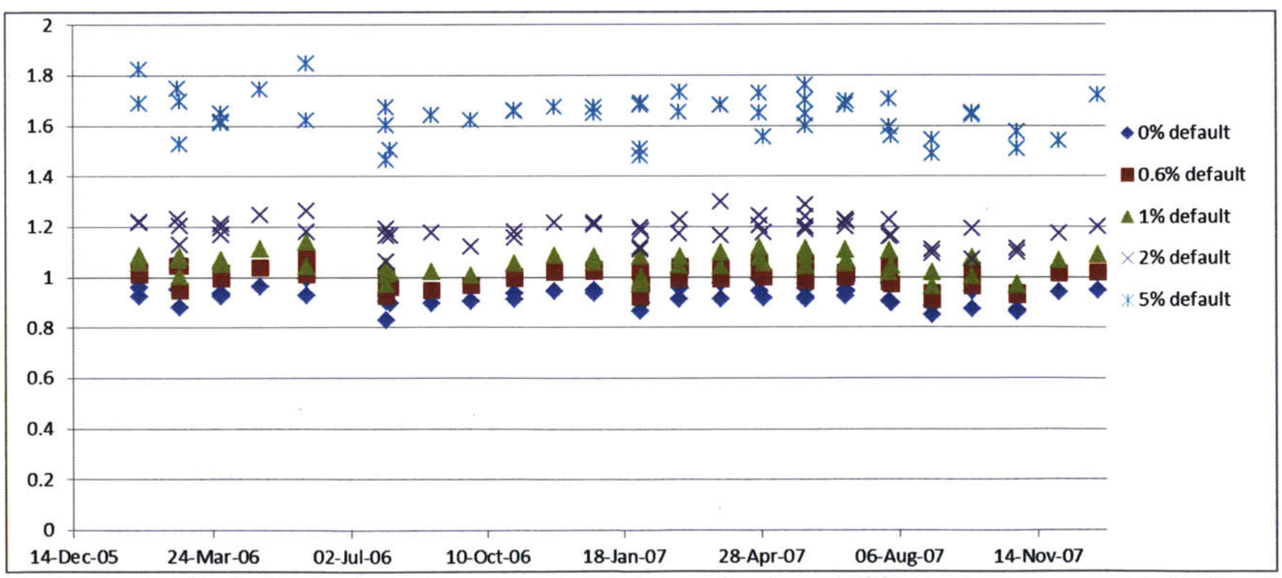

Figure 7.7- Actual return vs. expected return of prime MBSs using various default scenarios

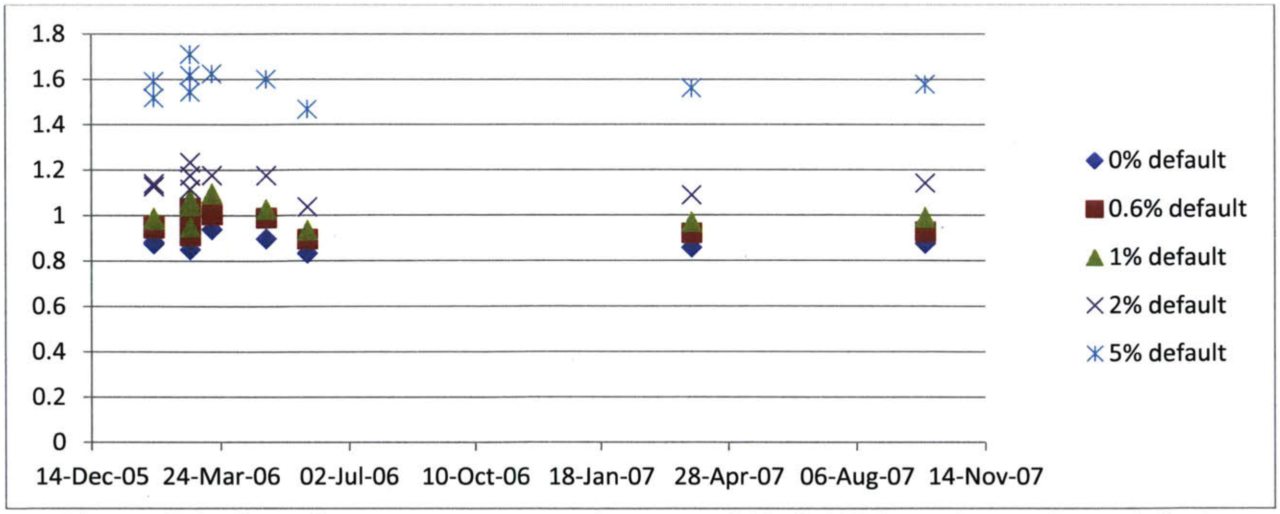

Figure 7.8- Actual return vs. expected return of Alt-A MBSs using various default scenarios

As for the Alt-A MBSs, a very similar result to the prime MBSs is found. The 5% default rate scenario yields around a 50% better result than expected, as shown in the blue snowflake icon in the above figure. The best fit for the actual data to the expected default rate is approximately 1%, as represented by the green triangle in Figure 7.8.

Lastly, we get to the subprime MBSs. These are known to be the riskiest securities available on the market. Now the question is what type of default rate should have been baked into the model? Looking at the data we see that a 1% annualized default rate no longer yields a return of 100% of the expected capital as was the case with the Alt-A MBSs; it is much lower. If the asset manager had a 1% default rate baked into the model- which is much higher than the 0.007% standard default rate- they would have experienced around a 30% loss from their expected returns. Many of the industry veterans thought that housing prices couldn't go down and there wouldn't be many defaults (Hayre 2006). If the asset manager approximated the defaults as 0%, the actual returns would be 40% lower than expected. Another way to interpret this plot is to say that there should have been an expected average rate of default per year around 4.3% in the asset manager's model to have the same realized value.

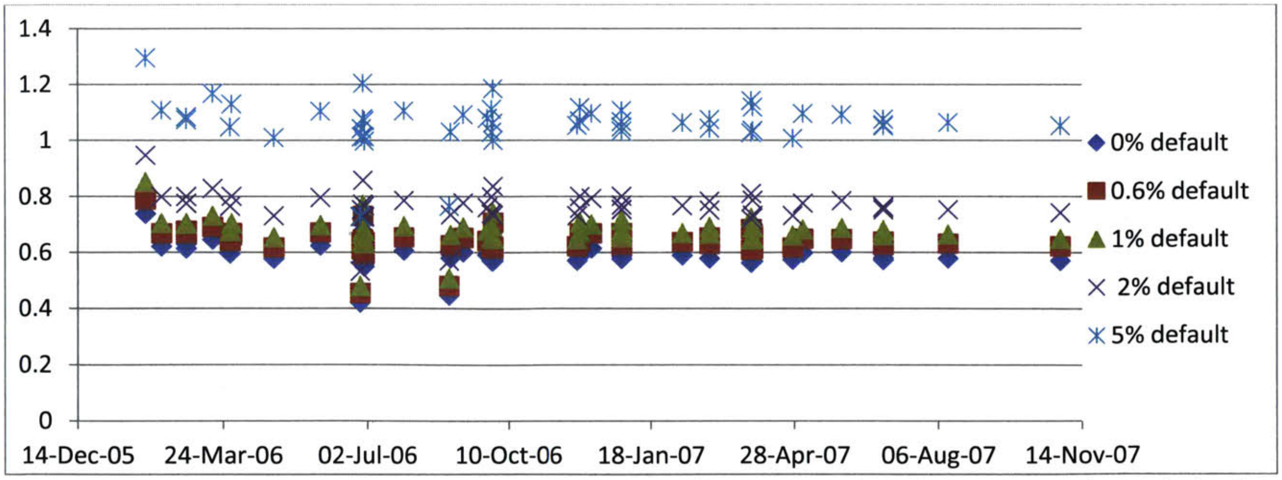

Figure 7.9- Actual return vs. expected return of subprime MBSs using various default scenarios

There are two components to determining what the losses would be for Countrywide Financial: the total losses of the MBS and what fraction of MBSs Countrywide held on to. It is unknown if these MBSs are the only MBSs that Countrywide Financial had on its books at the time, so these numbers represent minimum absolute losses for whoever held the securities. Now how much was the total loss in each of the MBS classes- prime, Alt-A, and subprime? Summing up the losses in the above figures we get the table below. People are typically very visual learners so these data have also been put into Table 7.1. It should be noted that dnc stands for did not calculate (due to time constraints). One can see that as the level of risk goes up, the expected default rate that matches the data goes up, which makes intuitive sense. Using the data, the primes should be using an annual default rate of approximately 0.6% while the ALT-A MBS should have been using a default rate of 0.7%. The subprime MBSs are where the data get interesting. These data suggest that the subprime MBSs should have baked in a 4.3% annual default rate over approximately 360 months (~30 years)! This is a staggering default rate when compared to the standard SDA model or even many multiples of it. As we know now, this was not priced into the model which led to enormous losses for whoever held these securities.

	Actual Value as Calculated ($B)	Expected Value ($B)						
		r=0%	r=0.6%	r =1%	r=2%	r=4%	r=4.3%	r=5%
Prime	42.416	46.004	42.608	40.392	35.889	dnc	dnc	25.948
Alt-A	8.049	8.828	8.190	7.757	6.849	dnc	dnc	4.935
Subprime	58.149	98.455	90.857	86.224	76.206	60.507	58.782	55.777

Table 7.1- Expected value of MBS pools by type and actual MBS data

Looking at the table above, we see the raw calculated values of the MBS portfolio by credit score and expected default rate (r). For instance, if the asset manager used the SDA peak of 0.6% annual defaults and extended this for 30 years, they would have come up with an expected value of $42.608B for the MBS prime pool. The actual value of the pool as calculated was $42.416B. If the asset manager priced in an annual rate of 0.07% defaults per year, this is almost 0% for our purposes. This yields a $46.004B expected value. Therefore if this was the prediction, the asset manager would actually see a loss of $3.5B as compared to its model. The worst case is if the asset manager predicted close to a 0% default rate; this would have yielded a $40B loss on whoever held the subprime MBSs! Being generous to Countrywide Financial's model might yield a 2% annual default rate. This is the same as saying that they would have had to predict that only 54.5% of the subprime mortgages would not default over 30 years which probably sounded like an absurd assumption. Let's use this 2% annual default to determine a lower bound on the potential losses. From Table 7.1 above it shows that this would lead to a valuation of all of the subprime MBSs of $76.206B when in fact the data shows that it should have been valued around $58.149B, a $18.057B loss. To better visualize this same data, it is displayed in Figure 7.10.

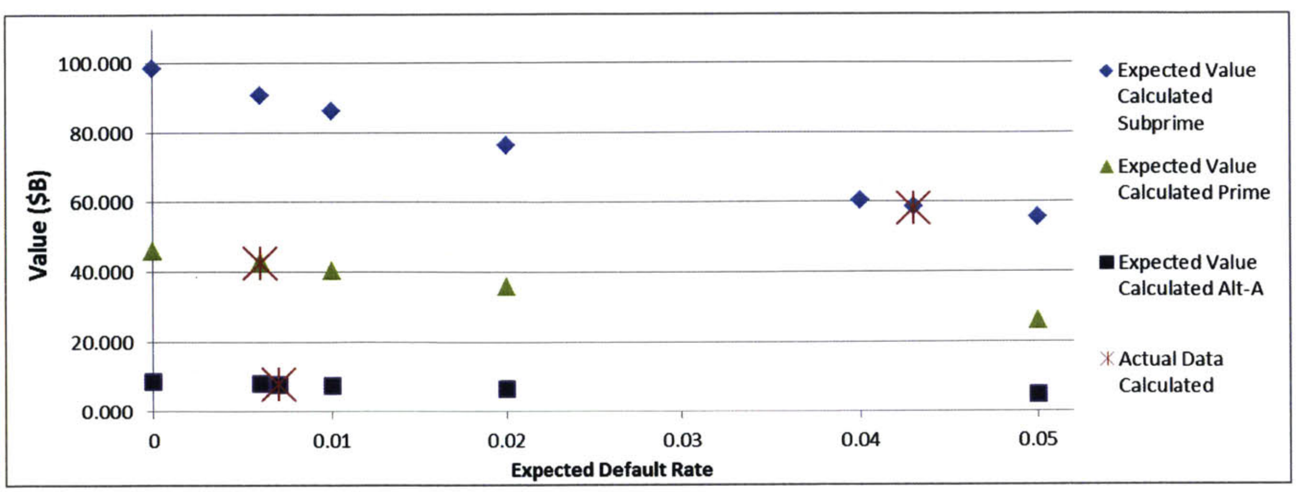

Figure 7.10- Expected value calculated and value using actual data in calculation of MBSs

