Government Policies, Residential Mortgage Defaults, and the Boom and Bust Cycle of Housing Prices

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Abstract

We develop a dynamic simulation model for residential home prices in an economy where defaults on residential mortgages negatively affect housing prices and aggregate income. This simulation model enables us to study the impact of subprime defaults on prime borrowers and the impact of various government policies on the housing market boom and bust cycle. In this regard, our key conclusions are that: (i) there is a contagion effect from subprime defaults to prime defaults due to the negative impact of subprime defaults on aggregate income, and (ii) monetary policy is the most effective tool for decreasing mortgage defaults and increasing aggregate home prices in contrast to alternative government fiscal policies designed to loosen mortgage credit.

Key words: Subprime, Home prices, Mortgage defaults, House Price Bubbles, Monetary policy, Fiscal policy

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1 Introduction

> *The financial crisis that began in August 2007 has been the most severe of the post-World War II era and, very possibly–once one takes into account the global scope of the crisis, its broad effects on a range of markets and institutions, and the number of systemically critical financial institutions that failed or came close to failure–the worst in modern history.*
> *Chairman Ben S. Bernanke*[1]

Easy access to cheap mortgage credit is claimed to have been a crucial source of the current financial crisis. According to this view, lax mortgage underwriting standards coupled with liberal government policies increased the demand for housing causing an unprecedented increase in home prices. In 2003, the American Dream Development Act became law and provided financing for low income families. The program was created to assist home buyers by providing funds for down payments, closing costs and other expenses. Between 2004 and 2007, Fannie Mae and Freddie Mac became the largest buyers of subprime and Alt-A mortgages, stimulating the growth of the subprime mortgage market. Following several legislative initiatives, Fannie Mae and Freddie Mac purchased over $6 trillion of mortgages from 1992 to 2008.[2] Combined, this easy access to credit generated the alleged bubble in home prices. As interest rates rose and the supply of new home buyers became exhausted, subprime mortgage defaults increased to unprecedented levels and home prices collapsed. This was the beginning of what came to be known as the Great Recession, a term discussed by Rampbell (2009) after it was used by Dominique Strauss-Kahn, managing director of the IMF, in a 2009 speech about the global economic crisis[3] .

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[1]At the Annual Meeting of the American Economic Association, Atlanta, Georgia January 3, 2010.

[2]Edward Pinto, Acorn and the Housing Bubble, WALL ST. J., Nov. 13, 2009, at A23 (article further details government policies that lowered mortgage lending standards to increase home ownership).

[3]Rampell, C. (2009). 'Great Recession: A Brief Etymology', New York Times, March 11, 2009.

Strauss-Kahn, Dominique, Opening Speech, March 10,2009, Changes: Successful Partnerships for Africa's Growth Challenge, IMF.

The purpose of this paper is to construct a dynamic simulation model for the evolution of aggregate home prices so that we can analyze the impact of subprime mortgage defaults on prime defaults, and the relative impact of various government policies on this evolution.

We take as given the evolution of the spot rate of interest. We develop a dynamic model for the impact of residential mortgage defaults on both aggregate income and home prices. The resulting model can be used, via simulation, to determine the impact of subprime defaults on prime defaults, and the relative impact of various governmental policies on home prices and mortgage defaults.

It has been argued by Børsum (2010) and Guiso, Sapienza, and Zingales (2009) that the increase in subprime borrowers and their subsequent defaults, increased the level of prime borrower defaults, generating a contagion effect. Our simulations confirm this statement. We show that an increase in subprime defaults reduces aggregate income and aggregate home prices, which in turn increases the level of prime defaults in the economy.

Fiscal and Monetary policy actions discussed to reduce the negative impact of mortgage defaults on home prices include the Federal Reserve Board's determination of the level of interest rates (Glaeser, Gottlieb, and Gyourko (2010); Bernanke (2010); Case (2000); Mishkin (2009); Caballero and Kurlat (2009)), the Fed's potential sale of mortgage backed securities purchased as part of the TALF program (Poterba (1984)), Fannie and Freddie Mac's continued support of the housing market via the easing of credit standards and the reduction of down payments in the issuance of mortgage loans (Aït-Sahalia, Andritzky, Jobst, Nowak, and Tamirisa (2010)), and traditional fiscal policy to reduce unemployment and increase GDP. Our analysis shows that each of these policy actions reduces mortgage defaults and has a positive effect on the level of home prices. The relative effectiveness of various credit loosening tools are analyzed. Perhaps surprisingly, monetary policy is the most effective of the policy tools considered, despite the fact that it is only an indirect tool influencing mortgage loans.

An outline for this paper is as follows. Section 2 develops the model used as a basis for the simulation analysis. Section 3 discusses the calibration of the model's parameters, while sections 4 and 5 provide the comparative static analysis of subprime to prime default contagion, and the governmental policies with respect to the mortgage market, respectively. In Section 6 we provide further comparative statics with respect to different macro-economic scenarios. Section 7 concludes the paper.

2 The Simulation Model

This section presents our simulation model for the residential housing market. At each date t, our economy consists of three sectors: interest rates as represented by the default free spot rate of interest r_t, aggregate income $\bar{Y}_t$, and aggregate home prices $\bar{H}_t$. We take the evolution of the spot rate of interest as given, and we develop a dynamic model for the impact of residential mortgage defaults on both aggregate income and home prices. For later usage, we normalize aggregate income by the population in the economy and aggregate house prices by the total number of homes in the economy. Subsequently, these will be referred to as the average income level and the average home price level, respectively.

To make homeowner mortgage defaults realistic and representative of actual housing markets, included within our model are two types of borrowers: prime and subprime. We assume there are $i = 1, ..., K$ different households with mortgages in the economy. The homes with mortgages are only a subset of the existing houses in the economy. We note that the average home price level $\bar{H}_t$ includes both the prices of the homes with and without mortgages.

The price of the i^{th} household's home at time t is denoted H_t^i. Each borrower purchases their home using a fixed rate mortgage. For the purposes of our analysis, the choice of using a fixed rate versus a floating rate loan is without loss of generality. There are two types of borrowers, prime and subprime, characterized by their credit score (quality) at time t, denoted by Φ_t^i where $\Phi_t^i = 1$ if the i^{th} household is a prime borrower and 0 if a subprime borrower.

We let the i^{th} home be financed with a 30 year *fixed rate mortgage.* If the home is purchased at time t, there is an initial down payment of $C(\Phi_t^i)H_t^i$

dollars where $C(\Phi_t^i)$ is the initial deposit to value ratio depending on the borrower's credit score. We assume that subprime borrowers have a smaller down payment, i.e. $C(0) < C(1)$, which makes them riskier loans to the lender. This is consistent with subprime borrowers having less wealth to invest in their home purchase.

The fixed rate at time t on this mortgage is calculated from the current default free bond yields implied by the corresponding default free spot rate of interest r_t. The bond yields are shifted in a parallel fashion by a credit spread. The credit spread $s(\Phi_t^i)$ depends on the borrower's credit quality and it is set higher for subprime borrowers due to their increased risk of default and the smaller recovery in the event of default.

The i^{th} borrower is endowed with a time t disposable income of Y_t^i dollars, which is related to their credit score.[4] Disposable income is quoted in annual terms. The borrower thus receives $\frac{Y_t^i}{12}$ at the beginning of each month. We assume that the i^{th} borrower's disposable income evolves through time according to a mean-reverting process:

$$dY_t^i = Y_t^i \left[\kappa_Y \left(\ln \left(R(\Phi_t^i)\bar{Y}_t \right) - \ln \left(Y_t^i \right) \right) dt + \sigma_Y dW_t^{Y,i} \right] \tag{1}$$

where $W_t^{Y,i}$ for $i = 1, .., K$ are independent standard Brownian motions, R is a deterministic function of the homeowner's credit score with $R(1) > R(0)$, and $\{Y_0^i, \kappa_Y, \sigma_Y\}$ are constants.

Schwartz (1997) discusses processes of this type and their applicability to commodity prices. An advantage is that the logarithm of the individual income follows a Vasicek process, whose distribution function is known. We will use this feature in Section 3 to estimate the parameters of the process. Note that the long run level of income for the i^{th} household with credit score Φ_t^i is given as a percentage of the average income level in the economy, i.e. $R(\Phi_t^i)\bar{Y}_t$. This long run income level is higher for prime borrowers than it is for subprime borrowers.

We assume that individual home prices satisfy the following jump diffu-

[4] Disposable income is income after consumption. This income can be used for mortgage payments.

sion process:

$$dH_t^i = H_t^i \left[\kappa_H(\ln(\bar{H}_t) - \ln(H_t^i))dt + \sigma_H dW_t^{H,i} - L_H dU_t^i \right], \tag{2}$$

where $W_t^{H,i}$ for $i = 1, .., K$, are independent standard Brownian motions and $(H_0^i, \kappa_H, \sigma_H, L_H)$ are constants.

