Appendix to "Structuring Mortgages for Macroeconomic Stability"

This appendix provides additional details on the numerical solution of the model, on the data that we use to parameterize it, and additional model results.

A Numerical Solution

A.1 Borrowers' problem

We take the loan premia and the form of mortgage contact as given, and solve the borrower's problem using backward induction. In the last period ($t = T$) the agent simply decides whether or not to default on the outstanding debt. In case of no default the agent derives utility from terminal wealth (including housing wealth). In this period the value function corresponds to the indirect utility function. We then iterate backwards.

For every period t prior to T, and for each combination of values for the state variables, we optimize over the choice variables using a discrete grid search. We use an equally spaced grid for cash-on-hand (X_t) and for the log level of permanent income (z_t). In order to improve accuracy and efficiency of the solution we let the boundaries for the grid z_t to increase from period t to T.

We use a single debt grid for all the loan types under analysis. This has the advantage of keeping the possible loan amounts fixed across all our experiments (i.e. agents face the same choices when deciding to refinance). The density functions of the random variables (i.e. shocks to the earnings process) were approximated using Gaussian quadrature (Tauchen and Hussey (1991).[11] For points that do not lie on the state space grid, we evaluate the value function using a cubic spline interpolation for the cash-on-hand grid and a linear interpolation for the permanent income grid.

We calculate the value function associated with all possible values for the choice/control variables and optimize over these. In this way we obtain the optimal choices of consumption, refinancing to tap into home equity, mortgage prepayment, default, and when available whether to use a mortgage modification option (maturity extension or switch from a FRM to an ARM). In the case of the option to switch from a FRM to an ARM, we first solve the ARM problem and then the FRM problem. When solving the FRM problem, for each combination of the state variables, we look for the maximum between the FRM value function and the previously computed ARM value function. The agent decides to switch when the latter is higher, and this becomes the value for the value function.

The optimal policy functions together with simulated data for the random variables, allow us to simulate 400 economies, with 41 periods each. In each period 25 new borrowers enter the economy, so that at each point in time there are 550 borrowers in our simulated data (25

[11] Tauchen, George, and Robert Hussey (1991) "Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models." Econometrica 59, no. 2: 371-96.

borrowers $\times$ 21 periods). We drop the first 20 periods of the simulated data to ensure that our economy is on an overlapping generations steady-state. The borrowers' model statistics that we report are based on this simulated data.

A.2 Lender's problem

The representative lender has an infinite horizon, so that we solve its problem using value function iteration. We first use the borrowers' optimal choices to, at each point in time, calculate the total value of the loans outstanding and the mortgage cash-flows received by the lender. The cash-flows received can be positive, in case of a large incidence of mortgage payments, or negative, in case of a large incidence of refinancing with equity extraction. Naturally, the evolution of the mortgage cash-flows is related to the evolution of the total amount of loans outstanding. Equity extraction leads to a reduction in mortgage cash-flows and to an increase in the value of outstanding loans. We model the joint evolution of cash-flows and outstanding loans using 5×5 transition matrices. The values for these matrices are conditional on the level of the interest rates and the state of the business cycle.

In order to ensure the stationarity of the lender's problem, we scale it by permanent income. We find the lender's optimal choices by iterating on the value function, until the maximum absolute difference of the value function from one iteration the next (for each point of the state space) is smaller than 10^{-8}. Once the value function of the lender problem has converged, we use the optimal consumption choices to derive a pricing kernel and the discount rates that we use to calculate the expected present discounted value of the loan cash-flows. We do so for each type of mortgage contract, and stabilization policy. The statistics that we report for the representative lender are based on the simulation of fifty thousand representative lenders for 200 periods, but dropping the first 50 periods as churn.

B Data

In this section, we give additional details on the data sources that we use to parameterize the model.

B.1 Treasury rates

For the parameterization of the real interest rate we first obtain market yields on U.S. Treasury securities at 1-year constant maturity, quoted on investment basis, for the period 1977/Q4 to 2014/Q3, at a quarterly frequency. These data are from the FED (series: $RIFLGFCY01\_N.M$). We then obtain data on expected inflation from the University of Michigan Survey of Consumers, included in the Federal Reserve Economic Database (FRED, series: $MICH$). We divide the gross annual nominal interest rate by one plus inflation expectations to calculate the expected gross real bond yields. Figure A.1 plots their evolution over the sample period (the shaded areas correspond to recession periods, according to the NBER recession dates).

The average real interest rate is equal to 1.59% (2.44%) in expansions (recessions). However, as it is clearly visible in Figure A.1, the higher average real rate in recessions is due to the early 1980s recession. If we use data from the beginning of 1985 onward, the average real interest rate is equal to 1.12% (0.04%) in expansions (recessions). Over this latter period, the unconditional mean real rate is 1% and the standard deviation is 2.5%. We use these data for our baseline parameterization.

More precisely, in our model log real interest rates can either be low or high. For a mean of 1% and a standard deviation of 2.5%, the two possible values for the log real rate are -1.5% and 3.5%. If real interest rates were i.i.d. and uncorrelated with the business cycle, there would be in each period an equal probability of a low/high rate. We adjust the probabilities of a low/high real rate to match the above recession/expansion means. This implies probabilities of a low/high real rate in recessions of 0.62/0.38. Similarly, the probabilities of a low/high rate in expansions is 0.48/0.52.

Figure A.1 shows that there is a decline in the level of the real interest interest rate over the sample period. This has motivated us to simulate our model for a low interest rate environment, i.e., a period when interest rates decrease and stay low for a long period of time.

B.2 Mortgage interest and default rates

We use mortgage interest rates from two sources. The first is the Monthly Interest Rate Survey conducted by the Federal Housing Finance Agency (FHFA). This survey collects information on average effective interest rates on both FRMs and ARMs.[12] It is available from 1986 until

[12]The data are available at `http://www.fhfa.gov/DataTools/Downloads/Pages/Public-Use-Databases.aspx`.

