Internet Appendix for "Houses as ATMs? Mortgage Refinancing and Macroeconomic Uncertainty"

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This appendix contains supplementary material for the paper. Section I provides additional evidence on counter-cyclical refinancing using state-level data. Section II documents additional data sources that we rely on to motivate some of the parameter choices made in model estimation and evaluation. Section III provides additional details of the sensitivity analysis for the structural parameters of the estimated model as well as of the numerical analysis of household deleveraging following the Great Recession in our estimated model vis-a-vis the data.

I. State-Level Evidence on Counter-Cyclical Refinancing

To further investigate the response of mortgage refinancing to economic activity, we use 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 the local economic activity variables are less synchronized with interest rates than are aggregate quantities, and households cannot diversify away state-level shocks.[1]

We use quarterly data on 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 total personal income (*TPI*), deflated using the national consumer

*Citation format: Hui Chen, Michaux and Nikolai Roussanov, Internet Appendix for "Houses as ATMs? Mortgage Refinancing and Macroeconomic Uncertainty," [DOI String]. Please note: Wiley-Blackwell is not responsible for the content or functionality of any additional information provided by the authors. Any queries (other than missing material) should be directed to the authors of the article.

[1]Hurst, Keys, Seru, and Vavra (2016) show that there is essentially no cross-state variation in mortgage rates on loans originated by government-sponsored enterprises (GSEs).

price index.[2] 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 D.C. 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.

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

$$\begin{aligned} REFI_t^{State} = {} & \beta_{Cycle}^{REFI} Cycle_t^{State} + \beta_H^{REFI} \Delta HPI_t^{State} + \beta_{CH}^{REFI} Cycle_t^{State} \times HPI_t^{State} + \bar{R}_t^i \\ & + \beta_w^{REFI} WAC_t^{State} + \beta_r^{REFI} R_t^{3M} + \beta_R^{REFI} R_t^{M30} + \beta_{Rl}^{REFI} R_{t-4}^{M30} + \beta_t + \beta_{State} + \epsilon_t, \end{aligned} \tag{IA.1}$$

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,[3] $Cycle^{State}$ is measures state-level aggregate economic conditions, ΔHPI_t measures house price appreciation using the two-year growth in the FHFA state-level house price index, which 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 (also provided by FHFA),[4] WAC_t^{State} is the weighted average coupon on conforming mortgage loans outstanding in the state in the first month of the quarter, which summarizes the rates currently paid by borrowers, $\mathbf{b}_t$ is a 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 the delayed response of households to economic conditions, and we include the interaction term between $Cycle$ and house price growth, orthogonalized with respect to both variables, to test whether a higher level of house prices helps relax the borrowing constraint, especially in bad times.

Table IA.I presents 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 quarter fixed effects are included, indicating that their

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

[3] We obtain similar results using refinance loan volume scaled by total personal income in the state.

[4] This variable is reported at the annual frequency; we generate quarterly observations via linear interpolation.

Table IA.I

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}	$\bar{R}^2$
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)				

Quarterly data, 1993.III to 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 year-on-year growth in the nonfarm payroll employment index scaled by the state population (*Payroll*, specifications 1 and 2), the State Coincident Economic Activity index (*CEAI*, specifications 3 and 4), or total personal income (*TPI*, deflated using the CPI, specifications 5 and 6). HPI is the two-year growth rate in the state-level house price index. $C_t \times H_t$ is the orthogonalized interaction term, that is, the residual from regressing the product of *Cycle* and HPI on a constant and both of these variables. WAC is the 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 parentheses (*Robust* indicates clustering by state, *NW* indicates Newey-West estimate of the covariance matrix with 20 lags).

presence does not simply proxy for variation in the aggregate term structure variables.

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 a higher WAC translates 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 relationship between refinancing and contemporaneous state-level mortgage rates is positive rather than negative, although not significant with time fixed effects, suggesting that it is mostly capturing aggregate variation in mortgage spreads, which are positively related to both default and prepayment risk and are likely to increase with rising demand for mortgage loans in a particular state.

