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Consumer Ruthlessness and Mortgage Default during the 2007 to 2009 Housing Bust

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ABSTRACT

From 2007 to 2009 U.S. house prices plunged and mortgage defaults surged. While ostensibly consistent with widespread "ruthless default," analysis of detailed mortgage and house price data indicates that borrowers do not walk away until they are deeply underwater—far deeper than traditional models predict. The evidence suggests that lender recourse is not the major driver of this result. We argue that emotional and behavioral factors play an important role in decisions to continue paying. Borrower reluctance to walk away implies that the moral hazard cost of default as a form of social insurance may be lower than suspected.

FROM 2007 TO 2009 HOUSE PRICES in the United States plunged, especially in many areas of Arizona, California, Florida, and Nevada (Figure 1). At roughly the same time, mortgage defaults surged, consistent with the predictions of option-theoretic models of mortgage pricing where borrowers "ruthlessly" default to maximize their wealth (Foster and Van Order (1984, 1985)). Numerous media anecdotes suggest that ruthless defaults were widespread, and the presumed wave of such defaults has led economists and policy makers to propose ways to address ruthless or strategic defaulters. In this paper, we assess how closely borrower behavior conforms to neoclassical models of default using rich microdata where we know the precise timing of defaults and the evolution of house prices at the ZIP code level.

We find that home equity has to turn deeply negative before most homeowners will exercise their default "option"—much more so than the neoclassical models predict. In particular, we estimate that the median borrower in our

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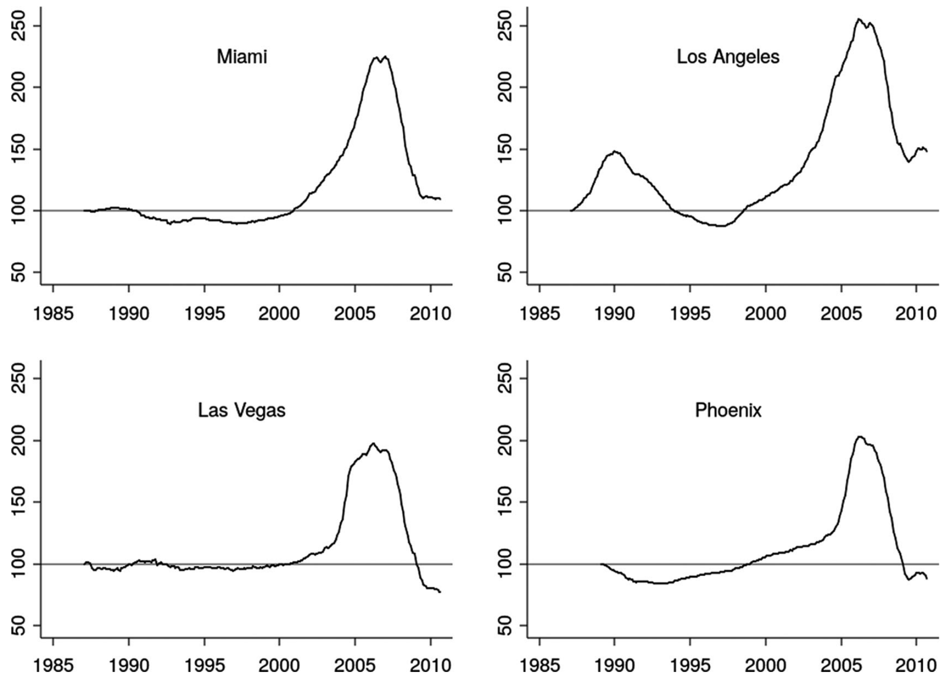

Figure 1. Home prices in selected metropolitan areas, January 1987 to August 2010. This figure shows home price indices from Case-Shiller for four major metropolitan areas in the four states that we study. The price indexes are adjusted for overall inflation using the all-urban Consumer Price Index (CPI) from the Bureau of Labor Statistics and are set to 100 in January 1987.

sample does not exercise the default option until his housing equity drops to −74% (i.e., the cumulative loan-to-home-value (CLTV) ratio is 174%, which equates to a loan balance—including first and second mortgages—of about \$348,000 on a \$200,000 house). In contrast, the traditional frictionless option-theoretic model predicts that default is certain once equity reaches about −20% (Kau, Keenan, and Kim (1994)).

Although many papers demonstrate that negative equity makes default more likely (e.g., Deng, Quigley, and van Order (2000), Bajari, Chu, and Park (2008), Foote, Gerardi, and Willen (2008)), understanding whether the ruthless model effectively characterizes consumer behavior requires further analysis. We develop a novel strategy to estimate the distribution of threshold equity values implied by the empirical relationship between equity and default. In a recent survey that Guiso, Sapienza, and Zingales (2013) draw on, homeowners were asked a series of questions to gauge how deeply underwater they would have to be to walk away from their mortgage. For example, the survey asks, "If the value of your mortgage exceeded the value of your house by \$50,000, would you walk away from your house even if you could afford to pay your monthly mortgage?" This type of question provides the intuition for our analysis, but we infer the threshold level of negative equity needed to induce default by examining actual payment decisions of people who bought their homes at the peak of the housing market in 2006 and started falling "underwater" soon thereafter. Although many borrowers *say* they would not default in certain situations, they may *act* differently.

The housing crisis has reignited a longstanding debate about whether mortgage borrowers ruthlessly exercise the default or put option. On the one hand, Cunningham and Hendershott (1984) propose that transaction and "psychic" costs could be substantial, and Foster and van Order (1985) provide initial empirical evidence of an underexercise of default by underwater borrowers.[1] On the other hand, Kau, Keenan, and Kim (1994) show that rational borrowers may not default until equity falls well below zero even in the absence of transaction costs, and argue that the available evidence supports the frictionless model.

Research on this topic can inform not just mortgage pricing questions, but also policy issues concerning the penalties for default, regulatory considerations, such as caps on loan-to-value ratios, and loss forecasting in the event that house prices severely decline again (e.g., stress tests). Moreover, considerable improvements in data on loan performance and house prices, as well as in econometric methods, can help answer these questions more precisely.

We focus primarily on the monthly payment status of over 125,000 nonprime home purchase loans originated in 2006 in Arizona, California, Florida, and Nevada, as well as a monthly measure of home equity computed from highly disaggregated ZIP code level house price indexes (HPI). All of the borrowers in this sample put no money down (a combined loan-to-value of 100) and many purchased homes in ZIP codes where house prices declined by over 50% between 2006 and 2009. These loans were packaged into private-label mortgage securities and defaulted at an extremely high rate, and have been a central focus of research on the triggers of the financial crisis. If borrowers typically refrain from walking away until their equity falls deeply and they are severely underwater, this would imply that borrower behavior largely deviates from that predicted by traditional option-theoretic models.

Because our main sample is not representative of the population of home buyers, we also examine a broader set of loans from an alternative data set that includes loans sold to Fannie Mae and Freddie Mac, loans held in banks' portfolios, and loans with modest down payments. If borrowers in this sample also tend not to default until falling deeply underwater, this would further support the view that mortgage borrowers' behavior generally deviates from the traditional model.

Our methodology addresses a key empirical challenge, namely, that default can occur because of liquidity shocks that necessitate default and lead to incorrect inferences about walk-away thresholds. If, for example, we observe an individual defaulting when his CLTV ratio hits 125% (or, equivalently, equity

[1] Subsequent work by Quigley and van Order (1995) also points to an underexercise of the default option.

hits −25%), it is possible that an income shock triggered the default and that −25% does not actually represent that individual walk-away threshold equity value. Even though we do not fully observe individual liquidity, it is important to recognize that default only occurs for two reasons—an unwillingness to pay (ruthless default), or an inability to pay. The former, by definition, is a response to negative equity, and so we can estimate the probability that a default at a given equity level was liquidity-driven, rather than ruthless, by estimating and then stripping out the effect of equity on default. We then incorporate these probabilities into the likelihood function for estimating the distribution of equity threshold values.

We estimate the effect of equity in a hazard model that takes advantage of variation across ZIP codes in the timing and extent of house price declines. As noted, all of the borrowers in the sample started with zero equity, so none of the identifying variation stems from individual down payment choices. Loan age fixed effects, quarter fixed effects, county-level time-varying economic conditions, and several other variables help control for liquidity shocks that might be correlated with house price shocks.[2] To the extent that the remaining unobserved liquidity shocks correlate with house price shocks, the true average threshold will be even *larger* than our estimate already suggests.

