FLAGS OF CAUTION FOR FUTURE DOWNTURNS
IN THE HOUSING MARKET PREDICTION
USING THE MARKOV CHAIN MODEL

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTER OF SCIENCE

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

DEPARTMENT OF MATHEMATICS

COLLEGE OF ARTS AND SCIENCES

BY

SUSAN EUSTICE OWENS, B. S.

DENTON, TEXAS

AUGUST 2013

TEXAS WOMAN'S UNIVERISTY
DENTON, TEXAS

May 2, 2013

To the Dean of the Graduate School:

I am submitting herewith a thesis written by Susan Eustice Owens entitled "Flags of Caution for Future Downturns in the Housing Market Prediction Using the Markov Chain Model." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Mathematics.

____
Dr. David D. Marshall, Major Professor

We have read this thesis and recommend its acceptance:

____

____

____
Department Chair

Accepted:

____
Interim Dean of the Graduate School

DEDICATION

For the unending support and love of my husband, Jim Owens.
He is my rock.

For the respected advice, from over thirty-five years
in the mortgage business, and the listening ear of my dad,
Richard E. Eustice.

ACKNOWLEDGMENTS

This thesis would not have been possible without the guidance and the help of several individuals who in one way or another contributed their valuable assistance in the preparation and completion of this study. My utmost gratitude goes to Professor David D. Marshall, my committee chair, who continually conveyed a spirit of encouragement. Without his continued availability, encouragement, and guidance, this thesis would only be a dream. I deeply appreciate Professor Don E. Edwards for his unending guidance in moving me toward completion; Professor Marie-Anne Demuynck, whose patient instruction helped me bring a more specialized look to the thesis; Paul Ingram for his sweet encouragement, guidance, and shared insights; and Dr. Turner D. Hogan for his instruction now and then, but mostly for encouraging me early on to become a mathematics instructor. I am grateful to the faculty of Texas Woman's University who helped me think critically, the TWU mathematic graduate students for their moral support, and Paula McCoy, who had her hands full and made me look "good enough."

Love and thanks go to my husband, Jim, children (Steve, Carrie, Troy, Raychel, Emily, Russell, Susan, Brittni, and Danny), and all the grandchildren.

And to the One above all of us, the Lord Jesus Christ, praise for answering my prayers and giving me strength to keep going despite my wanting to give up and walk away.

ABSTRACT

SUSAN EUSTICE OWENS

FLAGS OF CAUTION FOR FUTURE DOWNTURNS
IN THE HOUSING MARKET PREDICTION
USING THE MARKOV CHAIN MODEL

AUGUST 2013

The recent downturn in the United States housing market yielded a period of time akin to that of the Great Depression. Since the 1930s, there has never been an economic downturn in this country as close as that of the Great Depression era. The Depression experienced similarities to the current economic crisis but more important, the Great Depression's comparable statistical data raise flags of caution for future downturns in the housing market. One of the major similarities is a housing boom, which in both periods preceded a downturn. Precipitous growth reached unsustainable levels; then, a big decline burst the real estate bubble.

In this study the Markov Chain Model was used as a forecasting tool to evaluate the status of home mortgages and to demonstrate the capability to predict future housing economic crises. Statistical data from both eras were gathered and shown in a transition matrix.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The recent downturn in the United States housing market yielded a period of time akin to that of the Great Depression. Since the 1930s, there has never been an economic downturn in this country even remotely as close as that of the Great Depression era. The Great Depression experienced numerous similarities to the current economic crisis, called the Great Recession, but more important for this study, the Great Depression's comparable statistical data raise flags of caution for future downturns in the housing market. One of the major similarities is a housing boom, which in both periods preceded a downturn. In the 1920s and the 1990s, housing booms were motivated in part by extraordinarily high housing prices due to increased demand; therefore, the country's homebuilders were busy building and renovating. Precipitous growth reached an unsustainable level; then, a big decline burst the real estate bubble. Home foreclosures were then and are now at record highs (Garriga, Gavin, and Schlagenhauf, 2006).

In this study the terms *Great Depression* and *Great Recession* will be used. Many economists have debated the extent of what constitutes a depression and a recession, but there is not a common consensus.

More commonly, however, economists agree that depressions and recessions are determined by Gross Domestic Product (GDP) figures. A fair standard would be to say that if the GDP declines by more than 10 percent, it would be considered a depression while a recession's GDP figures are not quite as severe. In this paper, we will consider a depression as a severe recession and will use the terms Great Depression and Great Recession to differentiate between the two eras. The Great Depression's time period in this study is from 1920 to 1938; the Great Recession time period in this study is 1979 to 2011.

In both eras, as well as in-between, the United States government initiated several government programs or agencies to aid potential buyers, homeowners, and seriously delinquent homeowners in the home-buying and home-owning process. Many of these agencies affected the home mortgage pre-boom, bubble, and bust time periods.

In 1934, as a result of the Great Depression, the federal government created the Federal Housing Administration (FHA). The FHA insured long-term fixed-rate mortgages. The Federal National Mortgage Association (Fannie Mae) was created in 1938 to purchase FHA-insured mortgages, which was the beginning of a secondary market for home mortgages. Fannie Mae began purchasing loans insured by the Veterans Administration (VA), which the federal government established after World War I.

The creation of Fannie Mae gave the VA and FHA the opportunity to trade existing loans. Plus, it kept lenders actively promoting mortgage loans, resulting in a 15 percent increase in home buying from pre-World War II to 1965 (Wheelock, 2008).

In 1968, the government created the Government National Mortgage Association (Ginnie Mae) to assume some of Fannie Mae's functions. Ginnie Mae was authorized to guarantee principal and interest payments on its securities that were backed by VA and FHA loans. In 1970, they began to offer guaranteed mortgage-backed securities. To develop a secondary market for conventional mortgage loans, the Federal Home Loan Mortgage Corporation (Freddie Mac) was formed in 1970 (Garcia, Gavin, Schlagenhauf, 2006).

In 2003, President George W. Bush instigated a new law, the *American Dream Down Payment Initiative Act*, earmarking $200 million to be awarded to first-time homebuyers to help with the down payment and closing costs. A cycle of financial advances contributed to the ability of first-time households to buy homes with little or no down payment (Garcia, Gavin, Schlagenhauf, 2006).

In addition to the effect of government agencies on the home mortgage industry, other parallel factors in the two time periods contributed to the rise and fall of the housing bubble. Later, we will look at the status of mortgage payments, current mortgages, and foreclosed mortgages.

In this study the Markov Chain Model (Grimshaw, 2010) will be used as a forecasting tool. The two time periods, the Great Depression and the Great Recession, are divided into three stages of home building: housing pre-boom, housing bubble, and housing bust. In an effort to evaluate the status of home mortgages and to demonstrate the capability to predict future housing economic crises, statistical data from the Great Depression and the Great Recession were gathered and shown in a transition matrix. A transition matrix is a square matrix with elements in each row or column adding up to one, and the elements will transition from one state to another with a definite probability of being in any given state at the end of a defined period of time (Bronson & Costa, 2009).

In chapter 2, we will motivate the Markov chain in modeling home foreclosures in the two eras' three time periods. For each time period, a three-by-three matrix will be formed and will consider three states of mortgage payments. The three states are defined as current *(c)* on the monthly payment and foreclosed *(f)* or paid-off *(pd)*.

In chapter 3, the transition matrix entries become probabilities calculated from 1920 through 1938 data. The housing boom took off in the

1920s, peaked in 1926, and began to burst in 1930. This chapter will study the effects the Great Depression had on the housing market.

In chapter 4, we will study in detail the current Great Recession housing crisis. Many economists report that the current housing boom started in the 1960s, but for this investigation we will show the housing pre-boom was underway in 1979 through 1989. From 1990 to 2000, the housing bubble was in full swing. The housing bust, then, was during the time period 2001 to 2011. Some authors proclaim that 2010 statistics show the worst home foreclosure rates in history.

Chapter 5 will bring together the two studies of the Great Depression and the Great Recession. The transition matrices from each period will be set up each into the canonical form for the absorbing Markov chain.

Chapter 6 will conclude with a comparison of the data to show how accurate the model is in predicting the boom and bust of these two periods. We will discuss the limitations of the model and how to improve it.

CHAPTER II

THE MARKOV CHAIN MODEL AND THE HOME MORTGAGE LOAN MODEL

Evaluations of home mortgage loans, for the purpose of predicting foreclosures, are becoming ever more important due to the recent downturn in the housing market. To assess mortgage loan modeling techniques, a discrete-time three-by-three Markov chain transition matrix (in which the process changes from one state i to another state j with probability p_{ij}) will be used to evaluate loans moving from a current state *(c)* or delinquent *(d)* to a paid-off *(pd)* or foreclosure state *(f)*. In a discrete-time Markov chain, the system advances in a series of discrete time steps, with transitions occurring at each of the steps (Norman & Jeffers, 1988). A Markov chain is a simple, yet effective, model to describe movement through the two states. This model is easy to build and study through matrix testing. The Markov Chain is named after Russian mathematician A. A. Markov (1856-1922), who originated the theory of stochastic processes. Markov was an outstanding Russian mathematician, who studied and taught at the University of St. Petersburg and was a member of the Soviet Academy of Sciences (Anton & Kolman, 1982).

From the 2005 Mathematics and Statistics of Complex Systems workshop at the University of Queensland, a report came out that specified Markov chains are the simplest mathematical models for random phenomena that evolve over time. Their structure is sufficiently simple that one can say a great deal about their behavior, yet at the same time, the class of Markov chains is rich enough to serve in many applications. Indeed, Markov chains are the first and most important examples of stochastic models, which arise in areas as diverse as population biology, chemical kinetics and telecommunications (Sirl, 2005).

After evaluating the models, this study hopes to determine forecasts for future downturns in the housing market with a transition matrix of the Markov chain. This stochastic process is a mathematical model that evolves over time in a probabilistic manner. The Markov chain is a special kind of stochastic process where the outcome of an experiment depends only on the outcome of the previous experiment. Thus, the next state of the system depends only on the present state (Norman & Jeffers, 1988).

Loan payments follow a progression of states. The Markov Chain Model or, for this study, the Home Mortgage Loan (HML) Model, can be extremely useful to project the probability of foreclosures because the model preserves the phasing of each state. The discrete-time Markov chain limits the mortgage loan status to equally spaced time periods. For this study, end-of-year data is analyzed to determine distinct time points. The gap between distinct time points is known as the cycle length. A homogeneous Markov chain is one where these probabilities vary over time according to the status of the mortgage loan during the specified time period (Norman & Jeffers, 1988).

Three transition matrices will be used in each period to demonstrate the status of home mortgage loan payments. Historically, the Great Depression and the Great Recession are the only two distinct time periods in which this extreme fluctuation has occurred.