II. Additional Data

In this section we document additional data sources that motivate our numerical analysis in the paper.

A. Mortgage Rates

In the data, there is little variation in LTV and LTI among conventional (and, especially, conforming) 30-year fixed-rate loan borrowers (even within states). We use data from Fannie Mae on all residential mortgages originated and insured by FNMA between 2000 and 2015, and we confirm that the *within year* variation in mortgage rates as a function of LTV or FICO scores is on the order of 20 to 50 basis points prior to 2007, although there is a bit more cross-sectional variation during and after the crisis. The magnitude is even smaller if we ignore the deeply subprime loans and bins with low loan counts. In contrast, there is a lot more variation in mortgage rates across years (see Tables IA.II and IA.III for detailed examples).

B. House Price Volatility

Our calibration of the volatility of transitory innovations to house prices is consistent with those of "booming states" (states that experienced the largest house price growth leading up to 2007; see, for example, Dynan (2012)) during the period of 1975Q1 to 2017Q2. We estimate the volatility of transitory innovations to house prices at state level using quarterly

Table IA.II
30-Year Mortgage Rates, 2002 Origination

Average Interest Rate

FICO	LTV									
	0% - 10%	10% - 20%	20% - 30%	30% - 40%	40% - 50%	50% - 60%	60% - 70%	70% - 80%	80% - 90%	90% - 100%
300 - 355							6.00	7.00	6.38	
355 - 410						6.29	6.94	6.88	6.68	7.05
410 - 465		6.88	6.89	6.96	6.89	6.92	6.84	6.88	6.95	6.99
465 - 520		7.52	7.31	7.20	7.16	7.13	7.07	7.10	6.98	7.05
520 - 575	7.10	7.12	7.13	7.01	6.97	6.98	6.98	6.97	6.95	6.98
575 - 630	6.72	6.89	6.91	6.82	6.79	6.80	6.80	6.82	6.84	6.91
630 - 685	6.78	6.79	6.74	6.69	6.67	6.67	6.68	6.71	6.74	6.86
685 - 740	6.67	6.67	6.62	6.59	6.58	6.58	6.59	6.62	6.68	6.81
740 - 795	6.61	6.60	6.56	6.53	6.51	6.51	6.52	6.55	6.63	6.77
795 - 850	6.65	6.55	6.53	6.52	6.50	6.50	6.51	6.53	6.62	6.75

Loan Count

FICO	LTV									
	0% - 10%	10% - 20%	20% - 30%	30% - 40%	40% - 50%	50% - 60%	60% - 70%	70% - 80%	80% - 90%	90% - 100%
300 - 355	0	0	0	0	0	0	1	2	1	0
355 - 410	0	0	0	0	0	3	6	15	16	10
410 - 465	0	3	13	25	40	52	119	221	136	72
465 - 520	0	10	58	104	202	362	681	1023	456	268
520 - 575	5	64	280	594	1185	2422	4883	7766	4661	2798
575 - 630	36	237	905	1997	4243	9122	18318	36333	31614	24874
630 - 685	81	634	2392	5711	12223	25160	48417	114662	129130	98303
685 - 740	152	1362	5263	12770	25163	45447	78762	169303	203767	130519
740 - 795	292	3555	13210	30245	54758	86188	123735	212836	229273	107901
795 - 850	78	1288	4625	8602	13435	16985	19878	26079	25027	8784