Why do borrowers generally not walk away until they are very deeply underwater? We discuss three broad categories of reasons. First and foremost are standard financial considerations, such as lender recourse, the negative impact to credit access, and foregoing the possibilities of future loan modifications and house price gains. We argue that these factors are unlikely to drive default costs up enough to explain our result, especially given the offsetting financial benefit of free housing for many months between default and repossession of the house. Even in Arizona and California, where recourse is prohibited for home purchase loans, we find that most borrowers have high walkaway-CLTV thresholds.

The second category of factors are nonfinancial and "behavioral," and include overestimating default costs and home values, loss aversion, and emotional factors such as moral aversion to default or an attachment to one's house. We believe that such factors must be playing an important role in default decisions (or a lack thereof), though some may do so more than others. For example, survey evidence indicates that Americans widely consider ruthless default morally wrong (Fannie Mae (2010), Guiso, Sapienza, and Zingales (2013)).[3] In contrast, emotional attachment is probably not very important since the borrowers we study just moved into their house before prices started to collapse.

A third category relates to data issues that may bias our estimate. In particular, our assumption of a constant appreciation rate across all houses in a ZIP code may not be valid and hence may lead to measurement error. We

[2] As Green and Shoven (1986) explain, loan age is a key observed variable related to the arrival of shocks.

[3] Seiler (2016) finds that homeowners consider default less morally acceptable when defaulters earn a positive financial return on the default.

formally examine this concern by measuring heterogeneity in the housing stock of a given ZIP code and assessing whether such heterogeneity affects the results.

While purely ruthless defaults have occurred, our results suggest that a widespread inability to pay, combined with low or negative equity that makes selling one's house in the face of financial problems difficult (so-called "double-trigger" defaults), is more important.[4] Such widespread inability to pay stems from two sources. First, the severe recession beginning in 2007 led to substantial income losses across a large number of households. Indeed, recent research finds a strong connection between job loss and default (Hsu, Matsa, and Melzer (2014), Gerardi et al. (2015), Tian, Quercia, and Riley (2016)).[5] Second, the sharp rise in nonprime lending during the mid-2000s, which includes loans without income verification or any down payment, likely means that a substantial fraction of borrowers were financially unstable even at origination.

Our finding has important policy implications. Mortgage default can be viewed as a social insurance program as many states enforce various laws protecting borrowers (e.g., creditors must go through a lengthy process to repossess a house), thus passing on some of the costs of default to others. As with any social insurance program, moral hazard poses potential costs, and policy makers are clearly concerned about such costs. For example, lawmakers passed the Bankruptcy Abuse Prevention and Consumer Protection Act in 2005 to "make bankruptcy more embarrassing and more difficult."[6] As noted earlier, the recent spike in mortgage defaults along with numerous anecdotes about ruthless default reinforce the view that the stigma of default has waned, and may encourage lawmakers to make mortgage default more difficult. But if in fact consumers strongly prefer to avoid default, perhaps for moral or social reasons, then the moral hazard cost of the default option as a form of social insurance is already low.

The outline for the rest of the paper is as follows. In Section I, we define ruthless default. Section II describes our data sources. Section III presents our empirical analysis, which proceeds in two parts. In the first part, we estimate the nonlinear relationship between equity and default from a discrete-time hazard model. In the second part, we back out the distribution of walk-away values for borrowers in our sample that is implied by the estimated default-equity relationship. In Section IV we discuss in detail why borrowers might be so reluctant to walk away, and external validity issues. Finally, Section V concludes.

[4] Mayer et al. (2014) provide evidence of strategic default behavior. In particular, they find that some Countrywide borrowers defaulted to become eligible for a mortgage modification program, and would not have defaulted in the absence of the modification program.

[5] Consistent with our findings, Gerardi et al. (2015) identify very few strategic defaulters in their data, and also note that the majority of financially distressed and underwater homeowners continue to make mortgage payments.

[6] Senator Charles Grassley (R-Iowa) quoted in Donald Bartlett and James Steele, "Soaked by Congress," in *Time* magazine on May 7, 2000.

I. What Is "Ruthless Default?"

In the pure option-theoretic literature, ruthless or strategic default occurs when the value of a property falls below the cost of the mortgage and the borrower exercises an implicit put option to "sell" the house back to the lender (i.e., default) in order to maximize his financial wealth (Foster and van Order (1984, 1985)). These models abstract from transaction costs that occur in reality, but nevertheless predict that borrowers are unlikely to default when they are just slightly underwater (e.g., Kau, Keenan, and Kim (1994)). Because of the embedded put and call (prepay) options, the mortgage balance generally exceeds the true cost of the mortgage and thus ruthless default does not occur as soon as the house value sinks below the mortgage balance.

The default option insures against negative house price shocks. For someone not too deeply underwater, making the next payment can make financial sense if there is a good chance that house prices will rebound, as the default option continues to protect against losses. Kau, Keenan, and Kim (1994) conduct simulations based on this model and find that borrowers do not walk away until equity falls to about −20%.[7]

Of course, exercising the default option may entail certain financial costs that further lower the walk-away threshold, including legal costs, the costs of reduced access to credit, and so on. Previous research has intensely debated the importance that transaction costs might play in default decisions (see Vandell (1995) for a review). We discuss these factors in more detail in Section IV, but note here that institutional details particular to our sample and time frame help us rule out these factors as a principal explanation for our results. We therefore also discuss various non-economic and behavioral factors that might be playing role.

II. Data

A. Mortgage Microdata

Our primary source of data on mortgage performance is CoreLogic (formerly known as LoanPerformance). CoreLogic provides detailed information on the individual mortgages bundled into subprime and "alt-A" (collectively referred to as "nonprime") private-label securities. Subprime loans are generally characterized as loans to borrowers with low credit scores and/or little or no down payment, while alt-A securities typically involve mortgages with reduced or no documentation of the borrower's income and assets and have a higher proportion of interest-only mortgages and option ARMs. The CoreLogic data contain

[7] Kau, Keenan, and Kim (1994) also emphasize that the interest rate environment can affect the likelihood of default. A rising interest rate environment, for example, makes existing mortgages more valuable and reduces the likelihood of default (borrowers want to retain their favorable loan terms). During our observation period, however, rates were falling, which made existing mortgages less valuable to borrowers. Moreover, most borrowers in our sample took out adjustable-rate mortgages, reducing the option value of their mortgages associated with interest rate changes.

several loan characteristics at origination, including the borrower's FICO score, ZIP code of the property, the loan amount, loan-to-value ratio, interest rate, loan type (e.g., fixed rate or adjustable rate), and loan purpose (e.g., purchase or refinance). CoreLogic also tracks the following variables at a monthly frequency: the current interest rate, current loan balance, scheduled monthly payment, and payment status of the loan (e.g., current, 30 days delinquent, 60 days delinquent, etc.). The CoreLogic data cover the majority of securitized nonprime mortgages and thus provide information on a large number of loans originated during the peak of the most recent housing cycle (see Mayer and Pence (2008)).

B. ZIP Code HPI Data

To calculate housing equity for each loan in our sample in each month, we use ZIP code–level HPIs—also from CoreLogic. These HPIs are monthly repeat-sales indexes and are available for approximately 6,000 ZIP codes from 1976 to the present. The ZIP code coverage of the data set depends on factors such as state sales price disclosure laws, the corporate history of CoreLogic, and the typical volume of real estate transactions of a given ZIP code. To the extent that homeowners form beliefs about their home's value by observing sales prices on nearby homes, these ZIP code HPIs should be a good proxy for such beliefs. Alternatively, homeowners may obtain estimates of their house values using online resources, such as Zillow.com. Our comparison of the CoreLogic HPIs and the Zillow data indicates that the house price appreciation rates implied by Zillow are consistent with our ZIP code-level HPI data.[8]

Figure 2 shows the 1$^{\text{st}}$, 50$^{\text{th}}$, and 99$^{\text{th}}$ percentile ZIP codes in terms of house price declines between January 2006 and June 2009 among the ZIP codes in our sample. The 50$^{\text{th}}$ percentile ZIP code experienced a price decline of over 40% between January 2006 and June 2009, while the 1$^{\text{st}}$ and 99$^{\text{th}}$ percentile ZIP codes experienced drops of about 20% and 60%, respectively.

C. Estimating Equity

Following the convention in the mortgage default literature, we estimate a borrower's equity position ($\widehat{E}_{itz}$) as 100 minus the cumulative loan-to-value ratio, that is, for borrower i at month t in ZIP code z:

$$\begin{aligned} \widehat{E}_{itz} &= 100 - \widehat{CLTV}_{itz} \\ \widehat{CLTV}_{itz} &= \tfrac{\widehat{B}_{itz}}{\widehat{V}_{itz}} \cdot 100, \end{aligned} \tag{1}$$

[8] For example, in 5,063 ZIP codes where house price data are available from both Zillow and CoreLogic, the average decline in home value from January 2006 to December 2008 was about 16% in the Zillow data and about 18% in the CoreLogic data, and the correlation in ZIP code house price growth over this period between the two data sets is 0.87.