Homogeneous Markov Chain Properties

a) For each time period, every state in the system is in exactly one of the defined states; current, delinquent, paid-off or foreclosed. At the end of each time period, each object either moves to a new state or stays in the same state for another period.

b) The objects move from one state to the next according to the transition probabilities, which depend only on the current state (previous history is not taken into account). The total probability of movement from a state must equal one. Movement from a state to the same state does count as movement.

c) The transition probabilities do not change over time (the probability of going from stage A to stage B today is the same as it will be at any time in the future).

Three transition matrices will be used for each of the two time eras (six in all) to model the Markov chain.

The transition matrices have the following properties:

a) Each element of the transition matrix is a probability between 0 and 1.

b) The elements of each row of the transition matrix sum to one. This is due to the property of a Markov chain that objects move from one state to the next and the total probability of the movement must equal one.

c) The transition matrix must be square because it has a row and a column for each stage (Nering, 1974).

Another perspective of a discrete-time Markov chain is:

- S is a countable set of states
- P : S x S [0,1] is a probability matrix satisfying

$$\sum_{s' \epsilon S} P(s, s') = 1 \ for \ all \ s \ \epsilon \ S$$

- (state s is absorbing whenever P(s,s)=1)

One of the above-mentioned properties of the Markov chain significant to the Markov model says that given the entire past loan history of an individual, the present state depends only on the most recent past state. This property allows the model to be designated exclusively in terms of a time series transition matrix. The transition matrix contains the probabilities, $\{p_{ij}: i,j = 1, 2, \ldots n\}$, where p_{ij} represents the end of the time periods chosen. ($\sum_{j=1}^{n} p_{ij}$ =1 for all i) Data for the nationwide mortgage loans are observed to determine the three time periods of each era and used for each of the matrices so the probabilities are the same for each time period (Haeussler & Paul, 1996).

Home Mortgage Loan Model (HML)

The development of the HML Model is a classification of mortgage loans from the Great Depression and the Great Recession eras, using the three time periods from each era. This study further hopes to demonstrate and anticipate future foreclosures or downturns in the housing market. The HML Model will use the following variables:

Classification of Loan Payments

c = current on the home mortgage payment by the current owner;

d = delinquency of at least 90 days past due;

pd=home mortgage paid in full

f = foreclosed at auction and owned by the lender.

The HML Model Probabilities

P(c,d)	Moving from current to delinquent	Transition
P(c,pd)	Current to paid-off	Transition
P(c,f)	Current to foreclosed	Transition
P(c,c)	Staying current on the payment	Zero
P(d,c)	Delinquent back to current	Transition
P(d,pd)	Delinquent to paid-off	Transition
P(d,f)	Delinquent to foreclosed	Transition
P(d,d)	Staying delinquent	Zero

P(pd,pd)	Staying in paid-off	100%
P(pd,c)	Paid-off to current	Zero
P(pd,d)	Paid-off to delinquent	Zero
P(pd,f)	Paid-off to foreclosed	Zero
P(f,f)	Staying in the foreclosed state	100%
P(f,c)	Foreclosed to current	Zero
P(f,d)	Foreclosed to delinquent	Zero
P(f,pd)	Foreclosed to paid-off	Zero

One can wonder if there is ever a possibility of moving out of the mortgage loan state of either paid-off or foreclosed. For this study we will say that it is impossible to move from the state of foreclosure or paid-off back into a delinquent or current status. With a mortgage loan, if someone is current on a mortgage and continues to make payments, eventually the mortgage will be paid off; but if one does not make payments, it will move into a delinquent state. The loan will eventually move from delinquent back to current or from delinquent into foreclosure. Therefore, the Markov chain transition matrix is absorbing in the foreclosed *(f)* and paid-off *(pd)* state.

The *Probability of Absorption* theorem states that in an absorbing Markov chain, the probability that the process will be absorbed is 1.

Properties of an Absorbing Markov Chain

a) A state of a Markov chain is called absorbing if it is impossible to leave it.

b) A Markov chain is absorbing if it has at least one absorbing state (in this study, *pd* or *f*) and if from every state it is possible to go to an absorbing state (not necessarily in one step).

c) In an absorbing Markov chain, a state, which is not absorbing, is called transient (in this study, *c* and *d*). (Carroll, Sajadpour & Gonzalez, 2012)

The states of current and delinquent are transient states. Since there are both absorbing states, *pd* and *f,* and transient stages, *c* and *d*, the transition matrices have a canonical form showing the states *c* and *d* first and the states *pd and f* are last.

A transition matrix displays two structures, the result of each experiment is one of a set of discrete states and the result of an experiment depends only on the present stage, and not on any past stages.

Let $\{X_n\}$ represent a Markov chain where X_n is the status of a home mortgage loan at the beginning of the designated time period *n*. Let π (*n*) represent the probability distribution of a loan in the beginning of each time period *n*, and is a vector whose entries relate to the different Markov chain status of the loans. If the loan status state in the first of the time period *n* is known, then π_i (*n*) is a row vector with a one signifying the status of loan *i* and zeros in the other spaces.

The transition matrix moving from the start of the time period *n* to end of the time period *n*+1 of the Markov chain is shown as $P(n, n + 1)$, a matrix that contains the probabilities of movement between mortgage loans (Grimshaw & Alexander, 2010).

If the transition matrix is known, a prediction of the mortgage loan state probability distribution for next year can be fashioned using the previous year's loan status probability distribution. That is, for loan *i,* the loan status state probability distribution of end of time period n+1 is computed from $\pi_i\,(n+1) = \pi_i\,(n)\,P_i\,(n, n+1)$ if $\pi_i\,(n)$ and $P_i\,(n, n+1)$ are known (Grimshaw & Alexander, 2010).

In many applications of Markov processes, the initial state is known and we are interested in finding the state probabilities not only for the next observation, but also for more remote future observations. (Anton & Kolman, 1982) If the loan moves into the paid-off or foreclosed state, the movement back to delinquent or current is impossible, calling the two states absorbing states. States such as current and delinquent are transient states because they can move from one to another at any given time. We then call any Markov process with at least one absorbing state an absorbing Markov chain if it is possible to reach that absorbing state in some finite number of steps. Note that since it is possible for one to reach an absorbing state from any other state, the probability of eventually reaching an absorbing state is 1 or 100 percent (Grinstead & Snell, 1997).

Eventually, one of the two absorbing states will be reached. We would like to know, for future predictability; on average, how long will it take for the process to absorb?

The transition matrix of an absorbing Markov chain follows a canonical form, which means that the transient states come first (Warner, 2010). We will arrange the states in the matrix so transient states are first; we will define *r* as absorbing states (*pd and f*) and *t* as transient states (*c and d*). The following is a canonical form for *P:*

$$P = \begin{array}{c} \\ \text{TR.} \\ \text{ABS.} \end{array} \begin{array}{c} \begin{array}{cc} \text{TR.} & \text{ABS.} \end{array} \\ \left[\begin{array}{c|c} Q & R \\ \hline 0 & I \end{array} \right] \end{array}$$

I: is an *r x r* identity matrix

0: is an *r x t* zero matrix

R: is a nonzero *t x r* matrix, giving transition probabilities from transient to absorbing states

Q: is a *t x t* matrix, giving transition probabilities from transient to transient states

Theorems for an Absorbing Markov Chain

- *Given an absorbing Markov chain and an associated transition matrix in the canonical form described above, the matrix I – Q has an inverse N with* $N = I + Q + Q^2 + \ldots\ldots$ *The ij-entry of N is the expected number of times the chain is in state* s_j *given that the process started in state* s_i *.*

- *Let t_i be the expected number of steps before the chain is absorbed given that the chain starts in the transient state s_i , and let t be the column vector whose i^{th} entry is t_i . Then t = Nc (c is a column vector all of whose entries are 1).* (Grinstead & Snell, 1997)

As noted, the probability of reaching the absorbed state, paid-off *(pd)* or foreclosed *(f)*, is 100 percent and the first theorem promises to be able to compute *N,* the inverse of $(I – Q)^{-1}$ which is the raw numbers with units. This calculated matrix is called the fundamental matrix for *P.*

The second theorem allows the calculation of the transient states the expected number of states (probabilities) reached before absorption. The Markov process always starts in the transient state.

It is important to note that transient states (*c* and *d*) may revert back to previous transient states, may skip other transient states to go directly to absorbing, and could progress forward until reaching absorption.

We will now consider the loan status scenarios of the Great Depression and the Great Recession eras dividing into the three different time periods of pre-boom, bubble, and bust. It is important to study each because as mentioned several times in this paper, each time period leads into another.

In the next chapter, we will examine the data from the Great Depression to begin the modeling forecast.

CHAPTER III

THE GREAT DEPRESSION ERA

October 29, 1929, marks the beginning of the Great Depression era, which was considered the most severe economic depression to date. On that day, the sudden collapse of the United States stock market had rippling effects on employment, banks, good and services, and housing. Prior to the Great Depression, the early 1920s was a time of high living, incomes, and property values. For the first time in the country's history, more Americans lived in cities than on farms. Unprecedented economic growth and consumer spending swept over the country as the total wealth of the United States more than doubled. It was also an age of new technology with the invention of the automobile and the beginning of mass communication via radio and moving pictures. From 1920 to 1921, a short recession occurred, which gave rise to steep recovery and prosperity. The Federal Reserve expanded credit by setting below-market interest rates and low reserve needs that helped big banks, and the money supply actually grew by about 60 percent. As the economy pulled out of the recession, single-family housing construction rose rapidly, and many economists argued that the growth in housing investment outstripped demand; real estate speculation was widespread and fueled by careless lending practices. Any time that supply rises faster than demand, supply has to fall in order to regain balance (Wheelock, 1989).

By the end of the 1920s, "buying on margin" entered the American vocabulary as more and more Americans overspent and, as it turned out, became overconfident in the economy. Very few expected the crash that began in 1929, and no one predicted its severity. The Federal Reserve had tightened its monetary policy in 1928, causing a rise in interest rates, which triggered housing investment to fall. Some contend that the weakened housing market contributed to the onset of the Great Depression (Wheelock, 2008).

In the article written by David C. Wheelock of the St. Louis Federal Reserve Bank, Wheelock cited research from a 1937 publication, *Fifth Annual Report of the Federal Home Loan Bank Board*, which stated that in 1933 some 1,000 home loans were foreclosed every day. However, Wheelock wrote that the data to support the publication's claim was very limited and not trustworthy. He reported that this type of data was first available in 1926. Detailed and confirmed data on the mortgage delinquency status is non-existent for the 1930s. Wheelock also reported that a Department of Commerce study of 22 cities found, as of January 1934, almost 44 percent of urban, owner-occupied homes with a first mortgage were in default (Wheelock, 2008).