Table IA.III
30-Year Mortgage Rates, 2007 Origination

Average Interest Rate

FICO	LTV									
	0% - 10%	10% - 20%	20% - 30%	30% - 40%	40% - 50%	50% - 60%	60% - 70%	70% - 80%	80% - 90%	90% - 100%
300 - 355									6.13	6.75
355 - 410						7.25	6.06		6.50	
410 - 465		7.88	6.50	6.88	6.42	6.58	6.43	6.49	6.46	6.94
465 - 520		7.06	6.99	6.87	6.72	6.81	6.76	6.80	6.76	6.83
520 - 575	6.75	6.89	6.72	6.76	6.73	6.66	6.69	6.68	6.67	6.83
575 - 630	6.74	6.71	6.64	6.57	6.53	6.52	6.52	6.58	6.60	6.65
630 - 685	6.53	6.49	6.45	6.40	6.38	6.37	6.39	6.45	6.47	6.61
685 - 740	6.51	6.39	6.33	6.32	6.30	6.30	6.32	6.38	6.40	6.57
740 - 795	6.42	6.33	6.30	6.28	6.27	6.26	6.28	6.34	6.34	6.52
795 - 850	6.31	6.34	6.30	6.29	6.27	6.25	6.27	6.31	6.33	6.51

Loan Count

FICO	LTV									
	0% - 10%	10% - 20%	20% - 30%	30% - 40%	40% - 50%	50% - 60%	60% - 70%	70% - 80%	80% - 90%	90% - 100%
300 - 355	0	0	0	0	0	0	0	0	1	1
355 - 410	0	0	0	0	0	1	2	0	1	0
410 - 465	0	1	1	1	6	3	9	14	6	8
465 - 520	0	6	16	51	61	83	119	115	95	63
520 - 575	6	61	147	330	571	934	1470	1326	817	466
575 - 630	39	317	1039	2361	4673	8058	14171	18870	18347	10230
630 - 685	92	529	1903	4319	8554	15695	28125	49617	74554	40517
685 - 740	99	876	3067	6265	11600	19630	32523	60839	101418	41667
740 - 795	147	1735	5498	10781	18328	28669	42772	72050	128483	41897
795 - 850	134	1284	3743	6518	9451	12849	15304	20779	38116	9474

state-level house price indices from FHFA and state-level income. Figure IA.1 plots state-level volatility normalized by U.S. aggregate volatility against state-level house price growth in the period 2001 to 2006. We can see that the volatility of transitory innovations to house prices for the booming states (red diamonds) are between 1.5 to 2.8 times the U.S. value. In comparison, for our benchmark calibration, the volatility of transitory innovations to house prices is 1.7 times the U.S. value (after adjusting for idiosyncratic house price volatility).

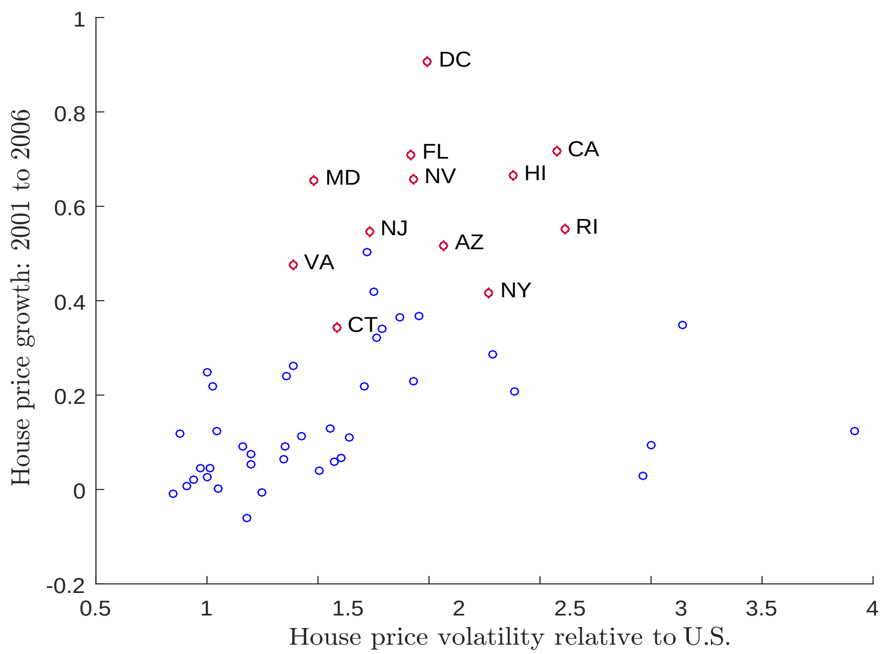

Figure IA.1. House price volatility by state.