	Expected Gains (%)						
	r=0%	r=0.6%	r =1%	r=2%	r=4%	r=4.3%	r=5%
Prime	-7.80%	-0.45%	5.01%	18.19%	dnc	dnc	63.47%
Alt-A	-8.83%	-1.72%	3.76%	17.51%	dnc	dnc	63.11%
Subprime	-40.94%	-36.00%	-32.56%	-23.69%	-3.90%	-1.08%	4.25%

Table 7.2- Expected Gains of MBS portfolios by credit type

Another way to view the same data is to see it as a percentage gain. This is shown above in Table 7.2. This table clearly indicates the delineation of expected gains versus expected losses. For instance, if an asset manager expected a 5% annual default rate for approximately 30 years on the subprime MBSs, they would have gained 4.25% compared to their expectation. They would have had to see this crisis coming to have this default rate inside their model. On the other hand, it is easy to see that if they expected a default rate of effectively 0%, this would lead to a loss of over 40% for all subprime MBS overall! This is a *significant* loss. It is unknown exactly what type of default model that Countrywide Financial was using at the time, but for the time being it will be assumed that that it is equivalent to something between 0%-2% annually, for 30 years. This gives us a range of 23.69% - 40.94% loss for all of the subprime MBSs originated at Countrywide Financial, as shown in Table 7.2. The only buckets of MBSs that are modelled to have positive returns are those with roughly over 1% annual default rate for primes and Alt-As, and around 5% annual default rates for the subprimes. These positive return scenarios are indicated by the thick box borders in Table 7.2, and lay at the right side of the table and are highest with the primes. This makes sense since if the modeler predicted a higher default rate than what actually happened, the expected return would be positive. Similarly, all of the negative percentage values are on the left, and the most negative values are on the lower left with the subprime mortgages when the expected annual default rate was 0%.

Now that the total losses for these MBSs have been examined, we can make estimates on what percentage of these MBS were held by Countrywide Financial. The question can be rephrased in a common question: when the game of musical chairs stops, who gets the last chair? In this situation it's asking how many MBSs is Countrywide Financial left with?

To answer this question, we turn to the publically available information as stated in the 2007 annual financial statement given to the SEC, available on the 29th of February 2008. In particular, from (US Securities and Exchange Commission 2007, 17) that:

"Recent disruptions in the public corporate debt and secondary mortgage markets have resulted in changes in our financing needs and how we finance our operations. Before August 2007, a substantial portion of our financing needs was met by the issuance of unsecured and asset-backed commercial paper and by the sale of mortgage loans into the secondary mortgage market, primarily in the form of MBS and ABS. The current lack of liquidity in those markets, particularly for non-agency-eligible mortgage loans, has resulted in an increase in our financing needs as we have to hold certain loans for longer periods of time pending sale and hold loans for investment that have become nonsalable due to market disruptions...We rely on the secondary mortgage market as a source of long-term capital to support our mortgage banking operations. In response to the recent decline in secondary mortgage market liquidity for non-agency-eligible mortgage loans, we have modified our product offerings such that the majority of loans we originate are eligible for sale to Fannie Mae, Freddie Mac or Ginnie Mae. At this time, virtually all non-agency-eligible loans are being held on our balance sheet."

There are a few key statements in this information. The first is that Countrywide Financial's old funding model was broken; they were no longer able to easily tap the secondary market to get unsecured mortgage financing after August 2007. The second piece of information is that the "current lack of liquidity... has resulted in an increase in our financing needs as we have to hold certain loans for longer periods of time pending sale and hold loans for investment that have become nonsalable due to market disruptions." This is directly saying that since they could no longer sell their MBSs and ABSs they couldn't use the proceeds to originate new or buy existing mortgages to securitize. The bigger piece of information from the snippet is that they had to hold the loans for longer periods of time because they couldn't sell them; the game of musical chairs ended and they were without a chair. They go on to say that "virtually all non-agency-eligible loans are being held on our balance sheet." This meant that there was no liquidity in the secondary market where they could sell these non-agency backed securities, so they had to keep them on their books. Therefore we can say with some certainty that there was a very high percentage of the subprime loans made or bought by Countrywide Financial couldn't be sold. Let's just assume this percentage to be about 80% for "virtually all non-agency-eligible loans." That indicates that roughly 80% of the subprime and Alt-A MBSs were kept on the books, and therefore Countrywide Financial would incur 80% of their losses. Since the Alt-A MBSs didn't seem to be that overpriced, our analysis can concentrate on just the subprime MBSs. Above we calculated that the losses would be in the range of \$18.057B to \$40.306B. ***If we take 80% of each of these numbers we come up with a range of losses attributed to Countrywide Financial of \$14.446B to \$32.245B***. As of Sept 30th, 2007 they only had \$4.77B of cash on the balance sheet- much less cash than was needed to withstand the tens of billions of dollars in losses (US Securities and Exchange Commission 2007). If the markets were liquid, they may have been able to liquidate other assets, but this was not the case at the time. They ended up being acquired by Bank of America on January 11th, 2008, for about \$4B (Mildenberg 2008).

Looking at current 2015 financial statements for the Bank of America- the entity that purchased Countrywide Financial in 2008- we can see Countrywide's total losses and exposure from 2004-2008. This is a slightly longer time frame than the 2006-2007 data that was examined above, but it gives a good indicator to what actually ended up happening. This data is found on page 53 of (US Securities and Exchange Commission 2015) and the table is shown below in Table 7.3. Although it is hard to read due to its width, over this time period it shows that the total principal defaulted or severely delinquent for Countrywide Financial was \$185B out of \$716B lent, for an overall default or severely delinquent rate of 25.8% over all products- prime, Alt-A, pay-option, home equity, and subprime. The subprimes for all of Bank of America's entities has a default or severely delinquent rate of 35%. Also, the interest on the principal is not included in the above losses. This effectively would lead to tens of billions of dollars more in losses than indicated. Unfortunately, there is no breakout specifically for Countrywide

Financial's subprime mortgages so we can't exactly compare apples to apples, although this table gives us a good estimate for principal losses and overall default percentages. With this data and analysis we can see that there were major market mispricings and extreme overvaluations in mortgage backed securities from 2004-2008; these mispricings along with illiquidity of the subprime MBSs resulted in extreme losses as calculated above and verified after the fact with actual data.

Overview of Non-Agency Securitization and Whole-Loan Balances from 2004 to 2008

	Principal Balance				Defaulted or Severely Delinquent	
(Dollars in billions)	Original Principal Balance	Outstanding Principal Balance September 30 2015	Outstanding Principal Balance 180 Days or More Past Due	Defaulted Principal Balance	Defaulted or Severely Delinquent	Borrower Made Less than 13 Payments
By Entity						
Bank of America	$ 100	$ 13	$ 2	$ 8	$ 10	$ 1
Countrywide						
BNY Mellon Settlement	409	89	19	88	107	15
Other	307	50	11	67	78	9
Total Countrywide	716	139	30	155	185	24
Merrill Lynch	72	12	2	20	22	4
First Franklin	82	12	2	29	31	5
Total [1, 2]	$ 970	$ 176	$ 36	$ 212	$ 248	$ 34
By Product						
Prime	$ 302	$ 48	$ 5	$ 29	$ 34	$ 2
Alt-A	173	40	8	42	50	7
Pay option	150	30	8	46	54	5
Subprime	251	46	13	75	88	17
Home equity	88	9	—	18	18	2
Other	6	3	2	2	4	1
Total	$ 970	$ 176	$ 36	$ 212	$ 248	$ 34

[1] Excludes transactions sponsored by Bank of America and Merrill Lynch where no representations or warranties were made.

[2] Includes exposures on third-party sponsored transactions related to legacy entity originations.

Table 7.3- Non-agency securitization from 2004-2008 for Bank of America

Chapter 8: Conclusions, Recommendations and Future Research

"You can't connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future. You have to trust in something - your gut, destiny, life, karma, whatever. This approach has never let me down, and it has made all the difference in my life."

-Steve Jobs, (BrainyQuote 2015)

"I never think of the future - it comes soon enough."

-Albert Einstein, (BrainyQuote 2015)

"Remembering that I'll be dead soon is the most important tool I've ever encountered to help me make the big choices in life. Because almost everything — all external expectations, all pride, all fear of embarrassment or failure — these things just fall away in the face of death, leaving only what is truly important. Remembering that you are going to die is the best way I know to avoid the trap of thinking you have something to lose."

-Steve Jobs, 2005 Stanford Univ. Commencement, (Stanford University 2005)

One of the goals of this thesis is to give a prescriptive framework for architecting the housing market as a whole. Using object process methodology (OPM) the object process diagram (OPD) can be created. The proposed architecture is shown in Figure 8.1 below. It has a few main functions: to create and continually modify the financial system architecture, to finance homeowners, to build new houses, to have an orderly transfer of house deeds, to set the rules in the securitization market, to help create CMOs and CDOs, and finally to assist in creating liquidity for the MBS market. Almost all of the agents in the system- mentioned in Chapter 2- are portrayed in this figure.

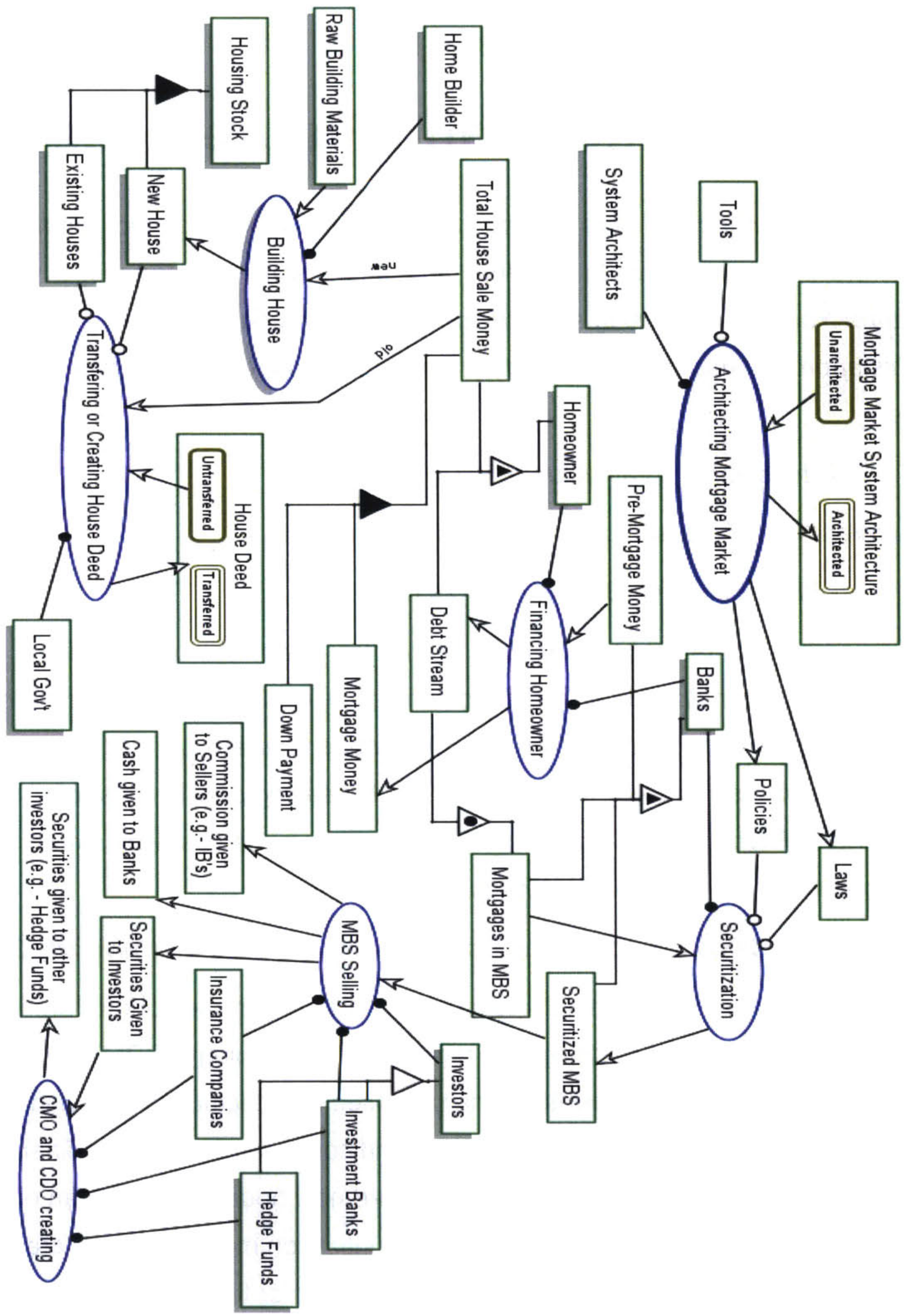

Figure 8.1- Proposed mortgage market system architecture

Figure 8.1 has many parts to it and needs to be described in more detail. First, the rectangular blocks represent objects. Objects can represent operands, agents, and instruments in the real world. Agents are pretty self-explanatory, but instruments and operands need to be defined. Instruments are the formal objects that are used to perform processes. These are represented by a line with an unfilled circle at the end of it linking an instrument to a process. Operands are the objects that get transformed or destroyed by a process. Agents are linked to processes by a line with a filled circle. The arrows that go from an object to a process are indicating that the object is being destroyed by the process. Arrows going from processes to objects indicate the object is being created by the process. For our purposes, the last main type of arrow is the double arrow, which is an arrow going both ways. This shows that the process affects or modifies the object's attribute's state in some way. All of this is shown in Figure 8.2 as an easy reference.