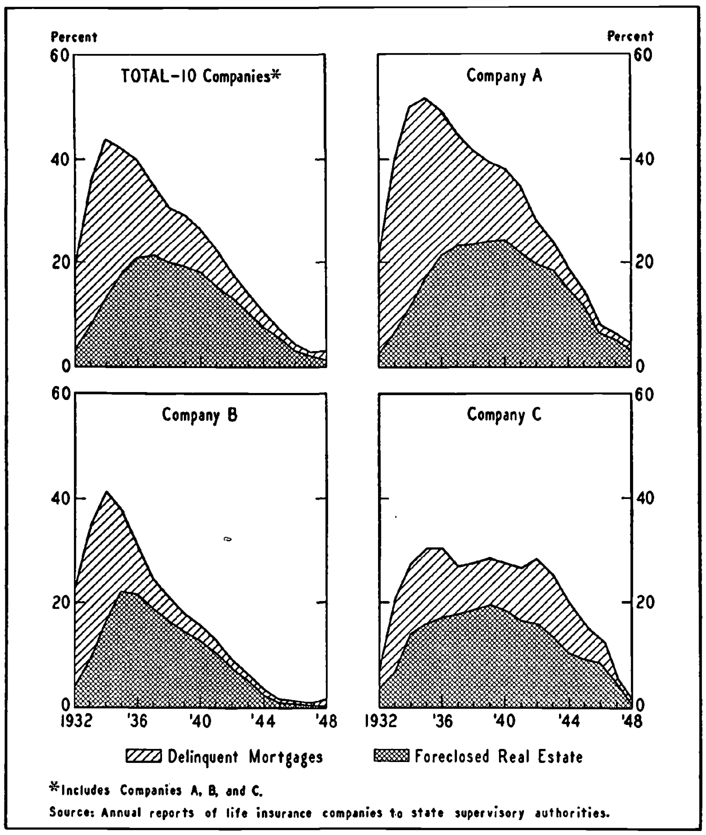
Unlike current-day lending practices, loaning money for mortgages in the 1930s was controlled by four financial institutions—commercial banks, life insurance companies, mutual savings banks, and savings and loans—and each differed in their mortgage terms.

From a National Bureau of Economic Research (NBER) report in a publication titled *Commercial Bank Activities in Urban Mortgage Financing (Behrens, 1952)* the most striking statistic revealed by the study of foreclosure rates on the sample loans was the tendency for a higher percentage of the mortgage loans made during periods of relatively high construction activity, high real estate values, and high levels of business and personal income to go to foreclosure than for loans made under less favorable economic conditions. Thus, the sample of loans made in the pre-boom time period, 1920–1925, had a better-than-average foreclosure rate as compared to those made in the bust time period, 1930–1938. This same description can be used for the more accurate data gathered from post-World War II into the current era. From the 1950s, and for the next forty years, the foreclosure rates stayed at or below the 1 percent mark. This was a time for elevated real estate values and personal income levels. The current-day bust time period, 2001–2011, is parallel to that of 1930–1938, which could also be known as a real estate correction with falling real estate values and lower personal income (Behrens, 1952).

NBER gathered urban mortgage loan experience sample data from 116 commercial banks and 24 leading life insurance companies for the time period 1920 to 1947. There is little statistical data from the Great Depression era reported by any of the institutions. From the publication, sample data figures for foreclosures from the 1920 to 1938 exist, but sample data for loan delinquency rates are vague. The NBER publication cited data from Raymond J. Saulnier, *Urban Mortgage Lending by Life Insurance Companies* (Saulnier, 1950). He stated that at the turn of the century and into the 1930s life insurance companies were major mortgage lending institutions. By 1929, life insurance companies held 16.2 percent of the total outstanding mortgage debt. Saulnier gathered data from 10 large life insurance companies, which reported delinquency rates data from the period 1932 through 1948. He specified that comparable data was not available for earlier years. However, he reported that of the 10 large life insurance companies (Figure 1) a proportion of foreclosed real estate to total loan and real estate investment for the companies rose from 0.3 percent at the end of 1929 to 3.4 percent at the close of 1932, which suggested that as few as 5 percent of the loans were delinquent in 1929. By the end of 1932, the proportion of delinquent rates had risen to 16 percent (Saulnier, 1950).

LOAN EXPERIENCE 81

CHART 11 — DELINQUENT URBAN MORTGAGE LOANS AND FORECLOSED URBAN REAL ESTATE IN PERCENT OF TOTAL URBAN MORTGAGE LOAN AND REAL ESTATE INVESTMENT FOR 10 LARGE LIFE INSURANCE COMPANIES, AT YEAR ENDS, 1932-48



In the early thirties most companies experienced a sharp rise in the proportion of their real estate investment held as delinquent mortgages and foreclosed properties. Companies differed, however, as to the timing of real estate sales, depending mainly on company policy and on the type of property held.

Figure 1 NBER report of 1950, page 81

The use of three variables, current on the loan payment, mortgage paid in full, and a foreclosed mortgage loan, does not appear to be a viable predictability tool for future economic downturns. Adding the variable *delinquency*, and more movement in the transient states *current to delinquent*, will render a better tool for predictability. Since delinquency sample data from Saulnier's report is the only reported data found, a simulation data figure of 5 percent delinquency rate is used in two time periods, pre-boom, 1920 to 1925, and bubble, 1926 to 1929. From 1932 to 1938, sample data from the insurance companies' report averaged 16 percent delinquency rate. For this study, 16 percent is used for the bust period, 1930 to 1938.

Great Depression Pre-Boom Time Period

(1920 TO 1925)

In this study, we look at circumstances leading up to, during, and the beginning of the end of the Depression to determine the time periods studied. Single-family housing starts data are the most reliable figures. Mid-1918 marked the beginning of the rise in new home construction with a slight and short correction during the recession until 1922. Along with new home construction, home mortgage loans began to rise in 1920. Therefore, we study data from 1920 to 1925 as the housing pre-boom time period.

During the 1920s, delinquency and foreclosure rates remained low. Most of the real estate loans were short in duration and, because of the economics times of the period, there was a high paid-in-full mortgage rate.

Table 1

Foreclosure Rates Depression Pre-boom Time Period

Foreclosure Rates for a Sample of Urban Mortgage Loans
10 Leading Life Insurance Companies &
116 Commercial Banks (1920 to 1925)

Year	Institution	Total Loans	Total Foreclosed	Foreclosure Rate
1920	Life Insurance Companies	73	2	
	Commercial Banks	103	2	.0227 *
1921	Life Insurance Companies	119	2	
	Commercial Banks	85	3	.0245
1922	Life Insurance Companies	170	4	
	Commercial Banks	158	3	.0213
1923	Life Insurance Companies	209	12	
	Commercial Banks	207	4	.0385
1924	Life Insurance Companies	280	25	
	Commercial Banks	247	9	.0645
1925	Life Insurance Companies	359	48	
	Commercial Banks	283	29	.1200
Average Foreclosure Rate (1920-1925)				.0624

*Used in initial prob. vector 1920

The transition diagram (Figure 2) below depicts the mortgage loan situation of this pre-boom time period and shows the four states and the probabilities of going from one state to another. States *pd* and *f* are absorbing with circled arrows indicating a probability of 1.

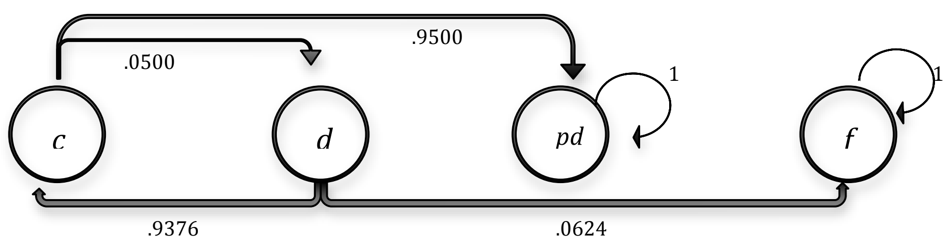


Figure 2: Transition diagram depression pre-boom

The Pre-boom Transition Matrix (P_{dpb})

$$P_{dpb} = \begin{array}{c} \\ c \\ d \\ pd \\ f \end{array} \begin{array}{c} \begin{array}{cccc} \boldsymbol{c} & \boldsymbol{d} & \boldsymbol{pd} & \boldsymbol{f} \end{array} \\ \begin{bmatrix} 0 & 0.0500 & 0.9500 & 0 \\ 0.9376 & 0 & 0 & 0.0624 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

Figure 3: Transition matrix depression pre-boom

The initial state of the pre-boom period is 1920. From the data reviewed in the NBER publication for this study, we will use 48.06 percent in the current state, 5 percent in delinquency, 45 percent in paid-off and 2.27 percent in the foreclosed state. The distributions can be written as a probability vector *(X_0)*.

A probability vector is a matrix of only one row, having nonnegative entries, with the sum of the entries equal to 1.

$$X_0 = \begin{bmatrix} 0.4806 & 0.0500 & 0.4500 & 0.0227 \end{bmatrix}$$

Suppose a Markov chain has initial probability vector $X_0 = [\, i_1 \; i_2 \; i_3 \ldots\ldots i_n]$ and transition matrix P_{dpb}. The probability vector after *n* repetitions of the experiment is

$$X_0 * (P_{dpb})^n$$

Using this information, the distribution status of mortgage loans for future pre-boom time periods are computed (Table 2). The initial probability vector (X_0), give the distribution of the status of loans in 1920.

$$X_0 = \begin{bmatrix} 0.4806 & 0.0500 & 0.4500 & 0.0227 \end{bmatrix}$$

Table 2

Distribution of Loan Status After n Periods (GD Pre-boom)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	.0469	.0240	.9066	.0258
2	.0225	.0023	.9511	.0273
3	.0022	.0011	.9725	.0275
4	.0011	.0001	.9750	.0275

Great Depression Housing Bubble Time Period

(1926 TO 1929)

Housing bubbles usually start with an increase in demand. Beginning in 1923, as the Federal Reserve lowered rates and the economy grew, new home construction and the home mortgage loan soared to all-time highs. Many families were choosing the life and conveniences of the city and were moving from farms to homes in the city.

Data show the housing bubble peaked in 1926. Some analysts believe the hurricane of 1926 in Florida pierced the bubble, but house prices, new home construction, and home mortgage loan data show that the boom and bust were, in fact, nationwide phenomena, and their causes and consequences remain unclear (Harvard Business School, 2013). Before the unexpected Great Depression, the mortgage foreclosure rates climbed in 1925 to 12 percent.

As shown in table 3, the foreclosure rate rose at a steady pace until it peaked in 1929. The bubble time period we will use in this study is 1926 to 1929.