In expression (2), the diffusion process' drift mean reverts around the average home price level, $\bar{H}_t$. The jump process U_t^i counts the number of mortgage defaults related to house i up to time t. We allow each home to have multiple owners and, therefore, multiple defaults. Thus, the cumulative number of defaults process in the economy up to time t denoted U_t is given by

$$U_t = \sum_{i=1}^{K} U_t^i. \tag{3}$$

A borrower defaults if two events occur: (1) the borrower's income is not enough to cover their mortgage payments, and (2) he does not have enough equity on the house to refinance. Without loss of generality, we set the level of equity below which refinancing cannot occur to be 5%. If a refinancing can occur, to lower his interest payments, the borrower obtains a fixed rate mortgage with a teaser rate that is structured as follows: for the first two years the borrower pays the reduced amount of $0.8P$ where P is the annuity payment of an ordinary 30 year fixed rate mortgage. After this teaser rate period is over, the borrower's payments are reset so that the present value of the remaining loan payments match the outstanding loan balance. We assume that a prime household in distress can only refinance at the subprime spread $s(0)$ since his credit quality is now that of subprime.

A home changes ownership in our economy after default. We assume that the new owner will also borrow to purchase the house. With probability p^P we let the new borrower be a prime credit and with probability $p^{SP} = 1 - p^P$ subprime. We assume that these probabilities are constant across time.

To model the fluctuations in the aggregate economy, as mentioned previously, the three sectors considered are the default free spot rate of interest

r_t, the average income level $\bar{Y}_t$, and the average home price level $\bar{H}_t$. These macro-variables are assumed to satisfy the following jump diffusion processes:

$$dr_t = \kappa_r(\bar{r} - r_t)\,dt + \sigma_r dW_t^r, \tag{4}$$

$$d\bar{Y}_t = \bar{Y}_t\left[\mu_Y dt + \bar{\sigma}_Y\left(\rho_{Yr} dW_t^r + \sqrt{1-\rho_{Yr}^2}\, dW_t^Y\right) - \eta dN_t\right], \ \textit{and} \tag{5}$$

$$d\bar{H}_t = \bar{H}_t\left[\mu_H dt + \bar{\sigma}_H\left(\rho_{Hr} dW_t^r + \hat{\rho}_{HY} dW_t^Y + \hat{\rho}_H dW_t^H\right) - \bar{L_H} dU_t\right] \tag{6}$$

where W_t^r, W_t^Y and W_t^H are independent and standard Brownian motions, $(r_0,\ \kappa_r,\ \bar{r},\ \sigma_r)$, $\left(\bar{Y}_0, \mu_Y, \bar{\sigma}_Y,\ \rho_{Yr},\ \eta\right)$, $\left(\bar{H}_0, \mu_H,\ \bar{\sigma}_H,\ \rho_{Hr},\ \hat{\rho}_{HY},\ \hat{\rho}_H\right)$ are constants with

$$\hat{\rho}_{HY} \equiv \frac{\rho_{HY} - \rho_{Yr}\rho_{Hr}}{\sqrt{1-\rho_{Yr}^2}} \qquad \text{and} \qquad \hat{\rho}_H \equiv \sqrt{1-\rho_{Hr}^2 - \hat{\rho}_{HY}^2}. \tag{7}$$

Expression (4) gives the evolution of the spot rate process. Consistent with the empirical evidence presented by Sanders and Unal (1988) and Smith (2002), the spot rate follows a mean reverting process with long run level $\bar{r}$.

Expression (5) gives the evolution of the average income level in the economy. The correlation between the interest rate and average income level process is captured by the term $(\bar{\sigma}_Y \rho_{Yr} dW_t^r)$. To incorporate the impact of a loss in wealth (i.e. economic income declines) to those homeowners who do not have mortgages when mortgage defaults occur in the economy, we add the jump component $(-\eta dN_t)$ to the change in average income where N_t is a Poisson-process with time-varying intensity β_t. The jump intensity process β_t is given by

$$d\beta_t = \kappa_\beta\left(\bar{\beta} - \beta_t\right)dt + L_\beta dU_t \tag{8}$$

where U_t is the aggregate number of defaults in the economy and $\left(\beta_0, \kappa_\beta, \bar{\beta}, L_\beta\right)$ are constants. Note that as the aggregate number of defaults increase, the likelihood of a decline in average income increases as measured by β_t.

Last, expression (6) gives the evolution for the average home price level in our economy. This is the variable of interest. First note that the correlation to interest rates and average income is captured by the terms $\bar{H}_t\bar{\sigma}_H(\rho_{Hr} dW_t^r)$ and $\bar{H}_t\bar{\sigma}_H\left(\hat{\rho}_{HY} dW_t^Y\right)$, respectively. The direct impact of defaults on the aggregate house price level is captured by the jump term $\bar{H}_t \left(\bar{L_H} dU_t\right)$ where $\bar{L_H}$ is a constant.

We see that average home price level will decrease by $\bar{L_H}$ percent when the number of aggregate defaults increase. This explicitly captures the impact of home mortgage defaults on the aggregate level of house prices in the economy. The effect on non-foreclosed houses is supported by a number of papers. Børsum (2010) shows this effect in an equilibrium model. Campbell, Giglio, and Pathak (2009) use data on house transactions in the state of Massachusetts from 1988 to 2008 to show that foreclosures that take place within a quarter of a mile of a house lower the price at which it is sold. Immergluck and Smith (2006) estimate this effect within an eighth of a mile for data from Chicago in 1999. Lin, Rosenblatt, and Yao (2009) use data from Chicago for 2003 and 2006 and estimate the radius to be half a mile. In contrast, voluntary sales do not appear to negatively affect house prices, so we do not include their impact in the evolution, see Campbell, Giglio, and Pathak (2009).

Combined, the system of equations (4) - (6) determine the evolutions of the relevant variables in our economy. In particular, expression (6) gives the dynamics for the average home price level, as a complex function of the defaults in the mortgage loan market. To understand the impact of various regulatory policies on housing prices and mortgage defaults, we calibrate the parameters of this system to match those in the U.S. economy, and we simulate the various paths implied by our dynamic economy. In the following, we refer to expected values of certain characteristics unless otherwise stated. In particular, $a > b$ means that a is greater than b in expectation, but not necessarily for every realization of the simulated economy.

3 Parameter Calibration

This section discusses the parameter calibration used in the simulations. Tables 1 to 4 provide the calibrated parameters.

Table 1 summarizes the macro-economic parameters used in the processes for the short rate r_t, the average house price $\bar{H}_t$, and the income level $\bar{Y}_t$.

They are calibrated to data starting in 1987 and ending before the year 2000. We select this time period because the Case-Shiller House Price Index is only available from 1987 onwards. We do not use data after 2000 to exclude effects related to the housing bubble. We note that our choice of a sample period reflects a growing economy with increasing aggregate income and housing prices.

The short rate parameters are calculated using the maximum likelihood method on weekly quotes of the 3-month Treasury rates published by the Board of Governors of the Federal Reserve System. We set the initial value equal to the mean reversion level, i.e. $r_0 = \bar{r}$.

The average house price parameters are derived from the Case-Shiller Composite 10 house price index. For parameter estimation, we assume that U_t is a Poisson process. To estimate the intensity, we use data on U.S. foreclosure rates from Elmer and Seelig (1998). The average annual foreclose rate from 1987 to 1997 is 0.90%. Given the relevant geographical area consists of 200 mortgage financed houses, we arrive at an intensity estimate of 1.802 defaults per year. We initially fix the decrease in average houses prices due to defaults, the jump size, $\bar{L}_H = 0.005$. Campbell, Giglio, and Pathak (2009) find that houses within 0.05 miles of a foreclosed home lose about 1% in value.[5] We use half of this value for our initial estimate. Next, using this intensity and jump size, we then match the first two moments of the log-returns of the average house price $\bar{H}_t$ to the empirical moments. As a result we obtain the estimates for μ_H and $\bar{\sigma}_H$ found in Table 1. Because these parameter estimates are fundamental to our simulations, we perform robustness tests for these parameter values in the appendix. These robustness tests confirm the conclusions based on these initial estimates.

