Online Appendix to: "The Effect of House Prices on Household Borrowing: A New Approach"*

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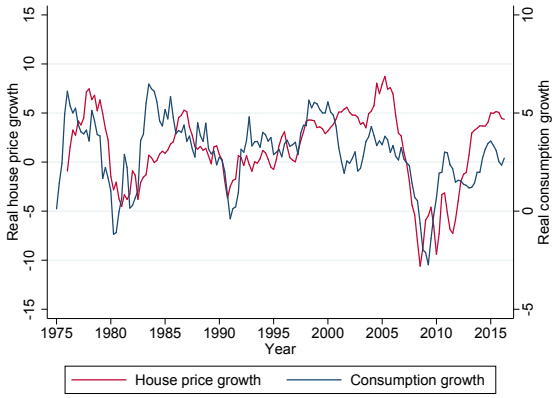
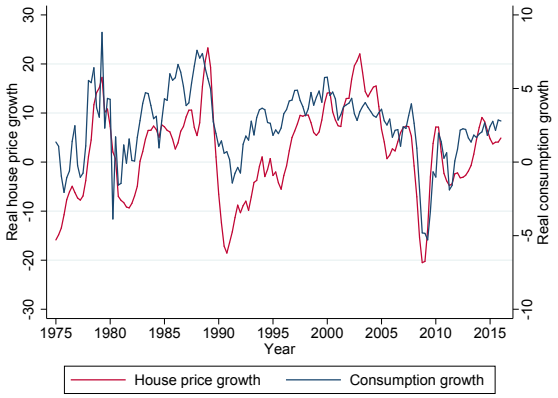
A Supplementary Figures and Tables

FIGURE A.I: AGGREGATE HOUSE PRICES, CONSUMPTION, AND MORTGAGE DEBT

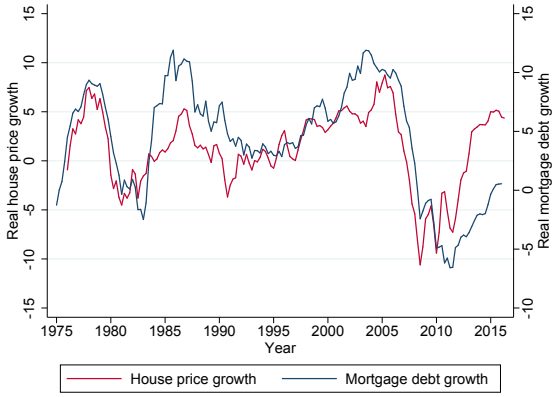
A: U.S. House Price vs Consumption Growth



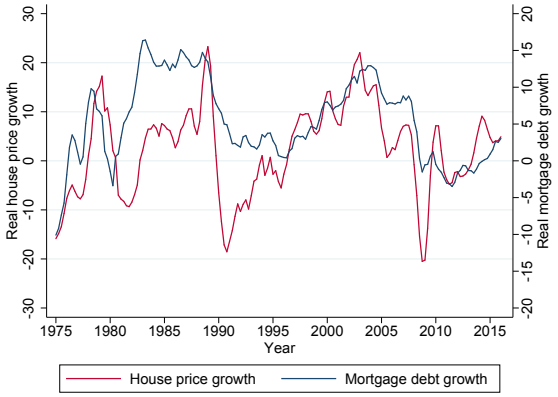
B: U.K. House Price vs Consumption Growth



C: U.S. House Price vs Mortgage Debt Growth

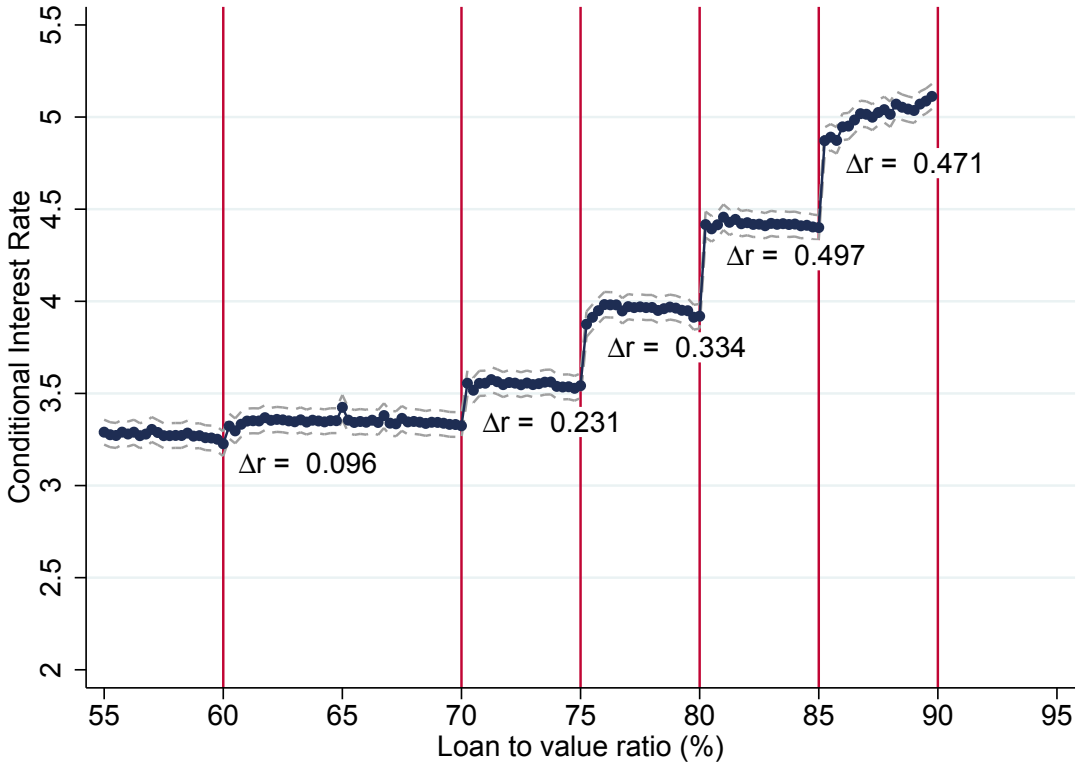


D: U.K. House Price vs Mortgage Debt Growth



Notes: U.S. house price data are from the Federal Reserve Economic Data, U.S. consumption data are from the BEA National Income and Product Accounts, and U.S. mortgage debt data are from the U.S. Flow of Funds. U.K. house price data are from the Nationwide Index, U.K. consumption data are from the ONS National Accounts, and U.K. mortgage debt data are from the Bank of England. All growth rates are log differences multiplied by 100.