Table 3

Foreclosure Rates Depression Bubble Time Period

Foreclosure Rates for a Sample of Urban Mortgage Loans
10 Leading Life Insurance Companies &
116 Commercial Banks (1926 to 1929)

Year	Institution	Total Loans	Total Foreclosed	Foreclosure Rate
1926	Life Insurance Companies	479	86	
	Commercial Banks	242	25	.1540 *
1927	Life Insurance Companies	414	92	
	Commercial Banks	266	27	.1750
1928	Life Insurance Companies	411	99	
	Commercial Banks	263	34	.1974
1929	Life Insurance Companies	398	105	
	Commercial Banks	203	25	.2163
Average Foreclosure Rate (1920-1925)				.1842

**Used in initial probability vector 1926*

The transition diagram (Figure 4) below depicts the mortgage loan situation of this bubble time period and shows the four states and the probabilities of going from one state to another. States *pd* and *f* are absorbing with circled arrows indicating a probability of 1.

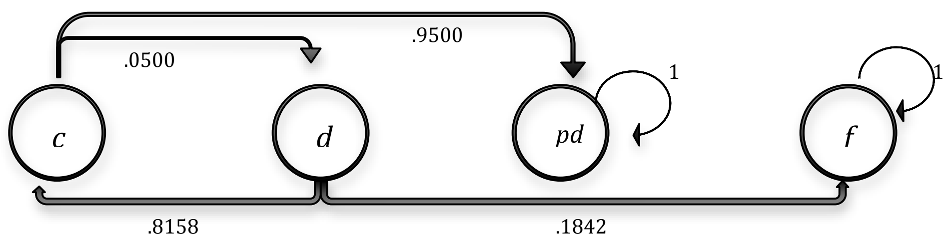


Figure 4: Transition diagram depression bubble

The Bubble Transition Matrix (P_{dbu})

$$
P_{dbu} = \begin{array}{c} \\ \textbf{c} \\ \textbf{d} \\ \textbf{pd} \\ \textbf{f} \end{array} \begin{array}{c} \begin{array}{cccc} \textbf{c} & \textbf{d} & \textbf{pd} & \textbf{f} \end{array} \\ \begin{bmatrix} 0 & 0.0500 & 0.9500 & 0 \\ 0.8158 & 0 & 0 & 0.1842 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}
$$

Figure 5: Transition matrix depression bubble

The initial state of the bubble period is 1926 with 59.6 percent in the current state, 5 percent in delinquency, 20 percent in paid-off and 15.4 percent in the foreclosed state. The distributions are written in the probability vector *(X_0)*.

$$X_0 = \begin{bmatrix} 0.5960 & 0.0500 & 0.2000 & 0.1540 \end{bmatrix}$$

$$X_0 * (P_{dbu})^n$$

From this information, table 4 displays the distribution status of mortgage loans for future bubble time periods. The initial probability vector, which reports the distribution of the status of loans in 1920, is [0.5960 0.0500 0.2000 0.1540].

Table 4

Distribution of Loan Status After n Periods (GD Bubble)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	.0408	.0298	.7662	.1632
2	.0243	.0020	.8050	.1687
3	.0017	.0012	.8281	.1691
4	.0010	.0001	.8296	.1693

Great Depression Housing Bust Time Period

(1930 TO 1938)

In 1929, housing starts fell at record rates, bottoming out at an all-time low in 1933. Interest rates began to climb in 1928 when the Federal Reserve stiffened monetary policy to stem speculative activity, especially in the stock market, and housing investment began to fall. Housing starts plunged drastically after the business cycle peak in mid-1929; home mortgage loan applications fell drastically, as well, from 1929 to 1930. As seen in table 5 on the next page, 1930 marked the descent of foreclosure rates from the high of 1929. We will use 1930 to 1938 as the bust time period.

Table 5

Foreclosure Rates Depression Bust Time Period

Foreclosure Rates for a Sample of Urban Mortgage Loans
10 Leading Life Insurance Companies &
116 Commercial Banks (1930 to 1938)

Year	Institution	Total Loans	Total Foreclosed	Foreclosure Rate
1930	Life Insurance Companies	348	71	
	Commercial Banks	162	11	.1608*
1931	Life Insurance Companies	301	58	
	Commercial Banks	151	10	.1504
1932	Life Insurance Companies	103	10	
	Commercial Banks	61	4	.0854
1933	Life Insurance Companies	24	0	
	Commercial Banks	48	1	.01389
1934	Life Insurance Companies	33	2	
	Commercial Banks	55	0	.0
1935	Life Insurance Companies	88	3	
	Commercial Banks	142	2	.0217
1936	Life Insurance Companies	202	4	
	Commercial Banks	175	5	.0239
1937	Life Insurance Companies	252	4	
	Commercial Banks	229	5	.0187
1938	Life Insurance Companies	298	6	
	Commercial Banks	239	1	.0130
Average Foreclosure Rate (1930-1938)				.0677

**Used in initial probability vector 1930*

The transition diagram (Figure 6) below depicts the mortgage loan situation of this pre-boom time period and shows the four states and the probabilities of going from one state to another. States *pd* and *f* are absorbing with circled arrows indicating a probability of 1.

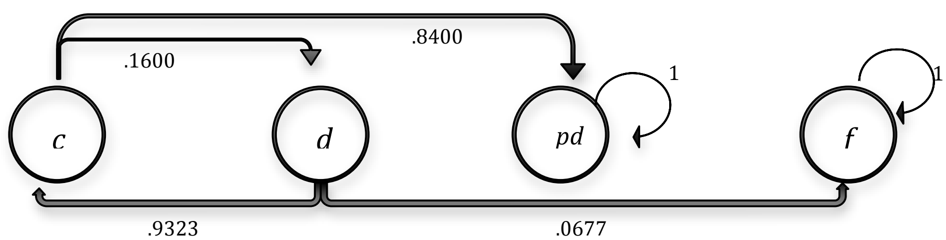


Figure 6 Transition diagram depression bust

The Bust Transition Matrix (P_{db})

$$P_{db} = \begin{array}{c} \\ c \\ d \\ pd \\ f \end{array} \begin{array}{c} \begin{array}{cccc} \textbf{c} & \textbf{d} & \textbf{pd} & \textbf{f} \end{array} \\ \begin{bmatrix} 0 & 0.1600 & 0.8400 & 0 \\ 0.9323 & 0 & 0 & 0.0677 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

Figure 7 Transition matrix depression bust

The initial state of the pre-boom period is 1920 with 45 percent in the current state, 16.29 percent in delinquency, 22.63 percent in paid-off and 6.77

percent in the foreclosed state. The distributions are written in the probability vector *(X_0)*.

$$X_0 = \begin{bmatrix} 0.4500 & 0.1629 & 0.2263 & 0.1608 \end{bmatrix}$$

The probability vector after *n* repetitions of the experiment is

$$X_0 * (P_{dpb})^n$$

Using this information, one can compute the distribution status of mortgage loans for future bust time periods (Table 6). The initial probability vector, which reports the distribution of the status of loans in 1930, is [0.4500 0.1629 0.2263 0.0677].

Table 6

Distribution of Loan Status After n Periods (GD Bust)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	.1519	.0720	.6043	.1718
2	.0671	.00243	.7319	.1767
3	.0227	.0107	.7883	.1783
4	.0100	.0036	.8073	.1791

It is evident from each time period that the results seem to approach the numbers in the probability vectors. The long-range trend is for either the loan to be paid-off or foreclosed. After four time periods, the foreclosure rates of pre-boom are 0.0275, bubble 0.1693, and bust 0.1719.

CHAPTER IV

THE GREAT RECESSION ERA

In this chapter, we will use the Home Mortgage Loan Model to evaluate the current economic crisis, the Great Recession. There has not been any time period since the Great Depression that remotely compares to the housing market as it is today. For example, during most lifetimes in the current era, buying a home was the American way of life, not to mention it was a solid place for an investment. Not since World War II have homes lost equity. The devaluation of personal homeownership has contributed significantly to the current economic crisis, giving rise to home foreclosures comparable to the Great Depression. As homes devalue, property taxes decline, affecting the amount of money that state and local governments have to operate. A large financial downturn and a rise in home foreclosures point, in part, to the devaluation of real estate.

As stated in chapter 3, this era will be divided into three time periods—pre-boom, bubble, and bust—using the Markov Chain transition matrix to inspect the current data. First, we will look at how the current era was divided for this study.

Toward the end of World War II, the homeownership rate began to increase. In fact, the rate grew until reaching 64 percent of the population in 1965. For the next 30 years, in spite of a wide variety of policies at all levels of government aimed at stimulating homeownership, this rate seemed fixed permanently near the 64 percent level. However, in 1997, the trend turned upward again and reached 69 percent by 2004 (Garriga, Gavin & Schlagenhauf, 2006). According to 2012 data from the Housing Vacancy Survey of the 2005 U.S. Census Bureau, slightly more than 69 percent of the U.S. population owned a home.

Great Recession Pre-boom Time Period

(1979 TO 1989)

In this study, data from the National Delinquency Survey of the Mortgage Bankers Association (MBA) has been reviewed carefully (see Appendix A). The statistics from the MBA report are from a voluntary survey of more than 120 mortgage lenders, which include banks, commercial banks, thrifts, savings and loan associations, sub-servicers, and life insurance companies. Of the mortgages being serviced, an average of 1 percent of the delinquent loans were foreclosed. This figure remained fixed for the next 10 years. The pre-boom time period yielded an average of 9.1 million mortgages serviced in the U.S. with approximately 95 percent of the current mortgages paid-off and 5 percent delinquent loan payments. Of the delinquent loans, 90 percent moved back into current with slightly less than 1 percent into foreclosure. Therefore, for this study, 1979 to 1989 is used as the pre-boom time period.

Table 7

Transition Rates of Great Recession Pre-boom

Year	Current	PaidOff	PdRate	Delinquent	DelRate	ForeclosureRate
1979	7,288,043	6,951,195	.	336,848	.	0.0057
1980	7,106,257	6,753,502	.	352,755	.	0.0058
1981	7,425,639	7,036,498	.	389,141	.	0.0066
1982	8,198,724	7,745,884	.	452,840	.	0.0084
1983	8,730,616	8,242,575	.	488,041	.	0.0087
1984	9,210,535	8,688,995	.	521,539	.	0.0085
1985	9,272,236	8,731,457	.	540,779	.	0.0091
1986	9,740,079	9,199,158	.	540,921	.	0.0101
1987	9,926,795	9,433,143	.	493,652	.	0.0103
1988	10,367,559	9,871,940	.	495,619	.	0.0107
1989	12,708,979	12,101,164	.	607,815	.	0.0130
.	9,088,678	8,614,137		474,541		.
PaidOff and Delinquent Rate			**0.9478**		**0.0522**	
Sum of Foreclosure Rate (per MBA)						**0.0969**
Delinquent to Current (1 – *f*) = 0.9031						

Note: The data for this study was based off of the Mortgage Loans Serviced, Foreclosures Started and Total Past Due numbers from The National Delinquency Survey of The Mortgage Bankers Association.