Symbol	—●	—○	—▷	◁—▷
Meaning	The source object/state is an agent of the target process	The source object/state is an instrument of the target process	The source/target process yields/consumes the target/source object	The source object is affected by the target process

Figure 8.2- OPM procedural links (Wikipedia, the free encyclopedia 2015)

Similarly, the structural relations, shown in Figure 8.3, can be interpreted as follows. The objects attached to a filled in triangle symbol represents the elements contained in the parent object. An object attached to a filled triangle within an unfilled triangle indicates that the object that is under the symbol is an attribute of the object above the symbol. Lastly, the unfilled triangle indicates that the object below the symbol is a specialization of the object above the symbol. Alternatively it can be stated that the object above the symbol is a generalization of the object below the symbol.

Symbol	▲	▲ within △	△
Meaning	Relates a whole to its parts	Relates an exhibitor to its attributes	Relates a general thing to its specializations

Figure 8.3- OPM fundamental structural relations (Wikipedia, the free encyclopedia 2015)

Now that the overall system and OPM has been discussed, the most important sub-process, architecting the mortgage market, should be examined more in depth. One can see that the goal of the architecting mortgage market process is to have the state of the mortgage market system architecture go from unarchitected to architected. To achieve this, the system architects are needed along with tools. The system architects consist of the major players in the market such as insurance companies, ratings agencies, banks, investors, homebuilders the Federal Reserve, and the US government, who is a proxy for the homeowners. The conceptual tools that can be used to architect this system are system dynamics, the stakeholder value network, network analysis, OPDs (using tools like Opcat) like the ones in this chapter, financial instrument valuation tools, and other tools such as attractors and cascading effects. Other tools and concepts that could be considered are emergence, complexity, self-organization, ecosystems, interdependence, adaptation and thinking of these financial systems on different scales. In terms of the system shown in Figure 8.1 and 8.4 above, the first step is to do system analysis and simulation in order to achieve a realistic housing market system model, which has been attempted in part previously in Chapters 5 through 7. This consists of creating models for financing the homeowner, rating securities, investing by financial institutions, building house by homebuilders, the selling of houses, and the securitization of MBS's. After creating the model, rules and policies are suggested and debated. The outcome of this is that actual laws, rules, and policies are added, deleted or modified. These laws, rules, and policies need to be implemented by the various agents that are experts in execution. In this way, these laws, rules, and policies and markets are created, destroyed, or altered to change the system as a whole.

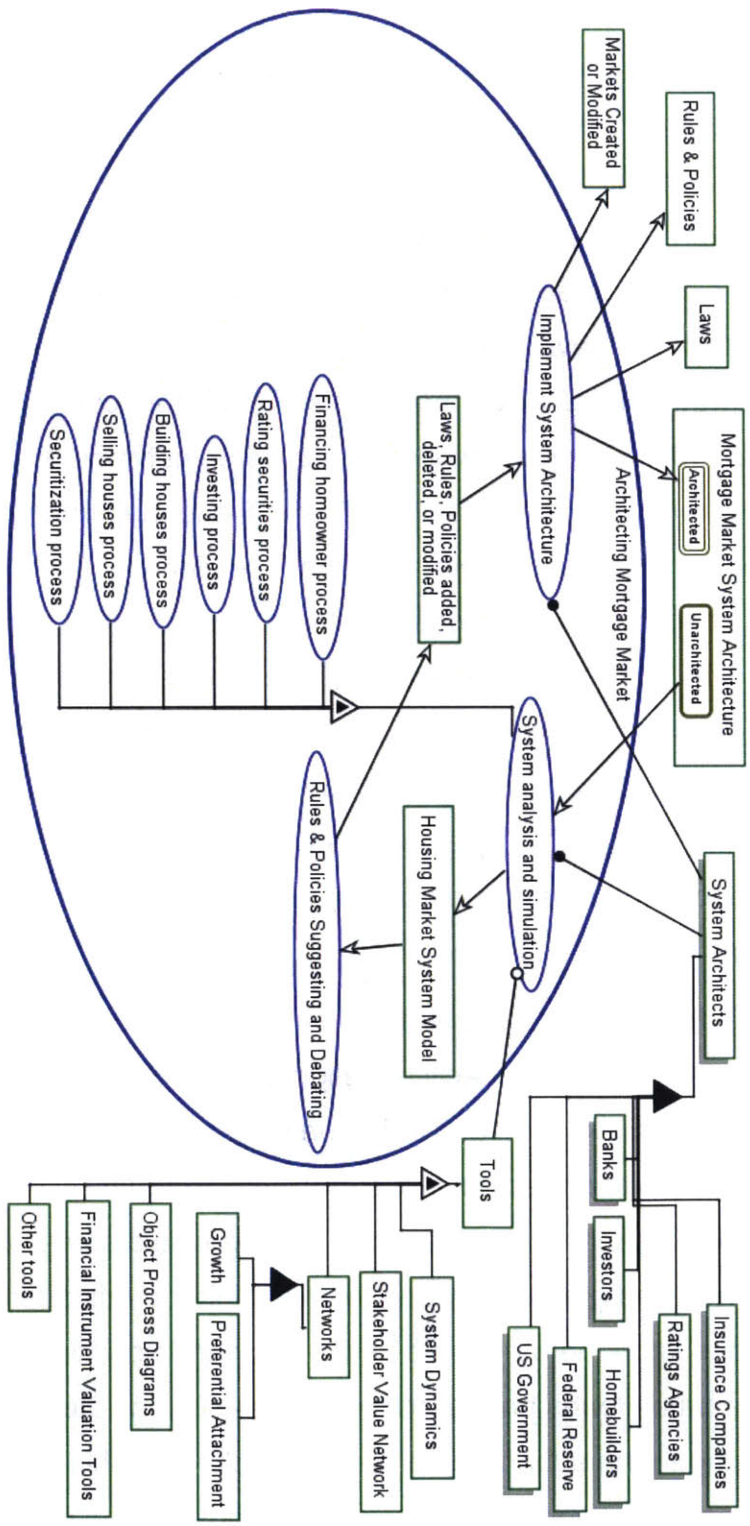

Figure 8.4- Architecting Mortgage Market sub process with contributions and future work

Now that the topic of system architecture has been discussed, what other things should be considered when modeling the housing market system? Two concepts covered in the previous chapters come to mind: the incentive structure for the various agents in the system and the system's dynamics, both physical and informatical. Other things not discussed explicitly in this thesis are shadow banking transparency issues and the fact that major financial hubs- like large banks e.g.- Countrywide Financial and insurers like AIG- are considerable network failure points in scale-free networks. Scale-free networks are ones that have the two requirements in creation of preferential attachment and growth, both of which are surmised to be part of this financial system (Barabasi and Albert 1999). If the network is a scale free network, the distribution of network connections follows a power law. If a few of these major network nodes (e.g.- Countrywide Financial, AIG, Freddie Mac, Fannie Mae, Bank of America, etc.) were to go down in a short period of time, the network itself could break apart into many unconnected parts which will have significantly fewer connections, which is a bad outcome. A last suggestion for improving the system with a law would be to make it mandatory for all banks that originate a mortgage to hold on to a portion of all of the classes of MBS and not just the 'B' class as it is written currently. This way there is much less incentive to discard unwanted portions of the risk spectrum to make sure the bank originates loans that can be repaid.

A for the incentive structure of the agents in the system, the business models may need to be changed in order to facilitate aligning incentives. For instance, in order to slow the rate of the MBS creation and sale, the investment banks and ratings agencies may need to change their business model from commission based to "subscription" or quality based. In this way they could get paid some constant amount per year for the service and get incentivized to have higher credit quality MBS. Another thing that can be done is on the other side of the stock and flow diagram: have the banks only originate prime loans and let other entities- such as the federal government- take the risk of lending to the subprime homeowners directly. This may reduce the incentive of having as many mortgages originated as possible, whether they are good or bad. Similar to the investment banks and ratings agencies, a business model that is subscription or quality based may work better to incentivize the banks not to have as high of a throughput of mortgages that preys on the subprime borrower with teaser rates or no money down mortgages. In addition, if possible, the Federal Reserve may need to temper their rate hikes and reductions to reduce the oscillatory behavior of the housing market. The alteration of the interest rates to extremely low levels encourages much more flow of money which cause the mortgage standards to reduce and availability of credit to rapidly increase. This causes many more potential subprime homeowners to enter the market and unknowingly be signing up to be foreclosed upon at a later date.

When simulating the housing system, it can be seen that the supply and demand have a large impact on the housing price. The price increase is largely due to the mortgage affordability and standards in place at the time, and secondarily to the population increase and percentage of people interested in owning a house. The average house price decrease is largely determined by the existing housing stock. These factors affect the average house price and then the mortgage affordability which in turn affects the number of new houses built. The new houses that are built increase the housing stock while the number of houses demolished decreases it. The number of mortgages originated is determined by the number of existing house sales, new house purchases, and finally refinances. The number of mortgages at any one time is determined by the flow of the mortgages originated by the market participants, the mortgages purchased, and the securitization or sale of these mortgages. The sale of the MBSs is influenced by the investor demand which is determined by the perception of making profit, the interest rates, and the ability of GSEs to purchase MBSs. Also, the fear of missing out played a large part in driving the dynamics at the investment in MBS level. The more entities profited off the housing market, the more other entities were interested in the space. All of these agents and their respective incentives govern the dynamics of the system and can be predicted to the 1st order using the system dynamics model developed.

In terms of the fundamentals of the housing market there are some future threats or opportunities depending on the stakeholder. Future threats to the housing market as seen from the current homeowners' and current mortgage buyers' point of view are 3D printed houses: these affect the average price of an existing house since the number of houses supplied to the market will shortly be much higher due to their cost of around $5,000 (Costrel and Rega 2015). Other agents in the system, such as the homeowners, will see a drastic reduction of home prices and the number of people that can afford houses will skyrocket, not just in the US, but worldwide. This new technology will primarily affect the lower end of the market since it is expected that people who are well off will continue to have their houses made by current home builders.

One social trend that is and will continue to affect the housing market is the fact that people want to live in and around the city. More and more people are moving from rural lands to urban areas, as shown in Figure 8.5 below (US Census Bureau 1995 and Berg 2012). Edward Glaeser shows in this book Triumph of the City that "the high price of urban land leads naturally to multiunit dwellings, and 85 percent of such dwellings are renter-occupied." (Glaeser 2011, 264). Future dwelling- both house and apartment complex- analyses will need to take into consideration the fact that in the downtown areas of large cities many people do not own houses but in fact rent units in multiunit dwellings. This will surely influence the overall demand for housing in the coming decades.

