Houses as ATMs?
Mortgage Refinancing and Macroeconomic Uncertainty*

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Abstract

Homeowners refinancing a mortgage can convert home equity into liquid assets - and consumption - by obtaining a larger loan. Using both aggregate and state-level data we show that mortgage refinancing activity increases when economic conditions deteriorate, even after controlling for the cyclical behavior of interest rates, with a larger fraction of loans involving cash-out (equity extraction) at the onset of a recession. We develop a quantitative model in order to investigate the role of mortgage refinancing as a mechanism for smoothing consumption by liquidity constrained households, focusing on the interaction of the aggregate economic conditions, house prices, and idiosyncratic labor income risk. We show that counter-cyclical labor income uncertainty together with constraints on loan amounts give rise to preemptive cash-out as households fear that deteriorating economic conditions will make it harder to access home equity in the future.

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1 Introduction

Long-term mortgages with a fixed rate and an option to prepay the outstanding balance prior to maturity, typically by obtaining a new loan (refinancing), have long been the mainstay of the U.S. housing market. A large fraction of refinance loans - on average about 70% - involve "cash-out," i.e. an increase in the loan balance and the corresponding decrease in home equity. Over the period from 1993 through 2010 U.S. households extracted over $1.7 trillion of home equity via refinancing, corresponding on average to 11.5% of new loan balances.[1] We investigate the role of mortgage refinancing as a mechanism through which households can relax liquidity constraints in response to aggregate and idiosyncratic shocks.

We focus on the interaction between the interest rate variation and macroeconomic conditions in affecting household decisions. The decision to refinance a mortgage either to take advantage of the lower interest rates or to take out home equity for consumption-smoothing purposes trades off the benefits of refinancing against the costs of originating a new loan, both financial and non-pecuniary. Fluctuations in interest rates that determine the strength of the financial incentive to refinance alone are not sufficient to capture all of the movement in the aggregate prepayment/refinancing activity in the data (e.g., Boudoukh, Richardson, Stanton, and Whitelaw (1997), Gabaix, Krishnamurthy, and Vigneron (2007)). It is the interaction of the two motives for refinancing that underscores its potential importance for the effectiveness of monetary policy.[2]

Empirically, interest rates are pro-cyclical, falling in economic downturns, when both aggregate income falls and its cross-sectional dispersion rises. Consequently, the option to prepay an existing fixed-rate mortgage (FRM) is more likely to be in the money at a time when households are constrained and experiencing a need to tap their home equity (if it exists), in effect providing

[1] These figures are conservative as they are based on estimates for conforming loans provided by Freddie Mac and therefore exclude certain kinds of mortgage loans, such as subprime. In particular, survey-based analysis in Greenspan and Kennedy (2008) suggests much greater magnitudes of home equity extraction.

[2] Mortgage refinancing featured prominently in Alan Greenspan's defense of low interest rates as a way of stimulating household consumption during the "jobless recovery" from the 2001 recession: "Overall, the economy has made impressive gains in output and real incomes; however, progress in creating jobs has been limited. ... The very low level of interest rates ... encouraged household spending through a variety of channels. ... The lowest home mortgage rates in decades were a major contributor ... engendering a large extraction of cash from home equity. A significant part of that cash supported personal consumption expenditures and home improvement. In addition, many households took out cash in the process of refinancing, often using the proceeds to substitute for higher-cost consumer debt. That refinancing also permitted some households to lower the monthly carrying costs for their homes and thus freed up funds for other expenditures." (Testimony of Chairman Alan Greenspan; Federal Reserve Board's semiannual Monetary Policy Report to the Congress Before the Committee on Financial Services, U.S. House of Representatives, February 11, 2004).

a form of insurance. Indeed, we show that in the data, mortgage refinancing activity appears to respond to macroeconomic conditions, even after controlling for the cyclicality of mortgage rates, using both aggregate and state-level data. Refinancing activity spikes with measures of macroeconomic uncertainty such as the implied stock market volatility and unemployment claims, and is lower in states that experience higher rates of economic growth. Refinancing is positively related to growth in house prices, which drives the tightness of the collateral constraint, while more refinancing households extract home equity as the economy enters into recessions, even before interest rates fall.

We build a dynamic model of household mortgage financing that replicates these stylized facts. The model also helps quantify the degree to which refinancing costs as well as the lack of home equity constrain the ability of households to smooth consumption in the face of macroeconomic uncertainty. In our model, households face uninsurable idiosyncratic and aggregate labor income risk, and their only means of borrowing is via a home mortgage. The mortgage repayment and refinancing behavior is driven by both the purely financial motive of minimizing the borrowing costs (as in Campbell and Cocco (2003)) and by the consumption smoothing motive (or, in other words, optimal household leverage choice). Since housing is a form of wealth, households adjust their home equity in response to house prices, which we assume grow at the same long run rate as does personal income. Thus, the "wealth effect" leads households to rebalance their portfolios by converting home equity into liquid assets and consumption following positive economic news. At the same time, large negative transitory shocks to individual incomes force households to use home equity to alleviate the liquidity constraint (as in Hurst and Stafford (2004)).

We analyze the economic forces contributing to the relative strengths of the smoothing effect and the wealth effect. An important feature of our model is the counter-cyclical volatility of idiosyncratic labor income growth, documented by Storesletten, Telmer, and Yaron (2004) (see also Meghir and Pistaferri (2004)). This property of the labor income process implies that a macroeconomic downturn should coincide with a spike in refinancing activity because more households become liquidity constrained, provided that the cost of refinancing is low enough and households still have enough home equity. Requiring that refinanced loan amount is not too large relative to current household income - a common practice among mortgage lenders - implies that households will cash out home equity at the onset of a recession, i.e. when uncertainty about future income increases. Relaxing the loan-to-income constraint mutes the effect of time-varying volatility so that the aggregate refinancing behavior is dominated by the wealth effect, similarly to an economy with homoscedastic income shocks. The preemptive cash-out behavior we identify is a unique feature of our model, which combines long-term mortgage loans with time-varying economic uncertainty. In models with short-term loans households cannot ride out periods of high uncertainty by borrowing against their homes since falling house prices during a recession lead to painful "deleveraging": households are forced to repay their loans as tightening collateral constraints make rolling them over more difficult (e.g. Favilukis, Ludvigson, and Van Nieuwerburgh (2011) and Midrigan and Philippon (2011)).[3]

In a quantitative calibration of the model that targets the main features of income, consumption, and mortgage data we show that the dynamics of labor income are key for generating counter-cyclical refinancing and cash-out behavior. On the one hand, counter-cyclical idiosyncratic labor income risk is important for cyclical behavior of refinancing. On the other hand, riskier idiosyncratic income implied greater precautionary saving, i.e. greater liquid asset holdings and lower mortgage balances on average. Further, highly persistent labor income processes advocated in the recent literature imply that idiosyncratic shocks are very difficult to smooth, and therefore dampen the effect of economic cycles on refinancing behavior. Thus observed refinancing behavior contains useful information for understanding the dynamics of individual labor income.

A better understanding of the links between mortgage refinancing and macroeconomic conditions is important for several reasons. First, while previous models have predominantly focused on refinancing as exercise of an interest rate option, our results show that the liquidity-driven motive can significantly amplify the demand for refinancing under certain macroeconomic conditions. This is important for pricing prepayment risk in mortgage-related assets (e.g., Duarte, Longstaff, and Yu (2007) show that agency-backed mortgage backed securities are subject to macroeconomic risk captured by stock returns), as well as for understanding the relation between refinancing activity in the mortgage markets and volatility in other fixed income markets (see, e.g., Duarte (2008)). Second, our model can quantify the welfare implications of refinancing costs in a rather rich economic setting, which can help evaluate policy proposals of stimulating the economy through relaxing

[3]Empirical evidence in Carroll, Slacálek, and Sommer (2012) suggests that the increase in labor income uncertainty, rather than the tightening of credit constraints by themselves, is likely the driver of the consumption decline during the Great Recession.

refinancing constraints.

1.1 Literature

There is a large literature on mortgage refinancing decision, with different strands focusing on different facets of the optimal solution to the problem faced by the household.

The fixed-income asset pricing literature focuses on the optimal exercise of the call option embedded in the mortgage (e.g. Dunn and McConnell (1981), Dunn and Spatt (2005)). The wide divergence of prepayment behavior across households has been modeled by attributing it to implicit heterogeneity in the costs of refinancing (e.g. Stanton (1995), Deng, Quigley, and Van Order (2000)), both explicit and implicit, in particular those arising from behavioral biases (e.g. Agarwal, Driscoll, and Laibson (2002)). Campbell and Cocco (2003) and Koijen, Van Hemert, and Van Nieuwerburgh (2009) analyze the choice between adjustable and fixed-rate mortgages. Longstaff (2004) and Mayer, Piskorski, and Tchistyi (2010) consider equilibrium mortgage rates in environments where refinancing is constrained by borrower creditworthiness. Downing, Stanton, and Wallace (2005) consider the interaction between the mortgage prepayment and default decision and the explicit role of house prices.

The literature on housing collateral emphasizes the implicit risk-sharing role of mortgage finance and its impact on risk premia (e.g. Lustig and Van Nieuwerburgh (2005), Favilukis, Ludvigson, and Van Nieuwerburgh (2011)). Some evidence supporting the importance of housing collateral has been documented using variation in consumption responses to income at the regional level (Caplin, Freeman, and Tracy (1997), Lustig and Van Nieuwerburgh (2010)). Hurst and Stafford (2004) explicitly consider the role of mortgage refinancing as a mechanism of accessing home equity for the purpose of smoothing consumption over time and provide household-level evidence. Gan (2010) reports similar evidence using data on households in Hong Kong. Gerardi, Rosen, and Willen (2010) also use micro-level data to show that the mortgage securitization improved households' ability to smooth their housing consumption over time, while Campbell and Hercowitz (2005) use a structural model to argue that the increased accessibility of housing collateral due to such financial innovations contributed to the "Great Moderation" of the business cycles in the recent decades.

A large literature aims to understand the importance of housing wealth for determining consumption (e.g., Carroll, Otsuka, and Slacalek (2011), Case, Quigley, and Shiller (2011)). Piazzesi and Schneider (2009) study the interaction of housing and uninsurable inflation risk in household wealth portfolios within a temporary equilibrium framework. Our model is closely related to that in Attanasio, Leicester, and Wakefield (2011) who focus on the sensitivity of consumption to housing wealth by matching key features of the U.K. housing market, while Rios-Rull and Sanchez-Marcos (2008) endogenize house prices in a similar environment. Landvoigt, Piazzesi, and Schneider (2012) evaluate the impact of credit availability on the cross-section of house prices in an assignment framework. Chatterjee and Eyigungor (2011) study mortgage default in a model with both long-term loans and endogenous pricing of debt and housing collateral, but without the possibility of refinancing.

Finally, our paper is related to the literature on household liquidity management. The focus of this literature is on the role of transaction costs (as in the tradition Baumol-Tobin inventory models) in inhibiting households' ability to self-insure by accumulating financial assets (e.g., Alvarez, Guiso, and Lippi (2010) and Kaplan and Violante (2011)). Some of the key trade-offs are present in our model where housing plays the role of an illiquid asset.

2 Empirical evidence

2.1 Aggregate level evidence

In this section, we discuss empirical evidence on how refinancing activity at the aggregate level relates to interest rates and macroeconomic conditions. The key variable capturing mortgage refinancing by households that we use is the index of mortgage applications compiled by the Mortgage Bankers Association (MBA Refi Index), which is available from 1990 to 2011. In addition, we also examine the quarterly cash-out data from Freddie Mac for the period from 1985 to 2011.