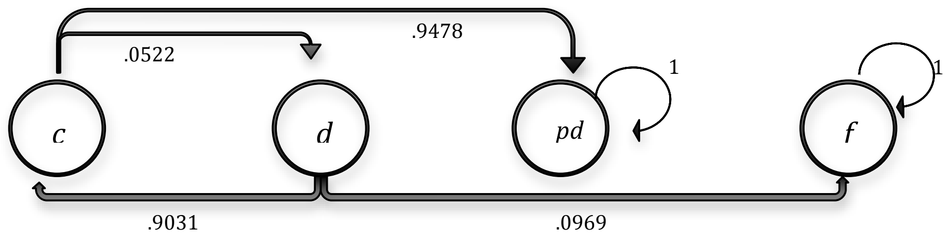


Figure 8 Transition diagram recession pre-boom

The Pre-boom Matrix (P_{pb})

$$P_{pb} = \begin{array}{c} \\ c \\ d \\ pd \\ f \end{array} \begin{array}{c} \begin{array}{cccc} c & d & pd & f \end{array} \\ \begin{bmatrix} 0 & 0.0522 & 0.9478 & 0 \\ 0.9031 & 0 & 0 & 0.0969 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

Figure 9 Transition matrix recession pre-boom

The initial state of the recession pre-boom period is 1979 with 34.19 percent in the current state, 4.63 percent in delinquency, 61.03 percent paid-off and .15 percent in the foreclosure state. The distributions are written in the probability vector (X_0).

$$X_0 = \begin{bmatrix} 0.3419 & 0.0463 & 0.6103 & 0.0015 \end{bmatrix}$$

The probability vector after *n* repetitions of the experiment is

$$X_0 * (P_{pb})^n$$

Using this information, one can compute the distribution status of the mortgage loans for future recession pre-boom periods. The initial probability vector, [0.3419 0.0463 0.6103 0.0015], reports the distribution of the status of loans in 1979.

Table 8

Distribution of Loan Status After n Periods (GR Pre-boom)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	0.0418	0.0179	0.9344	0.0060
2	0.0161	0.0022	0.9740	0.0077
3	0.0020	0.0008	0.9893	0.0080
4	0.0008	0.0001	0.9911	0.0080

Great Recession Housing Bubble Time Period

(1990 TO 2000)

As the housing trends began to turn upward in 1995, many factors caused this bubble in the housing market. Low mortgage rates, changes in housing policy demographics, and innovations in financial markets increased access to mortgage finance mainly by reducing down payment constraints and allowing younger people to buy (Garriga, Carvin & Schlagenhauf, 2006). In the 1990s, an average of 15 percent of delinquent loans moved into foreclosure. For this study, it has been determined to use the years 1990 through 2000 as the boom or, as many economists call it, the bubble. This bubble was actually bigger than that of the Great Depression as there was more housing inventory to work with, which helps to explain why this shift is truly distinct from previous recessions.

Table 9

Transition Rates of Great Recession Bubble

Year	Current	PaidOff	PdRate	Delinquent	DelRate	ForeclosureRate
1990	15,007,668	14,307,678	.	699,991	.	0.0125
1991	16,030,584	15,225,816	.	804,768	.	0.0134
1992	16,368,404	15,621,027	.	747,376	.	0.0132
1993	17,350,135	16,617,249	.	732,886	.	0.0126
1994	19,033,671	18,254,262	.	779,408	.	0.0132
1995	20,788,760	19,906,248	.	882,511	.	0.0131
1996	22,049,894	21,096,617	.	953,277	.	0.0138
1997	22,854,032	21,870,711	.	983,321	.	0.0141
1998	23,792,360	22,735,073	.	1,057,287	.	0.0149
1999	27,485,686	26,317,526	.	1,168,160	.	0.0146
2000	29,429,526	28,138,919	.	1,290,607	.	0.0152
.	20,926,429	20,008,284		918,145		.
PaidOff and Delinquent Rate			**0.9561**		**0.0439**	
Sum of Foreclosure Rate						**0.1506**
Delinquent to Current (1– *f*) = 0.8494						

Note: The data for this study was based off of the Mortgage Loans Serviced, Foreclosures Started and Total Past Due numbers from The National Delinquency Survey of The Mortgage Bankers Association.

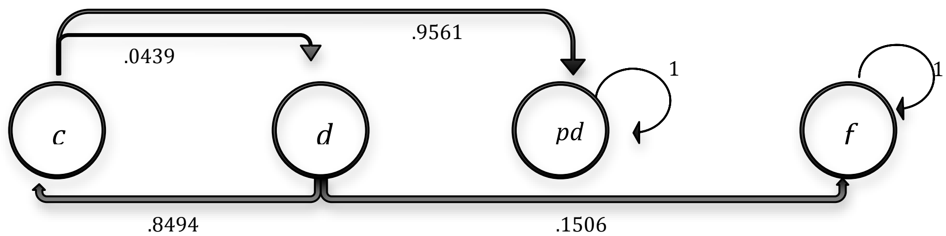


Figure10 Transition diagram recession bubble

The Bubble Transition Matrix (P_{bu})

$$P_{bu} = \begin{array}{c} \\ c \\ d \\ pd \\ f \end{array} \begin{array}{c} \begin{array}{cccc} c & d & pd & f \end{array} \\ \begin{bmatrix} 0 & 0.0439 & 0.9561 & 0 \\ 0.8494 & 0 & 0 & 0.1506 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

Figure 11 Transition matrix recession bubble

The initial state of the bubble period is 1990 with 23.01 percent are current on their loan, 4.66 percent delinquent, 71.08 percent have paid-off and 1.25 percent have moved into foreclosure. The distributions are written in the probability vector (X_0).

$$X_0 = \begin{bmatrix} 0.2301 & 0.0466 & 0.7108 & 0.0125 \end{bmatrix}$$

The probability vector after *n* repetitions of the experiment is

$$X_0 * (P_{bu})^n$$

Using this information, the distribution status can be computed on future mortgage loans in a bubble period of time. The initial probability vector, which reports the distribution of the status of loans in 1990, is [0.2301 0.0466 0.7108 0.0125].

Table 10

Distribution of Loan Status After n Periods (GR Bubble)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	0.0400	0.0101	0.9308	0.0195
2	0.0086	0.0017	0.9687	0.0210
3	0.0015	0.0004	0.9768	0.0213
4	0.0003	0.0000	0.9783	0.0214

Great Recession Housing Bust Time Period

(2001 TO 2011)

Next, the collapse of the housing bubble gave rise to the housing market bust. The housing bust had a tremendous impact on home valuation, homebuilders, real estate (land and commercial), ad valorem taxes, and the nation's mortgage markets, giving rise to the foreclosure rate. In the first quarter of 2008, the total mortgages serviced in the U.S. began a steady decline. This was the first decline in at least ten years. Note that it is not unusual to report a decline in the number of mortgages serviced from one quarter to the next, but that decline will often rebound the following quarter. At year-end 2008, mortgage loans serviced peaked at a historic high of almost 46 million. By the end of the year 2011, only 43.5 million mortgage loans were being serviced. Of loans being serviced from 2001 through 2011, 32 percent of the mortgages in delinquency went into foreclosure, this being the highest foreclosure rate since 1931. The year 2009 yielded a foreclosure rate of 23 percent as compared to 1931 when the National Bureau of Economic Research (NBER) sample survey of 116 commercial banks showed almost 7 percent. Therefore, for this study, 2001 through 2011 is designated as the bust time period.

Table 11

Transition Rates of Great Recession Bust

Year	Current	PaidOff	PdRate	Delinquent	DelRate	ForeclosureRate
2001	31,864,248	30,235,899	.	1,628,349	.	0.0179
2002	33,592,875	31,878,081	.	1,714,794	.	0.0180
2003	35,266,040	33,597,180	.	1,668,860	.	0.0166
2004	38,598,047	36,867,110	.	1,730,937	.	0.0173
2005	40,303,596	38,510,094	.	1,793,502	.	0.0164
2006	42,477,803	40,520,266	.	1,957,537	.	0.0184
2007	44,887,042	42,485,708	.	2,401,334	.	0.0284
2008	45,379,447	42,244,639	.	3,134,808	.	0.0426
2009	44,693,238	40,506,886	.	4,186,352	.	0.0537
2010	44,124,714	40,008,920	.	4,115,794	.	0.0495
2011	43,508,268	39,990,475	.	3,517,793	.	0.0412
.	40,426,847	37,895,023		2,531,824		.
PaidOff and Delinquent Rate			**0.9374**		**0.0626**	
Sum of the Foreclosure Rates						**0.3200**
Delinquent to Current (1-*f*) = 0.6800						

Note: The data for this study was based off of the Mortgage Loans Serviced, Foreclosures Started and Total Past Due numbers from The National Delinquency Survey of The Mortgage Bankers Association.

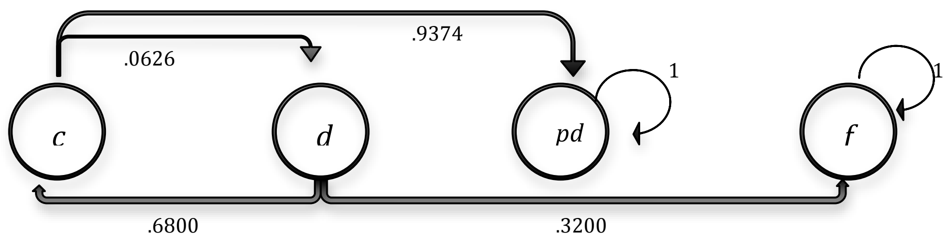


Figure 12 Transition diagram recession bust

The Bust Transition Matrix (P_b)

$$
P_b = \begin{array}{c} \\ c \\ d \\ p \\ f \end{array}
\begin{array}{c} \begin{array}{cccc} c & d & pd & f \end{array} \\
\begin{bmatrix} 0 & 0.0626 & 0.9374 & 0 \\ 0.6800 & 0 & 0 & 0.3200 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}
$$

Figure 13 Transition matrix recession bust

The initial state of the bust period is 2000 with 51.22 percent in the current state, 5.11 percent in delinquency, 41.88 percent in paid-off, and 1.79 percent in the foreclosed state. Note the spread in the foreclosure rate during the bust period. The distributions are written in the probability vector (X_0).

$$X_0 = \begin{bmatrix} 0.5122 & 0.0511 & 0.4188 & 0.0179 \end{bmatrix}$$

The probability vector after *n* repetitions of the experiment is

$$X_0 * (P_b)$$

Using this information, one can compute the distribution status of mortgage loans for future bust time periods. The Bust initial probability vector, [0.5122 0.0511 0.4188 0.0179] yields the distribution of the status of mortgage loans in 2000.