III. Estimated Model: Inspecting the Mechanism

A. Sensitivity analysis

Here analyze the sensitivity of the simulated moments to the estimated parameters, which underpins our structural identification. Table IA.IV displays the values of simulated moments for different values of the key parameters in Θ, compared to the baseline case. For each of the seven estimated parameters, we consider two values equidistant from the point estimates in either direction. Our discussion focuses on the key effect of each of the parameters.

Subjective Discount Factor δ. Making households more patient via a larger δ increases the prevalence of homeownership and increases household savings in the form of liquid asset holdings and home equity while lowering average mortgage balances. HELOC balances stay essentially the same (even though a HELOC is more expensive than the mortgage on average in terms of the interest rate, it can be cheaper to access when liquidity is needed). As mortgage balances decline with higher δ, so does the frequency of refinancing and the sensitivity of refinancing to interest rates (β_R^{REFI} closer to zero). When the benefit of interest savings from refinancing is small, only those suffering from large income shocks find it worthwhile to pay the fixed costs of refinancing, as evidenced by the higher loan-to-income ratios and cash-out share for the new loans after refinancing. Moreover, under higher δ, while households cash-out more following negative aggregate income shocks (more negative β_Z), consumption growth is still more affected by income shocks (larger β_Z^C), suggesting that households save the cashed-out home equity rather than consume it. Finally, the average consumption-to-income ratio is higher with more patient households, again due to the fact that they have accumulated more savings via liquid assets and home equity.

Coefficient of Relative Risk Aversion γ. Increasing the risk aversion leads to more precautionary savings in the forms of liquid asset holdings and home equity (through both higher homeownership and lower mortgage balances), but also reduces the use of HELOCs as households accumulate enough liquid assets. Refinancing is driven mainly by the need to withdraw home equity rather than the purely financial incentive of lowering the mortgage rate, as cash-out/refi ratios increase in risk aversion and the sensitivity of refinancing to mortgage rate β_R^{REFI} moves closer to zero. Like patient households, risk-averse households also cash-out more following negative aggregate consumption shocks (more negative β_Z) and shocks to mortgage rates (more negative β_R).

Intertemporal Elasticity of Substitution ψ. A higher IES lowers liquid asset holdings, increases mortgage balances, and raises consumption volatility. This is due to the reason that households are less concerned with smoothing consumption over time, and the effects are qualitatively similar to those of lower risk aversion. However, while a lower risk aversion coefficient reduces homeownership (which is driven by a weaker precautionary savings motive), a higher IES raises homeownership. This is because the higher IES makes the refinancing option associated with owning a house more valuable, and thus households can better take advantage of house price appreciation and the drop in interest rate.

The IES is also important for the dynamics of refinancing and cash-out. With a higher ψ, households are more willing to substitute consumption over time, and therefore both cash-out and consumption respond more to changes in the interest rate, as shown in a more negative β_R and a larger β_R^C.

Costs of Refinancing ϕ_0, ϕ_1. Raising the quasi-fixed cost ϕ_0 of refinancing reduces the frequency of refinancing while increasing new loan size and its cash-out component. Since costly refinancing makes mortgages effectively more expensive, average mortgage balances decline, as does homeownership. The effect on total leverage is partly offset by higher HELOC balances. Since lower mortgage balances reduce the risk in the household balance sheet, the precautionary motive for holding liquid assets is also lower. Raising the proportional cost parameter ϕ_1 has very similar effects. It might appear surprising that a higher proportional refinancing cost increases the average new loan size and the cash-out share. This is driven by the composition effect: households are less likely to refinance for the purpose of lowering mortgage rates (β_R^{REFI} is -0.83 with high ϕ_1, compared to -1.09 in the baseline case) but more likely to refinance to cash-out home equity.