The income level parameters are derived from monthly data on the compensation of employees published by the Bureau of Economic Analysis. To simplify the estimation of the income parameters, we assume that the intensity β_t of the Poisson process N_t is constant and equal to its mean reversion level $\bar{\beta}$. Additionally, we fix the jump size η using the following heuristic: η

[5] Similar estimates are obtained by Immergluck and Smith (2006) who estimate a 0.9% decrease in home values within 0.125 miles of a foreclosed home.

measures the loss in average wealth due to housing defaults in the economy. This is due to the loss in housing wealth and mortgage loan values. We set η equal to the percentage of wealth in the economy that housing represents multiplied by the average yield on housing. The percentage of wealth is 31.8% according to the 2007 Survey of Consumer Finances published by the Federal Reserve Board. The average yield on housing is 6% according to Poterba and Sinai (2008). The result is an η of 1.21%. To obtain estimates for the drift and volatility parameters (μ_Y and $\bar{\sigma}_Y$) we match the empirical moments for the logarithmic returns of average income. For this purpose we used data on the compensation of employees published in the Flow of Funds and Accounts of the United States report published by the Federal Reserve.

The initial value of the average house price is normalized to 100. To estimate the initial value of the average income we need the ratio between house prices and income. We use Realtor data on existing house sales from 2005 and scale them down to 1999 using the FHFA purchase-only house price index. For the initial value of the average income we use the Consumer Expenditure Survey. It does not distinguish between homeowners with and without mortgages prior to 2003. The homeowner income divided by the income of a homeowner with mortgage is very stable at 85.56% from 2003 to 2006. We use this ratio to transform the 1999 homeowner income to the income of a homeowner with a mortgage.

For the correlations between the spot rate of interest, the average house value and the average income level, we use estimates of these parameters from the literature (see, e.g., Kraft and Munk (2008) and the references therein).

Table 2 summarizes the micro-economic parameters used in the individual house value process H_t^i and the individual income process Y_t^i. These parameters are particularly hard to estimate since no data on individual house price and income dynamics is available. Campbell, Giglio, and Pathak (2009) argue that the loss given default of an individual house is $L_H = 27\%$. Demyanyk and Hemert (2007) use data from the Office of Federal Housing Enterprise Oversight and estimate a house-by-house volatility of 8.05%, which we use as our volatility parameter σ_H.

To estimate the mean reversion speed of individual houses we tried several different specifications of the process and methods of estimation. The following procedure delivers reasonable results. First, we discretize the dynamics of the logarithm of the individual house prices

$$\ln(H^i_{t_{j+1}}) - \ln(H^i_{t_j}) = \left[\ln(\bar{H}_{t_j}) - \ln(H^i_{t_j})\right] \kappa_H \Delta_t - \frac{1}{2}\sigma_H^2 \Delta_t + \sigma_H \sqrt{\Delta_t} Z, \quad (9)$$

where Z is standard-normally distributed. Then, we run the regression

$$\ln(L_{j+1}) = a \ln(L_j) + b \ln(N_j) + \epsilon, \quad (10)$$

where L is a local Case-Shiller index (e.g. for Las Vegas or Los Angeles) and N is the nationwide Case-Shiller Composite 10 index. The time series consists of monthly quotes from 1987 to 1999. From these regressions we can recover κ_H via $\kappa_H = \frac{1-a}{\Delta_t}$. Regions with $\kappa_H > 0.1$ are Los Angeles, San Diego, San Fransisco, Washington and Las Vegas. We use the average κ_H from these regions. For Denver, Tampa, Boston, Charlotte and New York we cannot recover a positive κ_H.

We apply the same procedure to yearly GDP data on a state level from 1987 to 1999 to estimate the mean reversion speed κ_Y of the individual disposable income Y^i_t. We cannot recover κ_Y estimates from 15 states. We assume the volatility parameter σ_Y of individual disposable income is 0.25.

The mean reversion level of the individual disposable income Y^i_t is obtained by multiplying the average income level $\bar{Y}_t$ by the reduction factor $R(\Phi_t)$. We extract the prime income reduction factor from the Consumer Expenditure Survey of 2006 by subtracting the average expenditure from income after taxes of a homeowner with a mortgage and adding the expenditures related to the mortgage (mortgage interest and charges, mortgage principle paid on owned property). To obtain the subprime income reduction factor we assume that subprime households have 27% less income than prime households on average (see Agarwall, Ambrose, and Yildirim (2010)).

Table 3 summarizes the credit-related parameters. We assume that prime households have a loan-to-value (LTV) ratio of 80%. Demyanyk and Hemert (2007) use data from the Federal Housing Finance Agency. They report numbers on the combined LTV ratio for subprime loans[6] originated from 2001 to 2007. The subprime LTV in 2006 was 85.9%.

Demyanyk and Hemert (2007) also provide the average initial nominal rates on fixed rate mortgages, which are 6.18% for prime and 7.73% for subprime borrowers between 2004 and 2006. To match these initial nominal rates in our model we use a prime credit spread of $s(1) = 1.13\%$ and a subprime credit spread of $s(0) = 2.66\%$.

Debtors in distress may refinance if they have at least 5% of equity in their homes. Our results do not change significantly if we change this number (see Appendix). One refinancing opportunity is a new fixed rate mortgage (taking advantage of possibly improved interest rates). Another possibility is a 2/28 teaser credit. The reduced payment in the first two years is simply 80% of the market implied payment of an ordinary fixed rate mortgage for the identical amount. This is a simplified version of teaser credits that exist in practice and captures the main features of these loans. Robustness with respect to the payment reduction factor is discussed in the Appendix.

Table 4 summarizes the parameters used for the average income level jump intensity β_t. These parameters are hard to estimate. Fortunately, however, our results do not change significantly if we change these values (see the Appendix).

All estimates discussed so far are average values. To introduce heterogeneity into the population, we introduce a uniform distribution for the individual initial house values H_0^i between 80 and 120. We also distribute the initial individual disposable incomes Y_0^i uniformly between $R(\Phi_0^i)40.14$ and $R(\Phi_0^i)45.14$. In our simulation, prime households use 54.66% of their disposable income in the first month to make their fixed rate mortgage payment. Subprime households use 78.92% of their disposable income.

[6] In their work subprime credits are credits underlying subprime securities.

4 Subprime Default Contagion

This section studies the impact that the percentage of subprime borrowers has on both housing prices and the likelihood of prime borrowers defaulting in the economy - subprime contagion.

For this comparative statics, we vary the percentage of subprime versus prime borrowers in the economy from $SP = 0\%$ to $SP = 100\%$ in step sizes of 25%. Furthermore, consistent with these percentages, the probability of a new owner to be subprime in each of these cases is set such that $p^{SP} = SP$.

First, we consider the impact of the percentage of subprime borrowers on the average home price level. Figure 1 contains the graphs of the average home price over the next 30 years. As seen, although average home prices increase for all possible percentages of subprime borrowers, the higher the percentage of subprime borrowers, the lower the expected increase in home prices. In the long run, the percentage of subprime borrowers defaulting has a negative and lasting impact on the average home price level.

The impact of subprime default contagion on prime borrowers' defaults is contained in Table 5. This table provides the default probabilities of the original mortgage holders[7] over the 30 year life of their mortgages. As indicated, if there are only prime borrowers, they have a default probability of 1.25%. As the percentage of subprime borrowers increase, the default probability for the prime borrowers also increase. When subprime borrowers are 75% of the original population of borrowers, the prime borrowers default probability is at its highest level 2.07%.

To get a glimpse at the impact of this contagion effect in inflated markets, we increase the initial house prices by 5%. The corresponding default probabilities of original owners are stated in Table 6. We observe an increase in prime and subprime default probabilities. The relative increase of prime default probability from 0% subprime population to 75% subprime population rises from 65.60% to 98.55%. This indicates a worsening of the contagion effect in markets with higher house prices. We further investigate this phenomenon in the following section.

[7] An original owner is an owner at $t = 0$.

Our simulation results are consistent with the evidence available in the literature. Sabry and Okongwu (2009) note that subprime loans led to a deterioration of the mortgage market in general, and defaults on prime loans thereby increased. Agarwall, Ambrose, and Yildirim (2010) show subprime default spillover. Amromin and Paulson (2009) document an increase in prime mortgage default rates during the course of the subprime crisis. Harding, Rosenblatt, and Yao (2008) show that there is a neighborhood contagion effect where homes sold near a home in the foreclosure process sell at a discount. Schintler, Pelletiere, and Kulkarni (2010) observe a spatial contagion effect of neighborhoods with high foreclosure rates. Børsum (2010) presents a model of mortgage defaults where default of a minority group, such as subprime borrowers, may spread to a majority, such as prime borrowers. Last, Guiso, Sapienza, and Zingales (2009) present evidence that a greater number of defaults reduces the negative social stigma associated with default, resulting in a default contagion.