2008. In order to calculate mortgage premia, we subtract the previously described one-year treasury yields to the mortgage rates.

The second data source is FRED/FreddieMac data. Freddie Mac surveys lenders to obtain rates for the main mortgage products, including 30-year fixed-rate, 15-year fixed-rate, 5/1 hybrid amortizing adjustable-rate, and 1-year amortizing adjustable-rate mortgage products.[13] As before, we subtract bond yields to obtain mortgage premia.

Figure A.2 plots the evolution over time of the ARM mortgage premia. The recession months are shaded. It is important to note that the sample period covered in the two figures is not the same, and this is why the shaded areas are not aligned in the top and bottom figures. The figures show that mortgage premia tend to increase in recessions, and to decline slowly after they end. We have calculated the average mortgage premia in recessions (expansions). They are equal to 0.03 (0.017) in the FHFA data, and to 0.027 (0.014 in the Freddie Mac data. These are the values reported in the main text of the paper.

The data on charge-off rates and on foreclosure rates that we refer in the main body of the paper are from the Federal Reserve and from the Mortgage Bankers Association, respectively. The Federal Reserve data on charge-off rates are compiled quarterly by the Federal Financial Institutions Examination Council, and are available since the first quarter of 1991.[14] Charge-offs are the value of the loans and leases removed from the books of the lenders, and charged against loss reserves. The charge-off rate is the net charge-off (gross charge-offs minus recoveries) during a quarter, divided by the average loans outstanding over the same quarter. The values are annualized. The data from the Mortgage Bankers Association are quarterly and range from 1998Q2 to 2011Q1.[15]

Panel A of Figure A.3 plots the time-series of charge-off rates from the Federal Reserve and Panel B plots the foreclosure rates data from Mortgage Bankers Association. As before, we use the NBER recession dates to classify each quarter into recession/expansion.

B.3 House prices, LTV and LTI data

In order to parameterize the house prices in our model, in addition to the parameters from Campbell and Cocco (2015), we use annual data from the S&P/Case-Shiller U.S. National

[13]The data are available at `http://www.freddiemac.com/pmms/pmms_archives.html`.

[14]The data are available at `https://www.federalreserve.gov/datadownload/Review.aspx?rel=CHGDEL`. The series unique identifier is: $CHGDEL/CHGDEL/STFBQCSS\%STFBAILSS\_XDO\_MA\_N.Q$

[15]The Mortgage Bankers Association data are available through the Richmond Fed: `https://www.richmondfed.org/~/media/richmondfedorg/banking/markets_trends_and_statistics/trends/pdf/delinquency_and_foreclosure_rates.pdf`

Home Price Index, from 1981 to 2014 (FRED series: $CSUSHPISA$). We measure the annual change in logarithm of nominal house prices by taking first differences of the natural logarithm of the house price level at the end of the year. Similarly, we measure the annual change in the overall price level, by taking first differences of the natural logarithm of the consumer price index measured at the end of each calendar year (FRED series: $CPIAUCSL$). Finally, we measure log real house prices changes by taking the difference between the two series. We use these data and the NBER recession dates to parameterize the correlation between house price changes and the business cycle, as explained in the main body of the paper.

There is considerable variation in real house price changes across geographical areas. This variation is partly captured in Figure A.4, where we plot for each of the twenty cities in the S&P/Case-Shiller 20-city composite Home Price Index Data, the mean of the log of annual real house price changes and corresponding standard deviation.[16] The differences across areas are also due to the fact that the data only starts later than the first quarter of 1987 for some of them. In spite of this, the figure shows considerable variation in both the mean and standard deviation. The mean of the realized log real house price changes varies between negative values in Denver and Detroit and values as high as 0.02 in Portland and San Francisco. In our base parameterization, we have set the mean of log real house price changes equal to zero. However, we have also shown that our main results are robust of considering a positive value, equal to 0.01.

In our baseline parameterization, we have followed Campbell and Cocco (2015), in setting the standard deviation of the log of annual real house price changes to 16%. Figure A.4 shows that there is significant variation in the volatility of house price changes across metropolitan areas, ranging from roughly 4% in Cleveland to 14% in Las Vegas. These standard deviations are calculated based on metropolitan area house price indices, and they do not capture idiosyncratic house price risk within the areas. This provides a rationale for our use of a higher value for the standard deviation, equal to 16%. In Appendix C we study the robustness of our results to a lower standard deviation, equal to 10%.

We have obtained FHFA and Freddie Mac data on initial loan-to-value (LTV) and loan-to-income (LTI). More precisely, from the Monthly Interest Rate Survey (MIRS) of the FHFA we obtain monthly data on the average LTV and the average loan amount for conventional single-family new mortgages. We divide the latter by the median US household income from Census

[16]FRED series: $ATXRNSA$, $BOXRSA$, $CRXRNSA$, $CHXRSA$, $CEXRSA$, $DAXRNSA$, $DNXRSA$, $DEXRSA$, $LVXRNSA$, $LXXRSA$, $MIXRSA$, $MNXRSA$, $NYXRSA$, $PHXRSA$, $POXRSA$, $SDXRSA$, $SFXRSA$, $SEXRNSA$, $TPXRSA$, $WDXRSA$.

Bureau (series: $MEHOINUSA646N$), to obtain an estimate of initial LTI. The FHFA is available from 1973 to 2019 and the Census Bureau data data from 1984 to 2018.[17]

Panel A of Figure A.5 plots the time series evolution of the LTV and LTI measures. The average LTV is considerably stable over the sample period, at around 0.80. On the other hand, our LTI measure is increasing. This could be in part due to the fact that we are calculating a ratio of average loan amount to median household income. An increase in the proportion of expensive houses financed with mortgage debt that is not accompanied by an increase in the median household income will lead to increases in the average loan amount and LTI measure that we have calculated. Nonetheless, the figure provides a range of LTIs between 3.5 and 5, and it shows that LTIs tend to increase in booms and decline in recessions (as it can be seen by the decline in the early nineties and during the period of the Great Recession). We have solved our model alternative parameterizations, including initial LTI equal to 3.5 and 5.