Table IA.IV
Sensitivity Analysis

	Baseline	δ		γ		ψ		ν		ϕ_0		ϕ_1	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		0.874	0.966	1.518	6.071	0.151	0.603	0.067	0.268	0.077	0.309	0.007	0.028
All Households:													
Consumption/Income	0.71	0.68	0.74	0.69	0.74	0.71	0.72	0.73	0.70	0.72	0.71	0.71	0.71
Cons. growth vol, %	16.5	17.2	15.7	17.6	15.2	15.5	19.3	15.8	19.2	16.9	16.3	16.6	16.4
Homeownership rate, %	67.4	43.6	96.3	51.6	88.0	58.5	86.2	53.6	100.0	76.0	64.3	68.3	66.0
Homeowners:													
Liquid assets/Income	0.24	0.20	0.31	0.20	0.35	0.30	0.20	0.24	0.28	0.26	0.15	0.25	0.22
Mortgage/Income	0.94	1.34	0.56	1.34	0.51	0.92	1.07	0.91	1.43	1.22	0.45	1.00	0.84
HELOC/Income	0.09	0.08	0.09	0.08	0.07	0.07	0.11	0.08	0.09	0.08	0.12	0.08	0.09
Refinancing rate, %	11.1	17.4	6.6	17.2	6.2	11.5	12.5	11.0	15.9	17.2	4.8	12.0	9.7
Refi loan/Income	2.73	2.39	2.97	2.47	2.91	2.57	2.81	2.64	2.83	2.51	2.97	2.71	2.76
Dollar cash-out/Refi loan	0.51	0.42	0.56	0.41	0.60	0.52	0.49	0.51	0.46	0.43	0.62	0.50	0.54
Renters:													
Liquid assets/Income	0.15	0.07	0.38	0.08	0.34	0.18	0.19	0.13	0.09	0.16	0.14	0.15	0.15
Refinancing Regression:													
Coefficient on R, β_R^{REFI}	-0.97	-1.40	-0.66	-1.46	-0.56	-0.61	-1.54	-0.80	-1.35	-1.57	-0.26	-1.03	-0.83
Cash-Out Regression:													
Coefficient on R, β_R	-0.57	-0.25	-0.84	-0.32	-0.71	-0.26	-1.14	-0.35	-1.08	-0.72	-0.24	-0.54	-0.59
Coefficient on Z, β_Z	-0.19	-0.09	-0.24	-0.09	-0.20	-0.12	-0.38	-0.25	0.13	-0.18	-0.38	-0.18	-0.25
Coefficient on H, β_H	0.10	0.14	0.01	0.15	0.04	0.06	0.17	0.10	0.05	0.08	0.06	0.11	0.08
Aggregate Consumption:													
Growth volatility, %	3.9	3.9	4.0	4.0	4.1	4.0	4.5	3.6	5.3	4.2	3.7	3.9	3.8
Sensitivity to Z, β_Z^C	1.30	1.25	1.37	1.28	1.36	1.34	1.40	1.22	1.72	1.41	1.26	1.30	1.28
Sensitivity to H, β_H^C	0.09	0.14	0.04	0.13	0.06	0.10	0.08	0.10	0.06	0.08	0.08	0.09	0.09
Sensitivity to lagged r, β_r^C	0.13	0.06	0.20	0.09	0.18	0.07	0.26	0.09	0.24	0.15	0.12	0.13	0.13
Sensitivity to lagged R, β_R^C	0.17	0.08	0.26	0.12	0.23	0.07	0.39	0.12	0.33	0.22	0.15	0.18	0.17