5 Policy Analysis

This section uses our dynamic model to study the impact of different governmental fiscal and monetary policies on the creation and bursting of home price bubbles. We consider two possible scenarios at time 0: a home price bubble either exists or it does not. The no bubble scenario is called the "base case." In the base case the initial home price level is set to be $\bar{H}_0 = 100$ whereas in the bubble case it is 116.22. The increased initial average house price is calibrated as seen in Section 3. For the bubble scenario, the initial income level remains and the initial average house price is increased to match the ratio immediately before the onset of the crisis (2006).

The borrowers in both scenarios consist of 75% prime and 25% subprime households. All of the other parameters are as contained in Tables 1 to 4.

For the bubble scenario, at time $t = 0$, the prime borrowers use 63.53% of their income in the first month on mortgage payments whereas the subprime borrowers use 91.13%.

The following six fiscal and monetary policies are considered.

- **Monetary Policy** (MP). This policy reduces the initial spot rate of interest from $r_0 = 0.05104$ to $r_0 = 0.005$. Note that the mean reversion level of the spot rate process is not changed. We also simulate a
- **Moderate Monetary Policy** which reduces the initial spot rate of interest to $r_0 = 0.03$.
- **Restrictive Credits** (RC). This policy forces homeowners to have an initial down payment equal to 20% of the initial house value. In this policy both prime and subprime borrowers have the same initial down payment.
- **Easy Credit** (EC). Subprime borrowers are subsidized to the extent that they can borrow at the prime borrowers' spread, if their loan is originated in the first five years.
- **Tax Rebate** (TR). Every borrower receives an additional unit of income per year, which is distributed monthly. The result is a monthly income of $\frac{Y_t^i + 1.0}{12}$. The policy expires after five years.
- **Distress Relief** (DR). If a borrower cannot make his fixed rate mortgage payments, then he receives a relief of 15% of the outstanding loan balance (e.g. loan modification). The maturity remains the same so that the fixed rate payment is reduced. This relief is only given once and the policy runs for five years. After receiving the distress relief the home owner may not refinance into a teaser rate. The intuition is that the government is trying to help households only if they have financial difficulties.

The Federal Reserve Board manages the spot rate through standard monetary policy tools including trading Treasury securities, targeting the fed funds rate and using the discount window. In the credit crisis, the Fed also purchased mortgage-backed securities to keep mortgage rates low.[8] These regulatory policies are captured with the MP policy.

[8] See Wall Street Journal, March 17, 2010: Fed Ends Mortgage Purchases, Keeps Rates Low, by Jon Hilsenrath and Luca Di Leo; Wall Street Journal, March 26, 2010: Bernanke Edges Toward Asset Sales, by Jon Hilsenrath.

The next four fiscal policies were designed to affect the mortgage market directly. The US Treasury introduced a Home Affordable Modification Program (HAMP) to assist homeowners in distress. This program included incentives to borrowers and lenders to modify loans to reduce interest payments and principal balances.[9] These regulatory policy actions are captured via the EC, TR, and DR policies.

To reduce the number of mortgage failures in the future, proposals have been made to increase the size of down payments, and hence the homeowner's equity in loans at origination.[10] This is captured by the RC policy.

Before we report our results it is important to remember that in our model there is a trade off between defaults and the expected return on home prices. Given no defaults, the expected return on the average home price is $\mu_H = 0.043325$. In order to have an expected reduction in house prices, the negative jumps in the home price due to mortgage defaults must exceed the drift term. For our parametrization we would need 9 of the 200 houses to default over a single year to observe a reduction in the average house price. This impact of mortgage defaults on expected home price returns is the only mechanism through which home price bubbles can burst in our economy.

Our first comparative static is to study the impact of these different government policies on reducing the impact of a home price bubble bursting. In this regard, Figure 2 shows the average home price levels for the different policies in the bubble scenario as compared to the base scenario. Note that without any governmental policy, due to mortgage defaults, the bubble bursts between 9 and 10 years, when the average increase in housing prices is zero.

As one would expect, all government policies decrease the negative impact of mortgage defaults on the average home price level. Monetary policy and easy credit have the largest impact, followed by tax rebate, moderate monetary policy, restrictive credits and finally distress relief. Distress re-

[9]See Wall Street Journal, March 13, 2010: Mortgage-Rescue Program Benefits More Homeowners, by James Hagerty; Wall Street Journal, March 27, 2010: Time to Close the Door on Bailouts, by David Reilly; New York Times, March 25, 2010, U.S. Plans Big Expansion in Effort to Aid Homeowners, by David Streitfeld.

[10]See Wall Street Journal, October 1, 2009: Bill would require Higher Down Payments for FHA-Backed Loans.

lief shows the least improvement because borrowers cannot resort to teaser credits after they receive distress relief.

Our second comparative static studies whether these government policies can create bubbles. This is done by examining the impact that these governmental policies have on the base case. Figure 3 provides the results. The two policies which increase home prices the most are monetary policy and easy credit. Tax rebate has a larger impact than moderate monetary policy followed by restrictive credits and lastly distress relief.

We observe a house price decline in the first two years if a distress relief policy is applied. The reason is that households with a distress relief are more likely to default than households who obtain a teaser credit. We see that both monetary policy and easy credit are effective tools for increasing housing prices. Our results are consistent with the literature which argues that low interest rates and easy credit terms contributed to the housing bubble. Indeed, Mah-Hui (2008) cites the hubris of the financial industry, a loose monetary policy, and financial deregulation and innovation as reasons for the bubble. Coleman, LaCour-Little, and Vandell (2008) provide evidence that the true cause of the crisis stemmed from political, regulatory, and economic conditions that led to the creation of new financial products and a weakening of underwriting standards.

Our next set of comparative statics studies the impact of these various policies on mortgage defaults. It is useful to distinguish between the default probabilities of the original borrowers and of the new borrowers moving into the home after an original borrower defaults. Table 7 summarizes the default probabilities of the original prime and subprime borrowers. In all but one policy the default probabilities are decreased. The largest decrease occurs for monetary policy. This policy has also the strongest effect in the base scenario. For the bubble scenario, we observe a default probability of 10.17% for prime owners and 60.39% for subprime owners. Easy credit reduces both default probabilities to a third of their original values. The default probabilities of prime borrowers are reduced more than the subprime default probabilities with tax rebates and moderate monetary policy. Restrictive credit reduces subprime defaults from 60.39% to 40.01% and prime defaults by only 1.3%.

The difference between the tax rebate and moderate monetary policy is that tax rebate increase house prices in the first five years, which significantly drop after the policy expires. With moderate monetary policy the house price starts to decrease immediately, see Figure 2.

There is one result that appears puzzling. Distress relief increases the default probability of prime owners and reduces it for subprime owners. More precisely, the prime default probability without a policy is 10.17%, where the distress relief policy increases the default probability to 11.42%. This is because households that received a distress relief, by assumption, may not refinance using a teaser credit. A teaser credit is very effective in helping households through the crisis. The prime default probability does not increase (it is 6.72%) if a more significant distress relief policy is applied that reduces the credit volume by 20% (up from 15%).

Our findings are similar to those in literature regarding the reduction of future defaults. Sherlund (2008) studies policies such as skipping mortgage resets or lowering payments, and documents that such policies reduce defaults. Ding, Quercia, and Ratcliffe (2008) also show that loan modifications reduce second defaults, especially if interest payment reductions are a result of principal reductions.

6 Policy Analysis in Different Economies

In our previous simulations, the income level in the economy continues to grow despite increased mortgage defaults. This is in contrast to the real effects of the recent financial crisis that involved a GDP decrease of 2% in the fourth quarter of 2008. There are two reasons for our results. First, our model is calibrated to data ranging from 1987 to 1999. In this period, the US economy was growing substantially. The average annual GDP growth was about 5.9%. Second, our model focuses on the housing market and its impact on GDP. Additional effects, for example a simultaneous shock to the financial system, are not modeled.

To analyze the policies under adverse economic conditions, we introduce two additional economic states: stagnation and recession. For stagnation, we decrease the drift parameter $\bar{\mu}_Y$ by 2.5% such that the income level does not increase in the first ten years. For recession, we decrease $\bar{\mu}_Y$ by 3.5%. Figure 4 depicts the resulting income levels.

Table 8 summarizes the default probabilities of the original owners in both scenarios with the different policies. We observe higher default probabilities in adverse economic situations. Without any policy 34.32% of the original prime borrowers and 85.32% of the original subprime borrowers default in a stagnating economy. In recession, 67.84% of the original prime borrowers and 95.75% of the original subprime borrowers default. Monetary policy triggers the highest decline of the default rates in any of these economic settings. In stagnation, easy credit and restrictive credit improve prime and subprime default rates. Distress relief only decreases subprime default probabilities. Tax rebates and moderate monetary policy decrease the prime default probability more than they decrease subprime default probabilities. In a recession, there are two policies without a significant effect: restrictive credit and distress relief. Easy credit decreases both default probabilities. Tax rebates and moderate monetary policy reduce prime default probabilities by 15% and 30% but they have only have a small effect on subprime default probabilities.