We have also obtained origination data from the Freddie Mac Single Family Loan-Level dataset, that covers approximately 26.6 million mortgages originated between January 1, 1999 and December 31, 2017. We focus on those mortgages originated in the same Metropolitan Statistical Areas (MSAs) as those covered by the S&P Case-Shiller house price data that we have previously shown. The data includes information on the origination debt-to-income (DTI) ratio, defined as the ratio of the sum of the borrower's monthly debt payments and housing expenses to the total monthly income used to underwrite the loan.

Panel B of Figure A.5 plots the evolution over time of the average initial combined LTV. It is relatively stable over the sample period, at a value of around 0.80. This value is similar to the one in the FHFA data. This is the value for the initial LTV that we have considered in our model during recession years. Naturally, the sample of mortgages included in the data includes not only those buying a house early in life, whom we model, but also older homebuyers. The former are likely to have lower deposits and to take higher LTV mortgages when purchasing their houses. For this reason we have set the initial LTV to 0.9 in expansions, and we have also shown that our results are robust to the case in which the initial (and maximum) LTV in recessions and expansions are both equal to 0.9.

Panel B of Figure A.5 also shows the evolution over time of the average initial DTI. It varies between thirty and forty percent (depending on the year). In general, the highest DTI that a borrower can have and still qualify for a mortgage is 0.43. We calculate, within our model, a similar origination DTI measure, i.e. a measure of the ratio of debt payments and

[17]The Census Bureau data has an annual frequency whereas the FHFA data is monthly. In order to calculate LTI we use the annual average of the monthly loan amounts.

housing expenses to initial income, and compare it with the one in the Freddie Mac data. In our model, for the baseline parameterization of plain vanilla ARMs, an initial loan to income of 3.5, leads to average initial mortgage payments to income equal to roughly 0.26 (the average is calculated over the different initial aggregate states). We have also shown results for a higher initial loan to income, equal to 5. In this case, the average initial mortgage payments to income are equal to 0.37. These values are comparable to those in the data.

C Additional model results

In Table A.2 we provide additional model results for the baseline ARM and the maturity extension ARM. The different rows of the table report key model moments conditional on borrowers' decisions (default, mortgage refinance, make mortgage payments and extend maturity). The moments included are borrowers' income (measured as a ratio of initial income), log change in income, the level of the risk-free rate, mortgage payments to income, and the log change in house price.

Focusing first on the baseline ARM, Table A.2 shows that default is more prevalent among agents with low income, who have experienced significant declines in income and house values, and who face very large mortgage payments to income (of roughly fifty percent). On the other hand, those who decide to refinance their loans tend to have intermediate levels of income and mortgage payments to income, they have recently experience income declines, but house price increases. The latter provide an incentive for borrowers to refinance their loans and to tap into their home equity.

The statistics for the maturity extension ARM show that the option to extend is used by borrowers with low income and who have recently experienced income declines, but not with the lowest levels of income and the highest income declines who decide to default instead. However, the option leads to an increase in the average income of defaulters, as some of those with very low incomes choose to extend instead. The maturity extension option provides mortgage debt service relief among those who exercise it, with a reduction in the average mortgage payment to income from 0.267 to 0.099.

The option to extend maturity in the ARM contract can be used by borrowers to obtain cash-flow relief during bad times, but it can also be used strategically. Individuals in a situation of negative home equity can use the option to postpone loan principal repayments and bet on future house price increases. If price increases fail to materialize and house prices decline further, agents will then default in the following period. The deferral of principal repayments

means that individuals reach the later period with larger outstanding loan balances than if the option to defer were not available; this increases further the incentives to default and the losses to the lender in case of default.

To illustrate more clearly the strategic use of the option to extend maturity, in Table A.3 we report the loan decisions of borrowers in the period after they have exercised the option. The table answers the question, conditional on having exercised the option to extend the loan maturity at time t, what do agents do at time $t+1$? Do they go back to making their regular mortgage payments, do they use the option to extend the loan again (in case of a recession), do they default, refinance, or prepay the loan? The table reports the percentage of borrowers who makes each of these decisions conditional on the business cycle variable at $t+1$ and whether house prices decreased or increased between times t and $t+1$ (Panel A), or whether borrowers' income decreased or increased between times t and $t+1$ (Panel B).

This table has several interesting results. First, agents who have used the policy at t are very likely to use it again at $t+1$ if the economy is still in a recession. The probability of this happening varies between 0.78 and 0.91. Second, the majority of the individuals who have used the policy at t go back to making the regular mortgage payments at time $t+1$ in case the economy moves into an expansion. There are however significant quantitative differences depending on the realization of house price changes. Panel A shows that if the economy goes back to an expansion at $t+1$, a proportion of 0.095 of borrowers decide to default if house prices decrease compared to a 0.014 default rate if house prices increase.

Panel B reports probabilities conditional on the realized income change. If the economy goes back to an expansion at time $t+1$, 0.063 of agents decide to default if their income declines compared to 0.045 if their income increases. These default sensitivities reflect the strategic and cash-flow default motives of agents in our model, which also affect their exercise of the maturity extension option.

Table A.4 reports additional models statistics, mentioned in the main body of the paper, for the baseline FRM and the FRM with the option to convert to an ARM in recessions.

Tables A.5 and A.6 report additional model statistics for the plain vanilla ARM and maturity extension ARM, for the cases of a higher initial LTV of 0.9 in recessions (which is also the borrowing limit) and a higher initial LTI equal to 5, respectively The patterns are similar to those described above, but naturally the quantities are different. For instance, for the case of a higher loan amount, and for the plain vanilla ARM, default tends to occur at higher average incomes and higher mortgage payments to income. The maturity extension option provides more relief in case it is exercised.