Table 12

Distribution of Loan Status After n Periods (GR Bust)

After *n* time periods	Current	Delinquent	Paid-off	Foreclosed
1	0.0348	0.0321	0.8989	0.0346
2	0.0218	0.0022	0.9315	0.0445
3	0.0015	0.0014	0.9520	0.0452
4	0.0009	0.0001	0.9533	0.0456

Along with the Great Depression discussion in chapter 3, each of the time period results seem to approach the numbers in the probability vectors. In the Great Recession and the Great Depression, the long-range trend is for either the loan to be paid-off or foreclosed. The foreclosure rates stabilize after three or four time periods from each era.

CHAPTER V

ABSORBING PROBABILITIES

In this chapter, we will use the statistical data from each time period, with the use of the absorbing Markov chain to model mortgage loans. Eventually, the loan is either paid-off or foreclosed. Once the loan has entered one of the two states, it is impossible to leave. From the origination of the loan, it will ultimately terminate. All mortgage loans start in the current state and either move into the transient state of delinquency or into the absorbing state of paid-off. For this study, when a loan moves into the absorbing state of foreclosure, it must move from the delinquent state; although, the delinquent loan (transient state) can move back into current, the loan cannot move from current to foreclosed— it must come from the delinquent state.

Canonical Form of the Absorbing Markov Chain

We will now take the six time periods' transition matrix and set each up in canonical form. In canonical form, the transient states t come first, r absorbing states, I is the r x r identity matrix, and O is the r x t zero matrix. R is a non-zero t x r and Q is a t x t matrix. Since the possibility of reaching the absorbing states, (pd) and (f), is 1, we will answer on average how long will it take for the process to be absorbed (Warner, 2010).

$$P = \begin{array}{c|c|c} & \text{TR.} & \text{ABS.} \\ \hline \text{TR.} & Q & R \\ \hline \text{ABS.} & 0 & I \end{array}$$

I: is an *r x r* identity matrix

0: is an *r x t* zero matrix

R: is a nonzero *t x r* matrix, giving transition probabilities from transient to absorbing states

Q: is a *t x t* matrix, giving transition probabilities from transient to transient states

Each transition matrix from the two eras, six matrices in all, is set in canonical form to determine the probabilities and number of steps it will take to reach the probability.

The Great Depression Pre-boom (1920 TO 1929)

$$\left[\begin{array}{cc|cc} 0 & 0.0500 & 0.9500 & 0 \\ 0.9376 & 0 & 0 & 0.0624 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

From the transition matrix of the Great Depression era and pre-boom time period we will define the Q, R, I and 0 matrices.

$$Q = \begin{bmatrix} 0 & 0.0500 \\ 0.9376 & 0 \end{bmatrix} \text{ and } R = \begin{bmatrix} 0.9500 & 0 \\ 0 & 0.0624 \end{bmatrix} \text{ and } I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.0500 \\ -0.9376 & 1 \end{bmatrix}$$

The fundamental matrix for an absorbing Markov chain gives the expected number of times the mortgage loan process is in the delinquent state given the loan began in the current state. The fundamental matrix is defined by $F = (I - Q)^{-1}$. The application of the first theorem mentioned in Chapter II, and because the probability of reaching the absorbing state is one, F the inverse of (I – Q) can be computed. The inverse of $(I - Q)$ is found using the Gauss-Jordan method.

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.0492 & 0.0525 \\ 0.9837 & 1.0492 \end{bmatrix}$$

Next, the second theorem mentioned in chapter II is applied. Let t_i be the expected number of steps before the chain is absorbed given that the chain starts in the transient state s_{ij}. Let T be the column vector whose i^{th} entry is t_i and c is a volume vector all of whose entries are 1.

$$T = Fc$$

$$T = \begin{bmatrix} 1.0492 & 0.0525 \\ 0.9837 & 1.0492 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.1017 \\ 2.0329 \end{bmatrix}$$

During the Depression pre-boom era, it would be expected to go slightly more than one cycle to be paid-off or two cycles to move into foreclosure.

Finally, to find the final matrix and the probabilities we will multiply the fundamental matrix by R, where R is the left side of the canonical form matrix with the absorbing states.

$$FR = \begin{bmatrix} 0.9967 & 0.0033 \\ 0.9345 & 0.0655 \end{bmatrix}$$

During the pre-boom time period of the Great Depression we found the following probabilities of going from:

- Current to paid-off $P(c, pd)$ = 99.67%
- Current to delinquent $P(c, d)$ = 0.33%
- Delinquent back to current $P(d, c)$ = 93.45%
- Delinquent to foreclosed $P(d, f)$ = 6.55%

Great Depression Bubble (1926 to 1929)

$$\left[\begin{array}{cc|cc} 0 & 0.0500 & 0.9500 & 0 \\ 0.8158 & 0 & 0 & 0.1842 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

$$Q = \begin{bmatrix} 0 & 0.0500 \\ 0.8158 & 0 \end{bmatrix} \quad \text{and} \quad R = \begin{bmatrix} 0.9500 & 0 \\ 0 & 0.1842 \end{bmatrix} \quad \text{and} \quad I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.0500 \\ -0.8158 & 0 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.0425 & 0.0522 \\ 0.8505 & 1.0425 \end{bmatrix}$$

$$T = Fc = \begin{bmatrix} 1.0425 & 0.0522 \\ 0.8505 & 1.0425 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 0.9500 \\ 0.1842 \end{bmatrix}$$

$$FR = \begin{bmatrix} 1.0425 & 0.0522 \\ 0.8505 & 1.0425 \end{bmatrix} * \begin{bmatrix} 0.9500 & 0 \\ 0 & 0.1842 \end{bmatrix} = \begin{bmatrix} 0.9904 & 0.0096 \\ 0.8080 & 0.1920 \end{bmatrix}$$

$P(c, pd) = 99.04\%$

$P(c, f) = 0.96\%$

$P(d, pd) = 80.80\%$

$P(d, f) = 19.20\%$

Great Depression Bust (1930 to 1938)

$$P_{db} = \left[\begin{array}{cc|cc} 0 & 0.1600 & 0.8400 & 0 \\ 0.9323 & 0 & 0 & 0.0677 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

$$Q = \begin{bmatrix} 0 & 0.1600 \\ 0.9323 & 0 \end{bmatrix} \quad \text{and} \quad R = \begin{bmatrix} 0.8400 & 0 \\ 0 & 0.0677 \end{bmatrix} \quad \text{and} \quad I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.1600 \\ -0.9323 & 0 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.1753 & 0.1881 \\ 1.0958 & 1.1753 \end{bmatrix}$$

$$T = Fc = \begin{bmatrix} 1.1753 & 0.1881 \\ 1.0958 & 1.1753 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.3634 \\ 2.2711 \end{bmatrix}$$

$$FR = \begin{bmatrix} 1.1753 & 0.1881 \\ 1.0958 & 1.1753 \end{bmatrix} * \begin{bmatrix} 0.8400 & 0 \\ 0 & 0.0677 \end{bmatrix} = \begin{bmatrix} 0.9873 & 0.0127 \\ 0.9204 & 0.0796 \end{bmatrix}$$

$P(c, pd) = 98.73\%$

$P(c, f) = 1.27\%$

$P(d, pd) = 92.04\%$

$P(d, f) = 7.96\%$

Great Recession Pre-boom (1979 to 1989)

We will now review the data from the Great Recession era's three time periods with the use of the canonical form to find the fundamental matrix (F), the probabilities for each transient state moving into an absorbing state, the future predictability (FR) and on average how long will it take for the process to absorb (Fc).

$$P_{pb} = \left[\begin{array}{cc|cc} 0 & 0.0522 & 0.9478 & 0 \\ 0.9031 & 0 & 0 & 0.0969 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

$$Q = \begin{bmatrix} 0 & 0.0522 \\ 0.9031 & 0 \end{bmatrix} \quad \text{and} \quad R = \begin{bmatrix} 0.9478 & 0 \\ 0 & 0.0969 \end{bmatrix} \quad \text{and} \quad I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.0522 \\ -0.9031 & 1 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.0495 & 0.0548 \\ 0.9478 & 1.0495 \end{bmatrix}$$

$$T = Fc = \begin{bmatrix} 1.0495 & 0.0548 \\ 0.9478 & 1.0495 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.1043 \\ 1.9973 \end{bmatrix}$$

$$FR = \begin{bmatrix} 1.0495 & 0.0548 \\ 0.9478 & 1.0495 \end{bmatrix} * \begin{bmatrix} 0.9478 & 0 \\ 0 & 0.0969 \end{bmatrix} = \begin{bmatrix} 0.9947 & 0.0053 \\ 0.8983 & 0.1017 \end{bmatrix}$$

During the pre-boom time period of the Great Depression we found the following probabilities of going from:

- Current to paid-off $P(c, pd)$ = 99.47%
- Current to delinquent $P(c, d)$ = 0.53%
- Delinquent back to current $P(d, c)$ = 89.83%
- Delinquent to foreclosed $P(d, f)$ = 10.17%

Great Recession Bubble (1990 to 2000)

$$P_{bu} = \left[\begin{array}{cc|cc} 0 & 0.0439 & 0.9561 & 0 \\ 0.8494 & 0 & 0 & 0.1506 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

$$Q = \begin{bmatrix} 0 & 0.0439 \\ 00.8494 & 0 \end{bmatrix} \text{ and } R = \begin{bmatrix} 0.9561 & 0 \\ 0 & 0.1506 \end{bmatrix} \text{ and } I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.0439 \\ -0.8494 & 1 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.0387 & 0.0456 \\ 0.8823 & 1.0387 \end{bmatrix}$$

$$Fc = \begin{bmatrix} 1.0387 & 0.0456 \\ 0.8823 & 1.0387 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.0843 \\ 1.9210 \end{bmatrix}$$

$$FR = \begin{bmatrix} 1.0387 & 0.0456 \\ 0.8823 & 1.0387 \end{bmatrix} * \begin{bmatrix} 0.9561 & 0 \\ 0 & 0.1506 \end{bmatrix} = \begin{bmatrix} 0.9931 & 0.0069 \\ 0.8436 & 0.1564 \end{bmatrix}$$

$P(c, pd)$ = 99.31%

$P(c, f)$ = 0.69%

$P(d, pd)$ = 84.36%

$P(d, f)$ = 15.64%

Great Recession Bust (2001 to 2011)

$$P_b = \left[\begin{array}{cc|cc} 0 & 0.0626 & 0.9374 & 0 \\ 0.6800 & 0 & 0 & 0.3200 \\ \hline 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

$$Q = \begin{bmatrix} 0 & 0.0626 \\ 0.6800 & 0 \end{bmatrix} \text{ and } R = \begin{bmatrix} 0.9374 & 0 \\ 0 & 0.3200 \end{bmatrix} \text{ and } I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$I - Q = \begin{bmatrix} 1 & -0.0626 \\ -0.6800 & 1 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1.0445 & 0.0654 \\ 0.7102 & 1.0445 \end{bmatrix}$$

$$Fc = \begin{bmatrix} 1.0445 & 0.0654 \\ 0.7102 & 1.0445 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.1098 \\ 1.7547 \end{bmatrix}$$

$$FR = \begin{bmatrix} 1.0445 & 0.0654 \\ 0.7102 & 1.0445 \end{bmatrix} * \begin{bmatrix} 0.9374 & 0 \\ 0 & 0.3200 \end{bmatrix} = \begin{bmatrix} 0.9791 & 0.0209 \\ 0.6658 & 0.3342 \end{bmatrix}$$

$P(c, pd) = 97.91\%$

$P(c, f) = 2.09\%$

$P(d, pd) = 66.58\%$

$P(d, f) = 33.42\%$

In chapter 6, the data is summarized then interpreted to discuss the option of forming a predictability tool for future downturns in the housing market.