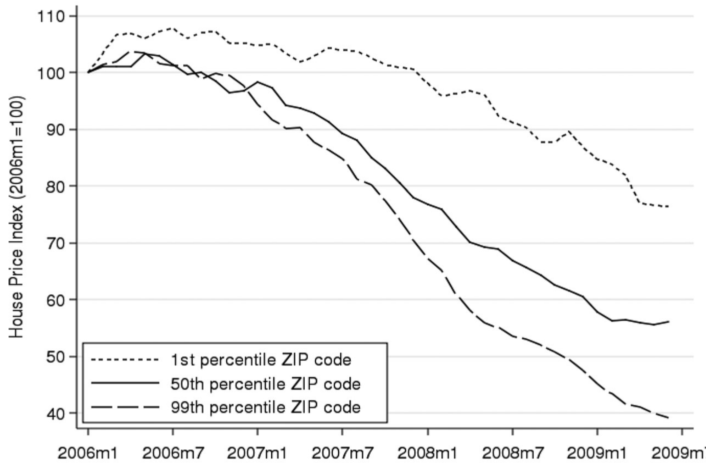

Figure 2. ZIP code house price declines from January 2006 to June 2009. This figure shows house price changes at the ZIP code level based on the CoreLogic HPIs for the 1st, 50th, and 99th percentile ZIP codes in our four-state sample in terms of overall HPI declines between January 2006 and June 2009.

where $\widehat{B}_{itz}$ is our estimate of the total loan balance and $\widehat{V}_{itz}$ is an estimate of the house value. Note that the borrower's equity can be negative when the borrower owes more than the value of his house and is underwater.

Although the CoreLogic data indicate whether a home purchase involves a junior lien, it lacks information on the payment status of the junior lien. For borrowers with a junior lien, we assume that it is paid down at the same rate as the first lien in estimating $\widehat{B}_{itz}$.[9] In other words, $\widehat{B}_{itz}$ equals the product of the unpaid principal balance of the first lien at time t and the ratio of the combined loan balance to the first-lien balance at origination. We estimate house values in the months after origination by adjusting the home value at origination (V_0) using the monthly ZIP code–level HPI:[10]

$$\widehat{V}_{itz} = V_{i0z} \cdot \frac{HPI_{tz}}{HPI_{0z}}. \tag{2}$$

D. Defining Default

We define default as being 90+ days delinquent for two consecutive months, and we define the month of the default *decision* as three months prior to the month in which the loan reaches the 90+ day delinquency mark. One might

[9] This assumption appears to be reasonable based on our comparison of the overall pay-down rate of all first liens with that of all junior liens in the CoreLogic data.

[10] The sale price, calculated by dividing the first-lien loan amount at origination by the initial CLTV, forms our measure of initial home value.

be inclined to define default as entering the foreclosure process, but the start of foreclosure depends on when the lender decides to file a notice of default, whereas halting mortgage payments reflects borrowers' decisions. Since we are interested in the borrower's equity position when he decides to default, our definition is more appropriate.

E. Sample Selection

We selected our sample to help accurately measure equity and to identify arguably exogenous variation in equity across otherwise similar borrowers. We focus on nonprime first-lien home purchase mortgages for single-family owner-occupancy homes originated in 2006 with a CLTV of 100% in Arizona, California, Florida, and Nevada.[11] Notably, about two-thirds of the nonprime purchase mortgages originated in 2006 in these states had a CLTV of 100%.

Our sample has three important advantages. First, selecting borrowers with a CLTV at origination of 100% helps avoid measurement error due to unobserved additional mortgages—it is unlikely for borrowers to have another mortgage in addition to the reported loans financing 100% of the purchase price. Second, the decline in prices soon after these borrowers purchased their home in 2006 makes the refinance option largely irrelevant. As such, with our sample, we avoid the problem of many borrowers exiting the sample via a refinance before defaulting.[12] The price decline and lack of home equity also make it unlikely that borrowers took out an unobservable junior mortgage after the initial home purchase. Third, we exclude refinance mortgages because CLTV is potentially mismeasured for these loans. More precisely, outstanding junior liens, which may not be simultaneously refinanced, are not reported at the time the refinance occurs, and the appraised house value is often not recorded.

F. Summary Statistics

Table I provides summary statistics for the loans in our sample and selected statistics for their counties or ZIP codes. We find that 87% of the loans in our sample defaulted by the end of the observation period (September 2009) by our definition of default.[13] The median CLTV at "termination"—either the month of default or the end of the observation period for loans that survive—was just

[11] Single-family housing includes "Planned Unit Developments," which generally are developments with communal amenities. We analyze condominium purchasers separately.

[12] Less than 7% of the mortgages in our data prepaid during the sample period. Almost all of these refinances occurred in late 2006 and early 2007, likely because house prices in some areas did not start to fall until then.

[13] One may be concerned that our definition of default leads to an overstatement of the default rate in the sample. Some borrowers who are 90+ days delinquent may self-cure and avoid foreclosure. Adelino, Gerardi, and Willen (2013) argue that such "self-cure risk" may partially explain why servicers have been reluctant and slow to renegotiate loans that are seriously delinquent. Unlike in their data, we find that only about 2% of loans that are 90+ days delinquent for two consecutive months in our sample cure during the observation period.

Table I
Summary Statistics

The top panel shows characteristics at the loan level for loans that had negative equity at termination; the bottom panel shows some characteristics of the ZIP codes where sample borrowers' properties were located based on Census 2000 data and weighted by ZIP code population. "Termination" refers to the last month of the sample period for loans that have not defaulted, and the month of default for loans that have defaulted. Unemployment rate data come from the Bureau of Labor Statistics and are measured quarterly. Credit card delinquency data are from TransUnion's Trend Data and are measured quarterly. ZIP code demographic data come from 2000 Census and are weighted by population in the ZIP code.

	(1) Mean	(2) Median	(3) *SD*
Loan Characteristics (N = 128,248)			
Defaulted during observation period	0.87	1.00	0.34
Home value at origination ($000's)	389.9	350.0	182.4
CLTV at termination	135.6	128.8	28.0
Equity at termination ($000's)	−86.3	−71.4	64.8
Scheduled monthly payments at termination ($)	1,998.3	1,796.7	922.8
Loan age at termination (months)	18.5	18.4	8.8
Interest rate at origination (%)	7.4	7.4	1.2
Interest rate at termination (%)	7.6	7.5	1.1
FICO score at origination	673.6	669.0	49.6
Low or no documentation	0.70	1.00	0.46
Originated in Arizona	0.11	0.00	0.31
Originated in California	0.55	1.00	0.50
Originated in Florida	0.27	0.00	0.44
Originated in Nevada	0.08	0.00	0.27
Four-quarter change in county unemployment rate at termination	1.76	1.30	1.56
Four-quarter change in county credit card 60 + day delinquency rate at termination	0.22	0.20	0.25
ZIP code characteristics in 2000 (N = 1,668)			
Median home value ($000's)	180.3	146.3	116.4
Median household income ($000's)	47.4	43.6	16.5
Fraction residents over age 25 w/bachelor's degree	0.24	0.21	0.14
Fraction residents Hispanic	0.27	0.19	0.22
Fraction residents Black	0.08	0.04	0.12

under 129% (which corresponds to equity of −29%; for ease of interpretation, we generally present results in terms of CLTV rather than equity), and the median loan age at termination was only about 18 months. The CLTV at the time of default was skewed toward higher CLTVs, or deeper levels of negative equity, which can also be seen in Figure 3. About half of default decisions occurred when the CLTV was less than 130%, but many default decisions occurred at CLTVs in excess of 170%. The interest rate at termination was nearly identical on average to that at origination, suggesting that interest rate changes were probably not a major factor behind the defaults in our sample. The median FICO score was 669.