For our next analysis, we reduce the drift of the average house price to simulate stationary and decreasing house prices. Stationary house prices are simulated by reducing the drift parameter $\bar{\mu}_Y$ by 1.5%. Declining house prices are simulated using a reduction of 3%. Figure 5 depicts the resulting average house price $\bar{H}_t$ in each setting. Table 9 summarizes the default probabilities of original owners with the different policies. The default probabilities increase by only a small margin due to reduced refinancing opportunities. This suggests that adverse house price movements only marginally affect house owners.

Finally, the individual's income volatility σ_Y is varied. We rerun our simulations with the volatility reduced/increased by 2%. The resulting default probabilities are summarized in Table 10. As might be expected, if the individual income's volatility increases, the default probabilities of households with a mortgage increase.

7 Conclusion

This paper develops a dynamic simulation model for aggregate home prices that depends on the level of subprime and prime mortgage defaults in the economy. We show that subprime mortgage defaults, via their impact on aggregate housing prices and aggregate incomes, increase the incidence of prime mortgage defaults. There is a subprime default contagion. Secondly, we show the relative impact of various government fiscal and monetary policies for improving the housing market. Interestingly, fiscal policies relating to direct government rebates or a loosening of borrowing standards have less of an impact than does monetary policy.

Type of Parameter	Parameter	Value
Short Rate r_t	Initial Value r_0	5.104%
	Mean Reversion Level $\bar{r}$	5.104%
	Mean Reversion Speed κ_r	0.14213
	Volatility σ_r	0.00781
Average House Price $\bar{H}_t$	Initial Value $\bar{H}_0$	100
	Drift μ_H	0.043325
	Volatility $\bar{\sigma}_H$	0.015243
	Loss given Default $\bar{L}_H$	0.005
Income Level $\bar{Y}_t$	Initial Value $\bar{Y}_0$	42.64
	Drift μ_Y	0.0598
	Volatility $\bar{\sigma}_Y$	0.02224
	Jump Size η	0.0121
Correlations	Real Estate - Income, ρHY	0.5723
	Real Estate - Short Rate, ρHr	0.65
	Income - Short Rate, ρYr	0

Table 1: Macro-Economic Parameters.

Type of Parameter	Parameter	Value
House Price H_t^i	Mean Reversion Speed κ_H	0.94811
	Volatility Parameter σ_H	0.0805
	Loss given Default L_H	0.27
Disposable Income Y_t^i	Mean Reversion Speed κ_Y	0.5372
	Volatility Parameter σ_Y	0.22
	Prime Income Reduction $R(1)$	0.2582
	Subprime Income Reduction $R(2)$	0.2323

Table 2: Micro-Economic Parameters.

Type of Parameter	Parameter	Value
Loan-To-Value Ratio $C(\Phi_t^i)$	Prime LTV C(1)	80%
	Subprime LTV C(0)	85.9%
Spread $s(\Phi_t^i)$	Prime Spread $s(1)$	0.011256
	Subprime Spread $s(0)$	0.026635

Table 3: Credit-Related Parameters.

Parameter	Value
Intial Value β_0	1.0
Mean Reversion Speed κ_β	1.0
Mean Reversion Level $\bar{\beta}$	1.0
Jump Size L_β	0.20

Table 4: Income Jump Intensity β_t Parameters.

	Prime	Subprime
SP0	1.25%	–
SP25	1.40%	22.09%
SP50	1.62%	24.91%
SP75	2.07%	27.67%
SP100	–	31.92%

Table 5: Probability to Default on Original Credit for Different Populations.

	Prime	Subprime
SP0	2.31%	–
SP25	2.69%	32.54%
SP50	3.32%	36.08%
SP75	4.59%	41.13%
SP100	–	% 49.76%

Table 6: Probability to Default on Original Credit for Different Populations. These numbers are created using a 5% increase in initial house prices.

Policy	Base Scenario		Bubble Scenario	
	Prime	Subprime	Prime	Subprime
Easy Credit	0.38%	4.57%	3.13%	19.00%
Restrictive Credit	1.31%	10.85%	8.86%	40.01%
Distress Relief	1.88%	14.60%	11.42%	44.89%
Tax Rebates	0.30%	10.21%	2.96%	36.85%
Monetary Policy	0.08%	3.76%	0.74%	16.30%
Moderate Monetary Policy	0.42%	10.96%	3.29%	36.72%
No Policy	1.40%	22.91%	10.17%	60.39%

Table 7: Probability to Default of Original Owners for Different Policies.

Original Prime Households	Normal Economy	Stagnation	Recession
Easy Credit	3.13%	15.63%	47.06%
Restrictive Credit	8.86%	28.72%	61.52%
Distress Relief	11.42%	33.22%	65.53%
Tax Rebates	2.96%	18.26%	54.10%
Monetary Policy	0.74%	2.55%	11.17%
Moderate Monetary Policy	3.29%	12.71%	37.10%
No Policy	10.17%	34.32%	67.84%
Original Subprime Households	Normal Economy	Stagnation	Recession
Easy Credit	19.00%	40.17%	67.99%
Restrictive Credit	40.01%	69.12%	88.44%
Distress Relief	44.89%	74.54%	91.58%
Tax Rebates	36.85%	69.01%	89.35%
Monetary Policy	16.30%	35.98%	57.45%
Moderate Monetary Policy	36.72%	63.95%	83.77%
No Policy	60.39%	85.32%	95.75%

Table 8: Default Probability of Original Owners in the Bubble Scenario for Different Policies. Normal economy results are simulated with the calibrated parameters from Tables 1-4. Stagnation reduces $\bar{\mu}_Y$ by 2.5%, Recession reduces $\bar{\mu}_Y$ by 3.5%.

Original Prime Households	Normal $\bar{H}_t$	Stationary $\bar{H}_t$	Declining $\bar{H}_t$
Easy Credit	3.13%	3.27%	3.46%
Restrictive Credit	8.86%	9.04%	9.38%
Distress Relief	11.42%	11.65%	11.99%
Tax Rebates	2.96%	3.10%	3.21%
Monetary Policy	0.74%	0.75%	0.76%
Moderate Monetary Policy	3.29%	3.38%	3.44%
No Policy	10.17%	10.46%	11.26%
Original Subprime Households	Normal $\bar{H}_t$	Stationary $\bar{H}_t$	Declining $\bar{H}_t$
Easy Credit	19.00%	19.69%	20.71%
Restrictive Credit	40.01%	40.31%	40.82%
Distress Relief	44.89%	45.11%	45.75%
Tax Rebates	36.85%	37.52%	38.67%
Monetary Policy	16.30%	16.73%	17.30%
Moderate Monetary Policy	36.72%	37.33%	38.18%
No Policy	60.39%	61.04%	62.41%

Table 9: Default Probability of Original Owners in the Bubble Scenario for Different Policies. Normal results are simulated with the calibrated parameters from Tables 1-4. Stationary $\bar{H}_t$ reduces $\bar{\mu}_H$ by 1.5%, declining $\bar{H}_t$ reduces $\bar{\mu}_H$ by 3.0%.

Original Prime Households	$\sigma_Y = 20\%$	$\sigma_Y = 22\%$	$\sigma_Y = 24\%$
Easy Credit	1.35%	3.13%	6.51%
Restrictive Credit	4.62%	8.86%	15.56%
Distress Relief	6.23%	11.42%	19.43%
Tax Rebates	1.23%	2.96%	6.38%
Monetary Policy	0.24%	0.74%	1.85%
Moderate Monetary Policy	1.41%	3.29%	6.76%
No Policy	5.32%	10.17%	17.81%
Original Subprime Households	$\sigma_Y = 20\%$	$\sigma_Y = 22\%$	$\sigma_Y = 24\%$
Easy Credit	13.16%	19.00%	26.60%
Restrictive Credit	30.93%	40.01%	50.55%
Distress Relief	34.02%	44.89%	56.78%
Tax Rebates	28.61%	36.85%	46.39%
Monetary Policy	10.61%	16.30%	23.56%
Moderate Monetary Policy	28.36%	36.72%	46.45%
No Policy	51.38%	60.39%	69.74%

Table 10: Default Probability of Original Owners in the Bubble Scenario with Varying Individual Income Volatility σ_Y.