In appendix B we have shown that there is considerable heterogeneity across geographical areas in the mean and standard deviation of house price changes. In Table A.7 we report results for a higher value of 1% for the average log real house price change (in the benchmark model it was 0%), and for a standard deviation equal to 10% (recall that the corresponding value for the baseline parameterization is 16%).

For the case of a higher house price growth, and compared with the benchmark model, there is an increase in the incidence of loan termination through refinancing and prepayment (as households tap into their home equity) and a reduction in default probabilities. The impact of house price growth on default is smaller than one might have expected (there is a small decline in the incidence of default from 0.013 to 0.012). The reason is that the higher expected real house price growth reduces the user cost of housing, making the default option relatively more attractive. The mean loan premia is slight lower than in the benchmark calibration.

The option to extend loan maturity is effective in stabilizing the economy with higher real house price growth. It leads to a shift in default from recessions to expansions and to smaller drops in borrowers' and in aggregate consumption during bad times. The option is welfare improving for both borrowers and lender.

For the case of lower house price volatility, and compared to the baseline parameterization, there are reductions in the mean mortgage premium and default rate. The option to default is less valuable, and so is the compensation for risk that the representative lender demands. The maturity extension option is still valuable in shifting default from recessions to extensions and in stabilizing aggregate consumption, but its quantitative effects and welfare benefits are slightly smaller than in the case of higher house price risk.

Figure A.1: Real interest rate

This figure plots the evolution over time of the expected real interest rate, calculated using nominal interest rates and inflation expectations. The nominal interest rate is the market yield on US Treasury securities at 1-year constant maturity, obtained from the FED. The data on expected inflation are from the University of Michigan Survey of Consumers. We divide the gross annual nominal interest rate by one plus inflation expectations to calculate the expected gross real bond yields. The figure plots the real yield. We give further details in Appendix B.1. The NBER recession periods are shaded.

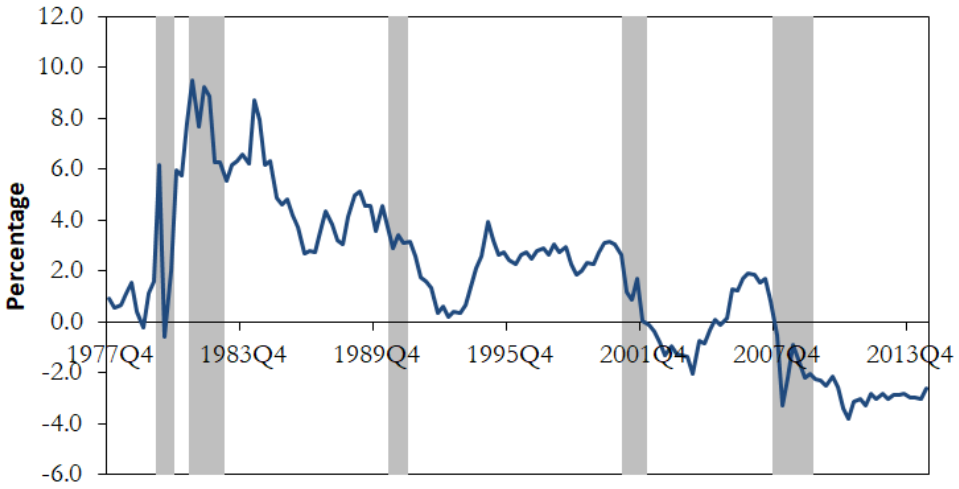
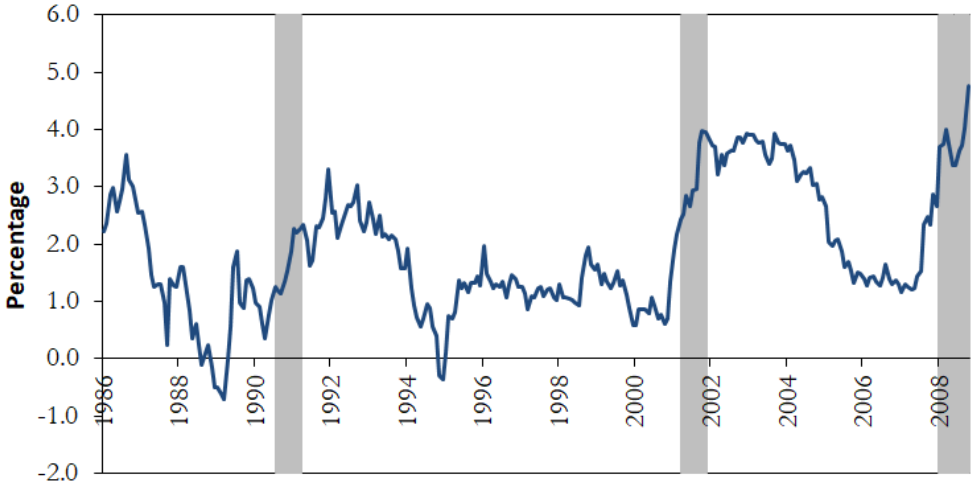


Figure A.2: ARM spreads over the 1-year Treasury rate

The figure plots the evolution over time of the difference between the ARM rate and the 1-year Treasury yield. In Panel A the mortgage rates are from the Monthly Interest Rate Survey conducted by the FHFA. In Panel B the mortgage rates are from Freddie Mac. The Treasury yields data are from the FED. We give further details in Appendix B.2. The NBER recession periods are shaded.