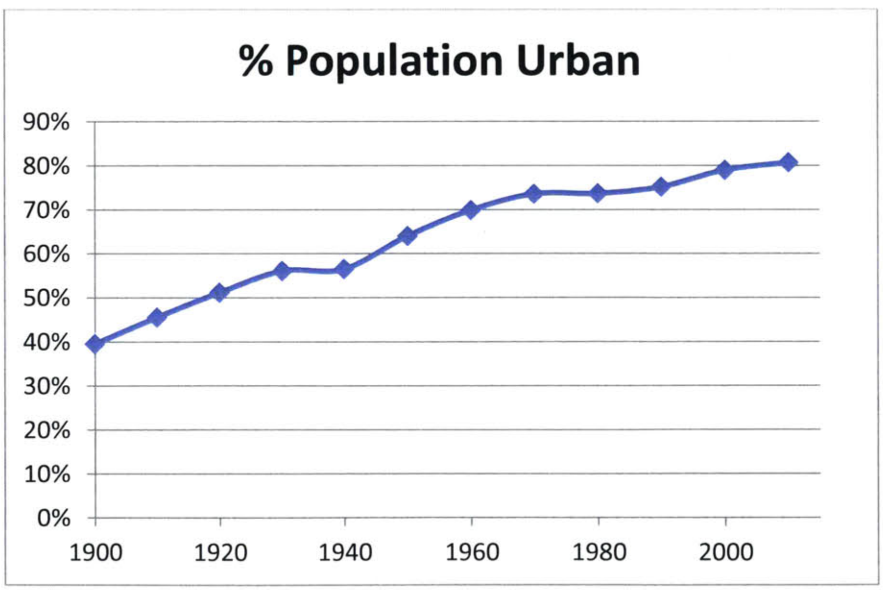

Figure 8.5- The percentage of the US population that is urban over time (data from US Census Bureau 1995 and Berg 2012)

In terms of future research, the topic of networks has not been addressed in this thesis although the author believes it to be an extremely important dynamic during the panic of late 2008 through early 2009. It would be particularly interesting to examine the actual network of the banks, insurance companies, and MBS investors to see how the financial network was connected at the time, and a few articles have recently addressed this (Elliott, Golub, and Jackson 2014, and Glasserman and Young 2015). It may turn out that the MBS financial market was a scale-free network much like other manmade networks like the Internet, World Wide Web, social networks and citation networks are. This type of network comes about due to two conditions being in place: preferential attachment and growth. The network needs to be growing, which it probably was, both in number of entities and number of transactions and linkages between MBSs and financial entities. Preferential attachment is a mechanism whereby the credit or wealth is given preferentially to those that already have it. If these two conditions are true, the outcomes of the system's network such as wealth or number of connections per entity are represented by a power law distribution, where few firms control most of the wealth due to their many connections (and consequently, complexity).

In addition to future research discussed above, researchers should look into other markets that utilize the asset securitization process and inspect overall credit trends. One such industry that is particularly interesting currently is the auto loan market. One can see from Figure 8.6 that the subprime auto loan market is experiencing a boom right now and the growth trend is very positive. While the auto loan market is much smaller than the mortgage market, it is an area that the author believes should be watched closely in the coming years. A very similar analysis to that done above could be completed for banks such as Santander Consumer USA and American Credit Acceptance. Many of these asset backed securities (ABS) have loans with "average FICO scores in the low to mid 500s." (Colomer 2015). Due to the low credit scores and low loan standards, these companies may be in trouble when the liquidity dries up in the secondary ABS markets, just like Countrywide Financial.

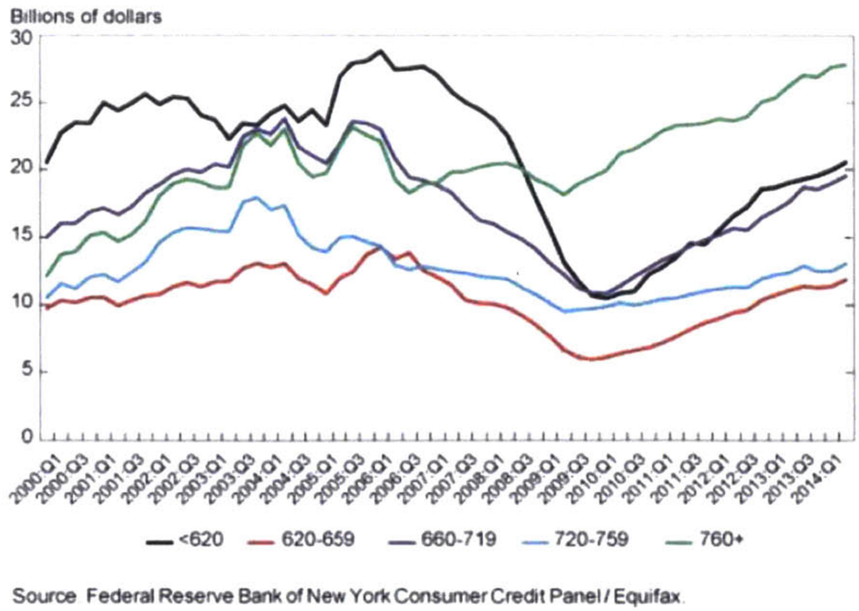

Figure 8.6- Auto loan originations by credit score (Griswold 2014)

It was shown early on in this thesis that the essence of money, debt, and their difference from obligations were at the heart of the mortgage financial instrument. If people only had obligations between one another, there wouldn't be a mortgage financial instrument. This would smother the housing market since then the only way to create a house would be by having neighbors, relatives, and friends help out. Because mortgages are a way of transferring and accounting for debt between parties that don't know each other, they allow for the finance of labor from unrelated parties to construct houses with a promise of repayment to the financiers by the homeowner over many years. Due to the absence of informal obligations in the housing market, it has been able to grow tremendously over the last century. In addition, the allocation of slices of risk along the risk spectrum to entities desiring varying levels of risk has allowed the prepayment and default risk of pools of mortgages. This has permitted more mortgages to be financed, which has led to overall lower interest rates on loans. The lower interest rate has enabled even more mortgages to be financed, thus enabling a robust reinforcing feedback loop. In essence, structured finance has enabled more houses to be able to be built than ever before, but it has also come with the cost of financial complexity. The complexity of the financial instruments created over the last few decades has also led to the lack of understanding of the system, to the detriment of many of the unsophisticated- and even some sophisticated- agents in the system. Even so, the mortgage boom, bust, and ensuing financial crisis could have been generally predicted as much as one to two years ahead of time using a long time frame and the system dynamics tool. Because the crisis could have been predicted, it possibly could have been thwarted if the right steps were taken.

In this last chapter, the author proposed that a housing market working group should be formed that consists of all of the agents in the ecosystem in order to create a financial system architecture that benefits all and provides stability to the market. In this way, the near system-wide calamity could be diverted in the future, and possibly save firms like Countrywide Financial from failure. In conclusion, with this macroeconomic view in mind, it was shown that Countrywide Financial could have been predicted to fail in the 2008 timeframe with a fair degree of certainty using the available tools outlined in this thesis.

Appendix

A. Scripts and functions for pricing MBSs

priceMultipleMBS.m

```
clear all
close all
%get file names from list

listFileName ='Subprime 2006-2007.xlsx';
%listFileName = 'Portfolio 2006-2008.xlsx';
xlRange = 'C:C';
[NUM,TXT,RAW] = xlsread(listFileName,xlRange);

for i=1:length(TXT)
  files(i) = TXT(i);
end

numRuns =1;
count =0;

%GIVENS:
r =0.02;
CDR =0.0425;     %change this variable
for k = 2:length(TXT)

  filename = sprintf('%s',files{k});
  for j= 0:CDR:CDR

    count =count+1
    MBS_price_total(k,count) = 0;
    for i=1:numRuns
      %filename
      [subprime, defaultProb, MBS_price, default, prepay] = PriceMBS(filename,1,1,1,r,j);

      MBS_price_total(k,count) = MBS_price_total(k,count) +MBS_price;
      %MBS_price_total(k,count)
    end
    MBS_price_total(k,count) = MBS_price_total(k,count)/numRuns;

  end
  count =0;
end
```