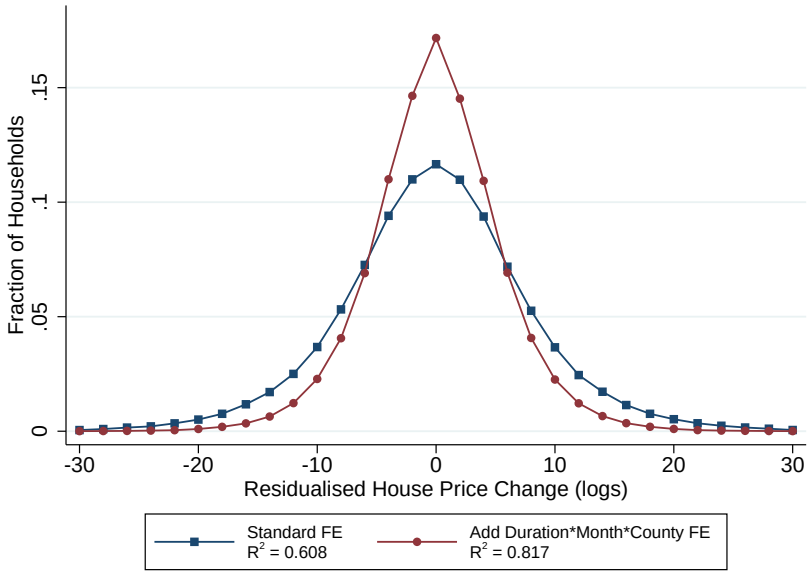
FIGURE A.II: INTEREST RATE SCHEDULE IN THE UNITED KINGDOM



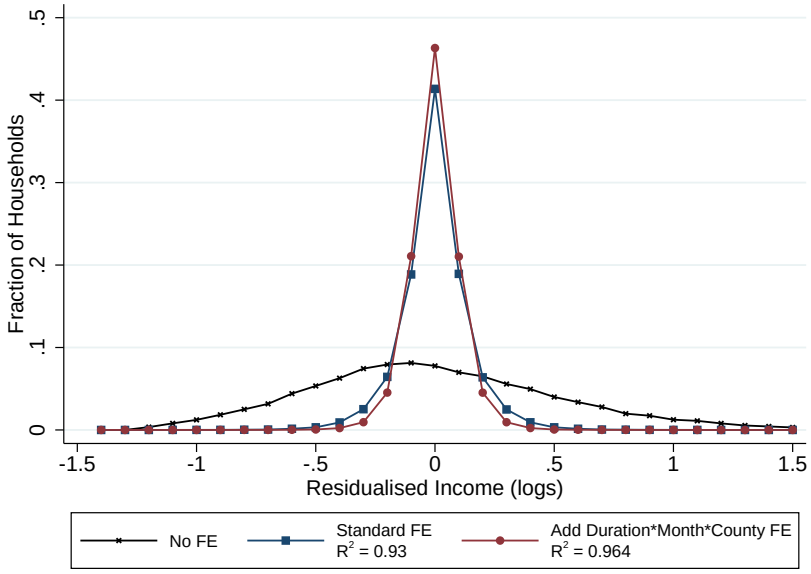
Notes: The figure shows the average mortgage interest rate in the United Kingdom (in %) as a step function of the LTV ratio, with sharp jumps (notches) at LTVs of 60%, 70%, 75%, 80%, and 85%. The figure plots coefficients (and confidence intervals) from a regression of the mortgage interest rate on dummies for each 0.25%-bin of the LTV distribution. To each coefficient, we add a constant equal to the mean predicted value of the interest rate from all the other covariates. The other covariates include non-parametric controls for lender, contract duration (time until reset), month of refinance, mortgage type (fixed interest rate / variable interest rate / capped interest rate / other), repayment type (interest only / capital and interest / other), term length, reason for refinance, age, couple indicator, and income. The figure is taken from Best *et al.* 2018 and further details are provided there.

FIGURE A.III: THE EXPLANATORY POWER OF MORTGAGE DURATION

A: Duration Explains Future Price Change



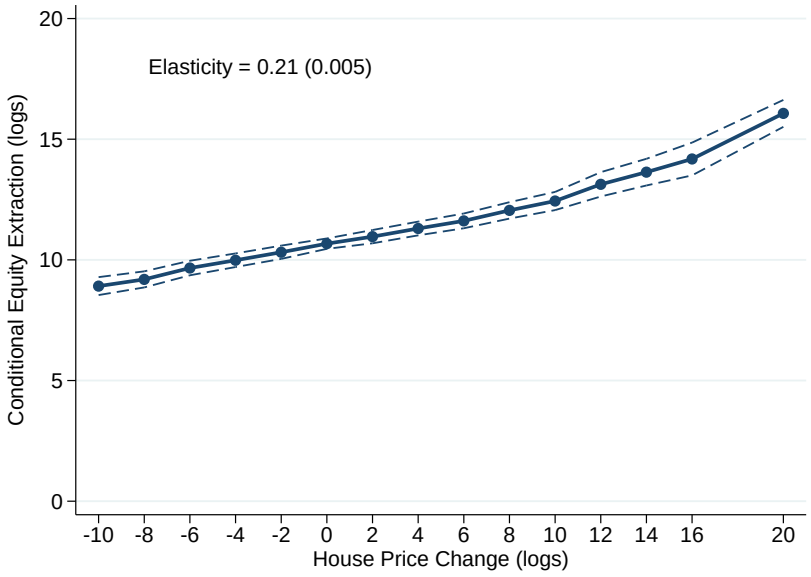
B: Duration Does Not Explain Future Income



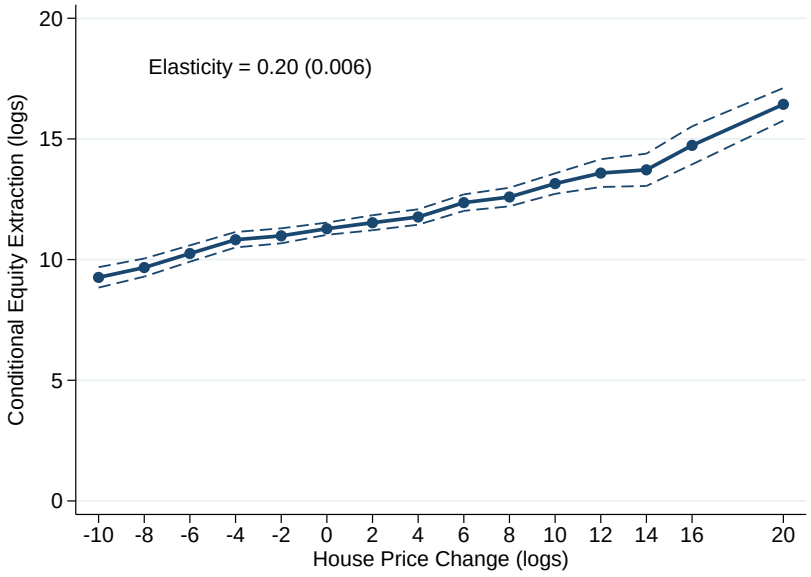
Notes: Panel A plots distributions of residualized house price growth, with and without fixed effects for the last contract duration choice (time until reset) interacted with month and county dummies. The panel shows that past duration choices can explain a large part of the residual price variation (having already absorbed fixed effect for household, month, and county x year). Panel B investigates if past duration choices can also explain residual income variation and shows that it cannot. The fact that past duration is able to predict house price growth, but not other determinants of borrowing such as income, makes it useful for identifying the effects of house prices on borrowing.