Figure 1 Panel A plots the Refi index (weekly) along with the 30-year mortgage rates. Not surprisingly, refinancing increased in the early 90s and especially around 2003, both of which are times with significant drops in mortgage rates. This is consistent with households refinancing to take advantage of newly available low mortgage rates. Panel B plots the Refi index with the VIX index, a measure of the implied volatility of the $S\&P$ 500 stock market index. The spikes in Refi in 1998, 2001, 2008, and 2009 all appear to coincide with spikes in the VIX. Panel C plots the Refi index with the year-on-year growth rate in industrial production. The Refi index rose significantly

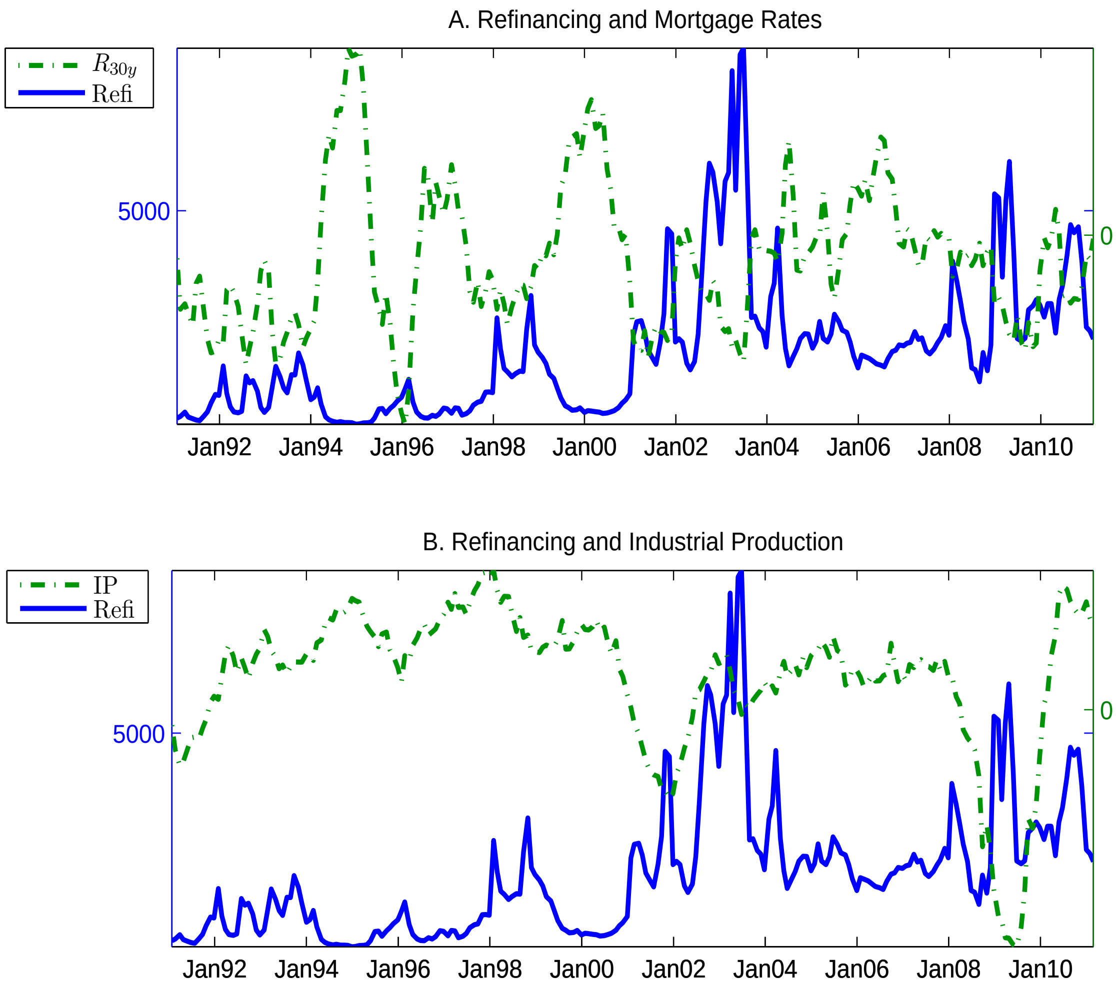

Figure 1: Refinancing, Interest Rates, and Macroeconomic Uncertainty

during the 2001 recession, and again in early 2008, the onset of the Great Recession. Panels B and C are suggestive evidence that households borrow against home equity (while they are not yet "under water") when experiencing bad income shocks or in anticipation of worsening economic conditions in the future.

We regress the (monthly average) Refi Index on a host of financial and macroeconomic variables:

$$REFI_t = b_0 + b_{IP}IP_t + b_{hpi}HPI_t + b_r R_t^{3m} + b_{r30}R_t^{M30} + b_{r30l}(R_t^{M30} - R_{t-12}^{M30}) + \epsilon_t, \qquad (1)$$

where R_t^{3M} is the 3-month Treasury Bill rate, R_t^{30Y} the 30-year fixed mortgage rate, R_{t-12}^{30Y} the 30-year fixed mortgage rate lagged by one year, HPI_t the year-on-year growth in the Case-Shiller

Table 1: Explaining the MBA Refinancing Index - Monthly

	1	2	3	4
IP_t	-0.60	-0.38	0.54	0.44
	(0.22)	(0.22)	(0.40)	(0.35)
$IP_t \times HPI_t$				-0.08
				(0.03)
$SPRD_t$			16.02	22.69
			(5.11)	(6.14)
HPI_t		0.36	0.58	0.64
		(0.21)	(0.24)	(0.22)
R_t^{M30}	-7.98	-5.79	-4.74	-5.24
	(1.25)	(1.18)	(1.36)	(1.16)
R_t^{3M}		-2.06	-1.37	-0.83
		(1.09)	(0.87)	(0.75)
$R_t^{M30} - R_{t-12}^{M30}$		-3.53	-4.84	-4.45
		(2.09)	(2.17)	(2.07)
Adj. R^2	0.56	0.62	0.68	0.70

NOTE: Monthly data, January 1990 - February 2011. Numbers in parentheses are Newey-West standard errors with 12 lags. The left-hand-side variable is the MBA refi index. IP_t is the one-year growth rate in industrial production. HPI_t is the real one-year growth in the FHFA house price index. $SPRD_t$ is the Baa-Aaa credit spread. R^{M30} is the average 30-year mortgage rate. R^{3M} is the 3-month t-bill rate.

housing price index, and IP_t the year-on-year change in the Industrial Production index (IP). Besides IP_t, macroeconomic conditions are proxied by the Baa-Aaa credit spread ($SPRD_t$).

Table 1 reports the results. The most important driver of mortgage refinancing are the current 30-year mortgage rate and the one-year change in the 30-year rate, both of which come in with a negative and robustly significant coefficient in all of the regressions. This is natural, as one of the primary reasons to refinance a mortgage is to take advantage of lower interest rates and thus lower interest payments, and a proxy for the potential interest saving is the gap between the current and lagged mortgage rates. It is also intuitive that past house price growth affects refinancing positively, as the wealth effect induces households to consume from home equity.

The other right-hand side variables are meant to capture the sensitivity of refinancing to the economic conditions. The Industrial Production growth, a direct measure of economic activity, has a significant and negative coefficient after controlling for current mortgage rate, but the significance becomes marginal after controlling for the short rate, changes in mortgage rates, and house price growth. The short rate captures the attractiveness short-duration borrowing options, such as adjustable rate mortgages (ARMs), which could partly explain the weaker effects of IP. Interestingly, leading industrial production growth by one month makes the effect stronger, consistent with the interpretation that households make their refinancing decisions in anticipation of future economic conditions. Once we include Baa-Aaa spread in the regression, the coefficient on industrial production growth turns positive and insignificant, while the coefficient on credit spread is positive and significant, again capturing the counter-cyclicality of refinancing. This result is consistent with a large body of evidence that financial variables such as the credit spread (the VIX index is another example) contain relevant information about the future state of the economy.

Finally, even in the presence of credit spread, the interaction of industrial production growth and past house price growth has a negative and significant coefficient. It suggests that households are more likely to refinance when economic condition weakens but the amount of home equity they have is large.

The aggregate refinancing index does not distinguish between cash-out refinancing (taking out a loan with a larger balance than the previous one) from those that result in the same or lower loan balances. We now examine how cash-outs react to macroeconomic conditions, which provide a more direct measure of household borrowing.

Figure 2 Panel A plots the time series of the percentage of refinancing for which the loan amount (i) is raised by 5% or more, (ii) remains the same, or (iii) is reduced by 5% or more. The data is from Freddie Mac for the period of Q1 of 1985 to Q1 of 2011. On average, 61% of refinancing over this period are cash-outs, which highlights the importance of cash-outs in mortgage refinancing. The share of cash-outs is visibly higher towards the end of each expansion, and it becomes lower after a recession. In contrast, the fraction of refinancing that do not result in a higher loan balance does not appear to have a clear business cycle pattern. The waves in the mid-90s and early 2000s instead correspond to periods of declines in mortgage rates, which is intuitive since the goal of such refinancing should be to reduce interest payments. Finally, the fraction of pay-down refinancing, those that result in a reduction in loan balance, typically rises following a recession, as households repay the loans they take out entering the recession. These pay-downs should also be associated with lower rates, for otherwise households could prepay rather than refinance their mortgages.

Like other types of refinancing, cash-outs can also be due to low interest rates. Thus, it is informative to examine under what conditions refinancing tends to lower loan rates. Panel B of

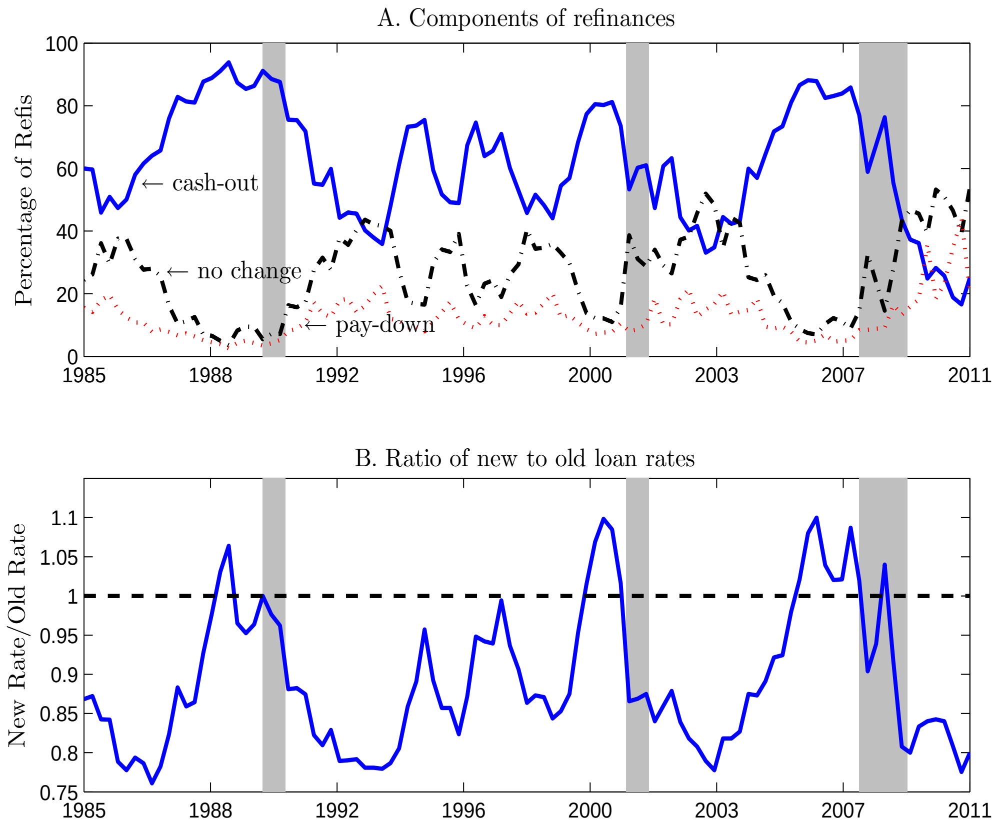

Figure 2: Panel A plots the percentage of refinancing resulting in 5% higher loan amount (cash-out), no change in loan amount, or lower loan amount (pay-down). Panel B plots the median ratio of new to old loan rates upon refinance.

Figure 2 plots the ratio of the median new mortgage rates on refinance loans to the old mortgage coupon rates k. Households tend to refinance despite higher rates towards the end of economic expansions, but at lower rates coming out of recessions. The correlation between this rate ratio and the cash-out share in Panel A is 78%. Together, they suggest that macroeconomic factors other than interest rates play an important role in determining the aggregate amount of cash-out refinancing.

Why do households refinance their mortgages at higher rates? One possibility is that they are borrowing against future income, either because their expected future income has become higher, or they are currently hit by a temporary drop in income. Given that labor income is not tradable and other non-collateralized personal loans (e.g., credit card loans) are expensive, the house can become a major source of credit for liquidity constrained households. A second, and related, reason is that households borrow preemptively when they expect future income to drop. Frictions such as loan-to-income ratio restriction, and more severe adverse selection due to higher income volatility in the cross section can make it more difficult (costly) to borrow in bad times, which will generate precautionary demand for borrowing before income has actually fallen. Third, households who need to borrow from the house might expect long term mortgage rates to rise in the future, so they may be attempting to "time the market" by taking out larger mortgages in anticipation and locking in the low rate. Fourth, households might expect house value to fall, which affects their future borrowing capacity through the loan-to-value ratio restriction.[4] Finally, if households expect higher returns from other types of investment (e.g., from the stock market or the housing market), they might borrow against the house in spite of high rates.

Finally, we examine to what extent do households rely on cash-out to smooth shocks to income. We normalize the dollar amount of total home equity cashed outs by year-ago personal income, and then regress it on real personal income growth, house price growth, and several interest rate variables:

$$CASHOUT_t = c_0 + c_{pi} PI_t + c_{hpi} HPI_t + c_r R_t^{3m} + c_{r30} R_t^{M30} + c_{r30l}(R_t^{M30} - R_{t-12}^{M30}) + \epsilon_t, \qquad (2)$$

where $CASHOUT_t$ is the total home equity extracted over a quarter scaled by the total quarterly personal income (lagged by one year), PI is past one-year real quarterly income growth, and the other variables are the same as defined in (1).

The results are shown in Table 2. Over the sample, growth in real personal income is only weakly negatively correlated with the cash-out to income ratio. However, after controlling for house price and interest rate information, the coefficient on personal income growth becomes significantly negative, again consistent with the interpretation that households use cash-out to smooth temporary negative income shocks. The magnitude of the coefficient can be interpreted as follows. If real income drops by 1%, households on average increase cash-out by 0.15-0.17% of income to offset this effect. Obviously, there will be significant heterogeneity across households in their cash-out responses to income shocks which we do not capture here. We explore these effects in our model.