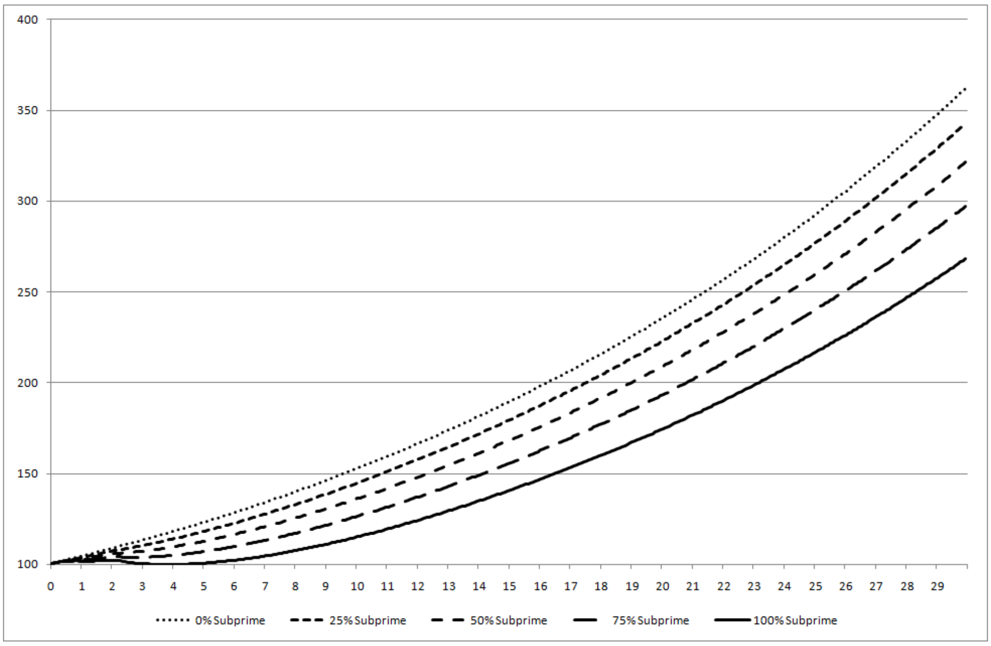

Figure 1: Average House Price in Each Month for Different Populations.

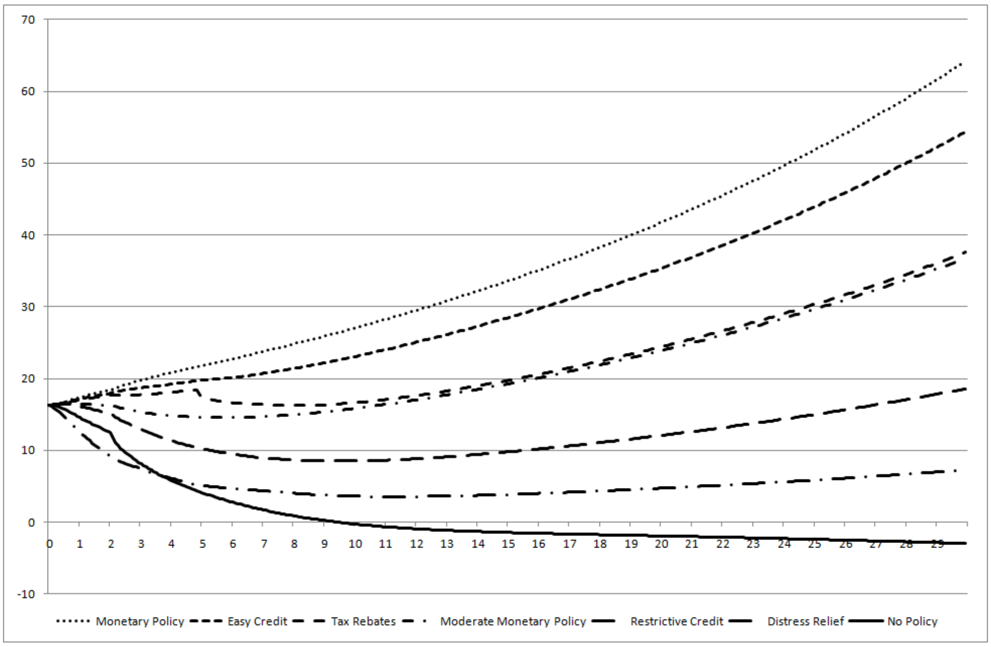

Figure 2: Average Increase in House Price over the Base Scenario in Each Month for Different Policies applied to the Bubble Scenario.

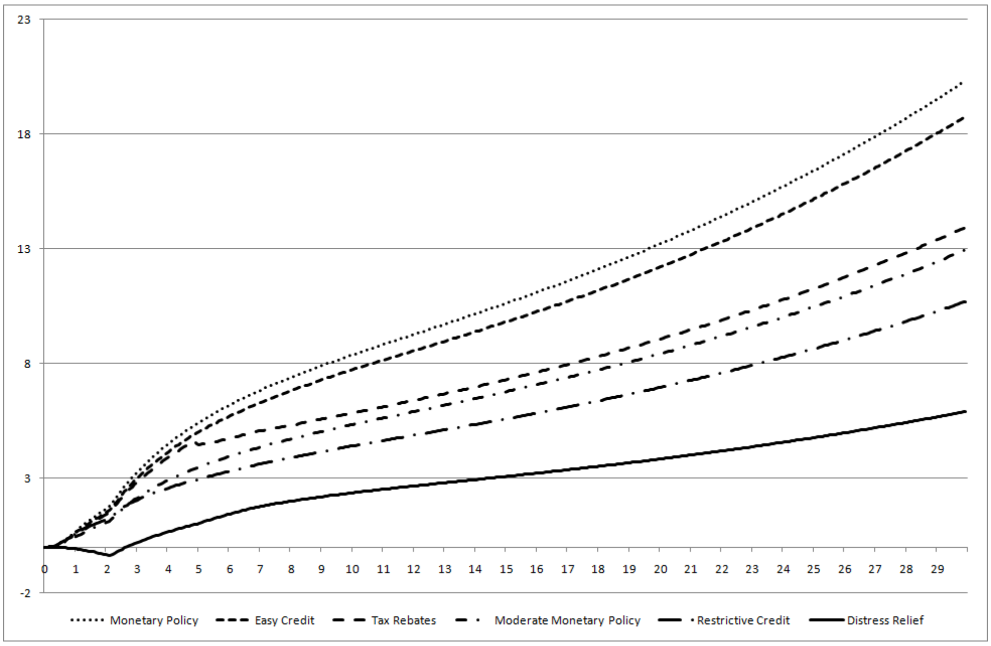

Figure 3: Average Increase in House Price over the Base Scenario in Each Month for Different Policies applied to the Base Scenario.

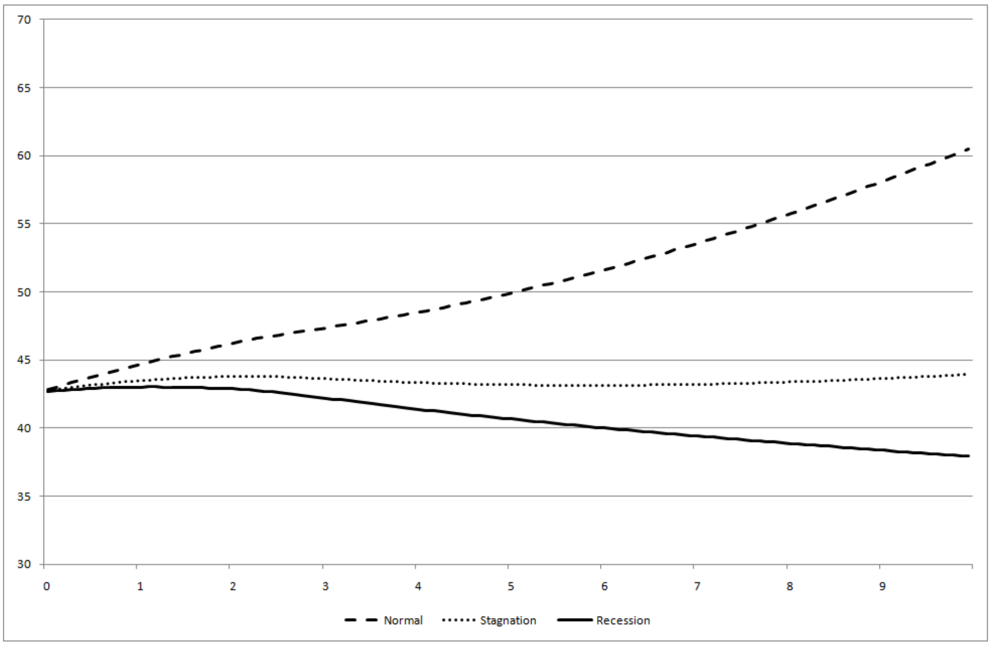

Figure 4: Income Level in the Bubble Scenario in each Month for different Economies.