FIGURE A.IV: EQUITY EXTRACTION VS HOUSE PRICE GROWTH USING ALTERNATIVE CONTROLS

A: Household and Month Fixed Effects

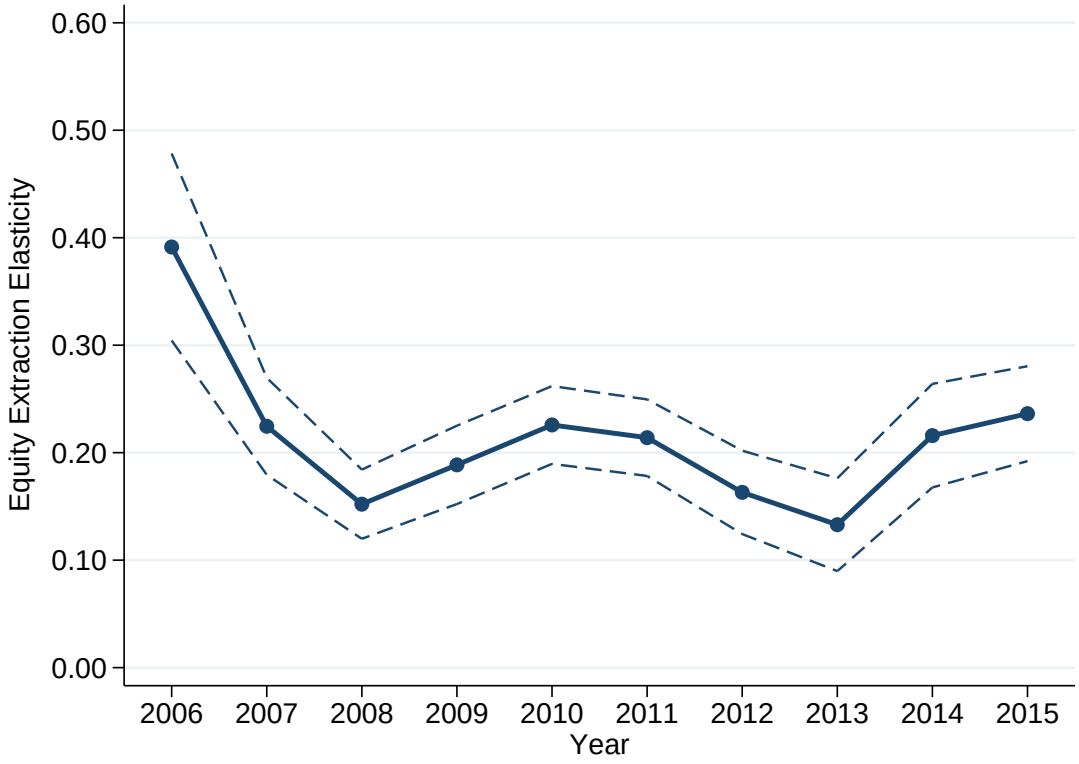


B: Household, Month, County × Year Fixed Effects and Household Controls



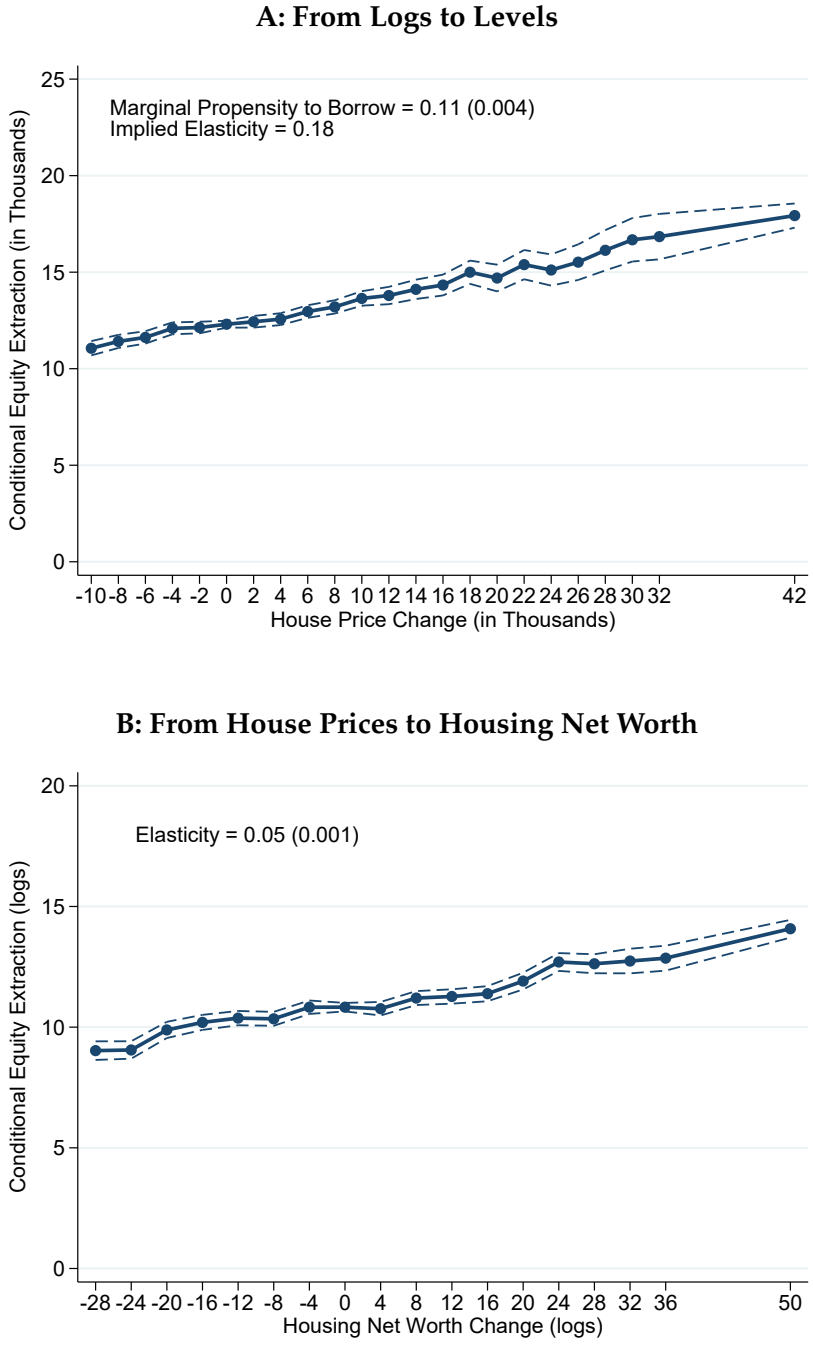
Notes: The panels plot conditional equity extraction in different bins of house price growth based on the fixed effects specification (2). The plotted points are the estimated coefficients on house price growth dummies, adding a constant equal to the mean predicted value of equity extraction from all the other covariates. In Panel A, the other covariates are fixed effects for household and month. In Panel B, the other covariates are fixed effects for household, month, county x year, and household controls. The household controls include income level, income growth, mortgage interest rate, age, a dummy for couples, and dummies for a range of self-reported reasons for the current and the last refinances. The dashed lines represent 95% confidence intervals based on standard errors clustered by household. Each panel also reports the average equity extraction elasticity based on a log-linear specification. The figure shows that the relationship between equity extraction and house prices is almost perfectly log-linear, independent of which controls are included in the specification.