While cash-out is still negatively related to the level of 30-year mortgage rate, it is negatively

[4]Higher house price might also lead to more cash-out due to the wealth effect for those who own investment properties.

Table 2: Cashout and Personal Income

	1	2	3	4	5
PI_t	-0.015	-0.152	-0.143	-0.169	-0.167
	(0.112)	(0.050)	(0.039)	(0.048)	(0.054)
$PI_t \times HPI_t$					-0.345
					(1.819)
$SPRD_t$				0.403	0.389
				(0.294)	(0.340)
HPI_t		0.120		0.132	0.132
		(0.032)		(0.032)	(0.033)
HPI_t^{2Y}			0.086		
			(0.013)		
R_t^{M30}		-0.009	-0.007	-0.009	-0.009
		(0.003)	(0.002)	(0.003)	(0.003)
R_t^{3M}		0.003	0.002	0.003	0.003
		(0.002)	(0.001)	(0.002)	(0.002)
$R_t^{M30} - R_{t-12}^{M30}$		0.004	0.003	0.004	0.004
		(0.001)	(0.001)	(0.001)	(0.001)
Adj. R^2	-0.014	0.568	0.704	0.582	0.576

NOTE: Quarterly data, Q1 1993 - Q1 2011. Numbers in parentheses are Newey-West standard errors with 4 lags. The left-hand-side variable is the ratio of annualized dollar cash-out to personal income lagged by 4 quarters. PI_t is one-year real personal income growth. HPI_t is the real one-year growth in the FHFA house price index. HPI_t^{2Y} is the real two-year growth in the FHFA house price index. $SPRD_t$ is the Baa-Aaa credit spread. R^{M30} is the average 30-year mortgage rate. R^{3M} is the 3-month t-bill rate.

related to the term spread ($R^{M30} - R^{3M}$), and positively related to the one-year change in mortgage rate, the opposite of the case for refi (see Table 1). This is due to the fact that different components of refinancing depend on interest rates differently. When households refinance to lower their interest payments, the difference between the current mortgage rate and lagged mortgage rate is a proxy for the potential size of interest savings, which ought to be negatively related to the likelihood to refi. When households decide when to cash out, the level of current mortgage rate compared to the costs of other sources of financing as well as the expectation of future rates also matter. Thus, the fact that cash-out tends to rise with mortgage rates could be due to the costs of other sources of credit (e.g., credit card) rising faster than mortgage rates or expectation of an increase in future mortgage rates. Finally, similar to the case of refinancing, house price growth is positively related to cash-out, both because of the wealth effect of higher home value and the fact that the availability of home equity is required for cash-out. Credit spread is positively related to cash-out, but the effect is not significant.

2.2 State level evidence

To investigate the response of mortgage refinancing to economic activity further, we use state-level data on the origination of home mortgage loans at the state level. This potentially allows us to separate the effect of low interest rates from that of deteriorating economic conditions, insofar as there is heterogeneity in business conditions across states so that local economic activity variables are less synchronized with the interest rates than are aggregate quantities, and that households cannot diversify away state-level shocks.

We use quarterly data on the mortgage loans (both refinance and purchase) for each of the 50 states and D.C., based on aggregated Home Mortgage Disclosure Act (HMDA) reporting. We regress the quarterly changes in the number of loans taken in order to refinance existing mortgages (adjusted by the state population) on measures of economic conditions. We use three such measures, specifically growth rates of nonfarm payroll employment, of the State Coincident Economic Activity Index ($CEAI$), which combines information contained in nonfarm payrolls, unemployment, hours worked and wages, and trends with the Gross State Product (GSP), and of the total personal income (TPI), deflated using the national consumer price index.[5] We use year-on-year (log) growth rates of quarterly levels of these measures as the main explanatory variables.

House prices determine both the motive to refinance due to a wealth effect and the ability of households to borrow against the value of their homes (perhaps for reasons unrelated to consumption smoothing). Since economic conditions are correlated with the level of house prices, refinancing activity could be high under good economic conditions due to high house prices. Thus, to better capture the effect of consumption smoothing on refinancing, it is important to control for house price appreciation in our regression. We use the FHFA house price indices for the 50 states and DC as our measure of house prices. As before, we also control for aggregate variables: the 30 year mortgage rate (contemporaneous and lagged by one year) and the short-term interest rate.

[5]Unlike the payroll employment and personal income measures, $CEAI$ is not available for D.C.

We run pooled time series/cross-sectional regressions of the form:

$$REFI_t^{State} = b_{Cycle} Cycle_t^{State} + b_{HPI} \Delta HPI_t^{State} + b_{CH} Cycle_t^{State} \times HPI_t^{State} + \bar{R}_t^i$$
$$+ b_w WAC_t^{State} + b_r R_t^{3M} + b_{r30} R_t^{M30} + b_{r30l} R_{t-4}^{M30} + \mathbf{b}_t + \mathbf{b}_{State} + \epsilon_t, \qquad (3)$$

where $REFI_t^{State}$ is the number of refinance loans originated in state i over the quarter t, scaled by the state's population in the prior year. $Cycle^{State}$ is the variable that measures state-level aggregate economic conditions, ΔHPI_t measures house price appreciation using the 2-year growth in the FHFA state-level house price index that captures appreciation of the mortgaged properties, $\bar{R}_t^i$ is the average rate on newly originated conventional mortgages in state i over the past year,[6] WAC_t^{State} is the weighted average coupon on conforming mortgage loans outstanding in the state in the first month of the quarter that summarizes the rates currently paid by borrowers, $\mathbf{b}_t$ is the vector of quarter fixed effects that captures aggregate information not contained in other variables, and $\mathbf{b}_{State}$ a vector of state fixed effects. State fixed effects are important since there is substantial heterogeneity across states in the fixed costs associated with refinancing a mortgage (such as title insurance, taxes, etc.), which result in different average levels of refinancing as well as its sensitivity to aggregate variables. Given this specification, we are identifying the effect of within-state variation in economic conditions on refinancing. We include the lagged $Cycle$ variable to capture delayed response of households to economic conditions, and include an interaction term between $Cycle$ and the house price growth, orthogonalized with respect to both variables, to test whether higher level of house prices help relax the borrowing constraint especially in bad times.

Table 3 presents the results of the state-level regressions for different specifications (two different economic activity measures). The coefficients on the state-level business cycle variables in the first column are all negative and statistically significant in all but one specification (TPI without time fixed effects), consistent with the view that households are more likely to refinance their mortgages in a downturn. The state-level cycle variable remains significantly negatively related to refinancing when the quarter fixed effects are included, indicating that their presence does not simply proxy for variation in the aggregate term structure variables.

[6]This variable is available from FHFA at annual frequency; we interpolate it linearly to generate quarterly observations.

Table 3: State-level refinancing activity

	$Cycle_t$	HPI_t	$C_t \times H_t$	WAC	$\bar{R}_t^i$	R_t^{M30}	R_t^{3M}	R_{t-4}^{M30}	R^2
1	-0.29	0.17	-1.85	0.62	1.50	-1.70	-0.75	-0.20	0.61
Robust	[0.05]	[0.01]	[0.51]	[0.03]	[0.22]	[0.11]	[0.06]	[0.11]	
NW	[0.05]	[0.01]	[0.39]	[0.05]	[0.22]	[0.12]	[0.06]	[0.12]	
2	-0.24	0.10	-0.64	-2.74	0.32				0.89
Robust	[0.05]	[0.01]	[0.27]	[0.70]	[0.41]				
NW	[0.05]	[0.01]	[0.20]	[0.67]	[0.37]				
3	-0.10	0.16	-1.29	0.64	1.56	-1.79	-0.80	-0.23	0.60
Robust	[0.03]	[0.01]	[0.42]	[0.04]	[0.24]	[0.12]	[0.06]	[0.11]	
NW	[0.03]	[0.01]	[0.34]	[0.05]	[0.23]	[0.12]	[0.07]	[0.12]	
4	-0.14	0.10	-0.47	-2.62	0.36				0.89
Robust	[0.04]	[0.01]	[0.19]	[0.70]	[0.42]				
NW	[0.03]	[0.01]	[0.13]	[0.69]	[0.37]				
5	0.01	0.15	-1.89	0.61	1.84	-1.89	-1.00	-0.32	0.60
Robust	[0.03]	[0.01]	[0.54]	[0.04]	[0.27]	[0.14]	[0.06]	[0.11]	
NW	[0.03]	[0.01]	[0.37]	[0.05]	[0.26]	[0.13]	[0.07]	[0.13]	
6	-0.10	0.09	-0.36	-2.63	0.18				0.89
Robust	[0.03]	[0.01]	[0.25]	[0.70]	[0.44]				
NW	[0.03]	[0.01]	[0.22]	[0.70]	[0.39]				

NOTE: Quarterly data, 1993.III - 2009.IV (time subscript t is in monthly units). The dependent variable is the total number of newly originated refinance loans in the state over a quarter relative to the rescaled population of the state for the previous year (based on HMDA data). *Cycle* refers to the year-on-year growth in either the non-farm payroll employment index scaled by the state population (*Payroll*, specifications 1 - 2), State Coincident Economic Activity index in columns (*CEAI*, specifications 3 - 4), or the Total Personal Income (*TPI*, deflated using the CPI, specifications 5 - 6). HPI is the two-year growth rate of the state-level house price index. $C_t \times H_t$ is the orthogonalized interaction term, i.e. the residual from regressing the product of *Cycle* and HPI on a constant and both of these variables. WAC is weighted average coupon rate for conforming fixed-rate mortgages (equal-weighted average across FNMA and FHLMC loans) in a given state. $\bar{R}_t^i$ is the average coupon rate on all newly-originated conventional prime loans in the state over the quarter. Specifications 2, 4 and 6 have quarter fixed effects. Standard errors are in brackets (*Robust* are clustered by state, and NW are Newey-West with 20 lags).

As expected, house price appreciation is positively related to refinancing. In fact, the effects of the business cycle variables become stronger (more negative) after house price appreciation is taken into account, which helps tease out the rise in refinancing in good times due to house value appreciation (results without house price index are not reported). Moreover, the interaction terms of house prices and the cycle variables are negative and typically statistically significant, suggesting that higher levels of house prices are particularly important for refinancing during economic downturns.

Both the 30-year mortgage rates and the short-term interest rate have a significant negative effect on refinancing, as expected. Similarly, the WAC has a significant positive coefficient, consistent with the fact that it captures the rates currently paid by borrowers, so that higher WAC translated into a greater incentive to refinance if current rates are low. In the specification with time fixed effects (where aggregate interest rates are not included) WAC has a negative coefficient, potentially due to the fact that it may capture persistent state-specific variation in mortgage spreads that we cannot control for separately without detailed state-level data on mortgage rates. Interestingly, the effect of current state-level mortgage rates is positive rather than negative, although not significant with time fixed effect, suggesting that it is capturing mostly aggregate variation in mortgage spreads (which are positively related to both default and prepayment risk).

Another measure of refinancing is the total volume of refinance loans. Table 4 reports results of regressions (3) where $REFI_t^{State}$ is defined as the total dollar volume of newly originated refinance loans in state i over quarter t divided by the total personal income in the state over the previous quarter. The results are very similar: the $Cycle$ variable comes in negatively (and significantly different from zero in all but one specification), house prices have a strongly positive effect, and the interaction is negative, albeit not significant when time fixed effects are present.

3 The Model

This section presents a dynamic model of household decisions. This model will focus on understanding households' decisions on how much to consume, being a homeowner or a renter, how much to save and finance a house over time, as a function of idiosyncratic shocks to income and aggregate shocks to short-term interest rates, real growth, house value, and inflation.