Panel A: FHFA data



Panel B: Freddie Mac data

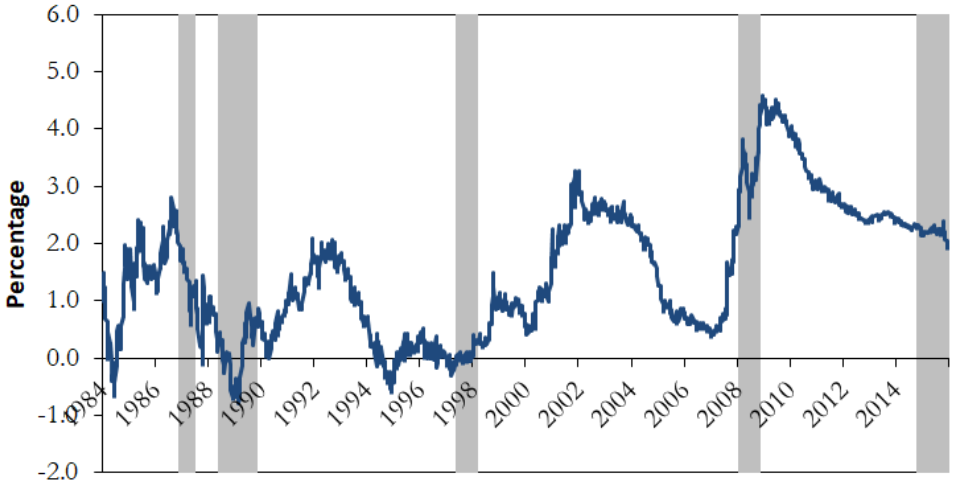
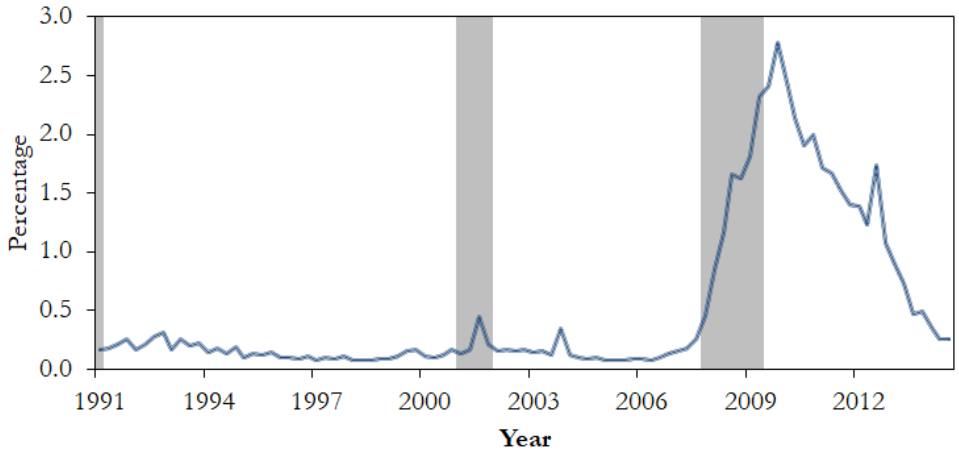


Figure A.3: Charge-off and foreclosure rates

Panel A plots the evolution over time of the charge-off rates, obtained from the FED. The charge-offs are the value of the loans and leases removed from the books of the lenders, and charged against loss reserves. The charge off rate is the net charge-off (gross charge-offs minus recoveries) during a quarter, divided by the average loans outstanding over the same quarter. The values plotted are annualized. Panel B reports the time-series evolution of the foreclosure rate, also annualized, obtained from the Mortgage Bankers Association. We give further details in Appendix B.2. The NBER recession periods are shaded.

Panel A: Charge-off rates



Panel B: Foreclosure rates

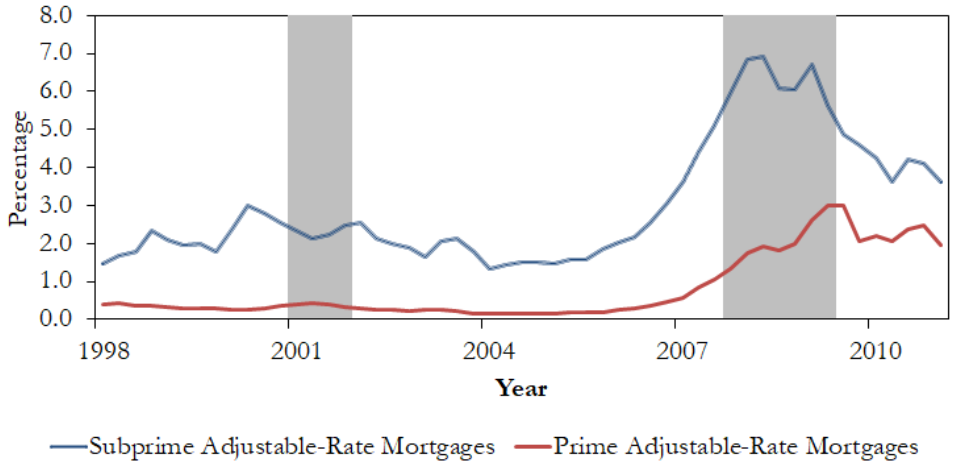


Figure A.4: Mean and standard deviation of real house price changes

The figure plots the mean and standard deviation of the annual log real house price changes for different US metropolitan areas. The data is from the individual time-series of house price indices that constitute the S&P/Case-Shiller 20-city composite Home Price Index Data, from the first quarter of 1987 to the third quarter of 2014. For certain areas the data only starts later than the third quarter of 1987. We first measure the annual change in nominal house prices by taking first differences of the natural logarithm of the house price level at the year end. Similarly, we measure the annual change in the overall price level, by taking first differences of the natural logarithm of the consumer price index measured at the year end. Finally, we measure log real house prices changes by calculating the difference between the two series.