FIGURE A.V: EQUITY EXTRACTION ELASTICITY BY YEAR



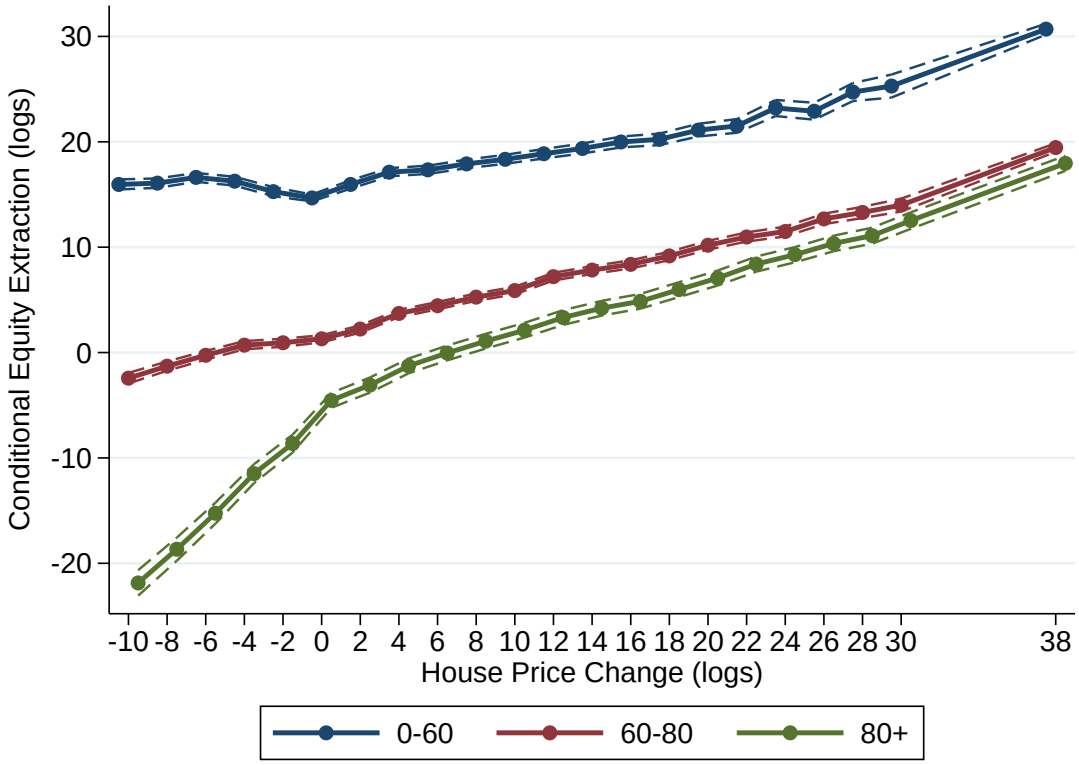
Notes: The figure reports the equity extraction elasticity for each year separately, showing that the elasticity is mildly pro-cyclical. The specification includes fixed effects for household, month, county x year, and household controls. The household controls include income level, income growth, mortgage interest rate, age, a dummy for couples, and dummies for a range of self-reported reasons for the current and the last refinances. The dashed lines represent 95% confidence intervals based on standard errors clustered by household.