3.1 Households

The economy is populated by ex-ante identical, infinitely lived households, indexed by i. We assume households have the same recursive utility over consumption as in Epstein and Zin (1991) and Weil (1990),

$$U_t = \max_{C_t} \left[(1-\beta)\, C_t^{\frac{1-\gamma}{\theta}} + \beta \mathbb{E}_t \left[U_{t+1}^{1-\gamma} \right]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}}.$$

Table 4: Refinance loan volume relative to total income

	$Cycle_t$	HPI_t	$C_t \times H_t$	WAC	$\bar{R}_t^i$	R_t^{M30}	R_t^{3M}	R_{t-4}^{M30}	R^2
1	-1.63	0.86	-6.78	2.30	7.77	-8.21	-3.69	-1.37	0.65
Robust	[0.26]	[0.05]	[2.52]	[0.16]	[1.17]	[0.58]	[0.28]	[0.53]	
NW	[0.25]	[0.05]	[1.77]	[0.20]	[1.07]	[0.59]	[0.31]	[0.57]	
2	-1.70	0.64	-2.52	-15.54	5.32				0.87
Robust	[0.35]	[0.08]	[1.83]	[5.19]	[2.45]				
NW	[0.30]	[0.06]	[1.43]	[4.57]	[2.21]				
3	-0.74	0.84	-4.92	2.39	7.93	-8.61	-3.80	-1.53	0.65
Robust	[0.16]	[0.05]	[1.94]	[0.17]	[1.22]	[0.62]	[0.31]	[0.53]	
NW	[0.16]	[0.05]	[1.41]	[0.21]	[1.13]	[0.61]	[0.33]	[0.59]	
4	-1.00	0.63	-1.92	-14.78	5.44				0.86
Robust	[0.21]	[0.07]	[1.17]	[5.41]	[2.47]				
NW	[0.19]	[0.06]	[0.83]	[4.74]	[2.23]				
5	-0.25	0.76	-7.14	2.30	8.98	-9.19	-4.69	-1.88	0.64
Robust	[0.14]	[0.05]	[2.72]	[0.18]	[1.28]	[0.69]	[0.29]	[0.54]	
NW	[0.15]	[0.04]	[1.81]	[0.20]	[1.21]	[0.64]	[0.32]	[0.63]	
6	-0.75	0.56	-1.17	-14.48	4.54				0.86
Robust	[0.17]	[0.07]	[1.84]	[5.26]	[2.46]				
NW	[0.15]	[0.06]	[1.50]	[4.77]	[2.27]				

NOTE: Quarterly data, 1993.III - 2009.IV (time subscript t is in monthly units). The dependent variable is the total dollar volume of newly originated refinance loans in the state over a quarter relative to the total personal income in the state for the previous quarter (based on HMDA data).*Cycle* refers to the year-on-year growth in either the non-farm payroll employment index scaled by the state population (*Payroll*, specifications 1 - 2), State Coincident Economic Activity index in columns (*CEAI*, specifications 3 - 4), or the Total Personal Income (*TPI*, deflated using the CPI, specifications 5 - 6). HPI is the two-year growth rate of the state-level house price index. $C_t \times H_t$ is the orthogonalized interaction term, i.e. the residual from regressing the product of *Cycle* and HPI on a constant and both of these variables. WAC is weighted average coupon rate for conforming fixed-rate mortgages (equal-weighted average across FNMA and FHLMC loans) in a given state. $\bar{R}_t^i$ is the average coupon rate on all newly-originated conventional prime loans in the state over the quarter. Specifications 2, 4 and 6 have quarter fixed effects. Standard errors are in brackets (*Robust* are clustered by state, and *NW* are Newey-West with 20 lags).

The parameters in these preferences include the discount factor β, the coefficient of relative risk aversion γ, and,

$$\theta = \frac{1-\gamma}{1-\frac{1}{\psi}},$$

where ψ is the elasticity of intertemporal substitution (EIS). The parameter θ is an index of the deviation with respect to the benchmark CRRA utility function (when $\theta = 1$, the inverse of the EIS coincides with risk aversion as in the CRRA case).

Each household is endowed with one unit of labor supplied inelastically that receives an after-tax wage $(1-\tau)y_{it}$. The idiosyncratic income process is stochastic and will be key in the optimal behavior.

Households can save using a one-period liquid asset a_{it} that pays nominal short rate, denoted by r_t. The households are prevented from borrowing (except through their mortgages), that is $a_{it} \geq 0$ for all t. All variables are nominal, and the price level at time t is denoted by p_t. We assume the (gross) inflation rate is constant, defined as $p_{t+1}/p_t = \pi$.

House price We make the assumption that nominal house prices H_t have a component that grows at the same rate as the economy (i.e. nominal aggregate income), as well as a component that represents the aggregate risk inherent in the housing market's transitory deviations from the trend in aggregate income. Therefore, the house price is

$$H_t = p_t \; Y_t \; \bar{H} \; \tilde{h}_t, \tag{4}$$

where $\bar{H}$ is the house price level (in terms of the consumption good), and the shocks $\tilde{h}_t$ are assumed to be stationary, so that real house price level is cointegrated with real aggregate income.

Labor income The nominal income process y_{it} for household i has an aggregate component, Y_t, as well as an idiosyncratic component, $\tilde{y}_{it}$. That is,

$$y_{it} = p_t \; Y_t \; \tilde{y}_{it}, \tag{5}$$

The growth rate of the aggregate real income Y_t is $Z_{t+1} = Y_{t+1}/Y_t$. The idiosyncratic labor income component $\tilde{y}_{it}$ follow an autoregressive process with state-dependent conditional volatility, i.e., heteroscedastic innovations, given by,

$$\log \tilde{y}_{it} = \log \mu_y(Z_t) + \rho_y \log \tilde{y}_{i,t-1} + \sigma(Z_t)\epsilon^y_{it}, \quad \epsilon^y_{it} \sim \mathcal{N}(0,1). \tag{6}$$

The counter-cyclical nature of the idiosyncratic labor income risk is emphasized by Storesletten, Telmer, and Yaron (2004). We calibrate $\mu_y(Z_t)$ so that the cross-sectional mean of the idiosyncratic components of income $\tilde{y}_{it}$ implied by the stationary distribution equals to unity in every period: $\log \mu_y(Z) = -\frac{1}{2}\frac{\sigma^2(Z)}{1+\rho_y}$

Summary of exogenous shocks In total, there are four aggregate state variables, summarized in the aggregate state vector $S_t \equiv (r_t, Z_t, H_t, \pi_t)$. We assume that S_t follows a first-order vector autoregressive process (VAR) in logarithms:

$$\log S_{t+1} = \mu_S + \Phi_S \log S_t + \sqrt{\Sigma_S}\epsilon^S_{t+1}. \tag{7}$$

For an individual household, the vector of exogenous state variables, denoted by s_{it}, contains the individual labor income and the aggregate states: $s_{it} \equiv (y_{it}, S_t)$. We assume that all households bear the same aggregate risks since we focus on the "average" households that is likely to need to use home equity to smooth consumption (there is some evidence in the recent literature that wealthier households are disproportionately affected by aggregate fluctuations - e.g., Parker and Vissing-Jorgensen (2009)).

3.2 Mortgages

For simplicity, mortgages in this economy are assumed to be perpetual interest-only mortgages. Households have to meet a mortgage payment every period, defined as the (fixed) mortgage coupon rate k_{it} times the mortgage balance due on the house b_{it}. Note that the households can deduct the mortgage interest expense, which is the full mortgage payment for an interest-only mortgage, from their taxable income y_{it}.

We assume that each household is initially endowed with a mortgage balance of b_{i0}, a mortgage rate equal to k_{i0}, and a house of value H_0. In other words, each household is endowed with home equity equal to $H_0 - b_{i0}$, and has to pay a mortgage annuity payment equal to $k_{i0}b_{i0}$. Households are only allowed to borrow a fraction of the full value of their home, that is they face the following constraint in mortgage financing,

$$b_{i,t+1} \leq \xi \ H_t, \tag{8}$$

where $\xi \in [0, 1]$ is the parameter that controls the tightness of the *loan-to-value constraint* (LTV). In addition, there is also a *loan-to-income constraint* (LTI):

$$b_{i,t+1} \leq \kappa \ y_{i,t}, \tag{9}$$

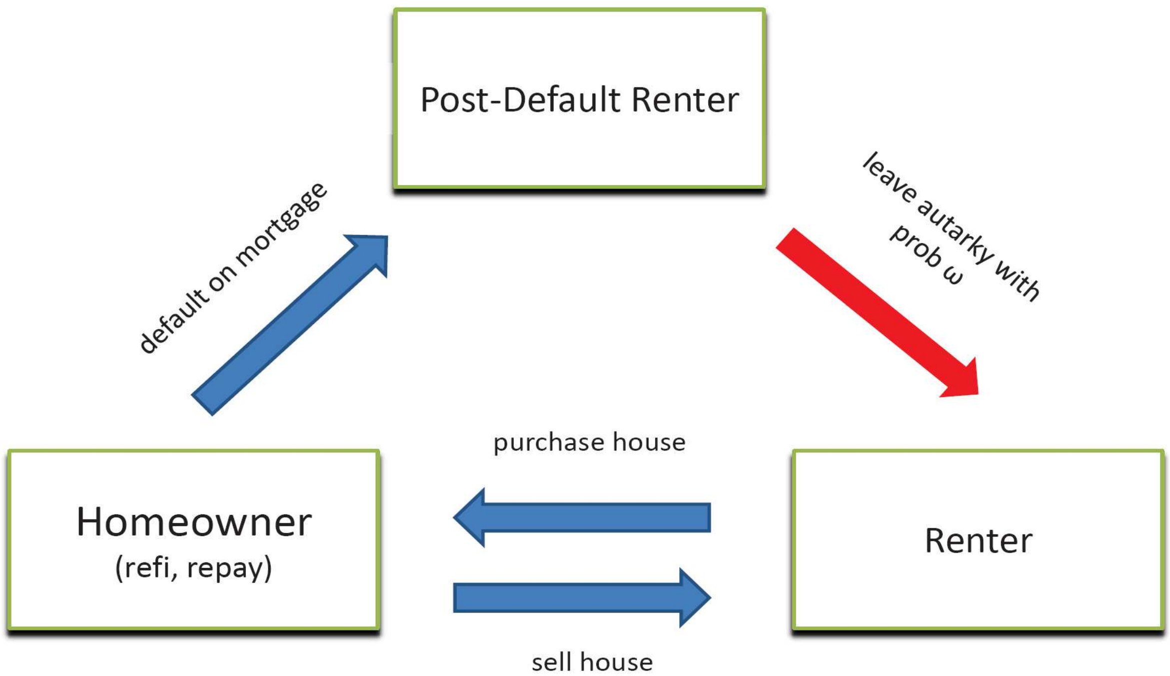

Figure 3: Home-owner, renter, and post-default renter diagram.

which mimics the debt-to-income constraint widely used in practice (there are no other forms of borrowing besides mortgage in our model).

As a home-owner, a household can choose to continue with the current mortgage by making the payments, repay part of the mortgage balance, sell the house at market value and become a renter, or simply default on the mortgage and rent. As a renter, a household can choose to remain a renter or buy a house.

Figure 3 shows a diagram that represents the households' homeownership decisions. This approach broadly follows Campbell and Cocco (2010) in the treatment of the homeownership and default decision.

Repayment Households can always repay their mortgage by reducing the outstanding loan balance on their home, that is when $b_{i,t+1} < b_{it}$. The repayment decision is denoted by the indicator $I_{it}^{RP} = 1$ if home loan balance is reduced and $I_{it}^{RP} = 0$ otherwise.

Refinancing Households also have the option to refinance their homes by increasing or reducing the outstanding loan balance, that is when $b_{i,t+1} \neq b_{it}$. The refinancing decision is denoted by the indicator $I_{it}^{RF} = 1$ if the home loan is refinanced and $I_{it}^{RF} = 0$ otherwise. When households decide to refinance, they will incur a cost captured by the function ϕ. For example, if a household "pulls out" an amount $(b_{i,t+1} - b_{it})$ from their home equity, they will incur a refinancing cost equal to $\phi(b_{i,t+1})$. Therefore the net proceeds from refinancing will in fact be equal to $b_{i,t+1} - b_{it} - \phi(b_{i,t+1})$, which is the loan increase/decrease net of refinancing cost. These refinancing costs can be thought of the time cost spent on the refinancing process, as well as direct finance fees associated with issuing a new mortgage. In this paper, we assume that refinancing costs have a fixed and proportional component.

When a household refinances, the old outstanding mortgage b_{it} is repaid in full using the proceeds of the new mortgage and the available assets. The new home loan is $b_{i,t+1}$, which is subject to both the loan-to-value (8) and loan-to-income (9) constraints, and the new mortgage coupon rate $k_{i,t+1}$ that is used to calculate future annuity payments is equal to the mortgage rate available to the household $R(S_t)$. Therefore by refinancing a household commits to repay an infinite stream of constant annuity payments equal to $R(S_t)b_{i,t+1}$, unless the mortgage is refinanced again in the future. The dynamics of the mortgage rate k_{it} will be

$$k_{i,t+1} = k_{it}\ (1 - I_{it}^{RF}) + R(S_t)\ I_{it}^{RF}. \tag{10}$$

Households can choose to merely pay their mortgage and neither refinance nor repay their home loan. This decision is denoted by the indicator $I_{it}^{NR} = 1$ if home loan and the mortgage rate are unchanged, and $I_{it}^{NR} = 0$ otherwise.

Default Home-owners have the option to default on their mortgages and become a renter. When a household defaults on its mortgage obligation b, its home is ceased, as well as a portion of its liquid assets, so that the household is left with ζa in liquid wealth. Thus, the parameter ζ could be seen as a way to capture full or partial recourse as well as other costs of default, such as their effect on credit history, in reduced form. Furthermore, the household that defaulted on its mortgage will be excluded from the housing market for a stochastic period of time. With probability ω each period, it will regain eligibility for becoming a home-owner, at which point the household can choose to buy or remain a renter.

Renting As a renter, a household must pay rent every period. For tractability, we assume that households will allocate a constant fraction of their consumption toward that rent expense every period.

In addition, we assume that households suffer a utility loss of not being home-owners. This simply states that households will prefer, all else equal, to live in a house they own rather than rent, and that a higher rent will afford a higher quality home, which in turn lower the loss of utility of renting versus owning.

3.3 Household Recursive Problem

In order to simplify notation, we drop subscripts t and use primes to denote next period variables. The problem for household i is to choose consumption c_i, the position in the liquid asset a_i', and whether to refinance I_i^{RF}, repay early I_i^{RP} (yielding new mortgage balance b_i'), or default on the mortgage, so as to maximize the expected lifetime utility of real consumption.