We merge county-level unemployment rates from the Bureau of Labor Statistics (BLS) and county level credit card 60 + day delinquency rates from

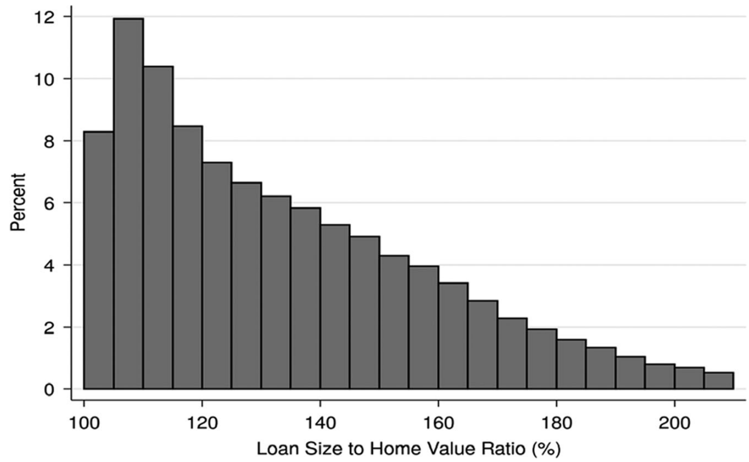

Figure 3. Distribution of the ratio cumulative loan size to home value (CLTV) at time of default decision. This figure shows the distribution of terminal CLTVs for borrowers who defaulted with zero or negative equity. See the text for our definition of default and for details on how we calculate CLTV.

TransUnion's TrenData with the CoreLogic data. Table I shows that the unemployment rate increased by 1.8 percentage points over the four quarters leading up to the termination month, while the credit card delinquency rate rose by 0.22 percentage points. In addition, we merge in select ZIP code characteristics from the 2000 Census. For the average ZIP code in our sample, the median home value was $180,000 and the median household income was just over $47,000. The substantially higher median home values at origination reported for loans in our sample largely reflect the fact that between 2000 and 2006 house values more than doubled in Arizona, California, Florida, and Nevada (recall Figure 1). About a quarter of the residents in the average ZIP code had at least a Bachelor's degree, 27% were Hispanic and 9% African-American. These averages are very similar to those of California overall, which is the state where the majority (55%) of sample loans were originated.

III. Empirical Analysis

A. Overview

We are interested in inferring the threshold level of negative equity needed to induce default. However, borrowers may not default due to equity considerations alone, which our estimation strategy will have to address. Consider three types of borrowers. Borrower A is exposed only to declining house prices. If she were to make a payment when equity was −30%, but not at −40%, we would infer that her walk-away value is between −30% and −40%. Borrower B, in contrast, is exposed to a random and severe income shock, such as a job loss, that triggers default. In his case, there is a binding cash-flow constraint and the depth of negative equity is unrelated to the timing of the default. Finally, consider Borrower C, who is exposed to a mild income shock that does not trigger default, but his marginal utility of cash-on-hand might increase as a result of this shock and make him more responsive to a decline in equity than Borrower A (Elul et al. (2010)).

The first part of our analysis nonparametrically estimates the relationship between equity and default in a discrete-time hazard model. Our main motivation here is to generate estimates of the probability that borrowers had to default because of a severe shock (like Borrower B) as opposed to making more of a ruthless decision in response to a decline in equity (like Borrowers A and C). These estimates feed into the second part of our analysis where we estimate the threshold level of negative equity at which the median borrower walks away. A simple model motivates the estimation strategy: borrowers have heterogeneous default costs drawn from a distribution, and they default when negative equity exceeds that cost. We use the results from the first part to identify defaults likely to have been liquidity induced, rather than equity-driven. Thus our estimated distribution will be one that is consistent with the relationship between equity and default estimated in the first part.

B. A "Naïve" Estimate

Table I provides a simple, but incorrect, estimate of the median walk-away threshold, showing that the median CLTV at termination in the sample was 129%, which corresponds to −29% equity. One reason this estimate is biased toward a lower CLTV, or higher level of equity, is that it ignores the possibility that many defaults arise from borrowers like Borrower B, who have no choice but to default because of a severe cash-flow problem and no equity, which makes selling the house impossible. The equity level at termination for these double-trigger defaults underestimates such borrowers' walk-away equity thresholds in the absence of cash-flow insolvency.

A second reason it is biased is that it ignores the fact that about 13% of borrowers in the sample "survived" through the end of our observation period (September 2009), that is, they continued to make payments on their mortgage during the entire sample period. For these borrowers, we allow for the possibility that their walk-away CLTV is higher than the highest CLTV level they experienced during the observation period. Our two-part empirical analysis addresses these identification and censoring issues.

C. The Unconditional Relationship between Equity and Default

Figure 4 displays the fraction of monthly payment decisions that default, within one-point-wide CLTV bins, similar to a typical raw hazard plot but in default-CLTV space rather than default-loan-age space. The raw data demonstrate a strong positive relationship between CLTVs and default decisions, as one would expect if borrowers are more likely to walk away as equity falls

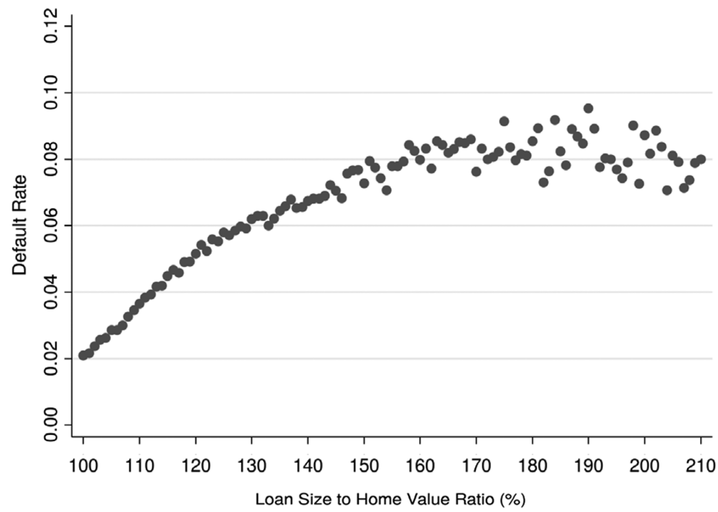

Figure 4. Unconditional relationship between default and the cumulative loan to home value ratio (CLTV). This figure shows the fraction of monthly decisions made at each CLTV level that were to default. CLTVs were rounded to the nearest integer and each data point reflects decisions made within a bin of one percentage point.

further below zero. The default rate at a CLTV of 150 is about four times that at a CLTV of 100. Note that Kau, Keenan, and Kim (1994) predict default should occur with near certainty once CLTV reaches about 120; these data do not come close to following that pattern. Moreover, this unconditional relationship *overstates* the true equity-default relationship (i.e., in this figure default appears more sensitive to equity than is actually the case). One reason is that equity began dropping soon after origination, but the delinquency hazard rate typically rises in the first couple of years after origination anyway.[14] Figure 5 shows the correlation between CLTV and loan age in our sample; our hazard regression conditions out confounding loan-age "effects." A second reason is that local job market conditions likely co-move with both house price declines and default. These conditions will be taken into account as well.

As noted in the introduction, equity does *not* vary in our sample because of initial borrower-specific choices about their down payment, since all of the borrowers in our sample bought their homes with no money down. Rather, the variation in equity (and, equivalently, CLTV) in our data set arises over time and through geographic differences in house price appreciation. Also, although we focus on just four states, as noted earlier there is considerable heterogeneity in house price appreciation rates across ZIP codes within these states (Figure 2).

[14] The Public Securities Association publishes a "standard default assumption" used widely in the mortgage industry where the probability of default, conditional on not having defaulted already, climbs during the first 30 months (Sherlund (2008)).

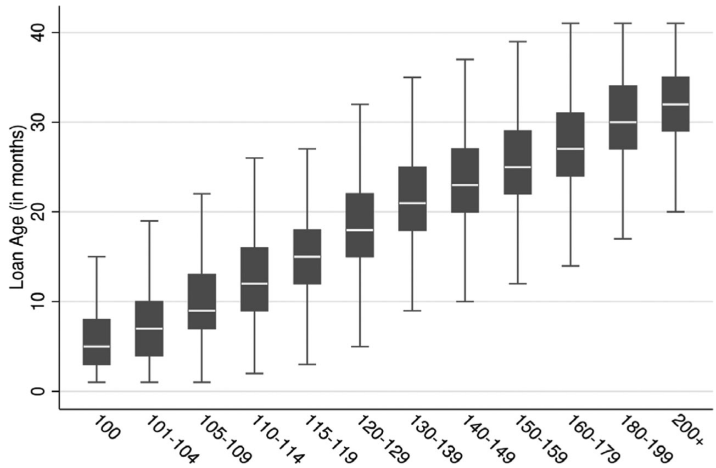

Figure 5. Distribution of loan age by cumulative loan size to home value (CLTV) ratio. This figure shows box plots of loan age within each CLTV group corresponding to the CLTV dummy variables we use in our default hazard regression. The box covers the 25th to 75th percentiles of loan age, and the line in the box corresponds to the median value; lines extend from the box the upper and lower adjacent values, with outside values not shown.