FIGURE A.VI: EQUITY EXTRACTION VS HOUSE PRICE GROWTH USING ALTERNATIVE SPECIFICATIONS



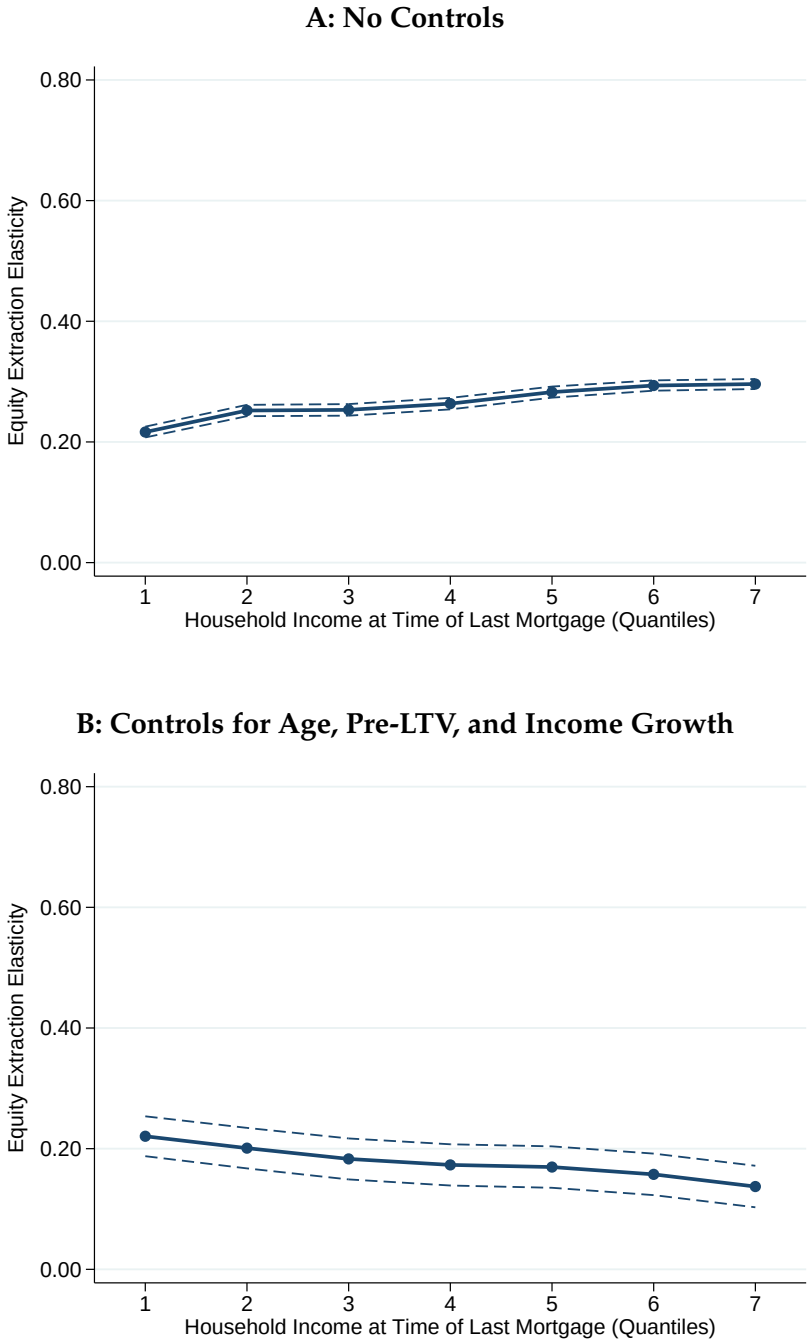
Notes: The figure investigates if the previous results are affected by moving from a log-specification to a level-specification (Panel A) and by moving from house prices to housing net worth as the explanatory variable (Panel B). We specify housing net worth as the house price minus *baseline* debt, as opposed to current debt, in order to avoid a clear endogeneity problem. This implies that the two elasticities are identified from the same source of variation in house prices. Apart from these changes, the panels are constructed in the same way as Figure 8. The alternative specifications are useful for obtaining different parameters. Panel A yields an estimate of the marginal propensity to borrow (equal to 0.11), while Panel B yields an estimate of the equity extraction elasticity with respect to housing net worth (equal to 0.05). The elasticity with respect to housing net worth is smaller because housing net worth is only a fraction of the house price, so any given log-change in house prices translates into a larger log-change in housing net worth.

FIGURE A.VII: HETEROGENEITY BY LTV NON-PARAMETRICALLY



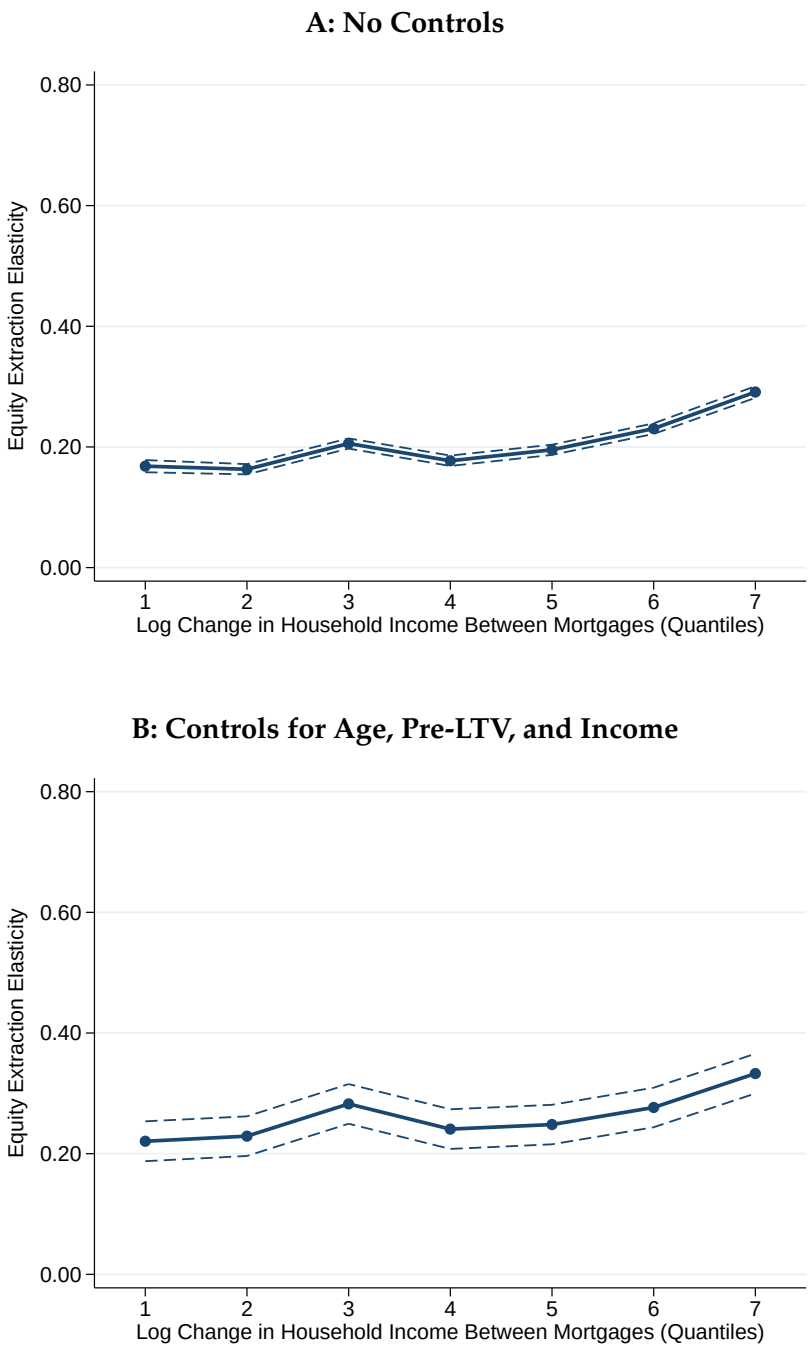
Notes: The figure plots average equity extraction in different bins of house price growth and in different bins of pre-determined LTV. Pre-LTV is defined as the LTV ratio at time t absent any equity extraction/injection at time t and absent any house price growth between t and $t-1$. The figure considers three bins of pre-LTV: low leverage (0-60%), intermediate leverage (60-80%), and high leverage (above 80%). The dashed lines represent 95% confidence intervals based on standard errors clustered by household. The figure shows that the *level* of equity extraction decreases with leverage, while the *slope* of equity extraction with respect to house price growth increases with leverage. This is consistent with the collateral channel.