3.3.1 Home-owner Problem

As a home-owner, a household chooses consumption and stock of liquid assets, but also has access to borrowing against his house. The household problem in the home-owner state can be formalized as follows,

$$U_i^h = \max_{a_i', b_i', I_i^{RF}} \left[(1-\beta)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta \mathbb{E} \left[\max \left(U_i^{h'}, U_i^{hr'}, U_i^{hd'} \right)^{1-\gamma} \right]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}},$$

subject to

$$\begin{aligned}
c_i + \frac{a_i'}{1+(1-\tau)r} + b_i &= (1-\tau)(y_i - k_i b_i) + a_i + b_i' - \phi(b_i')\ I_i^{RF}, && \text{(11a)} \\
k_i' &= k_i\ (1 - I_i^{RF}) + R\ I_i^{RF}, && \text{(11b)} \\
(b_i' - b_i)\ (1 - I_i^{RF}) &\leq 0, && \text{(11c)} \\
(b_i' - \xi\ H)\ I_i^{RF} &\leq 0, && \text{(11d)} \\
(b_i' - \kappa\ y_i)\ I_i^{RF} &\leq 0, && \text{(11e)} \\
a_i', c_i, b_i' &\geq 0. && \text{(11f)}
\end{aligned}$$

where we denote the value function of the household in the home-owner state by $U_i^h(a_i, b_i, k_i, s_i)$, by $U_i^{hr}(a_i, b_i, k_i, s_i)$ in a state of transition from home-owner to renter by selling the home, and by $U_i^{hd}(a_i, b_i, k_i, s_i)$ in a state of transition from home-owner to renter by defaulting on the mortgage.

We assume that the cost of refinancing is the sum of a fixed component and a proportional component. However, given that the economy is growing over time, the fixed cost of refinancing is assumed to be scaled with the nominal growth rate in the economy, that is, we assume the following functional form,

$$\phi(b_i') = pY\phi_0 + \phi_1 b_i'. \tag{12}$$

Home-owners have the option to sell their home at any time. When they do so, they repay the outstanding mortgage –including current mortgage coupon payment– using the proceeds, minus the transaction cost ϕ_2, and their stock of liquid assets. As a result, they become renters with savings equal to $H(1-\phi_2) - (1+(1-\tau)k)b + a$. The transition problem for the household from the home-owner to the renter state by selling its home is given by,

$$U_i^{hr}(a_i, b_i, k_i, s_i) = \max_{a_i'} \quad \left[(1-\beta)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta \mathbb{E}\left[U_i^r(a_i', s_i')^{1-\gamma}\right]^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}, \tag{13}$$

subject to

$$c_i + \frac{a_i'}{1+(1-\tau)r} \quad = \quad (1-\tau)(y_i - k_i b_i) + a_i + H(1-\phi_2) - b_i, \tag{14a}$$

$$a_i', c_i \quad \geq \quad 0. \tag{14b}$$

The transition problem for the household from the home-owner to the renter state by defaulting on its mortgage is given by,

$$U_i^{hd}(a_i, b_i, k_i, s_i) = \max_{a_i'} \quad \left[(1-\beta)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta \mathbb{E}\left[U_i^d(a_i', s_i')^{1-\gamma}\right]^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}, \tag{15}$$

subject to

$$c_i + \frac{a_i'}{1+(1-\tau)r} \quad = \quad (1-\tau)y_i + \zeta a_i, \tag{16a}$$

$$a_i', c_i \quad \geq \quad 0. \tag{16b}$$

3.3.2 Renter Problem

The value function of the household in the renter state (after selling a house, without being excluded from accessing home-ownership) is denoted by $U_i^r(a_i, s_i)$. The household problem in the renter state is given by,

$$U_i^r(a_i, s_i) = \max_{a_i'} \quad \left[(1-\beta)(1+\alpha)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta \mathbb{E}\left[\max\left(U_i^{rh}(a_i', s_i'), U_i^r(a_i', s_i')\right)^{1-\gamma}\right]^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}, \quad (17)$$

subject to the positivity of consumption and liquid wealth, and

$$c_i = \frac{1}{1+\eta}\left[(1-\tau)y_i + a_i - \frac{a_i'}{1+(1-\tau)r}\right]. \quad (18)$$

The parameter α governs the utility loss of renting (compared to owning). The parameter η determines the fraction of total expenditure used as rent. Specifically, we assume that rent expense each period is equal to a share $\eta/(1+\eta)$ of the per period expenditure, and so, conversely, consumption is a share $1/(1+\eta)$ of the per period expenditure.

The value function of the household in transition between the renter state and the home-owner state is denoted by $U_i^{rh}(a_i, s_i)$. The transition problem for the household from the renter to the home-owner state is,

$$U_i^{rh}(a_i, s_i) = \max_{a_i', b_i'} \quad \left[(1-\beta)(1+\alpha)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta\ \mathbb{E}\left[U_i^h(a_i', b_i', R, s_i')^{1-\gamma}\right]^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}, \quad (19)$$

subject to

$$c_i = \frac{1}{1+\eta}\left[(1-\tau)y_i + a_i - \frac{a_i'}{1+(1-\tau)r} + b_i' - (pY\phi_0 + \phi_1 b_i') - H(1-\phi_2)\right], \quad (20a)$$

$$b_i' \leq \xi\ H, \quad (20b)$$

$$b_i' \leq \kappa\ y_i, \quad (20c)$$

$$a_i', c_i, b_i' \geq 0. \quad (20d)$$

3.3.3 Post Default Renter Problem

The value function of the household in the renter state (after defaulting on the mortgage) is denoted by $U_i^d(a_i, s_i)$. The household problem in the post default renter state is given by,

$$U_i^d(a_i, s_i) = \max_{a_i'} \Bigg[(1-\beta)(1+\alpha)(c_i/p)^{\frac{1-\gamma}{\theta}} + \beta\mathbb{E}\left[(1-\omega)\left(U_i^d(a_i', s_i')\right)^{1-\gamma}\right]^{\frac{1}{\theta}} + \beta\mathbb{E}\left[\omega \max\left(U_i^{rh}(a_i', s_i'), U_i^r(a_i', s_i')\right)^{1-\gamma}\right]^{\frac{1}{\theta}}\Bigg]^{\frac{\theta}{1-\gamma}}, \tag{21}$$

subject to the positivity of consumption and liquid wealth, as well as the renter budget constraint (18).

3.4 Stationary Reformulation of the Household Recursive Problem

Given that households have recursive preferences, we can rescale the problem with respect to the price level p_t and the permanent aggregate income Y_t in order to make it stationary. We can rescale the variables, as well as the state vector such that the rescaled household problem is stationary. The algebraic details are given in the Appendix.

3.5 Household Optimal Policies

The optimal policies for liquid asset holdings, home loan, and mortgage rate are denoted by $a_i' = g_{i,a}(a, b, k, s)$, $b_i' = g_{i,b}(a, b, k, s)$, and $k_i' = g_{i,k}(a, b, k, s)$. In addition, the discrete refinancing policy is denoted by $I_i^{RF} = g_{i,RF}(a, b, k, s)$. The optimal repayment policy denoted by $I_i^{RP} = g_{i,RP}(a, b, k, s)$ can be constructed out of the optimal loan and refinancing policies,

$$I_i^{RP} = \mathbb{I}_{b_i' \neq b_i}\ (1 - I_i^{RF}).$$

Similarly the optimal no refinancing/repayment policy denoted by $I_i^{NR} = g_{i,NR}(a, b, k, s)$ can be constructed out of the optimal refinancing and repayment policies,

$$I_i^{NR} = 1 - I_i^{RP} - I_i^{RF}.$$

3.6 Simulations

The household problem is solved numerically and simulated data are generated using the optimal policies. We use a cross section of $N = 5,000$ households and compute the aggregate quantities defined in Section 3.7 along the time path of $T = 2,000$ (annual) periods.

Our simulation strategy is as follows. We start the simulations by randomly drawing pairs of liquid assets a_i and mortgage balance b_i over the state space for all N households in the cross section. Each period, besides simulating the exogenous state variables, we also simulate post-default renters' re-entry into mortgage markets (with probability ω). Then, we replicate the regressions that we ran in the data by running a number of regressions of the aggregate refinancing rate $REFI_t$ on the rates R_t, r_t, the macroeconomic growth rate Z_t, and the house price H_t. The benchmark calibration features a baseline level of stochastic volatility of income shocks.

3.7 Key Endogenous Aggregate Variables

For the purposes of analyzing the aggregate implications of households' optimal mortgage choices, we consider a cross-section of N households that follow optimal policies. The households are ex ante identical and are subject to an identical time series of aggregate shocks, that is all households face the same interest rates and macroeconomic shocks in the economy. However households are subject to different realizations of their idiosyncratic income shocks over time. We are interested in the behavior of aggregated household variables along the paths of aggregate state vector S_t. The consumption and financial policies of interest are given by,

$$\begin{aligned}
\text{Aggregate consumption: } C_t &= \frac{1}{N}\sum_{i=1}^{N} c_{it}, \\
\text{Aggregate liquid assets: } A_t &= \frac{1}{N}\sum_{i=1}^{N} a_{it}, \\
\text{Aggregate mortgage balance: } B_t &= \frac{1}{N}\sum_{i=1}^{N} b_{it}, \\
\text{Average mortgage coupon rate: } K_t &= \frac{1}{N}\sum_{i=1}^{N} k_{it}, \\
\text{Weighted average loan age: } WALA_t &= \frac{\sum_{i=1}^{N} b_{it} n_i}{\sum_{i=1}^{N} b_{it}},
\end{aligned}$$

where n_i is the number of periods since household i's current loan was originated.

The refinancing and cash-out policies of interest are defined as follows:

$$\begin{aligned}
\text{Aggregate refinancing rate: } REFI_t &= \frac{1}{N}\sum_{i=1}^{N} I_{it}^{RF}, \\
\text{Conditional dollar refinancing: } REFI_t^{\$} &= \frac{\sum_{i=1}^{N} b_{it+1} I_{it}^{RF}}{\sum_{i=1}^{N} I_{it}^{RF}}, \\
\text{Conditional dollar cash-out: } CASHOUT_t^{\$} &= \frac{\sum_{i=1}^{N} (b_{it+1} - b_{it}) I_{it}^{RF}}{\sum_{i=1}^{N} I_{it}^{RF}}.
\end{aligned}$$

The aggregate repayment behavior - i.e. the pay-down of mortgage balances - is defined as follows:

$$\begin{aligned}
\text{Aggregate repayment rate: } REP_t &= \frac{1}{N}\sum_{i=1}^{N} I_{it}^{RP}, \\
\text{Conditional dollar repayment: } REP_t^{\$} &= \frac{\sum_{i=1}^{N} (b_{it} - b_{it+1}) I_{it}^{RP}}{\sum_{i=1}^{N} I_{it}^{RP}}.
\end{aligned}$$

Finally, we are interested in the conditional prepayment rate:

$$\text{Conditional prepayment rate: } CPR_t = \frac{\sum_{i=1}^{N} \left((b_{it+1} - b_{it})\ I_{it}^{RP} + b_{it}\ I_{it}^{RF}\right)}{\sum_{i=1}^{N}\ b_{it}}.$$

4 Quantitative Results

This section describes the implications of the model in Section 3. To solve the model, we discretize the state space and apply standard numerical dynamic programming and then simulate the optimal policies for a large panel of households. We explain the choice of the key parameters of the model and characterize the solution.

4.1 Calibration

We calibrate the model in three steps. First, we specify the dynamics of the exogenous state variables based on empirical estimates. Second, we set the institutional parameters to broadly represent the environment faced by U.S. households. Third, we estimate the preference and transaction cost parameters to match the key moments of the data on household assets and mortgage refinancing.

4.1.1 Exogenous states

The model is calibrated at the yearly frequency. Therefore, we estimate a VAR(1) for the aggregate state variables using annual data:

$$\log S_{t+1} = \mu_S + \Phi_S \log S_t + \sqrt{\Sigma_S}\epsilon^S_{t+1}. \tag{22}$$

The variables we use are the U.S. GDP growth rate adjusted for CPI inflation (our proxy for the real growth variable Z in the model), the one-year Treasury bill rate as the nominal short rate r_t, and demeaned log house price-GDP ratio computed using the S&P Case-Shiller house price index (HPI) deflated using the CPI. The macroeconomic variables used - the CPI, the real GDP, the real HPI, and the HPI/GDP ratio are plotted in Figure 4. The last variable captures the notion of highly persistent but transitory deviations of house prices from the trend of real economic growth represented in the model by the state variable $\tilde{h}$. Given the relatively smooth evolution of inflation over the sample period we simplify the model and assume a constant inflation rate $\pi - 2.85$ percent per annum, thus excluding it from the state vector.

The descriptive statistics for these variables (as well as the 30-year conforming mortgage rate – our empirical proxy for R) and the estimated parameters of the VAR are reported in Table 5. We then approximate the VAR with a discrete-state Markov chain using the method of Tauchen and Hussey (1991)[7]. Overall the aggregate state is discretized using a total of 200 grid points.

The choice of the long-run mean of the ratio of house price to income $\bar{H} = 4$ is based on estimates obtained using micro data (in the Survey of Consumer Finances for 2001, a year when the house price to GDP ratio is close to its long-run mean, the average ratio of housing assets to income among homeowners with positive income equals approximately 3.95).