PriceMBS.m

```
function [subprime, defaultProb, MBS_price, default, prepay] = PriceMBS(filename,prepayModelOn,
defaultModelOn, DCFdiscountingOn, r, defaultAve)
%The goal of this function is to take the input file given by filename and
```

```
%output a price for the MBS using the created algoritm and existing
%algorithm

%defaultAve is the annual average default rate (CDR) as a static number, usually around
%0.05. If this is equal to 0, then the default rate per house is calculated

%prepayModelOn bit allows the prepay model to turn on

%defaultModelOn bit allows the default model to turn on

%DCFdiscountingOn bit allows the DCF discounting to turn on

%defaultProbability(FICO,CLTV,IR, HPIG)
%r is the term structure yield


%get MBS data from Excel file
run getMBSData.m;

%get default data
run default_data.m;

subprime = zeros(length(HV),1);
for i =1:length(HV)
   if FICO(i)>640
      subprime(i) =0;
      HPIG = 0.0194;
   else
      subprime(i) =1;
      HPIG = 0.0152;
   end
end

%Get Interest Rates to PSA values table
run IR2PSAtable.m;

%B = [defaultProb;subprime]';
%[C,I] = sort(B);
%figure(2)
%plot(C)

%percentage = lookupPSAtoPercentage(Interest Rate, month, Table of IR to PSA)
%x = lookupPSAtoPercentage(0.06,12,T);

%Get interest rates
run FederalReserveIR.m;

N = length(subprime);
default = zeros(N,1);
prepay = zeros(N,1);
DCF = zeros(N,1);
CF_stream = zeros(N,1);
cash1 = zeros(N,1);
```

```
defaultProb = zeros(N,1);

%create cash flow vetor from each house
for i=1:N
   CF(i) =PIAmt(i);%PMT(IR(i)/12,360,LV(i));
end

%variables
%monthsFromEnd =60;
%monthsFromBeg = 360+monthsFromEnd;
t_start =0;
%y= 0.01*FederalReserveIRvar(:,2);
%spread =0.02;

for j = 1:max(remainingTerm)
   Z(j) = exp(-(r)*(j/12-t_start));    %discount factor
end

%run MBS pricing model from month 1 to month 360
for j = 1:max(remainingTerm)

   for i =1:length(HV)


   if(j<12)   %2006, 12mo
      statistics(1,1) = Default_averages(2,3);    %prime ave
      statistics(1,2) = Default_averages(2,7);    %subprime ave
      statistics(2,1) = Default_explanatory_variable(2,3);    %prime    %HPI growth modifier
      statistics(2,2) = Default_explanatory_variable(2,7);    %subprime %HPI growth modifier
      statistics(3,1) = Default_explanatory_variable(3,3);    %prime    %FICO score modifier
      statistics(3,2) = Default_explanatory_variable(3,7);    %subprime %FICO score modifier
      statistics(4,1) = Default_explanatory_variable(4,3);    %prime    %Loan to value ratio (LTV) modifier
      statistics(4,2) = Default_explanatory_variable(4,7);    %subprime %Loan to value ratio (LTV)
modifier
      statistics(5,1) = Default_explanatory_variable(5,3);    %prime    %Interest rate at origination
modifier
      statistics(5,2) = Default_explanatory_variable(5,7);    %subprime %Interest rate at origination
modifier
      statistics(6,1) = loan_characteristics(2,3);        %average prime FICO score
      statistics(6,2) = loan_characteristics(2,7);        %average subprime FICO score
      statistics(7,1) = loan_characteristics(3,3);        %average prime LTV ratio
      statistics(7,2) = loan_characteristics(3,7);        %average subprime LTV ratio
      statistics(8,1) = loan_characteristics(4,3);        %average prime Interest rate at origination
      statistics(8,2) = loan_characteristics(4,7);        %average subprime Interest rate at origination
   elseif(j>=12)&&(j<18) %2007-2007.5, 18mo
      statistics(1,1) = Default_averages(3,3);    %prime ave
      statistics(1,2) = Default_averages(3,7);    %subprime ave
      statistics(2,1) = Default_explanatory_variable(2,4);    %prime    %HPI growth modifier
      statistics(2,2) = Default_explanatory_variable(2,8);    %subprime %HPI growth modifier
      statistics(3,1) = Default_explanatory_variable(3,4);    %prime    %FICO score modifier
      statistics(3,2) = Default_explanatory_variable(3,8);    %subprime %FICO score modifier
      statistics(4,1) = Default_explanatory_variable(4,4);    %prime    %Loan to value ratio (LTV) modifier
      statistics(4,2) = Default_explanatory_variable(4,8);    %subprime %Loan to value ratio (LTV)
modifier
```

```
    statistics(5,1) = Default_explanatory_variable(5,4);     %prime    %Interest rate at origination
modifier
    statistics(5,2) = Default_explanatory_variable(5,8);     %subprime %Interest rate at origination
modifier
    statistics(6,1) = loan_characteristics(2,4);           %average prime FICO score
    statistics(6,2) = loan_characteristics(2,8);           %average subprime FICO score
    statistics(7,1) = loan_characteristics(3,4);           %average prime LTV ratio
    statistics(7,2) = loan_characteristics(3,8);           %average subprime LTV ratio
    statistics(8,1) = loan_characteristics(4,4);           %average prime Interest rate at origination
    statistics(8,2) = loan_characteristics(4,8);           %average subprime Interest rate at origination
  elseif(j>=18)&&(j<=21) %2007.5-2007.75, 21mo
    statistics(1,1) = Default_averages(4,3);   %prime ave
    statistics(1,2) = Default_averages(4,7);   %subprime ave
    statistics(2,1) = Default_explanatory_variable(2,4);   %prime    %HPI growth modifier
    statistics(2,2) = Default_explanatory_variable(2,8);   %subprime %HPI growth modifier
    statistics(3,1) = Default_explanatory_variable(3,4);   %prime    %FICO score modifier
    statistics(3,2) = Default_explanatory_variable(3,8);   %subprime %FICO score modifier
    statistics(4,1) = Default_explanatory_variable(4,4);   %prime    %Loan to value ratio (LTV) modifier
    statistics(4,2) = Default_explanatory_variable(4,8);   %subprime %Loan to value ratio (LTV)
modifier
    statistics(5,1) = Default_explanatory_variable(5,4);   %prime    %Interest rate at origination
modifier
    statistics(5,2) = Default_explanatory_variable(5,8);   %subprime %Interest rate at origination
modifier
    statistics(6,1) = loan_characteristics(2,4);           %average prime FICO score
    statistics(6,2) = loan_characteristics(2,8);           %average subprime FICO score
    statistics(7,1) = loan_characteristics(3,4);           %average prime LTV ratio
    statistics(7,2) = loan_characteristics(3,8);           %average subprime LTV ratio
    statistics(8,1) = loan_characteristics(4,4);           %average prime Interest rate at origination
    statistics(8,2) = loan_characteristics(4,8);           %average subprime Interest rate at origination
  else %2007.75+
    statistics(1,1) = defaultAve;   %prime ave
    statistics(1,2) = defaultAve;   %subprime ave
    statistics(2,1) = 0;   %prime    %HPI growth modifier
    statistics(2,2) = 0;   %subprime %HPI growth modifier
    statistics(3,1) = 0;   %prime    %FICO score modifier
    statistics(3,2) = 0;   %subprime %FICO score modifier
    statistics(4,1) = 0;   %prime    %Loan to value ratio (LTV) modifier
    statistics(4,2) = 0;   %subprime %Loan to value ratio (LTV) modifier
    statistics(5,1) = 0;   %prime    %Interest rate at origination modifier
    statistics(5,2) = 0;   %subprime %Interest rate at origination modifier
    statistics(6,1) = loan_characteristics(2,4);           %average prime FICO score
    statistics(6,2) = loan_characteristics(2,8);           %average subprime FICO score
    statistics(7,1) = loan_characteristics(3,4);           %average prime LTV ratio
    statistics(7,2) = loan_characteristics(3,8);           %average subprime LTV ratio
    statistics(8,1) = loan_characteristics(4,4);           %average prime Interest rate at origination
    statistics(8,2) = loan_characteristics(4,8);           %average subprime Interest rate at origination
  end
    if( defaultAve ~= 0)
      defaultProb(i) = defaultAve;
    else
      defaultProb(i) = defaultProbability(FICO(i),CLTV(i),IR(i),HPIG, statistics );   %the probability of
default in the next period of time
    end

    %default? Yes or No
```

```
    if(default(i) == 0)    %if it hasn't defaulted yet
      if(rand(1)<defaultProb(i)/12)
        default(i) =1*defaultModelOn;
      end
    else                  %it has already defaulted

    end

    %Prepay? Yes or No
    if(prepay(i) == 0)    %if it hasn't prepaid yet
      prepayProb(i) = lookupPSAtoPercentage(0.06,j,T); %(IR, month, T) % IR for 100% PSA = 0.06
      if(rand(1)<prepayProb(i)/12)
        prepay(i) =1*prepayModelOn;
      end
    else                  %it has already prepaid

    end

      if(j<=remainingTerm(i))
      %CF(i) =PMT(IR(i)/12,360,HV(i));              %Cash Flow payments per homeowner in this
period in $k
      CF_stream(i) =(1-default(i))*(1-prepay(i))*CF(i);  %if no default or no prepayment, = CF(i)

      %cash1(i) = cash1(i)+CF_stream(i);

      DCF(i) = DCF(i)+PVdiscounting(max(Z(j)*DCFdiscountingOn,(1-
DCFdiscountingOn)),CF_stream(i));  %input of IR in months, static spread rate, and cash flow stream
      end
      Z(j)*DCFdiscountingOn;
  end

end
%mean(subprime)
%figure(3)
      %plot(prepay)
      %figure(4)
      %plot(default)
MBS_price = sum(DCF(:));

end
```

defaultProbability.m

```
%The probability that a particular homeowner will default using author's
%simple model

% 1st order approximation of default probability determined from:
%https://www.chicagofed.org/~/media/publications/profitwise-news-and-views/2010/pnv-aug2010-reed-
final-web-pdf.pdf

function defaultProb = defaultProbability(FICO,CLTV,IR, HPIG, statistics) %Percentage
%FICO = FICO score
%CLTV: combined loan to value ratio
```

```
%IR = interest rate of individual homeowner
%HPIG = home price index growth in last 12 month
%AD = average default in first X months (12, 18, 21) months

%all values are normalized
%data % taken from 2006
defaultMod =0;
AD = 0;
%modification on average default rate on Prime
%weighting vectors can change over time
if (FICO ==1000)||(FICO > 640)  %prime
   FICO_norm= FICO/statistics(6,1);
   CLTV_norm = CLTV/statistics(7,1);
   IR_norm = IR/statistics(8,1);
   HPIG_norm = HPIG/0.0194;
   defaultMod = (statistics(2,1)*HPIG_norm +statistics(3,1)*FICO_norm +statistics(4,1)*CLTV_norm
+statistics(5,1)*IR_norm ) - (statistics(2,1)+statistics(3,1)+statistics(4,1)+statistics(5,1));

   AD = statistics(1,1);
end

%modification on average default rate on Prime
if (FICO ==0)||(FICO <= 640)    %subprice
   FICO_norm= FICO/statistics(6,2);
   CLTV_norm = CLTV/statistics(7,2);
   IR_norm = IR/statistics(8,2);
   HPIG_norm = HPIG/0.0194;
   defaultMod = (statistics(2,2)*HPIG_norm +statistics(3,2)*FICO_norm +statistics(4,2)*CLTV_norm
+statistics(5,2)*IR_norm ) - (statistics(2,2)+statistics(3,2)+statistics(4,2)+statistics(5,2));

   AD = statistics(1,2);
end
defaultMod;
defaultProb = min(max(0,defaultMod+AD), 1);

end
```

default_data.m

```
Default_averages =[2004, 2005, 2006, 2007, 2004, 2005, 2006, 2007; %years      %prime      %subprime
        0.0243, 0.0239, 0.0433, 0.0493, 0.1119, 0.1622, 0.2379, 0.2548;  %default rate within 12mo
        0.0390, 0.0374, 0.0767, 0.0686, 0.1592, 0.2335, 0.3491, 0.3387; %default rate within 18mo
        0.0511, 0.0491, 0.1051, 0.0640, 0.2335, 0.3172, 0.4375, 0.3215]; %default rate within 21mo


Default_explanatory_variable = [2004, 2005, 2006, 2007, 2004, 2005, 2006, 2007;   %years     %prime
%subprime
        -0.01, -0.05, -0.42, -0.01, -0.18, -0.10, -0.17, 0.00;          %HPI growth modifier
        -0.53, -0.46, -0.41, -0.42, -0.33, -0.34, -0.24, -0.20;         %FICO score modifier
        0.04, 0.14, 0.27, 0.29, 0.05, 0.05, 0.08, 0.07;                %Loan to value ratio (LTV) modifier
        0.48, 0.29, 0.64, 0.66, 0.28, 0.21, 0.20, 0.21];               %Interest rate at origination modifier
```

```
loan_characteristics = [2004, 2005, 2006, 2007, 2004, 2005, 2006, 2007;    %years     %prime
%subprime
              710 715 708 706 617 611 607 597;                  %FICO prime    subprime
              0.7592 0.7489 0.7599 0.7775 0.7963 0.8069 0.8040 0.8056;    %Loan to value ratio prime
subprime
              0.056 0.060 0.067 0.065 0.071 0.075 0.085 0.084];               %Interest rate at origination
prime  subprime
```

getMBSData.m

```
%filename ='CWABS_2006-15_loan_tape.xls';

%Interest Rate
xlRange = 'O:O';
IR = .01*xlsread(filename,xlRange);

%FICO Score
xlRange = 'BG:BG';
FICO = xlsread(filename,xlRange);

%CLTV
xlRange ='AB:AB';
CLTV = .01*xlsread(filename,xlRange);

%Loan Value in thousands
xlRange ='N:N';
LV = xlsread(filename,xlRange);
sum(LV)

%Appraised House Value in thousands
xlRange ='L:L';
HV = .001*xlsread(filename,xlRange);

%monthly payment
xlRange = 'F:F';
PIAmt = xlsread(filename,xlRange);

%remaining term
xlRange = 'AC:AC';
remainingTerm = xlsread(filename,xlRange);
```

IR2PSAtable.m

```
%Interest Rate to PSA table, T
T = [10.00,0;6.00,0.01;3.00, 0.03; 2.00, 0.04;1.00,0.06;0.75,0.08;.5,.12];
```

lookupPSAtoPercentage.m

```
%The goal of the lookup function is to output a percentage of mortgages that
%will prepay in a given month: from IR --> PSA --> CPR --> p % (% prepay
%per month)
%The inputs are IR (Interest Rate), month, and T (IR --> PSA) table
```

```
function percentage = lookupPSAtoPercentage(IR, month, T)

%Lookup PSA first
  %if(IR > 0)&&(IR<=1)
  if(IR <= T(1,2))
     PSA = T(1,1);
  elseif(IR <= T(2,2))&&(IR > T(1,2))
     PSA = (T(2,1)-T(1,1))*IR/(T(2,2)-T(1,2))+T(1,1);
  elseif(IR <= T(3,2))&&(IR > T(2,2))
     PSA = (T(3,1)-T(2,1))*(IR-T(2,2))/(T(3,2)-T(2,2))+T(2,1);
  elseif(IR <= T(4,2))&&(IR > T(3,2))
     PSA = (T(4,1)-T(3,1))*(IR-T(3,2))/(T(4,2)-T(3,2))+T(3,1);
  elseif(IR <= T(5,2))&&(IR > T(4,2))
     PSA = (T(5,1)-T(4,1))*(IR-T(4,2))/(T(5,2)-T(4,2))+T(4,1);
  elseif(IR <= T(6,2))&&(IR > T(5,2))
     PSA = (T(6,1)-T(5,1))*(IR-T(5,2))/(T(6,2)-T(5,2))+T(5,1);
  elseif(IR <= T(7,2))&&(IR > T(6,2))
     PSA = (T(7,1)-T(6,1))*(IR-T(6,2))/(T(7,2)-T(6,2))+T(6,1);
  else   %if interest rate is really high use max value
     PSA = T(7,1);
  end

  prepayRate =0.06;
  %Calculate CPR using PSA, and month
  if(month <=0)
     CPR = 0;
  elseif(month <30)&&(month >0)
     CPR = PSA*(prepayRate/30)*month;
  else
     CPR = PSA*prepayRate;
  end

  percentage =1-(1-CPR)^(1/12);      %SMM rate

end
```

PVdiscounting.m

```
function Price =  PVdiscounting(Z,CF_stream)

Price = 0;
Price = Z*CF_stream;

end
```

PMT.m

```
function out = PMT(monthlyIR,numberMonths,loanSize)

out = loanSize/((1-(1/(1+monthlyIR))^numberMonths)/monthlyIR);

end
```

B. Data

All raw data (tranche, ID, File Name, Close Date, and Size) taken from Countrywide Financial website