FIGURE A.VIII: HETEROGENEITY IN BORROWING ELASTICITY BY INCOME



Notes: The figure shows heterogeneity in the equity extraction elasticity by income level (measured at the time of the last refinance event). Panel A is based on a univariate specification that investigates heterogeneity by income on its own, while Panel B is based on a multivariate specification allowing for heterogeneity in four dimensions simultaneously: LTV, age, income level, and income growth. The multivariate specification is shown in equation (5). The dashed lines give 95% confidence intervals based on standard errors clustered by household. The figure shows that there is relatively little heterogeneity in the borrowing elasticity by income level.

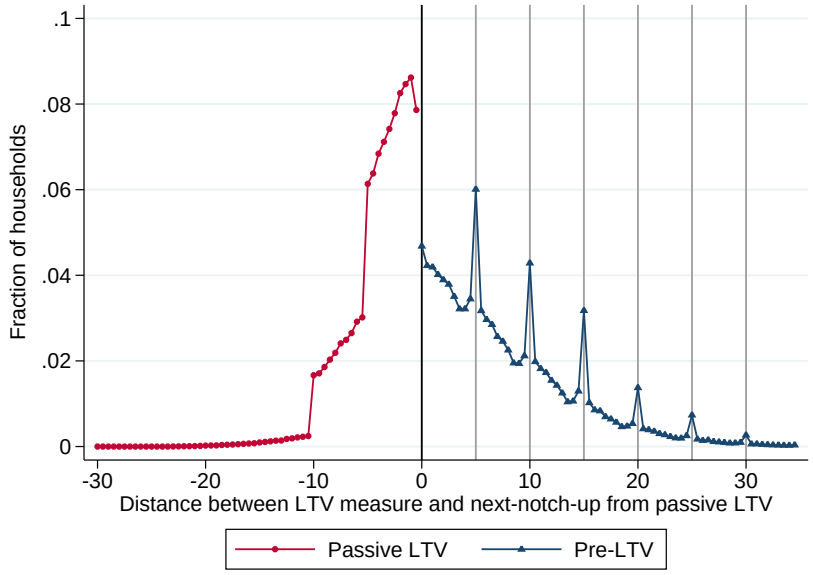
FIGURE A.IX: HETEROGENEITY IN BORROWING ELASTICITY BY INCOME GROWTH



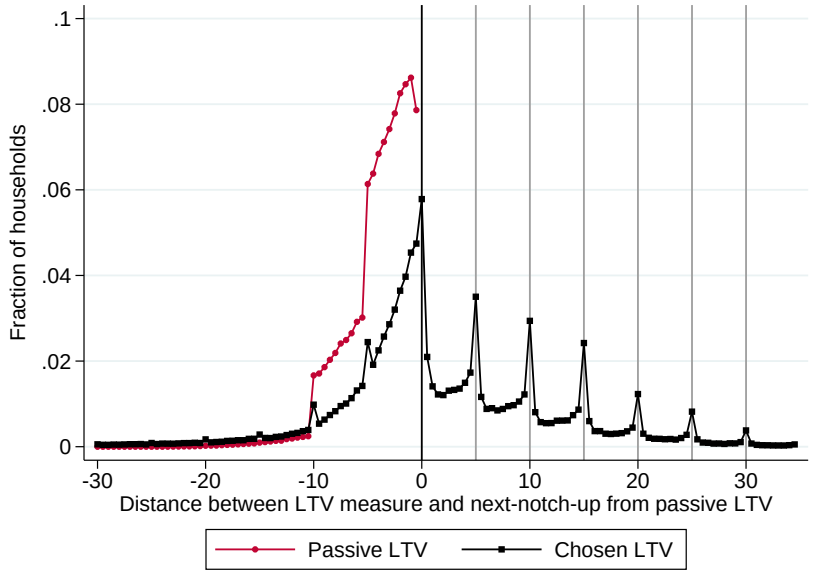
Notes: The figure shows heterogeneity in the equity extraction elasticity by income growth (measured as the log-change since the last refinance event). Panel A is based on a univariate specification that investigates heterogeneity by income growth on its own, while Panel B is based on a multivariate specification allowing for heterogeneity in four dimensions simultaneously: LTV, age, income level, and income growth. The multivariate specification is shown in equation 5. The dashed lines give 95% confidence intervals based on standard errors clustered by household. The figure shows that there is relatively little heterogeneity in the borrowing elasticity by income growth.