For tractability, we specify the mortgage rate R as an exogenous function of all the aggregate state variables. We choose the following specification,

$$\log R(S) = \kappa_0 + \kappa_1' \log S + \kappa_2 \log \tilde{h}_t^2. \tag{23}$$

[7]The real growth rate of the economy Z and the short rate r are both discretized using 5 grid points. The house price process $\tilde{h}$ is discretized using 8 grid points. Finally the inflation rate process π is represented by using a single point.

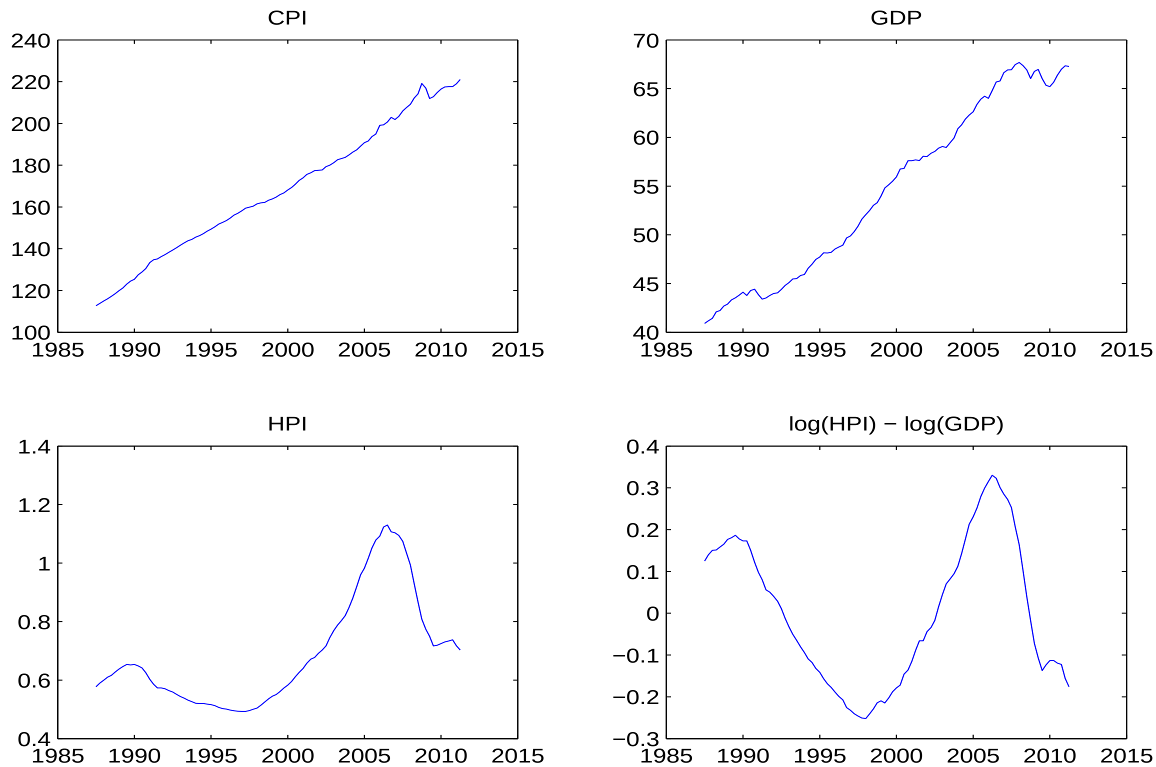

Figure 4: Inflation, real growth, and real house prices

Panel C of Table 5 reports the regression estimates of the coefficients of this relation using the empirical proxies for the state vector S and the mortgage rate R, with the corresponding standard errors. While only the constant and the interest-rate sensitivity are statistically significantly different from zero, we use all of the estimated coefficients in order to capture as much of potential comovement of the mortgage rate with the macroeconomic variables as possible.

The idiosyncratic component of the income process $\tilde{y}_{it}$ is discretized as a Markov chain with 32 grid points. The conditional volatility depends on whether the economy is in the good or bad state, that is we choose a two-state representation of the macroeconomic conditions, following Storesletten, Telmer, and Yaron (2007). We use volatility parameters that are on the higher end of their estimates in order to emphasize the effect of heteroscedasticity on refinancing. In our benchmark calibration, the conditional volatility of the log idiosyncratic income component in the good states (when Z is at the highest growth level) is $\sigma(Z_G) = 12\%$, whereas in the bad state (when Z is at the lowest growth level), the conditional volatility is high $\sigma(Z_B) = 21\%$. The autocorrelation parameter $\rho_y = 0.95$, consistently with estimates in Storesletten, Telmer, and Yaron (2007).

Table 5: Aggregate State Variables

Panel A: Descriptive Statistics

	GDP	HPI/GDP	r_t	R
Mean	1.893	0.000	4.414	7.308
Std	2.420	17.310	2.272	1.605
Autocorrelation	0.419	0.866	0.724	0.828
correlations:				
GDP		-0.153	0.064	0.060
HPI/GDP			0.104	0.089
r				0.892

Panel B: VAR Parameters

	μ	Φ_s			$\Sigma_s \times 10^{-3}$		
GDP	0.019	0.379	-0.051	-0.166	0.365	0.498	0.014
HPI/GDP	0.009	1.240	0.920	-0.921	0.498	4.884	0.197
r	0.000	0.306	0.008	0.809	0.014	0.197	0.125

Panel C: Mortgage Rate Parameters

κ_0	κ				R^2
	Z	h	r	h^2	
0.049	0.094	0.011	0.684	-0.270	0.949
(0.001)	(0.023)	(0.004)	(0.025)	(0.022)	

Table 8 summarizes both the exogenously set and the calibrated parameters other than those driving the aggregate state variables described above.

4.1.2 Institutional parameters

We follow Campbell and Cocco (2010) in specifying the main institutions features of the U.S. environment: income tax rate $\tau = 25\%$, housing collateral constraint for new mortgage loans such that loan-to-value ratio does not exceed $\xi = 80\%$, and the period of exclusion from debt markets for households who defaulted on a mortgage loan to be on average 7 years, represented in the model by the probability of return to credit markets after one year equal to $\omega = 0.15$. We deviate from them in allowing a monetary punishment upon default that is meant to capture both partial recourse and reputational costs by setting $\zeta = 50\%$ (i.e. households lose half of liquid assets upon default).

Table 6: Summary Statistics.

	Data	Model
Consumption and Financial Policies:		
Avg. Consumption to Income c/pY	0.66	0.56
Median Liquid Asset Holdings to Income a/pY	0.10	0.30
Median Mortgage Balance to Income b/pY	0.79	0.96
Refinancing:		
$REFI$	8.01%	18.2%
Conditional \$ $REFI$ to Income	1.90	1.25
Conditional \$ Cash-out to Income	0.22	0.33
Percentage of Home-owners	60%	57%

NOTE: Summary statistics of the simulated data, for different model specifications.

This parameter does not play a large role quantitatively, given that even under no recourse few households with substantial assets default in the model. All of these parameters are also reported in Table 8.

4.1.3 Calibrated parameters

We calibrate preference and transaction cost parameters by targeting 6 moments of the data: aggregate ratio of nondurable and non-housing services consumption to income (from NIPA), average ratio of liquid assets holdings to income and the average ratio of household debt to income (both based on 2001 SCF), the average number of refinance loans relative to the number homeowner households (based on HMDA and Census data) as well as the average loan-to-income and cashout-to-income ratios upon refinancing (from HMDA and Freddie Mac). Table 6 reports both the target empirical moments and the simulated moments from the benchmark model.

Given the non-linearity in the model, we cannot match all of the moments exactly. Average ratio of consumption to income at around 0.56 is somewhat lower than the 0.69 in the NIPA data (using both nondurable and durable goods expenditures, as well as non-housing services). The key tension in the model is between accumulating liquid assets for precautionary reasons and paying down debt, while borrowing to smooth consumption when liquid assets are insufficient. The model can match either the high average level of liquid assets or average level of debt, but not both simultaneously. This is due to the fact that the U.S. wealth distribution is highly skewed and so its mean is much higher than the median (1.33 vs. 0.10, according to the 2001 SCF). Since in our model households only differ in realizations of transitory variables, we cannot match the degree of inequality observed in the data. Consequently, we target the medians of both liquid asset holdings and debt balances.

In the model, the mortgage rates are higher than the subjective rate of time preference, so that mortgages are a costly form of borrowing and households prefer to pay down their balances. Still, the balances are repaid slowly enough that on average mortgage debt is a fraction 0.97 of household income, between the average ratio of household debt to income in 2001 SCF at 1.12 and the median of 0.79 .

The preference parameters implied by these moments are the subjective discount factor $\beta = 0.935$, the coefficient of relative risk aversion $\gamma = 2$, as well as the IES $\psi = 0.25$ a substantial unwillingness to substitute consumption intertemporally, while parameter $\alpha = 1.8$ implies that roughly two thirds of renter's consumption expenditures are related to housing services.

Households use debt primarily as a way of smoothing consumption, as well as a way of financing new home purchases. Existing debt balances are refinanced either to reduce the coupon rate k, or to cash-out equity for consumption purposes. The quasi-fixed and proportional costs of refinancing are identified by targeting empirically reasonable average refinancing rates, in terms of both frequency and loan size. Anecdotal evidence suggests that explicit costs of roughly $2\% - 5\%$ of loan amount are paid when refinancing a mortgage loan of average size, in addition to non-pecuniary information processing costs and the opportunity cost of time required to process the transaction. In the model we obtain a quasi-fixed cost of 6% of average permanent income and a proportional cost of 3% (which is comparable to the costs calibrated by Campbell and Cocco (2003)).[8]

These costs imply refinancing rates of about 13% (loans per year), compared to roughly 8% per year in the data (the latter number is based on the average number of refinance loans originated per year according to HMDA data, relative to the number of homeowner households according to the U.S. Census). The average ratio of new refinance loan size to income is very close to the empirical average of about 1.9. The average ratio of loan size to house value on refinance loans is 0.35 (its analog in the data is around 0.7). The weighted average loan age of 2.5 years is close to but lower that that in the data for agency pools (around 3.3 years), suggesting that the mortgage repayment

[8]Empirically the bulk of explicit cost of refinancing can be attributed to title insurance, which is proportional to house value, where as the non-monetary costs such as the opportunity cost of time spend searching for an attractive mortgage rate and preparing the necessary documents are likely quasi-fixed.

Table 7: Parameter Values

	Parameter	Value	Description
			Exogenous
Dynamics	ρ_y	0.95	Autocorrelation of y
	$\sigma(Z_B)$	0.21	Volatility of y for Z^B
	$\sigma(Z_G)$	0.12	Volatility of y for Z^G
	π	0.0285	Inflation rate
Institutions	τ	0.25	Income tax rate
	$\bar{H}$	4	House price relative to income, average
	ξ	0.80	Housing collateral constraint
	κ	3.50	Loan-to-income constraint
	ω	0.15	Probability of return to credit market after default
	ζ	0.50	1-ζ = confiscation rate of liquid assets upon default
			Estimated
Preferences	β	0.935	Subjective discount rate
	γ	2.0	Risk aversion
	ψ	0.25	Intertemporal elasticity of substitution
	η	1.80	$\eta/(1+\eta)$ = share of rental expense in consumption
Transaction costs	ϕ_0	0.001	Fixed cost of issuing new mortgage
	ϕ_1	0.01	Proportional cost of issuing new mortgage
	ϕ_2	0.75	Proportional cost of buying/selling a house

NOTE: The model is calibrated at the yearly frequency.

and refinancing occur in the model at empirically reasonable rates, but somewhat faster than in the data (the slightly lower average mortgage coupon rate paid by the households relative to the data is consistent with this).

On average, cash-outs equal to 33% of annual income, compared to 22% in the data, respectively. Estimates from the data are based on the average cash-out share of refinance originations for prime, conventional loans, as provided by Freddie Mac, and average loan-to-income data available from HMDA. To the extent that these estimates are representative of the U.S. homeowners, the model predicts too much cash-out as well as levels of mortgage balances that are too low.

The model does a reasonable job matching the level of liquid assets that households carry in the data. The level of liquid assets reflects the precautionary motive generated by non-diversifiable idiosyncratic labor income risk and the frictions in the credit market. In a riskier world, households will tend to accumulate more cash on hand as a buffer stock in order to self-insure against adverse idiosyncratic labor income shocks, especially when it is costly/difficult to borrow (against the house collateral, since we have ruled out uncollateralized lending). Given the spread between the borrowing and lending rates, carrying both cash balances and mortgage debt is costly, and therefore a stronger precautionary saving motive implies that households keep lower mortgage balances by repaying their debt more quickly, which is what the benchmark model shows in Table 6. The strength of the precautionary saving motive is therefore key for understanding quantitative features of the model, in the sense that it determines the ex-ante behavior of mortgage borrowers.

Note that there is tension in simultaneously matching the average magnitudes of household indebtedness and liquid asset holdings. For example, higher coefficients of risk aversion raises liquid asset holdings by strengthening the precautionary motive, but only at the expense of reducing mortgage borrowing dramatically (albeit still producing empirically reasonable dollar share of cash-out). It is likely that adding life-cycle to the model would help reconcile the averages of asset holdings and debt levels, potentially with the help from preferences in which bequests have luxury-good properties (e.g. Carroll (2000), DeNardi (2004), Roussanov (2010)).