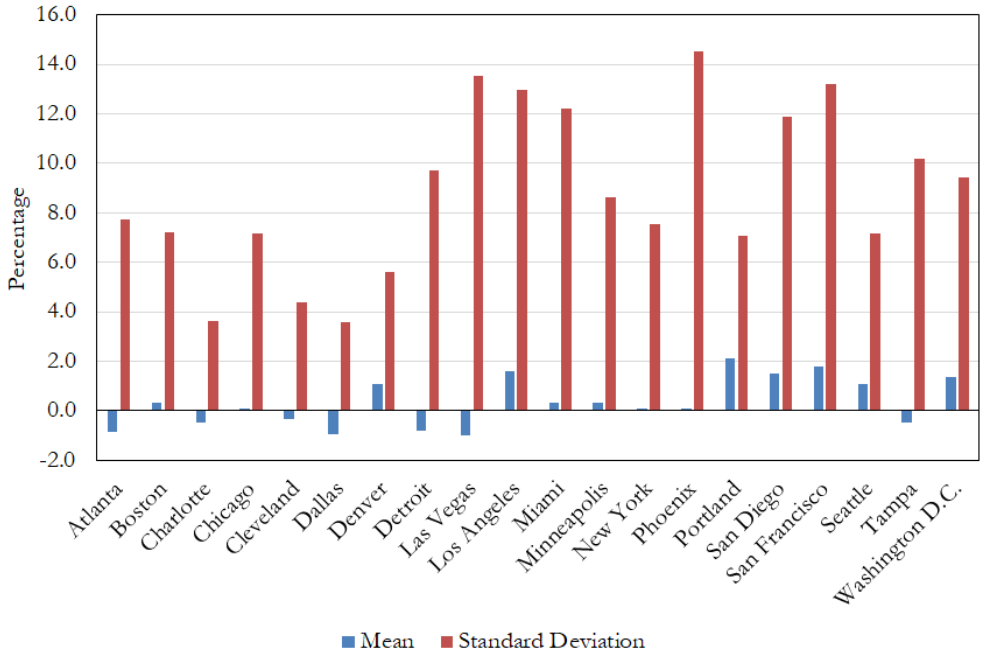


Figure A.5: Average initial LTI, initial mortgage payments to income and LTVs

Panel A plots the time-series evolution evolution of the average origination loan-to-value (LTV) of conventional single-family new mortgages using data from the Monthly Interest Rate survey (MIRS) of the FHFA. The loan-to-income (LTI) is calculated by using the average initial loan amount reported in the MIRS data divided by the median US household income obtained from the Census Bureau. Panel B plots the time series evolution of origination LTV, initial mortgage payments to income (DTI), and nominal house price growth using Freddie Mac data. We give further details in Appendix B.3.

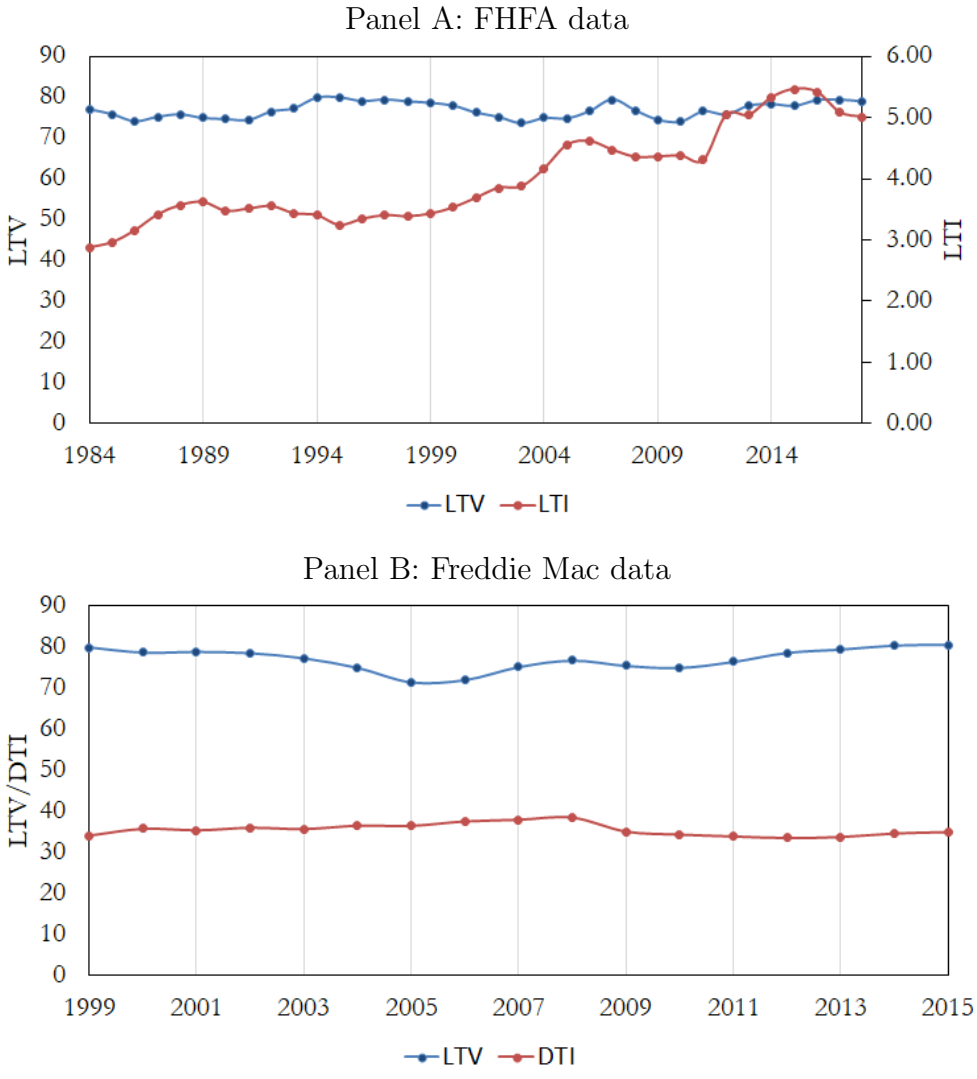


Table A.1: Borrowers' income process parameter values.

This table reports the borrowers' income process parameter values taken from Guvenen et. al (2014).