FIGURE A.X: HOUSE PRICE GROWTH AND BUNCHING AT COLLATERAL NOTCHES

A: Effect of House Price Growth on LTV Distribution

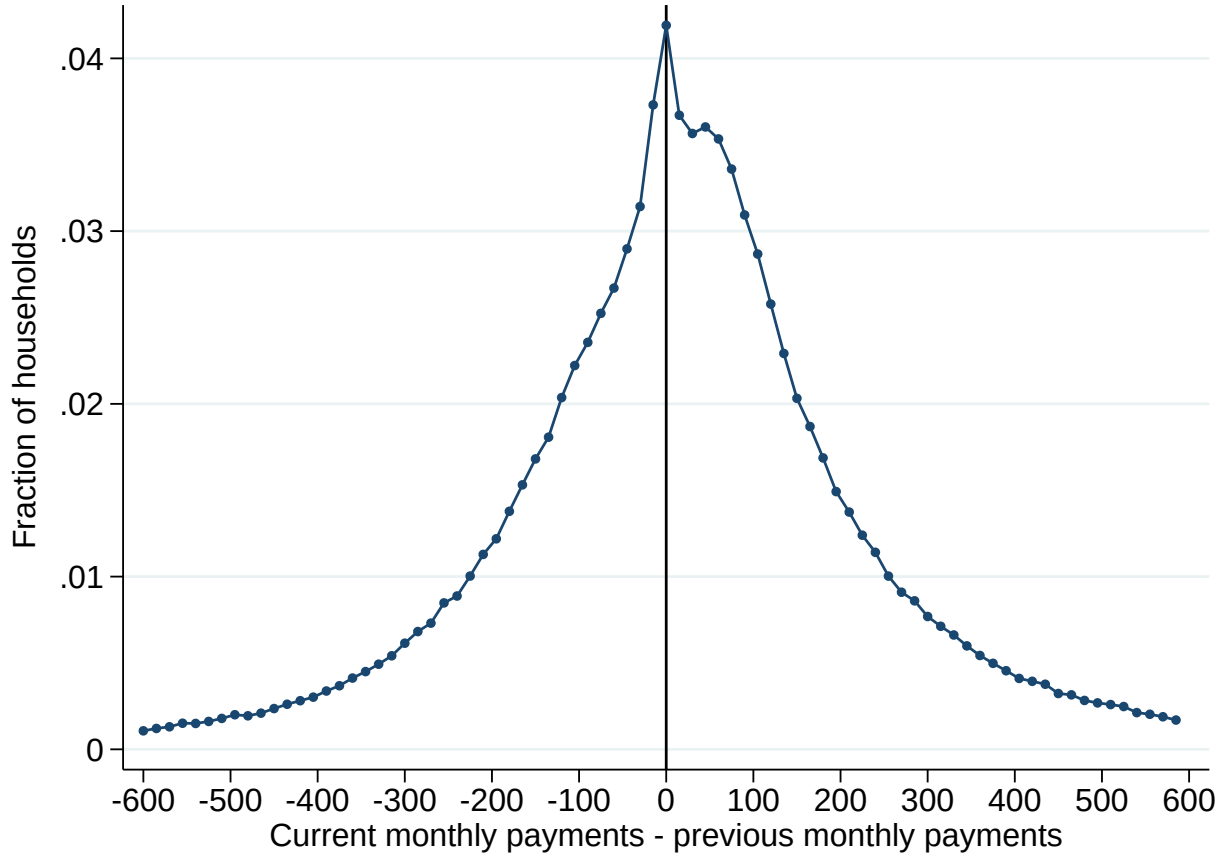


B: Effect of Equity Extraction on LTV Distribution



Notes: The figure is based on a sample of households who are pulled down to a lower notch by house price growth. The two panels show density distributions of three different LTV measures. The pre-LTV = D_{it}^{P}/P_{it-1} is the homeowner's LTV at time t given past mortgage choices (i.e., the debt level and amortization schedule chosen at time $t-1$, not including equity extraction at time t) and the old house price. The passive LTV = D_{it}^{P}/P_{it} is the homeowner's LTV given past mortgage choices and the new house price. The chosen LTV = D_{it}/P_{it} includes any equity extraction made at time t. The x-axis in each panel represents the distance between a given LTV measure and the next-notch-up from the passive LTV. Panel A illustrates the effects of house price growth by comparing the distributions of pre-LTV and passive LTV. This panel shows that house price growth moves homeowners from the positive to the negative range and eliminates bunching at interest rate notches. Panel B illustrates the effects of borrowing responses by comparing the distributions of the passive LTV and the chosen LTV. This panel shows that equity extraction largely recreates the qualitative pattern that existed before house price growth.

FIGURE A.XI: DISTRIBUTION OF THE CHANGE IN MONTHLY MORTGAGE PAYMENTS



Notes: The figure is based on a sample of households who are pulled down to a lower notch by house price growth. It shows the distribution of the difference (in GBP) between the household's current monthly mortgage payments and previous monthly payments.

TABLE A.I: THE EFFECT OF HOUSE PRICE GROWTH AT THE EXTENSIVE MARGIN

	(1)	(2)	(3)	(4)
Panel A: Full Sample				
Probability of Positive Equity Extraction	0.003	0.002	0.002	0.002
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1,384,346	1,384,346	1,311,734	1,173,626
Panel B: On-Time Sample				
Probability of Positive Equity Extraction	0.003	0.002	0.001	0.001
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	483,852	483,852	460,077	459,571
Panel C: Off-Time Sample				
Probability of Positive Equity Extraction	0.003	0.003	0.002	0.002
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	288,578	288,578	274,600	273,727
Panel D: Sample With Missing Durations				
Probability of Positive Equity Extraction	0.003	0.002	0.002	0.001
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	611,916	611,916	577,057	440,328
Control Variables:				
Month FE		×	×	×
Household FE		×	×	×
County x Year FE			×	×
Household Controls				×

Notes: The table reports estimates of the effect of house prices on the probability that households extract equity, across different specifications and samples. The outcome variable is a dummy for whether equity extraction was strictly positive (sample mean = 0.81). The treatment variable is house price growth (in logs), the standard treatment variable used in the main paper. Panel A considers the full sample, panel B considers the sample of on-time refinancers (defined as those who refinance between 2 months before and 6 months after reset rate onset), panel C considers the sample of off-time refinancers (defined as those who refinance more than 2 months before or more than 6 months after reset rate onset), and panel D considers the sample of refinancers with missing duration information. Standard errors are clustered by household and shown in parentheses. The household controls included in column (4) are income level, income growth, the last mortgage interest rate, the age of the borrower, a dummy for couples, and dummies for a range of self-reported reasons for the current and the last refinance (pure refinance / home improvement / debt consolidation / other).

TABLE A.II: EQUITY EXTRACTION ELASTICITIES USING REGIONAL HOUSE PRICE VARIATION

	(1)	(2)	(3)	(4)
Effect of County House Price Growth	11.961	4.466	4.538	3.879
	(1.146)	(0.797)	(0.814)	(0.724)
Observations	1,309,242	1,309,242	1,309,242	1,308,829
Control Variables:				
Month FE		×	×	×
County FE		×	×	×
Dummy for Couples, Income Level, Age			×	×
Reason for the Current Refinance				×

Notes: The table reports estimates of the effect of county house prices on equity extraction. The outcome variable is annualized equity extraction, i.e. equity extraction between the current and the last refinance events (in logs) divided by the number of years between the current and the last refinance events. The treatment variable is the log growth in average house prices for purchases in the county between the current and the previous year. The reasons for the current refinance include pure refinance, home improvement, debt consolidation, and other. Standard errors are clustered by county and given in parentheses. The table shows that the estimated effect of county house price growth is larger than the equity extraction elasticity reported in the main paper.

TABLE A.III: EQUITY EXTRACTION ELASTICITIES BY HOME IMPROVEMENT

	(1)	(2)	(3)	(4)
Panel A: Last Mortgage for Home Improvement				
Equity Extraction Elasticity	0.191	0.183	0.171	0.162
	(0.006)	(0.011)	(0.013)	(0.014)
Observations	114,566	114,566	108,237	96,613
Panel B: Last Mortgage Not for Home Improvement				
Equity Extraction Elasticity	0.213	0.198	0.189	0.184
	(0.003)	(0.006)	(0.007)	(0.007)
Observations	553,200	553,200	524,513	470,038
Panel C: Purpose of Last Mortgage Unknown				
Equity Extraction Elasticity	0.337	0.240	0.250	0.235
	(0.002)	(0.008)	(0.008)	(0.009)
Observations	716,580	716,580	678,984	606,975
Control Variables:				
Month FE		×	×	×
Household FE		×	×	×
County x Year FE			×	×
Household Controls				×

Notes: The table reports estimates of the equity extraction elasticity, splitting the estimation sample by whether the last equity extraction decision was made for home improvements or not. Panel A considers homeowners whose last refinance was for home improvements, Panel B considers homeowners whose last refinance was not for home improvements, while panel C considers homeowners whose last refinance purpose is missing in the data. Standard errors are clustered by household and shown in parentheses. The household controls included in column (4) are income level, income growth, the last mortgage interest rate, the age of the borrower, a dummy for couples, and dummies for the various reasons for both the last and current refinance (pure refinance / home improvement / debt consolidation / other). The table shows that, across the different fixed effects specifications, the estimated elasticity is quite stable across samples.