4.2 Benchmark model: income shocks only

Before examining the full model, we first study a special case of the model with only income shocks (by turning off shocks to interest rates, house prices, and inflation). Effectively, this is a model of incomplete markets and heteroscedastic idiosyncratic labor income risk, with the added effect of dynamic household leverage decisions. Thus this is the closest our setting comes to the classic Bewley (1977) model, the key difference being the addition of borrowing against housing collateral subject to transaction costs and partial insurance via state-contingent default. Because there are no fluctuations in the mortgage rates in this case, the only reason for households to refinance in this model is to extract home equity. Thus, this model enables us to focus solely on the part of refinancing activities driven by consumption smoothing motives.

Table 8 reports the results. Panel A reports some of the key moments for the model. In the baseline case of the benchmark model, there is heteroscedasticity in idiosyncratic labor income, and the loan-to-income constraint is imposed. The model does a reasonable job in matching both the volatility of aggregate consumption growth as well as the average volatility of individual consumption growth. In particular, the 14.2% volatility of individual consumption growth is lower

Table 8: Benchmark model

A. Moments

	Data	Baseline	Homoscedastic	No LTI
Aggregate consumption volatility	2.0%	3.3%	2.5%	3.3%
Individual consumption volatility	12.0%	14.2%	15.1%	13.6%
Liquid Asset Holdings to Income	0.23	0.52	0.40	0.38
Mortgage Balance to Income	0.79	0.92	1.11	1.07
$REFI$	8%	7.5%	7.8%	10.6%
Conditional \$ $REFI$ to Income	1.90	1.82	1.97	1.89
Percentage of Home-owner	60%	67%	62%	81%

B. Cyclicality of Refinancing

	Baseline		Homoscedastic		No LTI	
	Z	R^2	Z	R^2	Z	R^2
$REFI$	-0.12	0.02	0.26	0.19	0.42	0.31
$DOLLAR\ REFI/INCOME$	-1.47	0.30	-0.09	0.00	0.64	0.17
$CASHOUT/INCOME$	-1.19	0.58	-0.43	0.20	-0.04	0.01

compared to the volatility of individual income growth of 17.5% on average, which is the result of consumption smoothing. The model-implied liquid asset holding is 0.52, and the mortgage balance-to-income ratio is 0.92. In the data, the median liquid asset-to-income ratio is , while the median mortgage-balance-to-income ratio is 0.79. Finally, the model also generates reasonable refinancing rate ($REFI$ is the fraction of the households taking a refinance loan in a given period) and the average loan-to-income ratio upon refinancing (\$ $REFI$ to Income).

Panel B shows how refinancing and especially cash-out varies with the aggregate state, as captured by the aggregate income growth Z. In a regression of cashout-income ratio on the aggregate income growth, the coefficient is -1.19, and the R^2 is 58%. Both the refinancing rates and refi loan-to-income ratios also appear to be countercyclical.

To understand what drives the countercyclical cashout behavior, we conduct two comparative statics. First, we turn off the feature of heteroscedastic idiosyncratic labor income risk. Second, we remove the loan-to-income constraint.

As Panel A shows, while aggregate consumption volatility drops in the case of homoscedastic idiosyncratic labor income risk, individual consumption volatility actually rises. Moreover, households now hold less wealth in liquid assets (the liquid asset-to-income ratio drops to 0.4) and higher mortgage balances. Both changes are consistent with the nonlinear effect of heteroscedastic idiosyncratic labor income risk: the effect of higher idiosyncratic risk in the bad aggregate state on the precautionary savings motive of households dominates the effect of the lower idiosyncratic risk in the good state. As a result, the homoscedastic economy appears safer, which leads to lower savings and higher leverage. Similarly, when the loan-to-income constraint is removed, households can more easily borrow against their house to smooth consumption. This also results in lower individual consumption volatility, lower cash holdings, and higher mortgage balances.

While the cashout-to-income ratio is still countercyclical in the homoscedastic economy, refi rates becomes procyclical. The change in cyclicality of refinancing is even more pronounced when the loan-to-income constraint is removed. To understand these results, we need to examine the two separate channels of consumption smoothing. On the one hand, households expect higher income growth to persist in the good state. With incomplete markets, the only way to borrow against higher income in the future is through cashout. This part of refinancing is procyclical and helps facilitate consumption smoothing across time. On the other hand, idiosyncratic labor income risk rises in bad times. Thus, more households are likely to experience large drops in income and will cash out if they have sufficient home equity. This part of refinancing is countercyclical and helps facilitate consumption smoothing across states with different economic conditions. When heteroscedastic labor income risk is removed, the procyclical refi component dominates, which is why refinancing turns positive in that case.

In addition, there is also a “preemptive refinancing” motive at work. Due to the loan-to-income constraint, households with low income might be prevented from borrowing even if they have positive home equity. Thus, when facing high labor income risk, households will cash out in advance and hold onto the proceeds as cash to avoid being shut out of the credit market when negative income shock realizes. This “preemptive refinancing” is also countercyclical. In fact, by comparing the results in the economy with no LTI constraint with the homoscedastic economy, we can see that the effect of “preemptive refinancing” is quite strong.

Figure 5 plots the simulated empirical distributions of economy-wide aggregate cash-out (relative to aggregate income) conditional on the two states of the baseline economy: (G = high growth and B = low growth). These distributions are quite different: in bad aggregate state the aggregate cashout is higher. It is greater on average (about 9% of aggregate income vs. 5% on average in good states), and is more highly dispersed. In particular, the right tail of the distribution is heav-

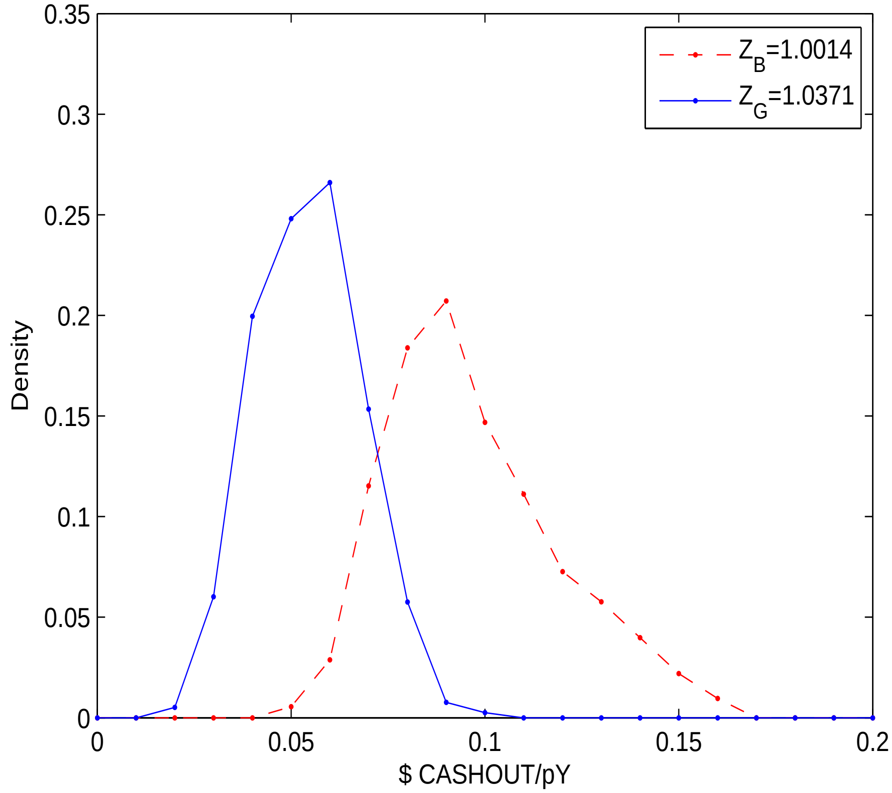

Figure 5: The figure plots the distributions of aggregate cash-out, relative to aggregate income, conditional on the good and bad realizations of the aggregate income growth rate Z.

ier in the bad states, with over 5% of the mass having average cash-out above 13% of aggregate income. Heteroscedastic income process implies that in bad aggregate states the probability of particularly low innovations of individual income are not uncommon, causing a substantial fraction of households to resort to extracting home equity for consumption purposes.

4.2.1 Behavior in the Cross-Section

In order to understand the refinancing behavior in the aggregate, it is important to understand the refinancing and repayment behavior at the household level. To accomplish this, we need to understand which households refinance and repay their mortgage. Because all households are ex-ante identical, they differ by their history of shocks, which in turn affect their level of liquid assets and mortgage balance. We use the simulated data to compute average refinancing and repayment rates, as well as the dollar amounts, across two dimensions: (i) level of period income relative to

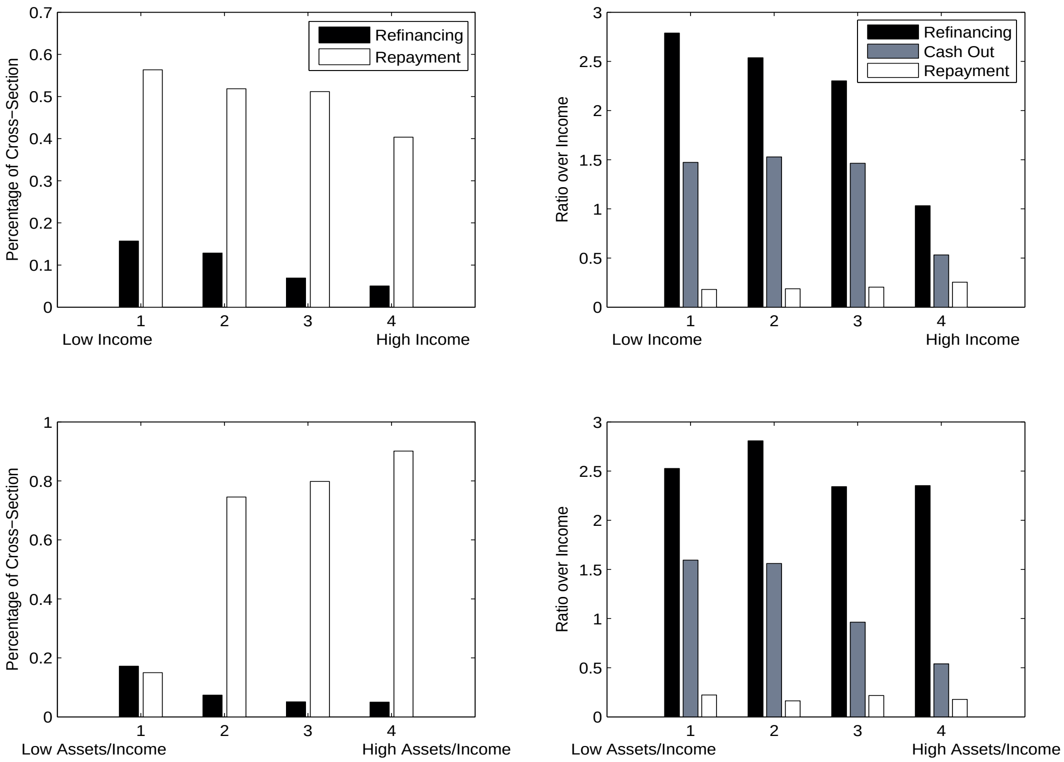

Figure 6: Refinancing and repayment rates (on the left panels), and dollar refinancing, cashout and repayment (on the right panels).

aggregate income (y_i/pY), and (ii) liquid assets to income ratio (a_i/pY).

Figure 6 plots averages by households sorted and grouped into four bins. The upper panel shows the results for the sort over income, while the lower panel shows the results for the sort over liquid assets. It is clear from these graphs that the households who refinance are those who experience very low income and have very low level of liquid assets. In contrast, households repay their mortgage at a higher rate when they are achieve high levels of income. Similarly households repay higher dollar amounts when their have higher stock of liquid assets. All of these qualitative results are consistent with the consumption smoothing motive: households repay their costly mortgage balance in good times -high level of income and assets- and refinance to pull out home equity in order to increase consumption in bad times -low level of income and assets.

Table 9: Full model

Model Specification	Data	(1) Baseline	(2) Homo.	(3) Higher σ_B	(4) No LTI	(5) 125% LTV
Consumption and Financial Policies:						
Consumption to Income c/pY	0.66	0.56	0.56	0.64	0.59	0.67
Income Growth $\sigma(\Delta \log y)$		18.0%	17.6%	23.9%	17.4%	17.6%
Consumption Growth $\sigma(\Delta \log c)$		18.0%	17.7%	20.5%	16.7%	18.4%
Liquid Assets to Income a/pY	0.10	0.30	0.29	0.44	0.26	0.35
Mortgage Balance to Income b/pY	0.79	0.96	1.03	0.41	1.60	1.02
WALA (years)	3.37	5.43	6.60	12.62	2.90	3.35
Refinancing:						
% of loans $REFI$	8.01%	18.22%	18.75%	14.44%	21.65%	25.63%
\$ $REFI$ to Income	1.90	1.25	1.30	0.80	1.98	1.30
\$ Cash-out to Income	0.22	0.33	0.33	0.26	0.44	0.35
Repayment:						
% of loans $REPAY$		26.97%	28.95%	12.13%	38.16%	39.50%
Conditional \$ $REPAY$ to Income		0.12	0.11	0.23	0.11	0.12
Ownership Status:						
Percentage of Home-owner	60%	56.7%	58.0%	54.8%	66.7%	80.3%

4.3 Full model

We now turn to the analysis of the full model specification. The comparative statics for this model are summarized in Table 9. They are broadly consistent with the results obtained in the simpler model, while simultaneously providing a better match to the data. The comparative statics show that a greater level of income uncertainty (higher σ_B) leads to higher level of assets and lower mortgage balances, consistent with precautionary demand for liquidity. Eliminating counter-cyclicality of income uncertainty has the opposite effect, as does the relaxation of the LTI and LTV constraints, since it eases cash-out refinancing: in all three cases, precautionary motive is weaker as the magnitude of bad shocks becomes smaller and liquidity constraints are less likely to bind when such shocks occur.