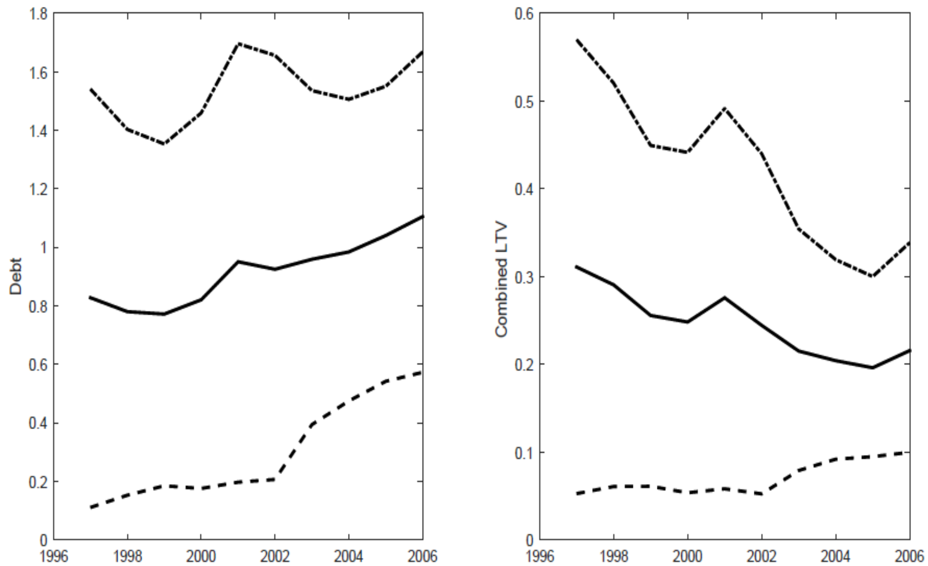

Figure IA.2. Household leverage over time (model).

B. Deleveraging

As evident in Figure 3 in the paper and Figure IA.2, despite the fact that our model matches the average LTI in the data well, the average LTV in our model is low compared to the data, and its distribution does not match the data very well. Two key factors lead to low LTVs: (1) direct preferences for homeownership (captured by the disutility of renting parameter ϖ, which is identified by matching the homeownership rate in the data) and (2) the indirect benefit of homeownership that derives endogenously from the collateral value of a house – it can be used to finance borrowing to smooth transitory income shocks.[5] Consistent with the value of homeownership, our comparative statics (Table A.1) show that both higher risk aversion (due to the precautionary motive across states) and lower IES (due to the greater preference for smoothness over time) lead to higher rates of homeownership.

Even for those poorer and more indebted households, the model implies a decline in the combined LTV during the housing boom as house prices rise (2004 to 2006). This is despite the fact that many of these households do cash out home equity over the period. Consequently, most of these households' LTVs do not rise above 100% when house prices fall. Figure IA.2 illustrates this feature of the model. It plots the evolution of simulated household leverage across groups with different initial leverage (sorted in 1997). The left panel plots mortgage debt relative to income for the bottom, middle, and top quintiles, while the right panel plots the combined LTV ratios (for both mortgage and HELOC) for the same three groups of households. As house prices grow in the 2000s, debt increases relative to income across the board (mean-reversion in income causes the three lines to converge

[5] This can occur even when house value is relatively low in the presence of transitory fluctuations in housing values, which is quite distinct from "cashing out" home equity via a sale, as in Campbell and Cocco (2015).

slightly, which is a second-order effect), while the combined LTVs are generally declining for the middle and top quintiles (until the end of the housing boom), and are below 50 % even for the highest leverage quintile.

The reason this happens is that the LTI constraint that we impose to capture the restrictions associated with conforming mortgage loans ends up binding for virtually all of the households refinancing their mortgage during this period long before the LTV constraint binds, simply because house prices are growing much faster than income. Moreover, those cashing out equity typically have more depressed incomes than the average household, making the LTI constraint even more likely to bind.