TABLE A.IV: EQUITY EXTRACTION ELASTICITIES BY WHETHER THE FIRST OBSERVATION WAS A PURCHASE OR REFINANCE

	(1)	(2)	(3)	(4)
Panel A: First Mortgage Observation is Purchase				
Equity Extraction Elasticity	0.318	0.240	0.243	0.220
	(0.002)	(0.007)	(0.007)	(0.008)
Observations	776,247	776,247	737,798	664,237
Panel B: First Mortgage Observation is Refinance				
Equity Extraction Elasticity	0.205	0.173	0.155	0.139
	(0.003)	(0.008)	(0.008)	(0.010)
Observations	580,745	580,745	549,272	488,992
Control Variables:				
Month FE		×	×	×
Household FE		×	×	×
County x Year FE			×	×
Household Controls				×

Notes: Panel A reports estimates of the equity extraction elasticity for households whose first observation in the data was a purchase, while Panel B reports estimates for households whose first observation in the data was a refinance. Standard errors are clustered by household and shown in parentheses. The household controls included in column (4) are income level, income growth, the last mortgage interest rate, the age of the borrower, a dummy for couples, and dummies for a range of self-reported reasons for the current and the last refinance (pure refinance / home improvement / debt consolidation / other).

B Collateral Channel: A Test Using Interest Notches

This section presents a further test using interest rate notches to investigate the importance of the collateral channel. Appendix Figure A.X analyzes the dynamic interaction between house price growth and bunching responses to interest notches. This figure focuses on the sample of households who are pulled down to a lower notch by house price growth, i.e. households whose collateral constraint is relaxed. For this analysis, it is useful to formally define three different LTV concepts. First, we define the pre-determined LTV = D_{it}^P / P_{it-1} as the homeowner's LTV at time t given past mortgage choices (the debt level and amortization schedule chosen at time $t-1$) and the old house price. Second, we define the passive LTV = D_{it}^P / P_{it} as the homeowner's LTV at time t given past mortgage choices and the new house price. This is the LTV that would apply if the homeowner simply rolled over her debt at time t, i.e. if she were "passive." Third, there is the actual chosen LTV = D_{it} / P_{it} that includes any equity extraction or injection at time t. By this terminology, the sample in the figure includes borrowers for whom the passive LTV is at least one notch down from their pre-determined LTV.

The figure shows two panels in which we compare the density distributions of the three LTV measures defined above. The x-axis in each panel represents the distance between a given LTV measure (pre-LTV, passive LTV, or chosen LTV) and the next-notch-up from the passive LTV. Panel A illustrates the implications of house price growth by comparing the distributions of pre-LTV and passive LTV. Two implications are worth highlighting. First, house price growth moves all borrowers from the positive range (in terms of their pre-LTV) to the negative range (in terms of their passive LTV). This follows from the fact that we are restricting the sample to households who are pulled down by at least one notch. Second, house price growth eliminates all bunching at interest notches: there is bunching at every notch in the pre-LTV distribution, but no bunching in the passive LTV distribution.[1]

How do borrowers respond to the relaxed collateral constraints? Panel B illustrates the implications of equity extraction behavior by comparing the distributions of the passive LTV and the final chosen LTV. Strikingly, equity extraction behavior largely recreates the qualitative pattern that existed before house price growth. We see a dramatic right-shift of the LTV distribution, moving

[1]The fact that the passive LTV distribution primarily falls in the bins $(-5, 0)$ and $(-10, -5)$, with a discrete drop between the two, is not a bunching response. It follows mechanically from the x-axis normalization and the fact that most homeowners are no longer 5 or 10 percentage points away from a notch. Furthermore, notice that bunching in the pre-LTV distribution is attenuated compared to the actual amount of bunching in the last refinance event due to amortization between the last and current refinance events.

borrowers back to around zero or into the positive range, and recreating bunching at notches. In other words, when house price growth pulls households below one or more notches (Panel A), most of them extract equity back to the next notch above (at zero) or a higher notch (in the positive range). Hence, this figure shows how house price growth interacts with bunching responses to interest notches in a way that is consistent with a collateral mechanism.[2,3]

[2]To be clear, what is new in Appendix Figure A.X compared to the more standard bunching analysis in Best *et al.* (2018) is the illustration of a dynamic interaction between house price growth and bunching responses.

[3]It is also conceivable that some refinancers are targeting their previous monthly mortgage payment rather than borrowing up to a soft collateral constraint. They might do so because of liquidity constraints or behavioral factors (see Di Maggio *et al.* 2017 for an analysis of the mortgage payment channel). To explore such effects, Appendix Figure A.XI shows the distribution of changes in monthly mortgage payments between the last and the current mortgage among homeowners who are pulled down to a lower notch by house price growth (i.e., the same sample as in Appendix Figure A.X). In this sample, monthly payments are always reduced by house price growth as it pulls them below interest notches. But the total net change in the payment depends on other factors such as changes over time in interest rate levels and the amount of equity they choose to extract. If homeowners extract equity to target an unchanged monthly mortgage payment, then we would see excess bunching at zero in Appendix Figure A.XI. There is arguably a small spike at zero, but overall the distribution is quite smooth. This shows that, in this setting, homeowners do not primarily target an unchanged mortgage payment when choosing equity extraction (while they do target collateral notches as shown above).

References

BEST, MICHAEL, CLOYNE, JAMES, ILZETZKI, ETHAN, & KLEVEN, HENRIK. 2018. Estimating the Elasticity of Intertemporal Substitution Using Mortgage Notches. Mimeo. 2, 17

DI MAGGIO, MARCO, KERMANI, AMIR, KEYS, BENJAMIN J., PISKORSKI, TOMASZ, RAMCHARAN, RODNEY, SERU, AMIT, & YAO, VINCENT. 2017. Interest Rate Pass-Through: Mortgage Rates, Household Consumption, and Voluntary Deleveraging. *American Economic Review*, **107**(11), 3550–88. 17