D. Step 1: Estimating the Relationship between Equity and Default

To address the identification concerns associated with the unconditional relationship, we estimate a discrete-time hazard model (see Allison (1982)):

$$P_{it} = \Lambda\left(A_{it} \cdot countygroup_j + \mathbf{X}_{it}\boldsymbol{\beta} + E_{it}\right), \tag{3}$$

where $P_{it} = \Pr(T_i = t | T_i \geq t, A_{it}, \mathbf{X}_{it}, E_{it})$, T_i is the month of borrower i's default decision, Λ is the logistic function, and E_{it} represents a set of 12 equity dummy variables that equal one when borrower i's equity in period t takes on a particular value and zero otherwise.[15] The baseline hazard specification is flexible, with 40 loan-age dummy variables (A_{it}) for each possible loan age for the observation period interacted with county group dummy variables ($countygroup_j$, j = 1, 2, 3), where the groups are based on changes in the county unemployment rate between June 2006 and June 2009. The vector X_{it} contains other variables that are related to the probability of default for liquidity reasons and may also be correlated with equity. These variables include: (1) quarterly time fixed effects, (2) the change in the individual mortgage's contract interest rate, (3) the four-quarter change in the county unemployment rate, and (4) the four-quarter change in the county credit card delinquency rate. The quarterly fixed effects account for common shocks across all four states in the sample. Interest rate changes capture the potential impact of interest rate resets on default, and changes in county-level unemployment and credit card delinquency rates

[15] More specifically, the value of equity is rounded to the nearest integer and the bins, labeled in terms of CLTV, are listed in Table II.

Table II

Logit Estimation of the Probability of Default

This table shows selected coefficients, standard errors, and odds ratios from estimating equation (3) in the text using 2.8 million loan-month observations. Other variables controlled for but not shown include quarterly time fixed effects and monthly loan-age fixed effects interacted with three county group dummies that indicate the extent to which the county unemployment rate increased between June 2006 and June 2009. Standard errors in parentheses are clustered at the county level.

	(1) Coefficient	(2) SE	(3) Odds Ratio
CLTV fixed effects (100% is the reference)			
CLTV between 101% and 104%	−0.004	(0.02)	1.00
CLTV between 105% and 109%	0.02	(0.02)	1.02
CLTV between 110% and 114%	0.10	(0.03)	1.11
CLTV between 115% and 119%	0.17	(0.04)	1.18
CLTV between 120% and 129%	0.29	(0.04)	1.33
CLTV between 130% and 139%	0.41	(0.05)	1.51
CLTV between 140% and 149%	0.51	(0.06)	1.67
CLTV between 150% and 159%	0.61	(0.05)	1.85
CLTV between 160% and 179%	0.73	(0.05)	2.07
CLTV between 180% and 199%	0.86	(0.05)	2.36
CLTV 200% or more	1.01	(0.08)	2.75
Change in interest rate	0.33	(0.02)	1.39
Change in interest rate lag 1	0.38	(0.02)	1.46
Change in interest rate lag 2	0.22	(0.01)	1.24
Change in unemployment rate	0.08	(0.08)	1.08
Change in unemployment rate squared	−0.01	(0.01)	0.99
Change in credit card delinquency rate	1.33	(0.18)	3.77
Change in credit card delinquency rate squared	−0.81	(0.24)	0.45

account for local, time-varying economic conditions. Finally, recognizing that defaults due to income shocks also require low or negative equity (otherwise a borrower in need of cash could sell his home), we exclude observations with positive equity when estimating the hazard model (equivalent to interacting the full set of covariates with an indicator variable for CLTV greater than or equal to 100).

Table II displays the coefficient estimates and standard errors from estimating (3) along with odds ratios. Clearly, higher CLTVs (deeper levels of negative equity) have stronger and highly significant effects on default. Changes in the interest rate and in county credit card delinquency rates also appear to be related to default.

Figure 6 summarizes the results by plotting predicted default probabilities (averaged within each observed equity bin) from our hazard model as a function of CLTV, as well as the predicted probabilities with the equity dummy variables turned off—as if equity were held fixed at zero (the omitted category) and did not contribute to defaults. We interpret the latter as the probability of default due to "liquidity shocks" or an inability to pay, whereas the difference between

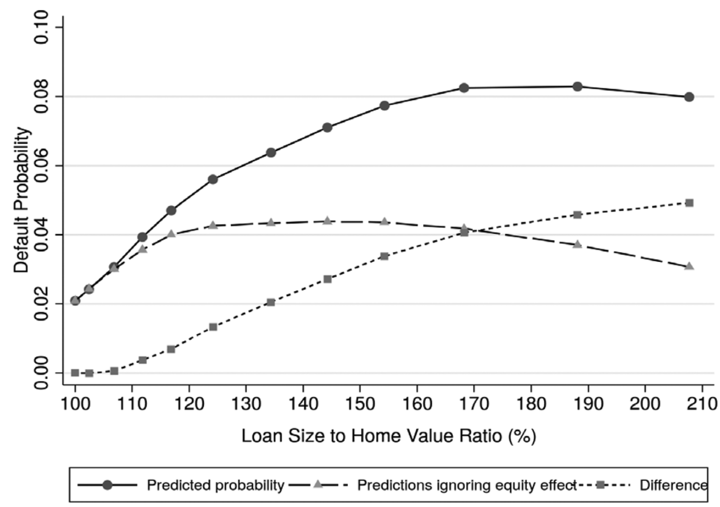

Figure 6. Decomposition of default probability by cumulative loan to home value (CLTV) ratio. The line with circles shows how the predicted probability of default estimated from our default model varies with CLTV. The control variables in the default model are listed in Table III, which also presents the estimated coefficients. The line with triangles shows the estimated probabilities after setting the coefficients on the CLTV dummies over 100% to zero. The line with squares shows the difference between the lines with circles and triangles.

the two functions, also shown, gives our estimate of the probability of walking away as a function of equity.[16]

Figure 6 suggests that almost all of the increase in the probability of default between CLTVs of 100 and 120 can be explained by liquidity problems. This result is intuitive; at CLTV ratios near 100, transaction costs and the still-realistic possibility that home values could rebound should minimize purely ruthless defaults. After that point, however, defaults due to liquidity shocks (the triangles) level off and the two functions diverge, implying that further increases in CLTV largely drive the *rising* default rate beyond CLTVs of 120.

E. Step 2: Estimating the Distribution of Walk-Away Equity Values

The second step of our estimation strategy aims to measure the level of negative equity that exceeds the costs of default and therefore triggers strategic default. We apply a maximum likelihood strategy that estimates the parameters of the walk-away equity distribution based on borrowers who default and those who do not. We infer from a borrower continuing to make loan payments that he has not yet experienced a level of negative equity (or a high enough CLTV) sufficient to induce default. A borrower who does not default by the end

[16] An implicit assumption in our analysis is that none of the defaults when equity equals zero (CLTV equals 100) are strategic.

of the observation period must have a default cost (C_i) that exceeds negative equity in this final period (i.e., $C_i > -E_{iT_i}$).[17]

On the other hand, we infer from a borrower defaulting in a given month (which by definition will be the terminal month for that loan) that he either experienced a severe liquidity shock that necessitated default due to a loss of income, divorce, or other financial hardship or met the condition that the benefit of default exceeds his cost of default ($C_i < -E_{iT_i}$). When there is a default-inducing liquidity shock, s_{iT_i} in the equations below equals one (think of Borrower B from our earlier discussion); otherwise it is equal to zero. In this case, we do not know what would have happened in the absence of illiquidity, but we can at least infer that $C_i > -E_{iT_i-1}$, as otherwise the borrower would have defaulted in a prior period.