Raw MBS Data: Alt-A & Prime

Series / Tranche	ID	File Name	Collateral	Close Date	Size
Countrywide MBS 2006-3	CWHL 2006-3	37105_cls.xls	ALT A	31-Jan-06	1,052,797,100
Countrywide MBS 2006-HYB1	CWHL 2006-HYB1	38389_cls.xls	ALT A	31-Jan-06	1,174,056,502
Countrywide MBS 2006-HYB3	CWHL 2006-HYB3	38391_cls.xls	ALT A	28-Apr-06	981,621,231
Countrywide MBS 2006-HYB4	CWHL 2006-HYB4	38392_cls.xls	ALT A	30-May-06	452,870,239
Countrywide MBS 2006-OA1	CWALT 2006-OA1	42089_cls.xls	ALT A	28-Feb-06	1,068,159,354
Countrywide MBS 2006-OA4	CWHL 2006-OA4	38395_cls.xls	ALT A	28-Feb-06	778,263,100
Countrywide MBS 2006-OA5	CWHL 2006-OA5	37169_cls.xls	ALT A	28-Feb-06	1,364,317,100
Countrywide MBS 2006-TM1	CWHL 2006-TM1	38397_cls.xls	ALT A	17-Mar-06	920,492,264
Countrywide MBS 2007-HY6	CWHL 2007-HY6	43309_cls.xls	ALT A	28-Sep-07	1,218,570,771
Countrywide MBS 2007-HYB2	CWHL 2007-HYB2	40275_cls.xls	ALT A	30-Mar-07	633,370,162
Countrywide MBS 2006-1	CWHL 2006-1	37162_cls.xls	Prime	30-Jan-06	375,999,710
Countrywide MBS 2006-10	CWHL 2006-10	38381_cls.xls	Prime	30-Mar-06	607,794,743
Countrywide MBS 2006-11	CWHL 2006-11	38385_cls.xls	Prime	27-Apr-06	629,999,855
Countrywide MBS 2006-12	CWHL 2006-12	38390_cls.xls	Prime	30-May-06	655,999,946
Countrywide MBS 2006-13	CWHL 2006-13	38366_cls.xls	Prime	28-Jul-06	521,999,957
Countrywide MBS 2006-14	CWHL 2006-14	38368_cls.xls	Prime	31-Jul-06	367,999,538
Countrywide MBS 2006-15	CWHL 2006-15	38896_cls.xls	Prime	30-Aug-06	398,999,274
Countrywide MBS 2006-16	CWHL 2006-16	39169_cls.xls	Prime	28-Sep-06	999,996,196
Countrywide MBS 2006-17	CWHL 2006-17	39366_cls.xls	Prime	30-Oct-06	520,984,825
Countrywide MBS 2006-18	CWHL 2006-18	37152_cls.xls	Prime	30-Oct-06	519,984,191
Countrywide MBS 2006-19	CWHL 2006-19	40280_cls.xls	Prime	29-Nov-06	1,247,997,961
Countrywide MBS 2006-20	CWHL 2006-20	40288_cls.xls	Prime	28-Dec-06	1,294,366,929
Countrywide MBS 2006-21	CWHL 2006-21	40265_cls.xls	Prime	28-Dec-06	1,021,991,738
Countrywide MBS 2006-6	CWHL 2006-6	37144_cls.xls	Prime	27-Feb-06	484,243,696
Countrywide MBS 2006-8	CWHL 2006-8	38386_cls.xls	Prime	30-Mar-06	781,999,969
Countrywide MBS 2006-9	CWHL 2006-9	38387_cls.xls	Prime	30-Mar-06	418,000,000
Countrywide MBS 2006-HYB2	CWHL 2006-HYB2	38394_cls.xls	Prime	28-Feb-06	665,877,411
Countrywide MBS 2006-HYB5	CWHL 2006-HYB5	38357_cls.xls	Prime	28-Jul-06	535,097,397
Countrywide MBS 2006-J1	CWHL 2006-J1	37161_cls.xls	Prime	30-Jan-06	408,913,754
Countrywide MBS 2006-J2	CWHL 2006-J2	37145_cls.xls	Prime	28-Feb-06	175,000,000
Countrywide MBS 2006-J3	CWHL 2006-J3	38393_cls.xls	Prime	30-May-06	217,254,137
Countrywide MBS 2006-J4	CWHL 2006-J4	38372_cls.xls	Prime	28-Jul-06	374,226,557
Countrywide MBS 2007-1	CWHL 2007-1	40278_cls.xls	Prime	30-Jan-07	2,292,413,644
Countrywide MBS 2007-10	CWHL 2007-10	41571_cls.xls	Prime	30-May-07	890,495,488
Countrywide MBS 2007-11	CWHL 2007-11	41904_cls.xls	Prime	28-Jun-07	1,436,347,458
Countrywide MBS 2007-12	CWHL 2007-12	41968_cls.xls	Prime	28-Jun-07	1,221,195,899
Countrywide MBS 2007-13	CWHL 2007-13	42223_cls.xls	Prime	28-Jun-07	574,962,714
Countrywide MBS 2007-14	CWHL 2007-14	42589_cls.xls	Prime	30-Jul-07	1,947,582,094
Countrywide MBS 2007-15	CWHL 2007-15	44021_cls.xls	Prime	30-Jul-07	3,170,431,763
Countrywide MBS 2007-16	CWHL 2007-16	42619_cls.xls	Prime	30-Aug-07	2,317,053,233
Countrywide MBS 2007-17	CWHL 2007-17	43291_cls.xls	Prime	30-Aug-07	1,918,125,739

Countrywide MBS 2007-18	CWHL 2007-18	43297_cls.xls	Prime	28-Sep-07	413,464,741
Countrywide MBS 2007-19	CWHL 2007-19	43302_cls.xls	Prime	30-Oct-07	868,592,455
Countrywide MBS 2007-2	CWHL 2007-2	43391_cls.xls	Prime	30-Jan-07	499,997,611
Countrywide MBS 2007-20	CWHL 2007-20	43517_cls.xls	Prime	30-Nov-07	585,728,528
Countrywide MBS 2007-21	CWHL 2007-21	41097_cls.xls	Prime	28-Dec-07	1,533,144,900
Countrywide MBS 2007-3	CWHL 2007-3	41329_cls.xls	Prime	27-Feb-07	2,055,330,857
Countrywide MBS 2007-4	CWHL 2007-4	41206_cls.xls	Prime	30-Mar-07	2,912,974,383
Countrywide MBS 2007-5	CWHL 2007-5	41570_cls.xls	Prime	30-Mar-07	4,759,483,482
Countrywide MBS 2007-6	CWHL 2007-6	41528_cls.xls	Prime	27-Apr-07	3,195,707,010
Countrywide MBS 2007-7	CWHL 2007-7	41584_cls.xls	Prime	27-Apr-07	1,264,490,832
Countrywide MBS 2007-8	CWHL 2007-8	41588_cls.xls	Prime	30-May-07	855,000,000
Countrywide MBS 2007-9	CWHL 2007-9	41101_cls.xls	Prime	30-May-07	1,450,199,790
Countrywide MBS 2007-HY1	CWHL 2007-HY1	42117_cls.xls	Prime	28-Feb-07	1,883,674,675
Countrywide MBS 2007-HY3	CWHL 2007-HY3	43300_cls.xls	Prime	30-Apr-07	2,172,450,590
Countrywide MBS 2007-HY4	CWHL 2007-HY4	41660_cls.xls	Prime	28-Sep-07	1,400,682,936
Countrywide MBS 2007-HY5	CWHL 2007-HY5	43310_cls.xls	Prime	31-Jul-07	364,383,859
Countrywide MBS 2007-HY7	CWHL 2007-HY7	40261_cls.xls	Prime	30-Oct-07	1,158,672,266
Countrywide MBS 2007-HYB1	CWHL 2007-HYB1	42236_cls.xls	Prime	30-Jan-07	636,625,427
Countrywide MBS 2007-J1	CWHL 2007-J1	41581_cls.xls	Prime	31-Jan-07	312,489,741
Countrywide MBS 2007-J2	CWHL 2007-J2	42227_cls.xls	Prime	30-May-07	695,675,305
Countrywide MBS 2007-J3	CWHL 2007-J3	40237_cls.xls	Prime	29-Jun-07	579,432,989

Using Data	r ~=0	0% default	r = 0.006	0.6% default	r =0.01	1% default	r =0.02	2% default	r =0.05	5% default
8.542E+08	9.738E+08	8.771E-01	9.029E+08	9.461E-01	8.669E+08	9.853E-01	7.576E+08	1.127E+00	5.627E+08	1.518E+00
1.381E+09	1.563E+09	8.838E-01	1.445E+09	9.558E-01	1.393E+09	9.913E-01	1.211E+09	1.140E+00	8.678E+08	1.592E+00
1.213E+09	1.348E+09	8.995E-01	1.224E+09	9.912E-01	1.179E+09	1.028E+00	1.031E+09	1.176E+00	7.573E+08	1.601E+00
5.240E+08	6.280E+08	8.344E-01	5.842E+08	8.970E-01	5.597E+08	9.362E-01	5.052E+08	1.037E+00	3.569E+08	1.468E+00
1.249E+09	1.468E+09	8.514E-01	1.368E+09	9.130E-01	1.313E+09	9.518E-01	1.119E+09	1.116E+00	8.090E+08	1.544E+00
6.119E+08	6.700E+08	9.133E-01	6.273E+08	9.754E-01	5.869E+08	1.043E+00	5.207E+08	1.175E+00	3.782E+08	1.618E+00
1.120E+09	1.197E+09	9.361E-01	1.084E+09	1.034E+00	1.047E+09	1.069E+00	9.081E+08	1.234E+00	6.547E+08	1.711E+00
7.935E+08	8.439E+08	9.403E-01	7.893E+08	1.005E+00	7.236E+08	1.097E+00	6.744E+08	1.177E+00	4.882E+08	1.625E+00
6.848E+08	7.813E+08	8.765E-01	7.383E+08	9.275E-01	6.909E+08	9.912E-01	6.000E+08	1.141E+00	4.335E+08	1.580E+00
4.118E+08	4.795E+08	8.589E-01	4.468E+08	9.217E-01	4.240E+08	9.712E-01	3.782E+08	1.089E+00	2.636E+08	1.562E+00
4.734E+08	5.124E+08	9.239E-01	4.694E+08	1.009E+00	4.477E+08	1.057E+00	3.901E+08	1.214E+00	2.803E+08	1.689E+00
8.440E+08	9.084E+08	9.292E-01	8.492E+08	9.939E-01	7.952E+08	1.061E+00	7.235E+08	1.167E+00	5.215E+08	1.619E+00
9.239E+08	9.601E+08	9.623E-01	8.900E+08	1.038E+00	8.293E+08	1.114E+00	7.411E+08	1.247E+00	5.292E+08	1.746E+00
9.360E+08	1.008E+09	9.281E-01	9.276E+08	1.009E+00	8.993E+08	1.041E+00	7.942E+08	1.179E+00	5.765E+08	1.624E+00
7.495E+08	8.080E+08	9.276E-01	7.447E+08	1.006E+00	7.185E+08	1.043E+00	6.294E+08	1.191E+00	4.482E+08	1.672E+00
5.212E+08	5.814E+08	8.965E-01	5.429E+08	9.601E-01	5.118E+08	1.018E+00	4.478E+08	1.164E+00	3.468E+08	1.503E+00
5.721E+08	6.387E+08	8.957E-01	6.053E+08	9.451E-01	5.597E+08	1.022E+00	4.860E+08	1.177E+00	3.481E+08	1.643E+00
1.411E+09	1.558E+09	9.054E-01	1.460E+09	9.658E-01	1.400E+09	1.008E+00	1.257E+09	1.122E+00	8.689E+08	1.623E+00
7.378E+08	7.897E+08	9.343E-01	7.416E+08	9.949E-01	7.006E+08	1.053E+00	6.251E+08	1.180E+00	4.451E+08	1.658E+00
7.318E+08	8.022E+08	9.123E-01	7.300E+08	1.003E+00	6.936E+08	1.055E+00	6.329E+08	1.156E+00	4.403E+08	1.662E+00
1.785E+09	1.890E+09	9.445E-01	1.756E+09	1.017E+00	1.648E+09	1.084E+00	1.471E+09	1.214E+00	1.068E+09	1.672E+00
1.482E+09	1.568E+09	9.453E-01	1.438E+09	1.030E+00	1.371E+09	1.081E+00	1.218E+09	1.216E+00	8.858E+08	1.673E+00
1.460E+09	1.558E+09	9.370E-01	1.428E+09	1.022E+00	1.379E+09	1.059E+00	1.209E+09	1.207E+00	8.859E+08	1.648E+00
7.073E+08	7.448E+08	9.496E-01	6.771E+08	1.044E+00	6.612E+08	1.070E+00	5.738E+08	1.233E+00	4.044E+08	1.749E+00
1.109E+09	1.185E+09	9.358E-01	1.091E+09	1.016E+00	1.035E+09	1.071E+00	9.159E+08	1.211E+00	6.719E+08	1.650E+00
5.909E+08	6.391E+08	9.245E-01	5.904E+08	1.001E+00	5.625E+08	1.051E+00	4.941E+08	1.196E+00	3.668E+08	1.611E+00
7.847E+08	8.926E+08	8.791E-01	8.289E+08	9.466E-01	7.820E+08	1.003E+00	6.954E+08	1.128E+00	5.132E+08	1.529E+00
6.461E+08	7.795E+08	8.289E-01	7.001E+08	9.228E-01	6.668E+08	9.689E-01	6.076E+08	1.063E+00	4.409E+08	1.466E+00
2.612E+08	2.728E+08	9.572E-01	2.551E+08	1.024E+00	2.406E+08	1.086E+00	2.139E+08	1.221E+00	1.432E+08	1.824E+00
5.976E+08	6.268E+08	9.534E-01	5.704E+08	1.048E+00	5.519E+08	1.083E+00	4.960E+08	1.205E+00	3.519E+08	1.698E+00
3.214E+08	3.237E+08	9.931E-01	2.995E+08	1.073E+00	2.820E+08	1.140E+00	2.549E+08	1.261E+00	1.739E+08	1.848E+00
5.276E+08	5.829E+08	9.052E-01	5.425E+08	9.725E-01	5.217E+08	1.011E+00	4.531E+08	1.164E+00	3.295E+08	1.601E+00
1.054E+09	1.122E+09	9.391E-01	1.030E+09	1.023E+00	9.760E+08	1.080E+00	8.807E+08	1.196E+00	6.266E+08	1.682E+00
8.869E+08	9.654E+08	9.187E-01	9.036E+08	9.815E-01	8.448E+08	1.050E+00	7.459E+08	1.189E+00	5.543E+08	1.600E+00
1.398E+09	1.513E+09	9.238E-01	1.398E+09	9.997E-01	1.326E+09	1.054E+00	1.167E+09	1.198E+00	8.307E+08	1.683E+00
8.211E+08	8.665E+08	9.477E-01	8.066E+08	1.018E+00	7.415E+08	1.107E+00	6.682E+08	1.229E+00	4.889E+08	1.679E+00
1.080E+09	1.110E+09	9.731E-01	1.034E+09	1.044E+00	9.763E+08	1.106E+00	8.786E+08	1.229E+00	6.334E+08	1.705E+00