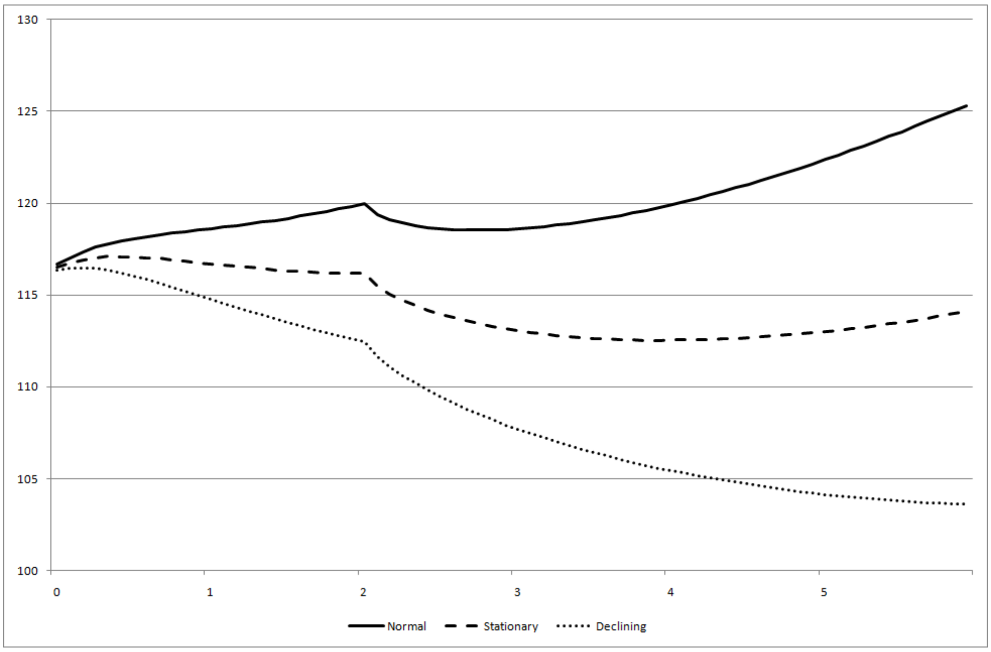

Figure 5: Average House Price $\bar{H}_t$ in the Bubble Scenario with different Drift $\bar{\mu_H}$.

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Appendix

This appendix provides robustness checks for the various parameters. The resulting default probabilities of the original owners are presented for two different settings:

- Varying populations in the base scenario. This corresponds to the contagion analysis from Section 4.
- Varying policies in the bubble scenario. This corresponds to the policy analysis from Section 5.

All our robustness checks confirm our previous results.

Tables 13 and 14 use different minimum equity requirements, which are needed to refinance a mortgage. The default probabilities increase only slightly with higher equity requirements.

Tables 15 and 16 use different jump sizes $\bar{L}_H$ for the average house price process $\bar{H}_t$. the default probabilities increase minimally with higher jump sizes.

Tables 17 and 18 use different mean reversion speeds κ_β for the process β_t. The default probabilities increase minimally with lower mean reversion speeds.

Tables 19 and 20 use different mean reversion levels $\bar{\beta}$ for the process β_t. The default probabilities increase only slightly with higher mean reversion levels.

Tables 21 and 22 use different jump sizes L_β for the process β_t. The default probabilities increase only slightly with higher jump sizes.

Our results are more sensitive to the teaser payment factor. Tables 11 and 12 use different teaser payment factors. The default probabilities increase sharply if the teaser payment factor increases. This is due to the fact that reduced payments are an advantage during the height of the crisis.

Finally, we use a jump size $\bar{L}_H = 0.0012$ and estimate new drift ($\mu_H = 0.00383$) and volatility ($\bar{\sigma}_H = 0.00161$) parameters (as outlined in Section 3).The results are in Tables 23 and 24.The results are similar to those obtained with the initial estimates.

Original Prime Households	80%	90%
SP0	1.25%	2.39%
SP25	1.40%	2.82%
SP50	1.62%	3.54%
SP75	1.98%	4.93%
Original Subprime Households	80%	90%
SP25	22.90%	30.38%
SP50	24.91%	34.10%
SP75	27.67%	39.54%
SP100	31.92%	48.69%

Table 11: Default Probability of Original Owners with Varying Teaser Payment Factors. Different populations are used for the base scenario. Our main results use a teaser payment factor of 80%.

Original Prime Households	80%	90%
Easy Credit	3.13%	7.24%
Restrictive Credit	8.86%	15.77%
Distress Relief	11.42%	13.48%
Tax Rebates	2.96%	6.16%
Monetary Policy	0.74%	1.01%
Moderate Monetary Policy	3.29%	5.44%
No Policy	10.17%	18.63%
Original Subprime Households	80%	90%
Easy Credit	19.00%	27.81%
Restrictive Credit	40.01%	51.45%
Distress Relief	44.89%	47.06%
Tax Rebates	36.85%	46.19%
Monetary Policy	16.30%	25.26%
Moderate Monetary Policy	36.72%	47.87%
No Policy	60.39%	71.18%

Table 12: Default Probability of Original Owners with Varying Teaser Payment Factors. All policies are applied to the bubble scenario. Our main results use a teaser payment factor of 80%.

Original Prime Households	10% Equity	5% Equity	0% Equity
SP0	1.31%	1.25%	1.23%
SP25	1.59%	1.40%	1.36%
SP50	2.10%	1.62%	1.52%
SP75	3.22%	1.98%	1.77%
Original Subprime Households	10% Equity	5% Equity	0% Equity
SP25	26.55%	22.90%	21.67%
SP50	30.28%	24.91%	23.24%
SP75	36.13%	27.67%	25.23%
SP100	46.47%	31.92%	27.88%

Table 13: Default Probability of Original Owners with Varying Minimal Equity Requirements to Refinance an Owners Mortgage. Different populations are used for the base scenario. Our main results use a minimal equity requirement of 5%.

Original Prime Households	10% Equity	5% Equity	0% Equity
Easy Credit	3.79%	3.13%	3.02%
Restrictive Credit	9.12%	8.86%	8.81%
Distress Relief	11.48%	11.42%	11.42%
Tax Rebates	3.23%	2.96%	2.90%
Monetary Policy	0.78%	0.74%	0.73%
Moderate Monetary Policy	3.56%	3.29%	3.24%
No Policy	11.15%	10.17%	9.99%
Original Subprime Households	10% Equity	5% Equity	0% Equity
Easy Credit	22.41%	19.00%	19.07%
Restrictive Credit	40.62%	40.01%	39.91%
Distress Relief	45.00%	44.89%	44.86%
Tax Rebates	39.46%	36.85%	36.16%
Monetary Policy	18.54%	16.30%	15.62%
Moderate Monetary Policy	39.68%	36.72%	36.02%
No Policy	62.83%	60.39%	59.89%

Table 14: Default Probability of Original Owners with Varying Minimal Equity Requirements to Refinance an Owners Mortgage. All policies are applied to the bubble scenario. Our main results use a minimal equity requirement of 5%.

Original Prime Households	$\bar{L}_H = 0.003$	$\bar{L}_H = 0.005$	$\bar{L}_H = 0.007$
SP0	1.25%	1.25%	1.25%
SP25	1.40%	1.40%	1.41%
SP50	1.60%	1.62%	1.66%
SP75	1.91%	1.98%	2.24%
Original Subprime Households	$\bar{L}_H = 0.003$	$\bar{L}_H = 0.005$	$\bar{L}_H = 0.007$
SP25	22.79%	22.90%	23.03%
SP50	24.62%	24.91%	25.41%
SP75	26.92%	27.67%	29.37%
SP100	29.91%	31.92%	37.33%

Table 15: Default Probability of Original Owners with Varying Jump Size Factor $\bar{L}_H$ for the Average House Price. Different populations are used for the base scenario. Our main results use $\bar{L}_H = 0.005$.