Finally, conditional on not experiencing a severe liquidity shock, if the borrower did not default in the previous period when his equity was $-E_{iT_i-1}$ but defaults in this period when he faces an equity of $-E_{iT_i}$, we can bound his cost of default to be between $-E_{iT_i-1}$ and $-E_{iT_i}$:

$$\begin{aligned} &\Pr(D_{iT_i} = 1 \mid E_{iT_i},\ E_{iT_i-1}, s_{iT_i} = 0) \\ &\quad = \Pr(-E_{iT_i-1} < C_i < -E_{iT_i} \mid E_{iT_i},\ E_{iT_i-1}, s_{iT_i} = 0). \end{aligned} \tag{4}$$

With all of these pieces in hand, we construct the likelihood function

$$\begin{aligned} &\prod_{i=1}^{N} [1 - F(E_{iT_i}|\theta)]^{1-D_{iT_i}} \cdot \\ &\qquad \left\{[1 - F(E_{iT_i-1}|\theta)]^{s_{iT_i}} \cdot [F(E_{iT_i}|\theta) - F(E_{iT_i-1}|\theta)]^{1-s_{iT_i}}\right\}^{D_{iT_i}}, \end{aligned} \tag{5}$$

where $F(\ )$ is the cumulative gamma density function and $\theta = (\mu, \kappa)$. For estimation purposes, we assume C_i is gamma-distributed with shape parameter μ and scale parameter κ. Gamma is a flexible distribution and has nonnegative support, corresponding to our assumption that C_i is nonnegative. Nondefaulters contribute $[1 - F(E_{iT_i}|\theta)]$ to the likelihood, while defaulters contribute $[1 - F(E_{iT_i-1}|\theta)]^{s_{iT_i}} \cdot [F(E_{iT_i}|\theta) - F(E_{iT_i-1}|\theta)]^{1-s_{iT_i}}$.

Note that we only use the terminal or final month of each loan for this second step. We therefore collapse the loan-month-level data set described earlier into a data set with just one observation per loan, specifically, the month of default or, for loans not observed to default, the final month of the observation period.

Our approach here is quite similar to estimating an average failure time from duration data, but with "failure" (i.e., default) occurring at a particular level of equity rather than at a particular time.[18] As with duration data, censoring is a problem. In our case, censoring occurs when $D_{iT_i} = 0$ or $s_{iT_i} = 1$. Thus, the

[17] Since prices fell roughly monotonically during the observation period, equity generally hit its lowest value in the final period, implying that a loan that is still alive at the end of the observation period must have $C_i > -E_{iT}$.

[18] See Greene's (2003) discussion on analyzing duration data.

first two bracketed expressions in equation (5) represent censored observations, while the last bracketed expression represents uncensored observations.

One final issue is that s_{iT_i} is not observed directly. Instead, we use the results from the first step of our analysis to estimate $\Pr(s_{iT_i} = 1 \mid E_{iT_i} = \varphi, D_{iT_i} = 1)$ for each integer value of equity, φ, in the sample. Thus, for each borrower who defaults, there is some probability that the observation is censored. To estimate this probability for each integer value of equity, first note that

$$\Pr(s_{iT_i} = 1 \mid E_{iT_i} = \varphi, D_{iT_i} = 1) = \frac{\Pr(s_{iT_i} = 1, \quad D_{iT_i} = 1 | \; E_{iT_i} = \varphi)}{\Pr(D_{iT_i} = 1 | \; E_{iT_i} = \varphi)}. \tag{6}$$

Moreover, $\Pr(s_{iT_i} = 1, \quad D_{iT_i} = 1 | \; E_{iT_i} = \varphi) = \Pr(s_{iT_i} = 1 | \; E_{iT_i} = \varphi)$ since a severe cash flow shock always induces default. Therefore, at each integer level of equity, we estimate $\Pr(s_{iT_i} = 1 \mid E_{iT_i} = \varphi, D_{iT_i} = 1)$ as

$$\frac{\sum_{i,t} \widehat{s}_{it} \cdot 1(E_{it} = \varphi)}{\sum_{i,t} D_{it} \cdot 1(E_{it} = \varphi)}, \tag{7}$$

where $\widehat{S}_{it}$ is the predicted value from the hazard model estimated earlier with the 12 equity dummy variables turned off (recall Figure 6).[19] For instance, because the solid and long-dash lines in Figure 6 basically overlap when negative equity is less than 10%, defaults that occur in this equity range will be almost entirely classified as censored ($s_{iT_i} = 1$).

Column (1) of Table III shows that, in the full sample, the estimated shape parameter (μ) is 2.83 and scale parameter (κ) is 27. These estimates imply that the median borrower walks away from his home when he has equity of −74%, or a CLTV ratio of 174 (again, for ease of interpretation and consistency with the literature, we express our results in terms of the CLTV ratio, which is simply 100 minus equity). The 75$^{\text{th}}$ percentile walk-away threshold value occurs when the CLTV ratio reaches 209, implying that 25% of borrowers would not default until their mortgage balance is more than twice their home's market value.

Figure 7 presents the cumulative distribution function (CDF) that corresponds to the estimated parameters of the $\Gamma(\mu, \kappa)$ distribution. The estimated CDF indicates that, in the absence of liquidity shocks, less than 10% of borrowers will have walked away by the time CLTV reaches 115 to 120, and, as already noted, only 50% default by the time CLTV reaches 174. Finally, the CDF also suggests that about 10% of borrowers do not walk away until their CLTV ratio exceeds 250, or a mortgage balance that is over 2.5 times their home's value. Our results contrast with theoretical results from Kau, Keenan, and Kim (1994), who estimate that all borrowers default around −20% equity, or a CLTV of 120.

To underscore the importance of accounting for liquidity shocks when estimating the median walk-away level of equity, we estimate the parameters

[19] To compute (7), we round equity to the nearest integer and then sum within each integer value.

Table III

Maximum Likelihood Parameter Estimates for the Distribution of Default Costs

Column (1) of the top panel presents our baseline gamma distribution parameter estimates based on the likelihood function shown in equation (5) of the text. Column (2) reports parameter estimates assuming that all defaults are ruthless, that is, that the only source of censoring stems from borrowers who do not default during the observation period. The bottom panel describes the estimated distributions of default costs or negative equity threshold values, presented in terms of the ratio of loan size to home value. Standard errors in parentheses are clustered at the county level.

	(1) Baseline Estimates	(2) Estimates Assuming $s_{iT} = 0$ for all i
Gamma shape parameter (μ)	2.99	1.24
	(0.12)	(0.03)
Gamma scale parameter (κ)	27.6	31.0
	(2.26)	(1.97)
Percentiles of the estimated distribution of default costs as percent of home value		
25^{th} percentile	148	114
Median	174	129
75^{th} percentile	209	154
N	128,248	128,248

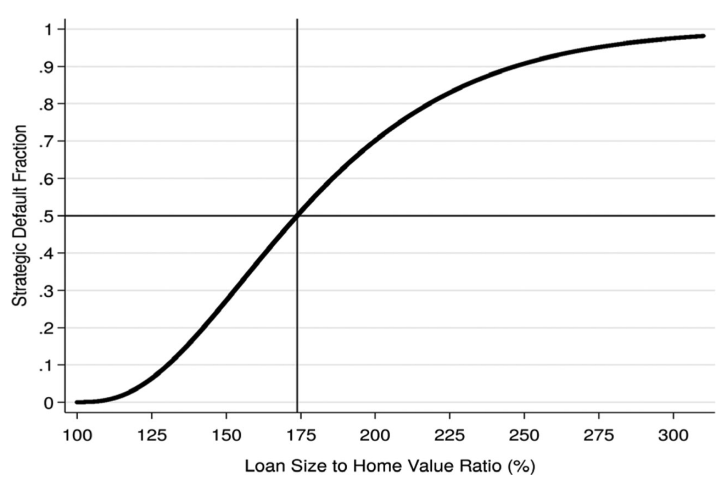

Figure 7. Estimated cumulative gamma distribution of default costs for sample borrowers. This figure shows the cumulative gamma distribution derived from our baseline estimate of the distribution of default costs or walk-away thresholds among sample borrowers', presented in terms of CLTV; as shown in Table III, our estimate of the gamma shape parameter (μ) is 2.99 and our estimate of the scale parameter (κ) is 27.6. The vertical line indicates the median value of the distribution.

assuming all defaults were ruthless (i.e., $s_{iT_i} = 0$ for all borrowers that default). In this case we find that the median borrower walks away when the CLTV ratio hits just 129 (Table III, column 2), which corresponds identically to the simple median CLTV at the time of default computed in Table I. Accounting for liquidity shocks among borrowers in the sample is thus quantitatively very important and failing to account for liquidity shocks would make borrowers appear far more ruthless.

F. Summary

Our main result that borrowers do not walk away until they are deeply underwater can be intuitively understood by looking back at Figures 3 and 6. Figure 3 shows the distribution of CLTV estimates at termination. About 40% of defaults in our sample occurred when CLTV is less than 120. At the same time, Figure 6 indicates that very few defaults at these relatively low levels of CLTV were statistically related to the depth of negative equity, suggesting that defaults in this range were largely induced by liquidity shocks. (This result makes sense theoretically; at CLTV levels closer to 100, transaction costs plus the possibility of a rebound in prices should minimize purely ruthless defaults.) Thus, our estimated distribution of walk-away values or default costs simply reflects the long tail of the distribution shown in Figure 3, and this accounts for why we estimate such a large median walk-away value.