Description	Parameter	Value
Log permanent income AR(1) coefficient	ρ	0.979
Prob. aggregate/idiosyncratic shock	p_1	0.49
Mean log earnings growth expansion (1)	μ_{1E}	0.119
Mean log earnings growth expansion (2)	μ_{2E}	-0.026
Mean log earnings growth recession (1)	μ_{1R}	-0.102
Mean log earnings growth recession (2)	μ_{2R}	0.094
St. dev permanent income shock (1)	σ_1	0.325
St. dev permanent income shock (2)	σ_2	0.001
St. dev temporary shock	σ_ϵ	0.186

Table A.2: Baseline ARM and Maturity Extension ARM - additional results

This table provides additional statistics that describe the borrowers' decisions for the baseline ARM and the maturity extension ARM. For each contract type, the first (second) column reports moments conditional on the economy being in a recession (expansion). The rows report the average borrowers' income and log change in income, risk-free interest rate, mortgage payments to income, and log change in house prices conditional on the borrowers' decisions (default, mortgage refinance, make mortgage payments and use the option (if available)). The data are obtained by simulating the model for each of the contract types.

	Baseline ARM		Mat Ext ARM	
	Recession	Expansion	Recession	Expansion
Income				
Default	0.614	0.643	0.701	0.648
Refinance	1.183	0.948	1.336	0.953
Pay	1.924	2.127	3.095	2.101
Use the option	n/a	n/a	1.105	n/a
Log Change in Income				
Default	-0.199	-0.099	-0.142	-0.080
Refinance	-0.178	-0.053	-0.199	-0.048
Pay	-0.005	0.047	0.018	0.047
Use the option	n/a	n/a	-0.027	n/a
Risk-Free Interest Rate				
Default	0.008	0.015	0.018	0.015
Refinance	0.014	0.020	0.015	0.020
Pay	0.004	0.011	0.000	0.011
Use the option	n/a	n/a	0.006	n/a
Mortgage Payment to Income				
Default	0.504	0.526	0.617	0.520
Refinance	0.365	0.388	0.355	0.377
Pay	0.244	0.241	0.230	0.247
If no option use	n/a	n/a	0.267	n/a
With option use	n/a	n/a	0.099	n/a
Log Change in House Prices				
Default	-0.156	-0.156	-0.138	-0.139
Refinance	0.039	0.102	0.052	0.107
Pay	-0.032	0.000	-0.014	0.000
Use the option	n/a	n/a	-0.044	n/a

Table A.3: Decisions in the period after the maturity extension policy is used.

This table describes the borrowers' decisions in the period after the maturity extension policy has been used. The decisions available depend on whether the economy is in a recession (first two columns) or in an expansion (last two columns). Panel A reports the percentage of borrowers who at $t+1$, conditional on having used the policy at t, go back to making mortgage payments, use the policy again, default, prepay or refinance, depending on whether house prices decrease or increase at $t+1$. Panel B reports the same decisions but conditional on an increase (decrease) in income. The data are obtained by simulating the model for the ARM with the option to extend maturity in recessions.

	Recession at t+1		Expansion at t+1	
	Panel A: House Price Changes			
Decision at t+1	$\Delta P^H_{t+1} < 0$	$\Delta P^H_{t+1} > 0$	$\Delta P^H_{t+1} < 0$	$\Delta P^H_{t+1} > 0$
Make mortgage payment	6.57	17.48	83.54	78.11
Use policy again	90.58	78.47	n/a	n/a
Default	1.75	0.28	9.53	1.42
Cashout	0.6	2.33	0.45	1.7
Refinance	0.5	1.44	6.49	18.77
	Panel B: Income Changes			
Decision at t+1	$\Delta Y_{i,t+1} < 0$	$\Delta Y_{i,t+1} > 0$	$\Delta Y_{i,t+1} < 0$	$\Delta Y_{i,t+1} > 0$
Make mortgage payment	7.78	13.59	77.67	83.31
Use policy again	87.73	84.14	n/a	n/a
Default	1.48	0.89	6.28	4.46
Cashout	1.76	0.85	1.4	0.84
Refinance	1.24	0.54	14.65	11.39

Table A.4: Baseline FRM and FRM with option to convert to ARM - additional results

This table provides additional statistics that describe the borrowers' decisions for the baseline FRM contract and the FRM with an option to switch to an ARM during recessions. For each contract type, the first (second) column reports moments conditional on the economy being in a recession (expansion). The rows report the average borrowers' income and log change in income, risk-free interest rate, mortgage payments to income, and log change in house prices conditional on the borrowers' decisions (default, mortgage refinance, make mortgage payments and use the option (if available)). The data are obtained by simulating the model for each of the contract types.

	Baseline FRM		FRM with option	
	Recession	Expansion	Recession	Expansion
Income				
Default	0.626	0.643	0.614	0.643
Refinance	1.168	1.044	1.208	0.989
Pay	1.926	2.118	2.099	2.128
Use the option	n/a	n/a	1.303	n/a
Log Change in Income				
Default	-0.189	-0.097	-0.200	-0.102
Refinance	-0.181	-0.044	-0.170	-0.053
Pay	-0.005	0.047	-0.004	0.048
Use the option	n/a	n/a	-0.012	n/a
Risk-Free Interest Rate				
Default	-0.005	0.001	0.006	0.009
Refinance	0.008	0.010	0.015	0.016
Pay	0.004	0.012	0.009	0.011
Use the option	n/a	n/a	-0.015	n/a
Mortgage Payment to Income				
Default	0.508	0.485	0.492	0.524
Refinance	0.331	0.335	0.352	0.376
Pay	0.259	0.239	0.254	0.248
If no option use	n/a	n/a	0.280	n/a
With option use	n/a	n/a	0.159	n/a
Log Change in House Prices				
Default	-0.154	-0.154	-0.156	-0.155
Refinance	0.043	0.104	0.038	0.103
Pay	-0.031	-0.001	-0.032	0.000
Use the option	n/a	n/a	-0.031	n/a

Table A.5: Higher LTV limit in recession - additional results

This table provides additional statistics that describe the borrowers' decisions for the baseline ARM and the maturity extension ARM, for the parameterization with a maximum LTV in recessions of 0.9. For each contract type, the first (second) column reports moments conditional on the economy being in a recession (expansion). The first four rows report the incidence of the different decisions. The remaining rows report the average loan to value and loan to income, borrowers' income, mortgage payments to income, and log change in house prices conditional on the borrowers' decisions (default, mortgage refinance, make mortgage payments and use the option (if available)).