This result might imply that the LTI constraint that we impose is too tight (as suggested by the highest-leverage quintile in Figure 3, Panel B in the paper) relative to what is observed in the data. Indeed, in one of the comparative statics exercises (column (3) in Table VIII), we relax the LTV constraint by raising ξ_{LTV} from 0.8 to 1. This raises average LTI from 0.94 to 1.10, and the default rate from 0.0% to 0.4%. If we completely remove the LTI constraint (Column (4) in Table 8), average LTI rises to 1.56, and the default rate rises to 0.6. Finally, when we simultaneously relax the LTV and LTI constraints (column (5) in Table VIII), average LTI rises to 2.07 and default rate rises to 2.1%. These results show that there are nonlinear effects on mortgage defaults coming from the interactions of the two constraints.

Relaxing the LTI constraint in a sensible way that captures the data would require us to model risk-based mortgage rate spreads and potentially allow for subprime-type mortgages, which is an interesting direction for future research. The point that we want to make in this paper is that a rise in house prices can generate a substantial increase in home equity borrowing, and not relying on binding LTV constraints makes is clear that this pattern is not mechanical but represents a true choice between liquid and illiquid wealth. It is well-known from prior empirical literature that default rates for mortgages that have LTV below 80% at origination are negligible (e.g., Elul, Souleles, Chomsisengphet, Glennon, and Hunt (2010)). Indeed, Laufer (2018) shows that using actual observed LTV ratios upon equity extraction as an input in model estimation helps match the probabilities of default, while constraining LTVs at 80% reduces defaults substantially.

Is the evolution of debt and liquid assets during the housing bust that is predicted by the model consistent with the data? We use data from PSID, where we sort mortgage-borrower households into bins based on their 2007 debt to income ratio, and follow these bins forward, as we do in the model. The results are plotted in Figure IA.3 below. We see that the model's prediction for the highest-leverage households actually does hold up in the data very strongly, which is a striking and important finding.

If anything, it is the least-levered households that behave differently in the data (relative to the model) as they also have a similarly high level of liquid assets at the start of the recession. The latter, however, is largely driven by stock holdings, as their holdings of safe liquid assets are similar to those of an "average" household. Excluding stocks and other similar risky assets does not change the conclusions for the most-levered quintile of households, even though their level of liquid assets is quantitatively somewhat lower than the model predicts if only safe assets are included, as demonstrated in Figure IA.4.