IV. Discussion

Here, we present in more detail the direct and ancillary evidence on the potential mechanisms for our main result that borrowers, on average, do not walk away unless they are deeply underwater. We first discuss standard financial costs of default from the perspective of a perfectly rational borrower. We then discuss nonpecuniary and behavioral considerations that might help explain the results. Finally, we address data issues that might affect the results and external validity.

A. Financial Costs of Default

One reason that underwater borrowers may not walk away is that the expected financial costs of default outweigh the benefits. These costs owe to creditor recourse, foregoing possible future house price appreciation, increased cost of credit, and potential loan modifications. We discuss each of these items below.

(i) *Creditor Recourse*: In some states, borrowers who default face the risk that lenders will pursue a deficiency judgment after a foreclosure (i.e., the lender will take legal action against the borrower to collect the difference between the foreclosure sale price and the remaining mortgage balance). While Florida and Nevada allow deficiency judgments, California and Arizona prohibit lender recourse on loans used to purchase one's

Table IV

Potential Mechanisms for the Estimated Distribution of Default Costs

This table shows descriptive statistics for various estimated distributions of default costs, or walk-away threshold values, for different subsamples of borrowers, measured in terms of the ratio of loan size to home value. In each case, we rerun both steps of the estimation.

	(1) 25th	(2) Median	(3) 75th	*N*
Baseline result	148	174	209	128,248
Borrowers in Arizona	137	161	194	13,487
Borrowers in California	147	172	205	70,299
Borrowers in Florida	156	191	237	34,171
Borrowers in Nevada	173	210	258	10,291
Only ZIP codes in the bottom quartile of historical volatility	144	173	212	30,323
Only ZIP codes in the top quartile of historical volatility	144	170	203	32,239
Nonrecourse and low historical volatility	142	165	197	10,882
Low financial sophistication (index <0)	148	174	209	49,741
High financial sophistication (index ≥0)	148	174	208	78,507

principal residence. Thus, borrowers in our sample in California and Arizona, if rational, should not be deterred from defaulting by the threat of recourse.[20] Consistent with the notion that recourse affects default decisions, Table IV shows that borrowers in Arizona and California have somewhat lower estimated walk-away thresholds than those in Florida and Nevada.[21] Still, the Arizona and California estimates of 161 and 172, respectively, suggest that recourse is not the primary reason why borrowers seem reluctant to walk away.

(ii) *Option Value*: When a borrower defaults, he forfeits exposure to upside risk in house prices in the near- to medium-term, while continuing to be insured on the downside by the default option (longer term, as discussed below in point iii, mortgage credit would likely be available to purchase another house).[22] The value of the default option should be relatively low in locations with little home price volatility, where a strong positive shock

[20] Also, nonrecourse mortgage debt that is erased through default is not counted as taxable income to the borrower. One caveat to this analysis is that some borrowers may have misrepresented their occupancy status, which may complicate their ability to walk away without facing lender recourse, although the available evidence suggests such borrowers may have been more likely to strategically default (Elul and Tilson (2015)).

[21] Ghent and Kudlyak (2011) provide evidence that recourse laws affect the probability of default.

[22] One caveat is that borrowers often have some time to reinstate a loan after they stop making payments (Ambrose and Buttimer (2000)). California, for instance, mandates a 90-day reinstatement period after the lender files a notice of default, which usually occurs only after the borrower is at least 120 days past due (Crews Cutts and Merrill (2008)). Thus, borrowers in California can stop making payments while retaining an option to reinstate the mortgage if the housing market rebounds.

to home values is unlikely. We turn to the ZIP codes where, measured over the period spanning 1982 to 2005, the ZIP code standard deviation in year-over-year house price appreciation is in the lowest quartile (among the roughly 7,000 ZIP codes covered by the CoreLogic HPI). Focusing solely on borrowers in low-volatility ZIP codes, we find a median walk-away CLTV threshold of 173 (Table IV).[23]

Alternatively, borrowers might hold optimistic subjective beliefs, whereby they believe there is a good chance that house prices will rebound strongly and quickly. However, empirical evidence suggests that expectations for asset prices are often informed by recent price changes (Case and Shiller (1989), Shiller (2007)). If borrowers tend to extrapolate, then the house price declines in 2007 and 2008 would lead to subjective beliefs of further declines rather than optimistic expectations. Indeed, according to the Reuters/University of Michigan Survey of Consumers, the fraction of respondents expecting house prices to increase in the next year decreased from 41% at the beginning of 2007 to just 22% by the third quarter of 2009.

(iii) *Credit Access*: Mortgage default can have a substantial effect on one's credit score and future credit access. VantageScore Solutions, a major credit scoring firm, estimates that a mortgage delinquency and foreclosure lowers credit scores by 21% given no other simultaneous delinquencies and an initially good score. However, Brevoort and Cooper (2013) note that consumers can recuperate their score in as little as nine months following foreclosure. This means that borrowing costs could revert to predefault levels quite quickly, especially for nonmortgage sources of credit where underwriting is based solely on credit scores. And while the foreclosure record stays on credit reports for seven years, the waiting period for a mortgage insured by the Federal Housing Administration (FHA) is only three years after foreclosure. FHA loans are available to anyone meeting its relaxed underwriting and down payment requirements (the majority of FHA loans have a CLTV of 96.5%). Historically, the FHA program has been a major source of credit for riskier borrowers, and just after the financial crisis FHA market share ballooned to over 40% of all owner-occupied home purchase loans in 2009 (Bhutta and Ringo (2015)). As we discuss in Section III.B, perhaps in reality these facts are not widely understood, but in a model with rational, well-informed borrowers, the credit access and reputation effects do not seem to justify the huge equity shortfalls needed to induce default in the data.

(iv) *Government Modifications*: Another financial cost of default is the foregone possibility of a loan modification, particularly one that significantly reduces principal, as opposed to temporary forbearance or extension of

[23] Following Banks et al. (2007), we calculate a local house price volatility measure using our ZIP-code-level HPIs. For every year in each ZIP code, we compute a five-year house price appreciation rate and use the estimated time-series standard deviation of this measure between 1981 and 2006 as our estimate of ZIP code house price volatility.

the amortization period, which do not have as large of an impact on changing the expected lifetime cost of the mortgage.

It is unclear why underwater borrowers would have expected to get a significant principal reduction. Haughwaut, Okah, and Tracy (2009) note that, historically, mortgage modifications have been quite unusual. They also document that only about 2% of nonprime securitized loans originated between 2004 and 2007 received a modification through mid-2009. Most of these modifications went to borrowers who had missed payments and nearly two-thirds of these modifications resulted in higher, not lower, mortgage balances. There were few, if any, notable loan modification programs available to borrowers until late 2008. A principal reduction loan modification program, "Hope for Homeowners," went into effect in late 2008 but modified very few mortgages as lender participation was voluntary. The Obama administration's flagship loan modification program, the Home Affordable Modification Program (HAMP), was not announced until March 2009, well into our sample period. A key aspect of HAMP is that it was originally designed to keep strategic defaulters ineligible as borrowers must demonstrate financial hardship, and it initially focused on temporarily reducing payments to keep them in line with available income, rather than using principal reduction.

(v) *Other Financial Considerations*: One additional cost consideration, of course, is the cost of finding and moving into another home. Although the monetary and nonmonetary costs could be high for those with impaired credit histories, such as a strategic defaulter, such costs could be lessened if borrowers initiate leases just before they stop making mortgage payments or if they have a cosignor. In addition, borrowers who default could save the money they would have otherwise used for mortgage payments until foreclosure, which is about 12 months, on average.[24] Then, if necessary, this money could be used to help secure a rental property.

In places where lenders do not have recourse, and the option value is arguably limited, the main financial costs of default are relocation costs and future credit access costs. Yet borrowers in such places still exhibit a high negative equity threshold for default. A borrower whose CLTV threshold is 150 with a loan balance of $200,000 increases his wealth by nearly $67,000 at the time of default, and can expect an additional benefit of about $8,000 to $9,000 over the coming year in free rent. It seems unlikely that relocation and credit access costs can account for these large values.

[24] See Crews Cutts and Merrill (2008) for a discussion of foreclosure timelines and how long it takes for a lender to complete a foreclosure. More recent research suggests that "right to cure" laws and foreclosure moratoria implemented across select states have lengthened timelines up to three years (see Gerardi, Lambie-Hanson, and Willen (2013)).

B. Nonfinancial Costs and Irrational Behavior

Since it seems unlikely that financial costs alone can explain large walk-away thresholds, we now turn to alternative nonfinancial or "behavioral" reasons for why homeowners may not respond more robustly to negative equity.