CHAPTER VI

MOTIVATION AND LIMITATIONS OF THE HML MODEL

The two time eras, the Great Depression and the Great Recession, are similar `in many aspects, but as far as historical statistics, the eras differ the most. The sample data from the Great Depression reviewed hundreds of loans per year and for this study the variable delinquent had to be simulated due to the fact there was unsubstantial records for delinquency. The Great Recession time period reviewed was from 1979 to 2011, and the sample size was millions of loans. Data figures for this era are detailed and accurate. To continue with the comparison study, a summary of the data from both eras is below.

Table 13

Great Depression Probability Summary

	Expected Number of Steps Before Chain is Absorbed	Probability
Pre-boom	Paid Off = 1.10 Foreclosed = 2.03	P(c, pd) = 99.67% P(c, f) = 0.33% P(d, pd) = 93.45% P(d, f) = 6.55%
Bubble	Paid Off = 0.95 Foreclosed = 0.18	P(c, pd) = 99.04% P(c, f) = 0.96% P(d, pd) = 80.80% P(d, f) = 19.20%
Bust	Paid Off = 1.36 Foreclosed = 2.27	P(c, pd) = 98.73% P(c, f) = 1.27% P(d, pd) = 92.04% P(d, f) = 7.96%

Table 14

Great Recession Probability Summary

	Expected Number of Steps Before Chain is Absorbed	Probability
Pre-boom	Paid Off = 1.10 Foreclosed = 2.00	P(c, pd) = 99.47% P(c, f) = 0.53% P(d, pd) = 89.83% P(d, f) = 10.17%
Bubble	Paid Off = 1.08 Foreclosed = 1.92	P(c, pd) = 99.31% P(c, f) = 0.69% P(d, pd) = 84.36% P(d, f) = 15.64%
Bust	Paid Off = 1.11 Foreclosed = 1.76	P(c, pd) = 97.91% P(c, f) = 2.09% P(d, pd) = 66.58% P(d, f) = 33.42%

From each era, clearly the probability of going from the transient state of current to the absorbing state of paid-off and current to the absorbing state of foreclosed is comparable. Also, the number of steps to move from the transient state to the absorbed state is the same for both eras: approximately one step to paid-off and two steps to foreclosed, except for that of the bust time period of the Great Recession, which is lower at 1.76 steps.

From the Great Recession era, there is a possibility of forming a predictability tool to forecast future foreclosure states due to the fact that data is reliable. However, from the Great Depression era, an accurate predictability tool cannot be formed without good sample data for mortgage loan delinquency rates.

HML Model Motivated

We use the HML Model on the Great Recession bust time period as an example.

During a "bust time period", a small town financial banking institution has a total book of mortgage loan business of $4,000,000. At the year's end $3,500,000 of the loans are current with $500,000 in delinquency.

By assuming the following:

- All of their current mortgage loans move as they mature into either a paid-off state or into a foreclosed state.
- All of their foreclosed mortgage loans move from the delinquent state.
- From the delinquent state a mortgage loan can move back into current.
- Once the mortgage loan is written off to foreclosed, the loan cannot be paid-off by the customer.
- Once the loan is paid or foreclosed, the mortgage loan is closed.
- Current and delinquent mortgage loans are the transient states.
- Paid-off and foreclosed mortgage loans are absorbing state.

a) What is the probability that their current loans will be paid-off?

Reviewing table 14, 97.91 percent or $3,426,850 of the institution's current loans will be paid-off.

b) What is the probability that their delinquent loans will eventually be foreclosed?

Reviewing table 14, there is a 33.42 percent probability of the delinquent mortgage loans being foreclosed. $500,000 of the same town bank's mortgage loan book of business is in delinquency, therefore, $167,100 of the mortgage loan business will be foreclosed.

The HML model from the Great Recession reveals a predictability aspect for future downturns. It is clear to see the foreclosure rates during this era are far worst than any other time in history. Also, research shows that both eras pre-boom time period led to a recession, which could reveal another predictability of the next recession.

The two eras are much alike, but because of the lack of more detailed mortgage loan data, it is very hard to compare them mathematically. Many authors have tried to compare the Great Depression to the Great Recession economically, mathematically, and fundamentally. Research clearly indicates the biggest difference between the two eras is the sub-prime lending of the current era. Many government affordable housing programs and the National Affordable Housing Act of 1990 led to a rise in sub-prime lending. These programs allowed the low income customers to purchase a home with a low down payment and low monthly payments for a small period of the mortgage loan. After a certain period of time, the monthly loan payments rose to a level that customers could not afford. Thus, many walked away from owning their home, causing the country's foreclosure rates to rise.

A comparison of the U.S. population to new home starts could render more comparable results. Comparably in the 1920s and the 2000s, the per-person new housing starts data peaked. The highest number of housing starts, in both the Great Depression and the Great Recession, occurred shortly before the economy moved into a recession. By 1930, new home start figures bottomed out as did the same figures in 2011. Using this measure, many economists believe this recent home mortgage economic crisis was actually worse than that of the Great Depression. There were so many more homes in inventory to work with that the current bubble time period was much bigger in scope.

This study has shown through the different ratios of housing to population, different government regulations or lack thereof, higher jobless rate in the Depression, and a very different fundamental way of life that comparing the two eras will not yield the proper predictability results hoped for. The more accurate HML Model is the use of current day statistics.

REFERENCES

Anton, H., & Kolman, B. (1982). *Mathematics with applications for the management, life, and social sciences* (2nd ed.). Orlando, FL: Academic Press, Inc.

Bronson, Richard & Costa, Gabriel (2009). *Matrix methods; applied linear algebra* (3rd ed.). Academic Press.

Behrens, Carl F., (1952). *Commercial bank activities in urban mortgage financing*. UMI.

Carroll, T., Sajadpour, S., & Gonzalez, J. (2012). *Absorbing chains*. Retrieved from https://www.csupomona.edu/~sparisay/Courses/TimExtra.docx

Federal Home Loan Bank Board (1937). Fifth Annual Report.

Garriga, C., Gavin W., & Schlagenhauf, D. (2006). Recent trends in homeownership. *Federal Reserve Bank of St. Louis Review*, September/October, 2006, 400-401.

Grimshaw, S., & Alexander, W. (2010). *Markov chain models for delinquency: Transition matrix estimation and forecasting*. Boise, ID: Works Progress Analytics.

Grinstead, C., & Snell, L. (1997). *Introduction to probability* (2nd ed.). Providence, RI: American Mathematical Society.

Haeussler, E., & Paul, R. (1996). *Introductory mathematical analysis of business, economics, and the life and social sciences* (8th ed.). Upper Saddle River, NJ: Prentice Hall.

Harvard Business School (2013). *Historical collections: the forgotten real estate boom of the 1920s.* Retrieved from http://www.library.hbs.edu/hc/crises/forgotten.html.

Nering, E. (1974). *Elementary linear algebra*. Philadelphia, PA: W. B. Sanders Company.

Norman, J., & Jeffers, R. (1988). *Practitioner's handbook on the modeling of dynamic change in ecosystems*. Retrieved from http://www.scopenvironment.org/downloadpubs/scope34/chapter6.html

Saulnier, R. (1950). *Urban mortgage lending by life insurance companies*. NBER. Princeton, NJ: Princeton University Press.

Sirl, D. (2005). *Markov chains: An introduction*. Retrieved from http://www.maths.uq.edu.au/MASCOS/Markov05.html

Warner, Stefan (2010). *Finite math & applied calculus (5th ed.).* Brooks Cole.

Wheelock, David C. (2008). The Federal response to home mortgage distress: Lessons from the Great Depression. *Federal Reserve Bank of St. Louis Review*, May/June, Part 1, 133–148.

Wheelock, David C. (1989). The Fed's failure to act as lender of last resort during the Great Depression 1929-1933. *Federal Reserve Bank of Chicago, Bank Structure and Competition*, 154–76.

APPENDIX A

Mortgage Bankers Association Permission Agreement

PERMISSION AGREEMENT

Date: April 1, 2013

The Mortgage Bankers Association of 1717 Rhode Island Avenue, NW, Washington, DC 20036 ("MBA") and Susan Owens ("Licensee"), enter into this Permission Agreement regarding the specified permitted use by Licensee of certain data from MBA's National Delinquency Survey, namely Mortgage Loans Serviced, Foreclosures Started and Total Past Due numbers from ~~1997~~ 1979 until 2011 (the "Data").

1. **Grant of Rights**. MBA hereby grants Licensee the right to use the Data to form the Markov chain in various stages of a mortgage loan broken down into time periods (Pre-Boom, Bubble and Bust). The results will be incorporated into Licensee's thesis entitled "Flags of Caution for Future Downturns in the Housing Market -- Predictions using the Markov Chain Model." Nothing in this paragraph is intended to give Licensee any right to publish the Data in any other way or to use the Data for any other purpose. Further, nothing in this paragraph is intended to give Licensee any right to reproduce, publish, distribute or sell the Data separate from the above mentioned thesis or to take any other action that would provide third parties with enough information that would serve as a substitute for the direct purchase of the Data from MBA.

2. **Acknowledgments.** Licensee agrees to acknowledge MBA as a source for the raw Data. Accordingly, during the term of this Agreement, MBA grants to Licensee a non-exclusive, non-transferable, royalty-free, limited license to use and reproduce MBA's name and trademarks as necessary to provide such attribution. This license shall continue until this Agreement terminates or unless and until MBA directs Licensee to cease using MBA's name in connection with Licensee's use of the Data.