	Baseline ARM		Mat Ext ARM	
	Recession	Expansion	Recession	Expansion
Incidence				
Default	0.023	0.015	0.005	0.018
Refinance	0.023	0.118	0.008	0.113
Pay	0.941	0.857	0.362	0.859
Use the option	n/a	n/a	0.614	n/a
Loan to Income				
Default	7.803	7.391	9.012	7.634
Refinance	6.153	5.002	6.642	5.143
Pay	3.004	2.701	1.364	2.879
Use the option	n/a	n/a	4.569	n/a
Loan to Value				
Default	1.347	1.337	1.505	1.457
Refinance (before refinancing)	0.586	0.677	0.534	0.693
Refinance (after refinancing)	0.681	0.811	0.642	0.819
Pay	0.813	0.791	0.705	0.847
Use the option	n/a	n/a	0.992	n/a
Income				
Default	0.614	0.641	0.670	0.647
Refinance	0.874	0.952	0.947	0.949
Pay	1.970	2.178	3.182	2.144
Use the option	n/a	n/a	1.130	n/a
Mortgage Payment to Income				
Default	0.520	0.539	0.655	0.528
Refinance	0.494	0.379	0.525	0.370
Pay	0.236	0.235	0.230	0.241
If no option use	n/a	n/a	0.259	n/a
With option use	n/a	n/a	0.097	n/a
Log Change in House Prices				
Default	-0.155	-0.155	-0.137	-0.138
Refinance	0.077	0.114	0.094	0.117
Pay	-0.032	-0.002	-0.015	-0.002
Use the option	n/a	n/a	-0.044	n/a

Table A.6: Higher initial LTI - additional results

This table provides additional statistics that describe the borrowers' decisions for the baseline ARM and the maturity extension ARM, for the parameterization with an initial LTI equal to 5. For each contract type, the first (second) column reports moments conditional on the economy being in a recession (expansion). The first four rows report the incidence of the different decisions. The remaining rows report the average loan to value and loan to income, borrowers' income, mortgage payments to income, and log change in house prices conditional on the borrowers' decisions (default, mortgage refinance, make mortgage payments and use the option (if available)).

	Baseline ARM		Mat Ext ARM	
	Recession	Expansion	Recession	Expansion
Incidence				
Default	0.030	0.021	0.006	0.024
Refinance	0.022	0.148	0.009	0.136
Pay	0.922	0.813	0.374	0.871
Use the option	n/a	n/a	0.670	n/a
Loan to Income				
Default	9.410	8.822	11.106	9.337
Refinance	5.923	6.449	6.121	6.602
Pay	4.281	3.802	1.874	4.069
Use the option	n/a	n/a	6.083	n/a
Loan to Value				
Default	1.340	1.334	1.518	1.451
Refinance (before refinancing)	0.463	0.701	0.411	0.709
Refinance (after refinancing)	0.536	0.811	0.487	0.816
Pay	0.844	0.825	0.734	0.877
Use the option	n/a	n/a	0.992	n/a
Income				
Default	0.732	0.764	0.766	0.757
Refinance	1.321	1.074	1.448	1.074
Pay	2.059	2.313	3.580	2.245
Use the option	n/a	n/a	1.230	n/a
Mortgage Payment to Income				
Default	0.605	0.626	0.799	0.620
Refinance	0.494	0.470	0.485	0.451
Pay	0.306	0.304	0.286	0.308
If no option use	n/a	n/a	0.328	n/a
With option use	n/a	n/a	0.099	n/a
Log Change in House Prices				
Default	-0.156	-0.156	-0.138	-0.140
Refinance	0.048	0.094	0.053	0.096
Pay	-0.031	-0.002	-0.010	-0.001
Use the option	n/a	n/a	-0.044	n/a

Table A.7: Alternative house price process parameter values

This table reports the results for the baseline ARMs and the maturity extension ARMs, for alternative parameterizations of the house price process: in Panel A we report results for the mean log house price change equal to 0.01; in Panel B the standard deviation of the log house price changes is equal to 0.10. In each of the panels, all the other parameters are set at their baseline values. The table follows the same format as Table 3.

	Baseline ARM		Mat. ext. ARM	
Description	Mean	Cyclicality	Mean	Cyclicality
Panel A: Positive house price growth				
Loan premium	0.019	-0.014	0.017	-0.014
Default rate	0.012	-0.006	0.011	0.009
Fraction using option	n/a	n/a	0.133	-0.602
Log change in ind. borrower cons.	0.040	0.073	0.039	0.066
Lender cash-on-hand/income	2.313	-2.007	3.055	-2.473
Log change in lender cons.	0.000	0.105	0.000	0.136
Log change in aggregate cons.	0.000	0.081	0.000	0.078
Welfare gain for borrowers			0.013	
Welfare gain for lender			0.004	
Panel B: Lower house price volatility				
Loan premium	0.016	-0.013	0.014	-0.013
Default rate	0.007	-0.003	0.007	0.006
Fraction using option	n/a	n/a	0.119	-0.537
Log change in ind. borrower cons.	0.041	0.074	0.040	0.066
Lender cash-on-hand/income	2.382	-2.022	3.159	-2.542
Log change in lender cons.	0.000	0.107	0.000	0.137
Log change in aggregate cons.	0.000	0.082	0.000	0.079
Welfare gain for borrowers			0.014	
Welfare gain for lender			-0.001	