1.453E+09	1.605E+09	9.053E-01	1.487E+09	9.769E-01	1.425E+09	1.020E+00	1.251E+09	1.161E+00	9.111E+08	1.595E+00
1.052E+09	1.238E+09	8.500E-01	1.158E+09	9.089E-01	1.094E+09	9.620E-01	9.617E+08	1.094E+00	7.073E+08	1.487E+00
1.196E+09	1.356E+09	8.820E-01	1.277E+09	9.366E-01	1.177E+09	1.016E+00	1.079E+09	1.108E+00	7.758E+08	1.542E+00
5.703E+08	6.537E+08	8.724E-01	5.933E+08	9.612E-01	5.680E+08	1.004E+00	5.341E+08	1.068E+00	3.475E+08	1.641E+00
6.296E+08	7.239E+08	8.698E-01	6.793E+08	9.269E-01	6.521E+08	9.655E-01	5.653E+08	1.114E+00	3.995E+08	1.576E+00
4.184E+08	4.839E+08	8.645E-01	4.541E+08	9.212E-01	4.236E+08	9.876E-01	3.772E+08	1.109E+00	2.779E+08	1.506E+00
1.135E+09	1.210E+09	9.373E-01	1.118E+09	1.015E+00	1.066E+09	1.065E+00	9.695E+08	1.170E+00	7.366E+08	1.540E+00
1.620E+09	1.711E+09	9.464E-01	1.589E+09	1.019E+00	1.485E+09	1.090E+00	1.352E+09	1.198E+00	9.405E+08	1.722E+00
1.484E+09	1.625E+09	9.132E-01	1.495E+09	9.922E-01	1.417E+09	1.047E+00	1.265E+09	1.173E+00	8.981E+08	1.652E+00
1.214E+09	1.246E+09	9.743E-01	1.177E+09	1.031E+00	1.106E+09	1.097E+00	9.342E+08	1.299E+00	7.220E+08	1.681E+00
1.034E+09	1.135E+09	9.110E-01	1.043E+09	9.908E-01	9.927E+08	1.041E+00	8.891E+08	1.162E+00	6.141E+08	1.683E+00
1.074E+09	1.084E+09	9.903E-01	1.024E+09	1.049E+00	9.630E+08	1.115E+00	8.628E+08	1.244E+00	6.215E+08	1.728E+00
1.199E+09	1.269E+09	9.444E-01	1.178E+09	1.018E+00	1.114E+09	1.076E+00	9.957E+08	1.204E+00	7.270E+08	1.649E+00
1.006E+09	1.036E+09	9.709E-01	9.512E+08	1.058E+00	9.030E+08	1.114E+00	7.819E+08	1.287E+00	5.715E+08	1.761E+00
4.916E+08	5.145E+08	9.555E-01	4.800E+08	1.024E+00	4.535E+08	1.084E+00	3.963E+08	1.240E+00	2.890E+08	1.701E+00
7.387E+08	7.727E+08	9.560E-01	7.086E+08	1.042E+00	6.833E+08	1.081E+00	6.029E+08	1.225E+00	4.267E+08	1.731E+00
7.851E+08	8.584E+08	9.147E-01	7.870E+08	9.976E-01	7.465E+08	1.052E+00	6.678E+08	1.176E+00	5.044E+08	1.556E+00
4.632E+08	4.910E+08	9.433E-01	4.507E+08	1.028E+00	4.296E+08	1.078E+00	3.888E+08	1.191E+00	2.809E+08	1.649E+00
1.510E+09	1.683E+09	8.972E-01	1.553E+09	9.722E-01	1.446E+09	1.044E+00	1.297E+09	1.164E+00	9.686E+08	1.559E+00
7.676E+08	8.928E+08	8.598E-01	8.222E+08	9.337E-01	7.922E+08	9.689E-01	6.995E+08	1.097E+00	5.086E+08	1.509E+00
7.572E+08	8.757E+08	8.646E-01	8.156E+08	9.284E-01	7.813E+08	9.691E-01	6.772E+08	1.118E+00	5.121E+08	1.479E+00
5.568E+08	6.226E+08	8.943E-01	5.737E+08	9.704E-01	5.570E+08	9.996E-01	4.708E+08	1.183E+00	3.296E+08	1.689E+00
3.092E+08	3.389E+08	9.125E-01	3.071E+08	1.007E+00	2.963E+08	1.044E+00	2.581E+08	1.198E+00	1.877E+08	1.647E+00
7.178E+08	7.602E+08	9.443E-01	7.106E+08	1.010E+00	6.703E+08	1.071E+00	5.891E+08	1.219E+00	4.228E+08	1.698E+00

Raw MBS Data: Subprime

Series / Tranche	ID	File Name	Close Date	Size
Countrywide ABS :	CWL 2006-1	37133_cls.xls	10-Feb-06	779779000
Countrywide ABS :	CWL 2006-2	37140_cls.xls	27-Feb-06	829175000
Countrywide ABS :	CWL 2006-3	37149_cls.xls	27-Feb-06	1361500000
Countrywide ABS :	CWL 2006-4	37135_cls.xls	17-Mar-06	631150000
Countrywide ABS :	CWL 2006-5	38049_cls.xls	28-Apr-06	734250000
Countrywide ABS :	CWL 2006-6	38074_cls.xls	29-Mar-06	1780200000
Countrywide ABS :	CWL 2006-7	38083_cls.xls	28-Jun-06	1028340000
Countrywide ABS :	CWL 2006-8	37955_cls.xls	28-Jun-06	1966000000
Countrywide ABS :	CWL 2006-9	38114_cls.xls	30-Jun-06	585772000
Countrywide ABS :	CWL 2006-10	38115_cls.xls	30-Jun-06	589600000
Countrywide ABS :	CWL 2006-11	38086_cls.xls	29-Jun-06	1846600000
Countrywide ABS :	CWL 2006-12	38130_cls.xls	30-Jun-06	1272700000
Countrywide ABS :	CWL 2006-13	38645_cls.xls	28-Jul-06	1602525000
Countrywide ABS :	CWL 2006-14	38596_cls.xls	08-Sep-06	1473750000
Countrywide ABS :	CWL 2006-15	39638_cls.xls	29-Sep-06	966000100
Countrywide ABS :	CWL 2006-16	39675_cls.xls	28-Sep-06	492250000
Countrywide ABS :	CWL 2006-17	39708_cls.xls	25-Sep-06	982500000
Countrywide ABS :	CWL 2006-18	39712_cls.xls	28-Sep-06	1670250000
Countrywide ABS :	CWL 2006-19	39721_cls.xls	29-Sep-06	882900000
Countrywide ABS :	CWL 2006-20	39671_cls.xls	28-Nov-06	982500000
Countrywide ABS :	CWL 2006-21	39674_cls.xls	30-Nov-06	1080750000
Countrywide ABS :	CWL 2006-22	39713_cls.xls	30-Nov-06	1572000000
Countrywide ABS :	CWL 2006-23	39734_cls.xls	08-Dec-06	1572000000
Countrywide ABS :	CWL 2006-24	40381_cls.xls	29-Dec-06	1320480000
Countrywide ABS :	CWL 2006-25	40394_cls.xls	29-Dec-06	1522875000
Countrywide ABS :	CWL 2006-26	40303_cls.xls	29-Dec-06	1179000000
Countrywide ABS :	CWL 2006-ABC1	38131_cls.xls	29-Jun-06	396600100
Countrywide ABS :	CWL 2006-BC1	38164_cls.xls	30-Mar-06	518175000
Countrywide ABS :	CWL 2006-BC2	38017_cls.xls	30-May-06	637000000
Countrywide ABS :	CWL 2006-BC3	39216_cls.xls	30-Aug-06	586500000
Countrywide ABS :	CWL 2006-BC4	39224_cls.xls	29-Sep-06	588600000
Countrywide ABS :	CWL 2006-BC5	40411_cls.xls	29-Dec-06	736878000

Countrywide ABS :	CWL 2006-IM1	37139_cls.xls	30-Jan-06	697200100
Countrywide ABS :	CWL 2006-SPS1	38244_cls.xls	27-Jun-06	230875100
Countrywide ABS :	CWL 2006-SPS2	38888_cls.xls	29-Aug-06	456500100
Countrywide ABS :	CWL 2007-1	40513_cls.xls	09-Feb-07	1965000000
Countrywide ABS :	CWL 2007-10	42174_cls.xls	29-Jun-07	985000000
Countrywide ABS :	CWL 2007-11	42208_cls.xls	29-Jun-07	788400000
Countrywide ABS :	CWL 2007-12	42723_cls.xls	13-Aug-07	1356326100
Countrywide ABS :	CWL 2007-13	43250_cls.xls	30-Oct-07	735600000
Countrywide ABS :	CWL 2007-2	40587_cls.xls	28-Feb-07	1529580000
Countrywide ABS :	CWL 2007-3	41191_cls.xls	29-Mar-07	735711000
Countrywide ABS :	CWL 2007-4	41203_cls.xls	29-Mar-07	959500000
Countrywide ABS :	CWL 2007-5	41356_cls.xls	30-Mar-07	1150000000
Countrywide ABS :	CWL 2007-6	41204_cls.xls	30-Mar-07	966000000
Countrywide ABS :	CWL 2007-7	41534_cls.xls	04-May-07	1070850000
Countrywide ABS :	CWL 2007-8	41535_cls.xls	31-May-07	1279850000
Countrywide ABS :	CWL 2007-BC1	40979_cls.xls	28-Feb-07	490500000
Countrywide ABS :	CWL 2007-BC2	41547_cls.xls	27-Apr-07	633750000
Countrywide ABS :	CWL 2007-BC3	42224_cls.xls	29-Jun-07	563492000

C. System Dynamics Model Documentation

(01) Actual Housing Prices = WITH LOOKUP (
Time,
([(0,0)-(121,400000)],(0,195600),(13,207000),(25,213200),(37,228700),(49
,246300),(61,274500),(73,297000),(85,305900),(
97,313600),(109,292600),(122,270900)))
Units: Dmnl

(02) "ave mortgages/MBS"=
5000
Units: Mortgages/MBS
There are about 5,000 mortgages per MBS

(03) Average existing home sales per month=
433000
Units: Mortgages/Month
The is the monthly average number of existing home sales over
the last 5 years and is approximately 433k homes.