Table 10 reports the results for the regressions using the simulated data for each of the model specifications for the aggregate levels of refinancing (average number of refi loans, total dollar amount of refinanced loans to income, and dollar cash-out to income) on the aggregate state variables. The key empirical relationship holds in the model: lower mortgage rates R imply greater

Table 10: Cyclical Behavior of Refi and Cash-out

Model Specification	R	Z	$\Delta \log H$	R^2
	1. Baseline			
$REFI$	-4.43	-0.86	0.11	0.17
$DOLLAR\ REFI/INCOME$	-9.23	-1.64	0.22	0.26
$CASHOUT/INCOME$	-2.95	-0.24	0.09	0.15
	2. Homoskedastic income shocks			
$REFI$	-5.61	-0.54	0.10	0.18
$DOLLAR\ REFI/INCOME$	-11.41	-0.88	0.20	0.27
$CASHOUT/INCOME$	-3.48	-0.02	0.09	0.18
	3. Higher σ_B			
$REFI$	-2.13	-0.28	0.17	0.18
$DOLLAR\ REFI/INCOME$	-3.74	-0.59	0.14	0.23
$CASHOUT/INCOME$	-1.83	0.01	0.03	0.12
	4. No LTI constraint			
$REFI$	-5.63	-1.48	0.20	0.12
$DOLLAR\ REFI/INCOME$	-14.61	-3.85	0.46	0.15
$CASHOUT/INCOME$	-4.76	-0.44	0.14	0.14
	5. LTV constraint relaxed to 125%			
$REFI$	-6.87	-1.01	0.15	0.20
$DOLLAR\ REFI/INCOME$	-13.89	-2.12	0.27	0.27
$CASHOUT/INCOME$	-4.35	-0.23	0.10	0.14

refinancing activity. Moreover, lower mortgage rates allow for larger refinanced loans (relative to income) and more equity extraction via cash-out.

As in the data, refinancing activity in the model is counter-cyclical, as it is negatively related to the aggregate labor income, captured by the negative coefficient on the rate of economic growth Z (after controlling for the mortgage rate). Also, the coefficient of refi on the house price growth variable ΔH is positive as it is in the data, consistent with the fact that higher levels of house prices help relax the collateral constraint. Cyclicality of refinancing (and especially cash-out) is critically dependent on the heteroscedastic income shocks, as under the homoscedasticity the effect weakens (and disappears for cash-out). Higher level of income risk has a similar effect since it forces households to carry lower balances and accumulate more liquid wealth. The latter points to the key role played by the recursive preferences, which allow the effect of intertemporal substitution to be separated from that of precautionary saving.

Relaxing the LTV constraint has little effect on the cyclicality of refinancing and cash-out, but raises the sensitivity of all these measures of refinancing behavior to mortgage rates. This is intuitive since it allows a larger number of household to take advantage of refinancing opportunities when interest rates fall. Finally, relaxing the LTI constraint leads to more countercyclical refinancing behavior. This is also to be expected as without the LTI constraint more households are able to use home-equity borrowing to smooth consumption following bad shocks (which are more likely in recessions). The reason this result is in contrast with that obtained under the simple benchmark model in Section 4.2 is that here we can control for house prices, which capture the bulk of the wealth effect (cashing out in anticipation of higher future income following a positive aggregate income growth shock, which is mildly persistent in our calibration).

These quantitative results help us understand the effect of state-dependent conditional mean and volatility of labor income on households aggregate refinancing activity. An increase in the riskiness of idiosyncratic income leads risk averse households to use their home equity with more caution. When the world is more uncertain, households will tend to hold more liquid assets and reduce their mortgage balance. This behavior also leads them to be less responsive to a decrease in mortgage rates. At the same time, the counter-cyclical volatility of idiosyncratic labor income risk is key for generating counter-cyclical refinancing.

Our model features rich dynamics of aggregate and idiosyncratic state variables. However, the model is still fairly parsimonious and therefore cannot match all features of the data. The model does help to account for the key qualitative and quantitative facts. In particular, our model is unique in being able to account for the fact that a large number of refinancing events occur at apparently disadvantageous terms as summarized by the median rate ratios plotted in figure 2, which comoves with the fraction of refinanced loans that involve cash-out. The correlation between the two series in the data is 0.77, where as the model-implied correlation is about half as large, at 0.33. It is possible that modeling a richer set of mortgage products may help account for the remainder.

5 Conclusion

We document counter-cyclical variation of aggregate mortgage refinancing and explore a model of household behavior in which mortgage refinancing is driven by both time-varying interest rates and by consumption-smoothing motives in the face of idiosyncratic labor income risk. The model is able to replicate the main features of the counter-cyclical refinancing activity. It also highlights the importance for understanding the cyclical dynamics of idiosyncratic labor income risk for evaluating the quantitative features of refinancing behavior.

Our model can also be used to study the aggregate consumption implications of the impediments to refinancing. Refinancing is difficult when house prices fall, or when banks are in distress. These tend to coincide with bad income/productivity shocks. When markets are incomplete, this can severely hinder households' ability to smooth consumption or hedge against deflation risk, and exacerbate recessions.

In order to evaluate the equilibrium effect of the counter-cyclical refinancing we could endogenize mortgage rates by introducing an exogenous stochastic discount factor calibrated to match the term-structure interest rates. It could be used to price a menu of mortgage contracts (consisting of coupon rates and loan-to-value ratios) conditional on household characteristics. In that we could build on the analysis of Dunn and Spatt (2005) and Longstaff (2004) to the setting where borrower's decisions are explicitly affected by labor income fluctuations. This would allow us to evaluate the welfare impact of refinancing costs by incorporating the equilibrium response of mortgage spreads to slower prepayment speeds.

Potential questions that could be addressed within this framework include: was 2001 recession mild because high house prices allow households to smooth consumption, given the low interest rate environment? Can the refinancing boom of early 2000's, widely seen as contributing to the financial crisis (e.g. Khandani, Lo, and Merton (2009), Mian and Sufi (2010)) be attributed to the persistent dispersion of labor income and its slow aggregate growth following the recession - the "jobless recovery"? Our results on the dynamics of cash-out suggest that it may be.

Appendix A – Stationary Reformulation of the Household Recursive Problems

Let the household utility be CRRA, $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, then we can rescale the problem with respect to the permanent aggregate income Y_t and the price level p_t in order to make it stationary (with recursive preferences the approach is essentially the same but the notation is slightly more cumbersome). Define the rescaled variables as follows,

$$a_{i,t+1} = p_t\ Y_t\ \tilde{a}_{i,t+1}, \quad b_{i,t+1} = p_t\ Y_t\ \tilde{b}_{i,t+1}, \quad \text{and} \quad c_{it} = p_{t-1}\ Y_{t-1}\ \tilde{c}_{it},$$

and the value functions as,

$$U_{it}^{j} = \left(\frac{Y_{t-1}\ p_{t-1}}{p_t}\right)^{1-\gamma} \tilde{U}_{it}^{j}, \quad \text{with } j \in \{h, r, d, hh, hr, hd, rh\}.$$

Then by taking advantage of homogeneity of the utility function, the original problem in the home-owner state can be restated as,

$$\begin{aligned} \tilde{U}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) \ &= \max_{\tilde{a}_i', \tilde{b}_i', I_i^{RF}} \quad u(\tilde{c}_i) \\ &+\beta\mathbb{E}\left[\left(\frac{\pi Z}{\pi'}\right)^{1-\gamma}\left(\omega \max\left(\tilde{U}_i^{h'}, \tilde{U}_i^{hr'}, \tilde{U}_i^{hd'}\right) + (1-\omega)\max\left(\tilde{U}_i^{hh'}, \tilde{U}_i^{hr'}, \tilde{U}_i^{hd'}\right)\right)\right], \end{aligned} \tag{24}$$

subject to,

$$\begin{aligned} \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1+(1-\tau)r} + \tilde{b}_i \ &= \ (1-\tau)(\pi Z \tilde{y}_i - k_i \tilde{b}_i) + \tilde{a}_i + \pi Z \tilde{b}_i' - \pi Z(\phi_0 + \phi_1 \tilde{b}_i') I_i^{RF}, \\ k_i' \ &= \ k_i\ (1 - I_i^{RF}) + R\ I_i^{RF}, \\ (\pi Z \tilde{b}_i' - \tilde{b}_i)\ (1 - I_i^{RF}) \ &\leq \ 0, \\ (\tilde{b}_i' - \xi\ \bar{H}\ \tilde{h})\ I_i^{RF} \ &\leq \ 0, \\ \tilde{a}_i, \tilde{c}_i, \tilde{b}_i' \ &\geq \ 0. \end{aligned}$$

When the household is not moving, the rescaled value function is defined as,

$$\tilde{V}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max\left(\tilde{U}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hr}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hd}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i)\right), \tag{25}$$

when the household is moving, the rescaled value function is defined as,

$$\tilde{V}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max\left(\tilde{U}_i^{hh}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hr}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hd}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i)\right), \tag{26}$$

The rescaled household problem in the post default renter state is given by,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}_i'} \quad (1+\alpha)\ u(\tilde{c}_i) + \beta\, \mathbb{E}\left[\left(\frac{\pi Z}{\pi'}\right)^{1-\gamma} \left((1-\omega)\tilde{U}_i^{re}(\tilde{a}_i', \tilde{s}_i') + \omega \max\left(\tilde{U}_i^{rh}(\tilde{a}_i', \tilde{s}_i'), \tilde{U}_i^{r}(\tilde{a}_i', \tilde{s}_i')\right)\right)\right], \tag{27}$$

subject to,

$$\begin{aligned} (1+\alpha)\ \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1+(1-\tau)r_t} &= (1-\tau)\pi Z \tilde{y}_i + \tilde{a}_i, \\ \tilde{a}_i, \tilde{c}_i &\geq 0. \end{aligned}$$

When in the post default renter state, the rescaled value function if becoming a home-owner is available is given by,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max\left(\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i), \tilde{U}_i^{r}(\tilde{a}_i, \tilde{s}_i)\right), \tag{28}$$

or if the home-owner-ship option is unavailable,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \tilde{U}_i^d(\tilde{a}_i, \tilde{s}_i). \tag{29}$$

The rescaled household problem in the post selling renter state is given by,

$$\tilde{U}_i^r(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}_i'} \quad (1+\alpha)\ u(\tilde{c}_i) + \beta\, \mathbb{E}\left[\left(\frac{\pi Z}{\pi'}\right)^{1-\gamma} \max\left(\tilde{U}_i^{rh}(\tilde{a}_i', \tilde{s}_i'), \tilde{U}_i^{r}(\tilde{a}_i', \tilde{s}_i')\right)\right], \tag{30}$$

subject to,

$$
\begin{aligned}
(1+\alpha)\ \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1+(1-\tau)r} &= (1-\tau)\pi Z \tilde{y}_i + \tilde{a}_i, \\
\tilde{a}_i, \tilde{c}_i &\geq 0.
\end{aligned}
$$

When in the post selling renter state, the rescaled value function is given by,

$$
\tilde{V}_i^r(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max\left(\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i), \tilde{U}_i^r(\tilde{a}_i, \tilde{s}_i)\right). \tag{31}
$$

The rescaled transition problem for the household from the renter to the home-owner state is given by,

$$
\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}_i', \tilde{b}_i'} \quad (1+\alpha)\ u(\tilde{c}_i) + \beta\ \mathbb{E}\left[\left(\frac{\pi Z}{\pi'}\right)^{1-\gamma} \tilde{U}_i^h(\tilde{a}_i', \tilde{b}_i', R, \tilde{s}_i')\right], \tag{32}
$$

subject to,

$$
\begin{aligned}
(1+\alpha)\ \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1+(1-\tau)r} + \pi Z \bar{H}\ \tilde{h} &= (1-\tau)\pi Z \tilde{y}_i + \tilde{a}_i + \pi Z \tilde{b}_i' - \pi Z(\phi_0 + \phi_1 \tilde{b}_i'), \\
\tilde{b}_i' &\leq \xi\ \bar{H}\ \tilde{h}, \\
\tilde{a}_i, \tilde{c}_i, \tilde{b}_i' &\geq 0.
\end{aligned}
$$

The new state vector $\tilde{s}_i \equiv (\tilde{y}_i, r, Z, \tilde{h}, \pi)$. In contrast to the original (nominal) formulation of the problem where the processes y_i and H are growing over time, the processes $\tilde{y}_i$ and $\tilde{h}$ in the rescaled problems are stationary.

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