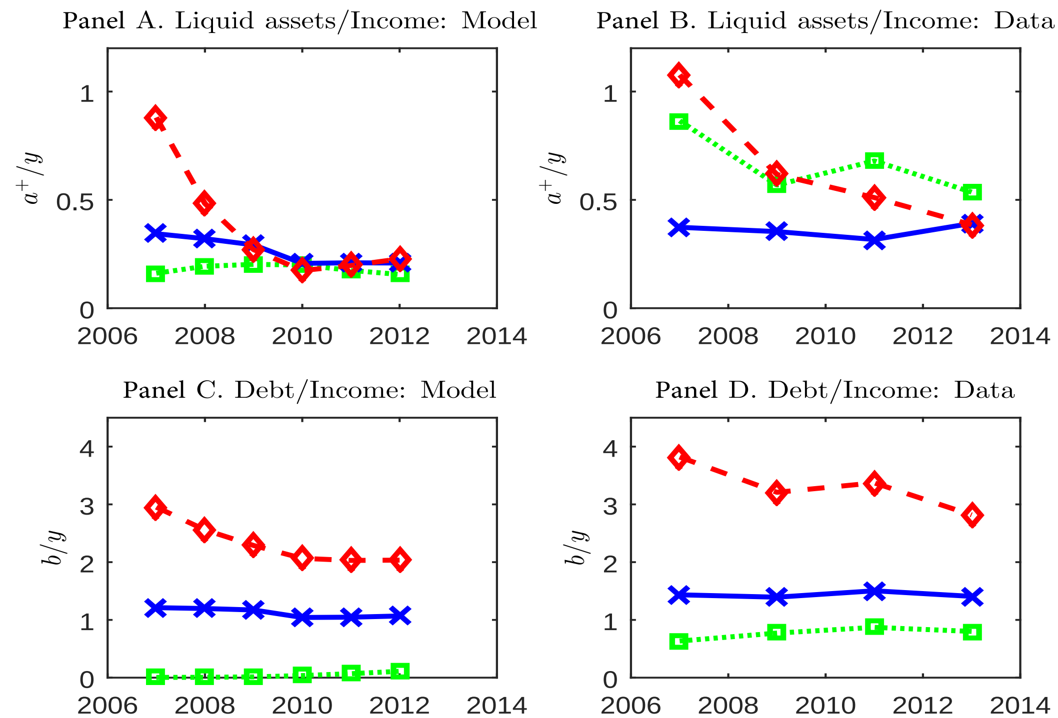

Figure IA.3. Household balance sheets, 2017-2013: model vs. data.

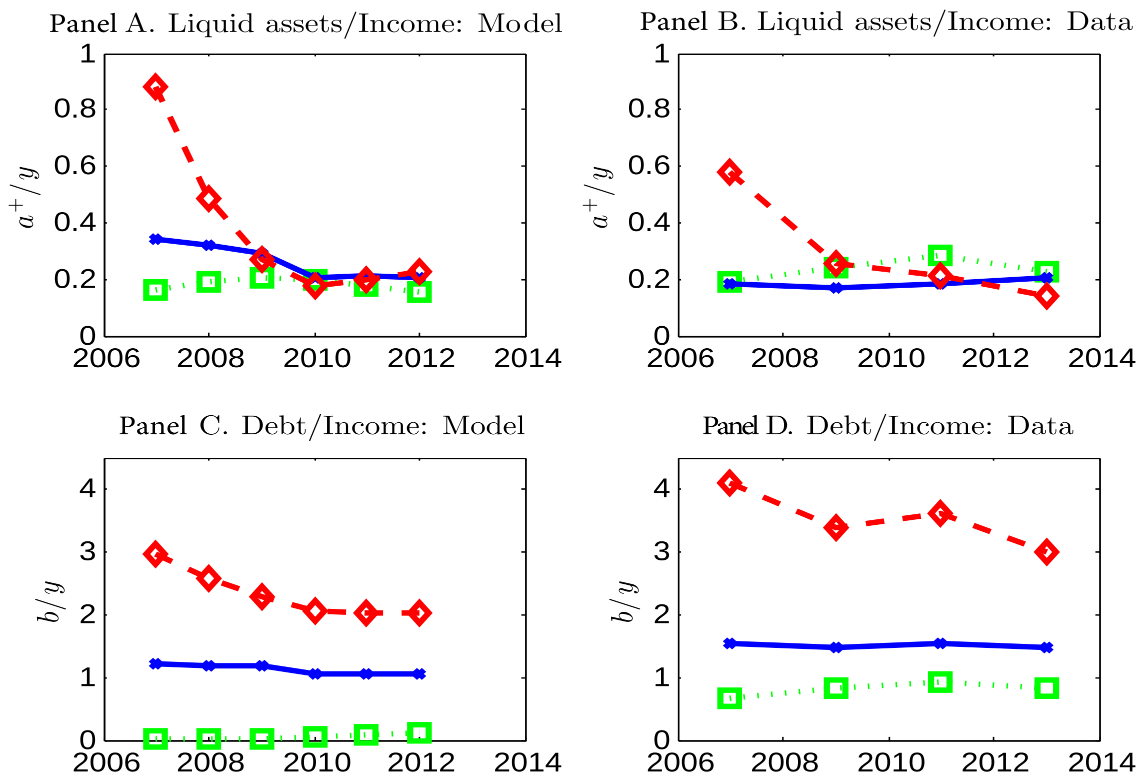

Figure IA.4. Household balance sheets, 2017-2013: model vs. data.
Note: liquid assets in PSID data include checking and savings account balances only.

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