Original Prime Households	$\bar{L}_H = 0.003$	$\bar{L}_H = 0.005$	$\bar{L}_H = 0.007$
Easy Credit	3.12%	3.13%	3.14%
Restrictive Credit	8.84%	8.86%	8.90%
Distress Relief	11.41%	11.42%	11.53%
Tax Rebates	2.96%	2.96%	2.96%
Monetary Policy	0.74%	0.74%	0.74%
Moderate Monetary Policy	3.28%	3.29%	3.30%
No Policy	10.11%	10.17%	10.41%
Original Subprime Households	$\bar{L}_H = 0.003$	$\bar{L}_H = 0.005$	$\bar{L}_H = 0.007$
Easy Credit	18.95%	19.00%	19.07%
Restrictive Credit	39.99%	40.01%	40.08%
Distress Relief	44.84%	44.89%	45.02%
Tax Rebates	36.82%	36.85%	36.93%
Monetary Policy	16.28%	16.30%	16.33%
Moderate Monetary Policy	36.65%	36.72%	36.86%
No Policy	60.24%	60.39%	60.83%

Table 16: Default Probability of Original Owners with Varying Jump Size Factor $\bar{L}_H$ for the Average House Price. All policies are applied to the bubble scenario. Our main results use $\bar{L}_H = 0.005$.

Original Prime Households	$\kappa_\beta = 0.75$	$\kappa_\beta = 1.00$	$\kappa_\beta = 1.25$
SP0	1.26%	1.25%	1.25%
SP25	1.45%	1.40%	1.38%
SP50	1.76%	1.62%	1.54%
SP75	2.45%	1.98%	1.81%
Original Subprime Households	$\kappa_\beta = 0.75$	$\kappa_\beta = 1.00$	$\kappa_\beta = 1.25$
SP25	23.36%	22.90%	22.62%
SP50	26.00%	24.91%	24.62%
SP75	29.86%	27.67%	26.48%
SP100	36.48%	31.92%	29.68%

Table 17: Default Probability of Original Owners with Varying Mean Reversion Speed κ_β of the Process β_t. Different populations are used for the base scenario. Our main results use $\kappa_\beta = 1.00$.

Original Prime Households	$\kappa_\beta = 0.75$	$\kappa_\beta = 1.00$	$\kappa_\beta = 1.25$
Easy Credit	3.30%	3.13%	3.02%
Restrictive Credit	9.67%	8.86%	8.40%
Distress Relief	12.93%	11.42%	10.68%
Tax Rebates	3.26%	2.96%	2.80%
Monetary Policy	0.75%	0.74%	0.73%
Moderate Monetary Policy	3.52%	3.29%	3.16%
No Policy	11.77%	10.17%	9.37%
Original Subprime Households	$\kappa_\beta = 0.75$	$\kappa_\beta = 1.00$	$\kappa_\beta = 1.25$
Easy Credit	19.43%	19.00%	18.72%
Restrictive Credit	41.95%	40.01%	38.82%
Distress Relief	47.82%	44.89%	43.23%
Tax Rebates	38.14%	36.85%	36.08%
Monetary Policy	16.55%	16.30%	16.12%
Moderate Monetary Policy	38.02%	36.72%	35.96%
No Policy	63.20%	60.39%	58.71%

Table 18: Default Probability of Original Owners with Varying Mean Reversion Speed κ_β of the Process β_t. All policies are applied to the bubble scenario. Our main results use $\kappa_\beta = 1.00$.

Original Prime Households	$\bar{\beta} = 0.90$	$\bar{\beta} = 1.00$	$\bar{\beta} = 1.10$
SP0	1.22%	1.25%	1.28%
SP25	1.36%	1.40%	1.44%
SP50	1.56%	1.62%	1.68%
SP75	1.90%	1.98%	2.08%
Original Subprime Households	$\bar{\beta} = 0.90$	$\bar{\beta} = 1.00$	$\bar{\beta} = 1.10$
SP25	22.49%	22.90%	23.31%
SP50	24.44%	24.91%	25.42%
SP75	27.08%	27.67%	28.28%
SP100	31.17%	31.92%	32.75%

Table 19: Default Probability of Original Owners with Varying Mean Reversion Level $\bar{\beta}$ of the Process β_t. Different populations are used for the base scenario. Our main results use $\bar{\beta} = 1.00$.

Original Prime Households	$\bar{\beta} = 0.90$	$\bar{\beta} = 1.00$	$\bar{\beta} = 1.10$
Easy Credit	3.00%	3.13%	3.29%
Restrictive Credit	8.60%	8.86%	9.13%
Distress Relief	11.10%	11.42%	11.72%
Tax Rebates	2.81%	2.96%	3.12%
Monetary Policy	0.72%	0.74%	0.77%
Moderate Monetary Policy	3.19%	3.29%	3.40%
No Policy	9.82%	10.17%	10.52%
Original Subprime Households	$\bar{\beta} = 0.90$	$\bar{\beta} = 1.00$	$\bar{\beta} = 1.10$
Easy Credit	18.63%	19.00%	19.42%
Restrictive Credit	39.31%	40.01%	40.73%
Distress Relief	44.14%	44.89%	45.61%
Tax Rebates	36.05%	36.85%	37.68%
Monetary Policy	15.91%	16.30%	16.71%
Moderate Monetary Policy	36.06%	36.72%	37.42%
No Policy	59.62%	60.39%	61.17%

Table 20: Default Probability of Original Owners with Varying Mean Reversion Level $\bar{\beta}$ of the Process β_t. All policies are applied to the bubble scenario. Our main results use $\bar{\beta} = 1.00$.

Original Prime Households	$L_\beta = 0.20$	$L_\beta = 0.25$	$L_\beta = 0.30$
SP0	1.24%	1.25%	1.25%
SP25	1.36%	1.40%	1.45%
SP50	1.52%	1.62%	1.75%
SP75	1.76%	1.98%	2.35%
Original Subprime Households	$L_\beta = 0.20$	$L_\beta = 0.25$	$L_\beta = 0.30$
SP25	22.54%	22.90%	23.29%
SP50	24.11%	24.91%	25.85%
SP75	26.19%	27.67%	29.50%
SP100	29.20%	31.92%	35.55%

Table 21: Default Probability of Original Owners with Varying Jump Size L_β of the Process β_t. Different populations are used for the base scenario. Our main results use $L_\beta = 0.25$.

Original Prime Households	$L_\beta = 0.20$	$L_\beta = 0.25$	$L_\beta = 0.30$
Easy Credit	3.00%	3.13%	3.28%
Restrictive Credit	8.30%	8.86%	9.54%
Distress Relief	10.49%	11.42%	12.69%
Tax Rebates	2.76%	2.96%	3.20%
Monetary Policy	0.73%	0.74%	0.76%
Moderate Monetary Policy	3.12%	3.29%	3.49%
No Policy	9.19%	10.17%	11.47%
Original Subprime Households	$L_\beta = 0.20$	$L_\beta = 0.25$	$L_\beta = 0.30$
Easy Credit	18.66%	19.00%	19.35%
Restrictive Credit	38.57%	40.01%	41.54%
Distress Relief	42.85%	44.89%	47.30%
Tax Rebates	35.93%	36.85%	37.84%
Monetary Policy	16.07%	16.30%	16.53%
Moderate Monetary Policy	35.80%	36.72%	37.78%
No Policy	58.38%	60.39%	62.66%

Table 22: Default Probability of Original Owners with Varying Jump Size L_β of the Process β_t. All policies are applied to the bubble scenario. Our main results use $L_\beta = 0.25$.

Original Prime Households	Std	CGP
SP0	1.25%	1.25%
SP25	1.40%	1.40%
SP50	1.62%	1.60%
SP75	1.98%	1.91%
Original Subprime Households	**Std**	**CGP**
SP25	22.90%	22.88%
SP50	24.91%	24.63%
SP75	27.67%	26.79%
SP100	31.92%	29.69%

Table 23: Default Probability of Original Owners. Std refers to our main calibration. CGP refers to an average house price calibration using $\bar{L}_H = 0.12\%$. Different populations are used for the base scenario. Our main calibration uses $\bar{L}_H = 0.5\%$.

Original Prime Households	Std	CGP
Easy Credit	3.13%	3.13%
Restrictive Credit	8.86%	8.85%
Distress Relief	11.42%	11.44%
Tax Rebates	2.96%	2.96%
Monetary Policy	0.74%	0.74%
Moderate Monetary Policy	3.29%	3.28%
No Policy	10.17%	10.13%
Original Subprime Households	**Std**	**CGP**
Easy Credit	19.00%	19.02%
Restrictive Credit	40.01%	40.00%
Distress Relief	44.89%	44.91%
Tax Rebates	36.85%	36.86%
Monetary Policy	16.30%	16.34%
Moderate Monetary Policy	36.72%	36.68%
No Policy	60.39%	60.23%

Table 24: Default Probability of Original Owners. Std refers to our main calibration. CGP refers to an average house price calibration using $\bar{L}_H = 0.12\%$. All policies are applied to the bubble scenario. Our main calibration uses $\bar{L}_H = 0.5\%$.