(04) Average House Price= INTEG (
price increase-price decrease,
195600)
Units: $

(05) Average IB profit=
0.08*Average MBS price*Average MBS sold per mo
Units: $
IB profit is determined by the commission rate of 8%, the
average MBS price, and the

(06) Average interest rate=
0.03
Units: Dmnl
http://finance.yahoo.com/blogs/talking-numbers/222-years-interest
-history-one-chart-173358843.html

(07) Average life of house=
150*12
Units: Month
The average life of a house is 150 years

(08) Average MBS price=
0.8*Average House Price*"ave mortgages/MBS"
Units: $
The average price of the MBS in our data set was $1B

(09) Average MBS sold per mo=
167
Units: MBS/Month
50 MBS sold per month on average

(10) Average mortgages bought per month=

5000
Units: Mortgages/Month
These are the total amount of mortgages that were bought by
Countrywide Financial.

(11) Average new home sales per month=
80000
Units: Mortgages/Month
The is the monthly average number of new home sales over the
last 5 years, and is around 85k/mo

(12) Average refinances per month=
100000
Units: Mortgages/Month
The is the monthly average number of refinances over the last 5
years.

(13) Average time to sell MBS=
2
Units: Month
It typically takes 3 months to sell a MBS

(14) Banks ability to raise cheap capital=
DELAY FIXED(MIN(1,MAX(0.2,0.01*(0.0001)*MBS sold to investors+0.39*(1-
Interest Rate
/Average interest rate)+0.6*IF THEN ELSE(Interest Rate<0.0525, 1.5 , 0)))
, 3, 0.7)
Units: **undefined**
1 being able to raise cheap capital. 0 being not able to raise
cheap capital. 50% MBS sold to investors and 50% Interest Rate

(15) Business due to ratings=
(1-"Gov't & Investor oversight")
Units: Dmnl
When there is more oversight, there is less business due to
increased ratings.

(16) Creditworthiness rating from ratings agencies=
DELAY FIXED((Perception of profit by increasing ratings), 1, 1)
Units: Dmnl
The higher the perceived profit, the more higher the credit
rating from the rating agencies

(17) Debt financing availability=
Perception of profit potential from debt markets
Units: Dmnl
If there is a perception of profit potential from the debt
markets, there is debt financing availability.

(18) Demand by homeowners=
MIN(1,MAX(0,(0.1*100*Population Growth/Population+0.1*Percentage homeowners
+0.8*Mortgage affordability)))
Units: Dmnl

50% population growth, 25%- % homeowners, 25% mortgage
affordability

(19) Existing home sales per month=
MIN(Housing Stock,1.2*(Mortgage affordability)*Average existing home sales per month
)
Units: Mortgages/Month
Assume each home sale is associated with one mortgage and that
the number of cash-only transactions is small.

(20) FINAL TIME = 122
Units: Month
The final time for the simulation.

(21) Fractional birth rate=
0.015/12
Units: Dmnl
% of population added every year

(22) Fractional death rate=
0.005/12
Units: **undefined**
% of population dying every year

(23) "Gov't & Investor oversight"=
0
Units: Dmnl
1 if there is a lot of government and investor oversight, and 0
if there is none.

(24) "Gov't incentives to increase homeownership of low-income households"=
0
Units: Dmnl
Can vary between -1 and 1. 0 is no incentives, 1 is many
incentives and -1 is negative incentives.

(25) Government oversight=
0.01
Units: Dmnl

(26) Growing MBS market = WITH LOOKUP (
Time,
([(0,0)-(122,10)],(0,0.7),(12,0.7),(24,0.9),(36,0.95),(48,0.95),(60,1),(
90,1),(96,0.6),(102,0.4),(108,0),(122,0.1)))
Units: Dmnl

(27) GSE MBS purchase of low income mortgages=
Average MBS sold per mo*(Debt financing availability+"Gov't incentives to increase homeownership of low-income households"
)
Units: MBS
As the amount of debt financing availability goes up, the GSEs

can purchase more MBS. In addition, if there are government incentives to purchase MBS from low income households, there will be more MBS purchases.

(28) Homeowner income=
50000
Units: $
This is the average income per household

(29) Houses Demolished=
Housing Stock/Average life of house
Units: Houses/Month
This is the rate at which the housing stock leaves the system

(30) Housing Stock= INTEG (
New houses built-Houses Demolished,
Initial housing stock)
Units: Houses
This is the total housing stock in the US

(31) IB profit=
0.08*MBS sold to investors*Average MBS price
Units: $
The investment bank profit is determined largely by the number of MBS sold to investors. We assume that the IB's make 8% commission in this model.

(32) Initial housing stock=
7.2e+007
Units: Houses
There were 121M houses in the US in 2001, of which 106.8 were occupied with 72M homeowners.

(33) INITIAL TIME = 0
Units: Month
The initial time for the simulation.

(34) Interest Rate=
DELAY FIXED(MIN(5.25,MAX(0.001,0.03+0.0225*Perception of Economy by Federal Reserve
)), 3, 0.05)
Units: Dmnl
3% average interest rate+ what the perception of the economy is by the Fed.

(35) Investor Demand=
GSE MBS purchase of low income mortgages+50*(Average interest rate/Interest Rate
+Perception of profit potential by investors)
Units: MBS
number of MBSs demanded

(36) MBS= INTEG (

Securitization of Mortgages-MBS sold to investors,
100)
Units: MBS
This is the number of MBS in the CF system at any one instant.

(37) MBS sold to investors=
SMOOTH(MAX(0,MBS-Investor Demand)/Time required to sell MBS , 1)
Units: MBS/Month
This is the number of MBS sold to investors every month and is given by the investor demand divided by the time required to sell the MBS.

(38) Mortgage affordability=
MIN(1,MAX(0,0.2*(1.5*Homeowner income/Average House Price)/"Normal income/price ratio"
+0.8*(1-1.2*Mortgage standards and financing availability)))
Units: **undefined**
Very affordable = 1, unaffordable = 0, 0.5 normal affordability

(39) Mortgage standards and financing availability=
DELAY FIXED(MAX(0,MIN(1,(1-Perception of profit potential by banks)-Government oversight
)), 3 , 0.29)
Units: Dmnl
from 0-1

(40) Mortgages= INTEG (
Mortgages Originated+Mortgages bought-"ave mortgages/MBS"*Securitization of Mortgages
,
100*"ave mortgages/MBS")
Units: Mortgages
The number of mortgages is determined by the initial value plus the the number of mortgages bought per unit of time minus the number securitized mortgages. Here we assume all of the mortgages are securitized and not sold directly.

(41) Mortgages bought=
Perception of profit potential by banks*Average mortgages bought per month
Units: **undefined**
The average number of mortgages that are bought per month is modified by the perception of profit potential.

(42) Mortgages Originated=
Existing home sales per month+New houses built+Refinances per Month
Units: MBS/Month
The total number of mortgages originated is the total of the refinances, existing and new home sales.

(43) New houses built=
0.8*Average new home sales per month*(0.5+Mortgage affordability)
Units: Houses/Month
The number of new houses built is determined by the average new

home sales per month and the affordability

(44) "Normal income/price ratio"=
1/3.5
Units: **undefined**

(45) other parts of economy = WITH LOOKUP (
Time,
([(0,0)-(122,10)],(0,0.95),(12,0.99),(18,0.8),(24,0.6),(30,0.4),(36,0.3)
,(40,0.3),(48,0.2),(60,0.2),(66,0.3),(72,0.7),(84,1),(96,1),(108,0.6),(122
,0)))
Units: Dmnl

(46) Percentage homeowners = WITH LOOKUP (Time,
([(0,0)-(122,1)],(0,0.65),(12,0.66),(25,0.67),(37,0.67),(55,0.69),(74,0.72
),(86,0.72),(98,0.73),(110,0.7),(122,0.7)))
Units: Dmnl
https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=

&cad=rja&uact=8&ved=0ahUKEwjDk4yewdvJAhXF4iYKHfJnCSgQjRwIBw&url=h
ttp%3A%2F%2Fwww.gallup.com%2Fpoll%2F182897%2Ffewer-non-
homeowners
-expect-buy-
home.aspx&psig=AFQjCNF6uHvOGwvBx_2c8iFuWKs_0Udsyg&ust
=1450187946469078

(47) Perception of Economy by Federal Reserve=
2*Strength of Economy-1
Units: Dmnl
1 is extremely well, -1 is terrible

(48) Perception of profit by increasing ratings=
MAX(0,MIN(1,Business due to ratings-"Gov't & Investor oversight"+0.5*Ratings
agency commission
))
Units: Dmnl
Max perception of profit = 1, min = 0. perception due to added
business due to ratings, the lack of gov't and investor
oversight, and improved by the commissions given.

(49) Perception of profit potential by banks=
0.5*Banks ability to raise cheap capital+0.5*Growing MBS market
Units: **undefined**
1 means high profit potential seen. 0 means low

(50) Perception of profit potential by IB's=
DELAY FIXED(MAX(0,MIN(1,0.25*(1-"Gov't & Investor oversight")+0.75*((IB profit
/Average IB profit)))), 1 , 1)
Units: Dmnl
When there is no oversight, and the previous IB profit is good,
the perception of profit potential is high (1). When this is the
opposite the value is 0.

(51) Perception of profit potential by investors=
DELAY FIXED(MAX(0,MIN(1,0.5*Average interest rate/Interest Rate + 0.5*IF THEN
ELSE
(Interest Rate<0.0525, 1 , 0))) , 1 , 1)
Units: **undefined**
As the interest rate decreases and number of MBS increases,
there is a higher perception of profit potential by investors

(52) Perception of profit potential from debt markets=
Strength of Economy
Units: Dmnl
As the strength of the economy goes up, the profit potential
from debt markets goes up.

(53) Population= INTEG (
Population Growth,
2.9e+008)
Units: People
Assume approximately 300M people in the US.

(54) Population Growth=
Population*(Fractional birth rate-Fractional death rate)
Units: People/Month
This gives the growth rate of people in the US per month

(55) price decrease=
4900*Housing Stock/7.2e+007
Units: $/Month

(56) price increase=
8100*Demand by homeowners
Units: $/Month

(57) Ratings agency commission=
1/Time required to sell MBS
Units: **undefined**
As the time required to sell MBS goes down, the commission goes
up.

(58) Refinances per Month=
Average refinances per month*(0.5*(Average interest rate/Interest Rate)+0.5
*Strength of Economy)
Units: Mortgages/Month
X refinances per year on average, modified by the interest rate
and the strength of the economy at half and half

(59) SAVEPER =
TIME STEP
Units: Month [0,?]
The frequency with which output is stored.

(60) Securitization of Mortgages=
(Mortgages/"ave mortgages/MBS")/Time required to securitize

Units: MBS/Month
The number of mortgages divided by the average number of mortgages in a MBS all divded by the time it takes to securitize.

(61) Strength of Economy=
MAX(0,MIN(1,other parts of economy))
Units: Dmnl
.2 for other sectors + 10% extra for existing home sales and 20% for new houses built so that 50% is the normal case for normalized home sales

(62) Time required to securitize=
(3-2*Perception of profit potential by banks)
Units: Month
3 month average securitization time minus 2mo* profit potential. If there is a high profit potential then the time to securitize goes down.

(63) Time required to sell MBS=
MAX(1,Average time to sell MBS*((1-Creditworthiness rating from ratings agencies)+Perception of profit potential by IB's))
Units: Month
The time that is required to sell the MBS is some multiple of the average time to sell a MBS normally modified by the creditworthiness rating from the ratings agencies and the perception of the profit potential by the investment banks.

(64) TIME STEP = 1
Units: Month [0,?]
The time step for the simulation.

(65) Total Price of all Mortgages=
Average House Price*Mortgages Originated
Units: **undefined**

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