3. **Certain Restrictions.** In its use of the Data, Licensee agrees not to intentionally use the Data in such a way as to alter the content, meaning and/or intent of the Data.

4. **Compensation.** Licensee will not pay a fee for the license granted in this Agreement.

5. **Ownership.** Licensee expressly acknowledges that MBA is the sole owner of all copyright, trademark and other proprietary and commercial property rights in the Data and Licensee agrees to cooperate with MBA in protecting such intellectual property rights as reasonably required, at MBA's expense. Licensee expressly acknowledges that no title or ownership rights to the Data or to any trademark, copyright or other proprietary rights in the Data are transferred to Licensee by this Agreement but only a right of limited use.

6. **Warranties and Disclaimers**. THE DATA IS PROVIDED ON AN "AS IS" BASIS, WITH NO WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY. USE OF THE DATA IS AT THE LICENSEE'S SOLE RISK. IN NO EVENT WILL MBA BE LIABLE FOR ANY DAMAGES WHATSOEVER TO LICENSEE OR ANY THIRD PARTIES ARISING OUT OF OR RELATED TO THE DATA AND THIS AGREEMENT, INCLUDING BUT NOT LIMITED TO INDIRECT, INCIDENTAL, SPECIAL, CONSEQUENTIAL OR PUNITIVE DAMAGES, INCLUDING LOST PROFITS AND LOST SAVINGS, WHETHER UNDER A CONTRACT, TORT OR ANY OTHER THEORY OF LIABILITY, EVEN IF MBA, LICENSEE, OR THE THIRD PARTY IS AWARE OF THE POSSIBILITY OF SUCH DAMAGES.

7. **General**. In any legal action between the parties, this Agreement shall be governed by and construed in accordance with the laws of the District of Columbia, without regard to its choice of law provisions. This Agreement may be amended only by written instrument signed by the parties hereto. Failure or delay by any party to enforce compliance with any term or condition of this Agreement does not constitute a waiver of such term or condition. A waiver of a breach of a term under this Agreement will not be deemed a waiver of any other or subsequent breach or a waiver of any other term. In the event that any term of this Agreement is determined to be invalid for any reason, this Agreement shall not be invalidated, but shall continue in full force and effect, except that the provision in question shall be deemed to have been deleted. Licensee shall not be entitled to assign its rights and obligations under this Agreement to any third party. This Agreement and any amendment or addendum hereto may be executed in one or more counterparts, each of which shall be an original, but all of which together shall constitute one instrument. This Agreement constitutes the entire agreement and understanding of the parties with respect to its subject matter and supersedes all oral communications and prior writings with respect thereto.

8. **Term.** At any time, the license granted by this Agreement may be terminated by MBA with written notice to Licensee provided however that, if such termination is not due to Licensee's breach of the license, Licensee will not have to withdraw the Data from any copies of the thesis already distributed.

Agreed and confirmed:

Mortgage Bankers Association

By: ____________________

Name: Emile J. Brinkmann

Title: SVP - Research

Date: 4/12/2013

Licensee: Susan Eustice Owens

By: ____________________

Name: Susan Eustice Owens

Title: Graduate Assistant

Date: **April 10, 2013**

APPENDIX B

Visual Basic Code by Dr. David D. Marshall

```
Private d$
Private Sub Command1_Click()
Dim pv(500), tm(500, 500), mc(500)
If IsNumeric(Text1.Text) = False Then
MsgBox "Input a value of n, then press Start"
Exit Sub
End If
d$ = Chr$(13) + Chr$(10)
N = Val(Text1.Text)

For i = 1 To N
For j = 1 To N
ps$ = "Input p for row " + Str(i) + " column " + Str(j) + ":"
tm(i, j) = Val(InputBox(ps$))

'INPUT tm(i, j)
Next j
Next i
For i = 1 To N
'Print "pv "; i

pv(i) = Val(InputBox("pv"))

'INPUT pv(i)
Next i
For i = 1 To N
For j = 1 To N
mc(i) = mc(i) + pv(j) * tm(j, i)
Next j
Next i
'Picture1.Cls

'Picture1.Print "Results:"
'For i = 1 To N
'Picture1.Print mc(i)
'Next i

t$ = "Results:" + d$
For i = 1 To N
t$ = t$ + Str(i) + "  " + Str(mc(i)) + d$
Next i
Text2.Text = ""
Text2.Text = t$
End Sub
Private Sub Command2_Click()
End
End Sub
Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""

End Sub
```

APPENDIX C

SAS Code for Tables 7, 9, and 11 Chapter IV

```
LIBNAME SLO 'f:\CSCI5663\SAS_data';

data SLO.mortgage_loans;
      input Year 1-4 Current 6-13 PaidOff 15-22 Delinquent 24-31
ForeclosureRate 33-41;
      informat Current comma10.0 PaidOff comma10.0;


datalines;
1979 7288043  6951195  336848   0.0057
1980 7106257  6753502  352755   0.0058
1981 7425639  7036498  389141   0.0066
1982 8198724  7745884  452840   0.0084
1983 8730616  8242575  488041   0.0087
1984 9210535  8688995  521539   0.0085
1985 9272236  8731457  540779   0.0091
1986 9740079  9199158  540921   0.0101
1987 9926795  9433143  493652   0.0103
1988 10367559 9871940  495619   0.0107
1989 12708979 12101164 607815   0.0130
1990 15007668 14307678 699991   0.0125
1991 16030584 15225816 804768   0.0134
1992 16368404 15621027 747376   0.0132
1993 17350135 16617249 732886   0.0126
1994 19033671 18254262 779408   0.0132
1995 20788760 19906248 882511   0.0131
1996 22049894 21096617 953277   0.0138
1997 22854032 21870711 983321   0.0141
1998 23792360 22735073 1057287  0.0149
1999 27485686 26317526 1168160  0.0146
2000 29429526 28138919 1290607  0.0152
2001 31864248 30235899 1628349  0.0179
2002 33592875 31878081 1741794  0.0180
2003 35266040 33597180 1668860  0.0166
2004 38598047 36867110 1730937  0.0173
2005 40303596 35510094 1793502  0.0164
2006 42477803 40520266 1957537  0.0184
2007 44887042 42485708 2401334  0.0284
2008 45379447 42244639 3134808  0.0426
2009 44597740 40506886 4186352  0.0537
2010 44124714 40008920 4115794  0.0495
2011 43508268 39990475 3517793  0.0412
;

run;

/* to separate the data into time periods*/

data SLO.mortgage_loans_Preboom;
      set SLO.mortgage_loans;
if Year>=1979 and Year<=1989 then output SLO.mortgage_loans_Preboom;
run;
```

```
/* to figure the mean of current, paidoff, delinquent in preboom*/

proc means data = SLO.mortgage_loans_Preboom MEAN;
      var Current PaidOff Delinquent;
      output OUT = SLO.Preboom_means MEAN(Current PaidOff Delinquent)=
Current PaidOff Delinquent;
run;

/* to bring all preboom data into report*/

proc append base = SLO.mortgage_loans_Preboom data = SLO.Preboom_means
force;
run;


data SLO.mortgage_loans_Preboom;
      set SLO.mortgage_loans_Preboom;
      DelRate = Delinquent/Current;
      PdRate = PaidOff/Current;
      If 1979<=Year<=1989 then do
      DelRate = '.';
      PdRate = '.';
      end;
run;


/*below is an attempt at proc tabulate and print.  proc print so I can
get the sum of the foreclosure rate*/

/*
proc print data = SLO.mortgage_loans_Preboom noobs;
      var Year ForeclosureRate;
      sum ForeclosureRate;
      title 'sumrate';
run;

proc tabulate data = SLO.mortgage_loans_Preboom;
      title 'test2';
      class Year;
      var ForeclosureRate;
      table Year,
                  ForeclosureRate*sum*f=comma.4;

run;  */


/*go to WORD*/

ods rtf file = 'f:\CSCI5663\preboom_report.rtf';
proc report data = SLO.mortgage_loans_Preboom nowindows;
```

```
      column Year Current PaidOff PdRate Delinquent DelRate
ForeclosureRate;
      format Current comma10.0 PaidOff comma10.0 Delinquent comma7.0;
      format PdRate comma.4 DelRate comma.4 ForeclosureRate comma.4;
      define Year / display;
      title '1979 to 1989';
run;
ods rtf close;



/*bubble time period */

data SLO.mortgage_loans_Bubble;
      set SLO.mortgage_loans;
if Year>=1990 and Year<=2000 then output SLO.mortgage_loans_Bubble;


proc means data = SLO.mortgage_loans_Bubble MEAN;
var Current PaidOff Delinquent;
output OUT = SLO.Bubble_means MEAN(Current PaidOff Delinquent)= Current
PaidOff Delinquent;
run;
proc append base = SLO.mortgage_loans_Bubble data = SLO.Bubble_means
force;

run;

data SLO.mortgage_loans_Bubble;
      set SLO.mortgage_loans_Bubble;
      DelRate = Delinquent/Current;
      PdRate = PaidOff/Current;
      If 1990<=Year<=2000 then do
      DelRate = '.';
      PdRate = '.';
      end;
run;

ods rtf file = 'f:\CSCI5663\Bubble_report.rtf';
proc report data = SLO.mortgage_loans_Bubble nowindows;
      column Year Current PaidOff PdRate Delinquent DelRate
ForeclosureRate;
      format Current comma10.0 PaidOff comma10.0 Delinquent comma10.0;
      format PdRate comma.4 DelRate comma.4 ForeclosureRate comma.4;
      define Year / display;
      title '1991-2000';
run;
ods rtf close;

/* bust time period*/
```

```
data SLO.mortgage_loans_Bust;
      set SLO.mortgage_loans;
if Year>=2001 and Year<=2011 then output SLO.mortgage_loans_Bust;

proc means data = SLO.mortgage_loans_Bust MEAN;
var Current PaidOff Delinquent;
output OUT = SLO.Bust_means MEAN(Current PaidOff Delinquent)= Current
PaidOff Delinquent;
run;

proc append base = SLO.mortgage_loans_Bust data = SLO.Bust_means force;
run;

data SLO.mortgage_loans_Bust;
      set SLO.mortgage_loans_Bust;
      DelRate = Delinquent/Current;
      PdRate = PaidOff/Current;
      If 2001<=Year<=2011 then do
      DelRate = '.';
      PdRate = '.';
      end;
run;

ods rtf file = 'f:\CSCI5663\Bust_report.rtf';
proc report data = SLO.mortgage_loans_Bust nowindows;
      column Year Current PaidOff PdRate Delinquent DelRate
ForeclosureRate;
      format Current comma10.0 PaidOff comma10.0 Delinquent comma10.0;
      format PdRate comma.4 DelRate comma.4 ForeclosureRate comma.4;
      define Year / display;
      title '2001-2011';
run;
ods rtf close;
```