(i) *Moral Aversion to Default and Other Emotional Factors*—Researchers have long hypothesized that there might be "psychic costs" of default (e.g., Cunningham and Hendershott (1984)). More recently, survey evidence suggests moral aversion and social stigma may have important effects on default decisions. For example, 9 out of 10 respondents in a national survey conducted by Fannie Mae in 2010 said it is wrong for borrowers who owe more on their house than it is worth to default on their mortgage. Similarly, Guiso, Sapienza, and Zingales (2013) find that about 80% of homeowners considered ruthless default morally wrong and, more importantly, such moral considerations were highly correlated with whether people expressed a willingness to default were they to find themselves deeply underwater. White (2010) argues that "shame or guilt" is a key reason many homeowners have not walked away despite large financial incentives to do so, noting anecdotal evidence along with social psychology research that finds individuals typically go to great lengths to preserve their identity as a moral person.

Another potential emotional factor is attachment to one's home. However, results from Guiso, Sapienza, and Zingales (2013) do not provide consistent evidence that having been in one's home over five years is related to the expressed willingness to default at a given level of negative equity. Moreover, our sample of borrowers bought their homes in 2006 with zero down payment, which arguably limits the scope for attachment before house prices crashed.

(ii) *Knowledge of Home Values*: Another important factor might be a tendency for homeowners to overestimate their home's value. In other words, although market data may suggest that someone is deeply underwater, that borrower may not actually realize or believe that their home's value has tumbled. Without being able to explicitly ask the borrowers in our sample about their perceptions of home values, it is difficult to precisely gauge the importance of this issue. That said, previous research on a broader sample indicates that on average people do *not* widely overestimate their home's value. For example, Goodman and Ittner (1992) find that the median homeowner overvalues his property by about 5–6%. More recently, Henriques (2013) finds almost no difference between median homeowner estimates of home price declines between 2007 and 2009 relative to declines measured using market indices. Moreover, the median "error" is zero throughout the range of home price declines, suggesting that homeowners often internalize declines in home values.

We also examine data from the 2009 Panel Study of Income Dynamics (PSID) and the 2010 Survey of Consumer Finance (SCF) to gauge the extent to which people who *acknowledge* being severely underwater continue to make timely mortgage payments. In the 2009 PSID, about 5% of homeowners with a mortgage reported negative equity of at least 50% (a CLTV over 150). Among these borrowers, 80% said they are current on their payments, 17% said they are behind, and 3% did not answer. In the 2010 SCF, just over 3% of homeowners with a mortgage reported a CLTV of at least 130, and among such borrowers about three-quarters said they were current on payments. Unfortunately, neither the PSID nor the SCF provide information on the extent to which borrowers are behind (i.e., 30 days, 90 days, foreclosure, etc.), but in the SCF, only half of deeply underwater borrowers who were also behind on payments said that they expect to eventually go into foreclosure. These data suggest that overestimates of home values are not the only reasons borrowers do not walk away more readily.

(iii) *Comprehension of Default Costs and Financial Sophistication*: White (2010) argues that excessive fear of the consequences of default is a powerful deterring force. For example, borrowers may take an extreme view that a foreclosure will cause permanent expulsion from credit markets. Of course, one consideration to keep in mind with respect to our sample is that many borrowers have relatively low credit scores and therefore may have a better-than-average understanding of the consequences of default (and thus less fear) due to previous default experiences.[25,26]

Putting that aside, perhaps our sample is comprised of borrowers with low levels of financial sophistication relative to the broader population, who are prone to overestimate the costs of default (or underestimate the benefits). Ideally, we would be able to precisely measure degrees of financial sophistication within our sample and assess its relationship with walk-away values. Measuring sophistication through household surveys like in Lusardi and Mitchell (2007) is not possible with our loan-level data. However, sophistication may be correlated with measures of wealth, income, and education.[27] With that in mind, we identified borrowers in our sample who might be the most sophisticated based on their home's value and average education and income of their zip code. We construct a "sophistication index" using these three variables. The index assigns a point each time a borrower's home value (normalized by his metropolitan statistical area's (MSA) median home value), average ZIP-code education,

[25] Low credit scores, of course, may also signal a relatively weak commitment to repay debt, or less moral aversion to default.

[26] Internet Appendix Table IAI reports past default experiences (on mortgages and other types of credit) prior to getting a mortgage in 2006 using data from Equifax. As seen in the first column, about half of borrowers with an Equifax credit score (similar to a FICO score) below 700 have experienced a major derogatory event prior to their home purchase, which suggests that many borrowers in our sample are likely to have had direct personal experience with default. The Internet Appendix is available in the online version of the article on the *Journal of Finance* website.

[27] For example, Campbell (2006) finds that wealthier, better educated, and higher income borrowers are more likely to refinance their mortgage optimally.

and median ZIP-code income is in the top quarter of each respective distribution. The index takes away a point each time a borrower's value for these variables is in the bottom quartile. In other cases, points are neither subtracted nor added to this index.

Table IV shows that borrowers in the top half of our sophistication index had basically the same walk-away threshold distribution as those in the lower half. Thus we are unable to find evidence that sophistication is correlated with walk-away thresholds. One reason may be that this index is only a very rough measure of sophistication. Another reason may be that other factors swamp the effects of sophistication. For example, both sophisticated and unsophisticated borrowers could have high moral aversion to default.

(iv) *Loss Aversion*: In models of loss aversion, homeowners recognize market values but exhibit disutility from realizing a loss on one's house (e.g., Genesove and Mayer (2001; GM), Engelhardt (2003)). GM, for example, show that homeowners facing a nominal loss (i.e., the current market value is less than their purchase price) are more likely to set an above-market asking price and keep their house on the market longer. They estimate that, on average, someone who paid $300,000 for a house and wanted to sell at a time when the market price was at $200,000 would list the house at about $230,000, hoping to attenuate the loss to some degree. Put another way, in the domain of losses, people take risk (e.g., wait and hope prices come back) to get back to the reference value and need to be compensated for giving up the gamble. GM and others, such as Gomes (2005), focus on selling an asset, but our context is the default decision. If there are little or no costs of default (as traditionally assumed), then the borrowers in our sample are effectively fully insured against "losses" (with loss defined relative to purchase price), since they put no money down. Thus, loss aversion would not affect default decisions in the absence of default costs. If default costs (real or imagined, pecuniary or not) exist, these might be considered losses (i.e., borrowers can "sell" their home back to the lender less a "haircut") and loss aversion would exacerbate the effect those losses have on borrowers' walk-away thresholds. But given GM's estimate, default costs would still have to be substantial to explain our results.

C. Identification and Data Concerns

In this subsection, we discuss the potential for bias due to measurement error and omitted variables.

(i) *Measurement Error in House Price Data and Equity*: To reliably identify the relationship between negative equity and default, we need a precise measure of borrower equity. As noted in Section II.E, two key features of our data are that unobserved junior liens are highly unlikely, and that we use HPIs at the ZIP code level. ZIP codes are relatively small areas (the

Table V
Robustness Checks on the Estimated Distribution of Default Costs

This table shows descriptive statistics for various estimated distributions of default costs, or walk-away threshold values, for different specifications or subsamples of borrowers, measured in terms of the ratio of loan size to home value. In each case, we rerun both steps of the estimation. Baseline estimates correspond to single-family borrowers. Condo estimates for AZ are not shown due to small sample size.

	(1) 25^{th}	(2) Median	(3) 75^{th}	(4) N
Baseline result	148	174	209	128,248
Weighting first stage by inverse of *SD* in prices of homes sold in 2006	146	174	213	128,248
Weighting first stage by ratio of 25^{th} to 75^{th} percentile in home values	149	174	209	128,248
Condo borrowers in CA	144	170	204	10,124
Condo borrowers in FL	145	183	236	9,824
Condo borrowers in NV	172	219	286	1,118
Excluding ZIP codes with very different all-in versus nondistressed HPI	148	173	203	97,436
Controlling for ZIP-code level foreclosure rate in 2006:H1	147	174	209	128,248

median ZIP in our sample is just 11 square miles), so it seems reasonable to assume that price *trends* do not vary widely within ZIP codes.

That said, within-ZIP trends might vary the least in those ZIP codes with relatively homogenous housing stocks. We therefore rerun the estimation allowing more homogeneous ZIP codes to receive a larger weight in estimating the relationship between equity and default. To do so, we construct two measures of within-ZIP-code homogeneity: the inverse of the standard deviation in the price of homes sold in 2006 and the ratio of the 25^{th} percentile of home values to the 75^{th} percentile in a ZIP code.[28] These homogeneity measures enter as weights in the first stage of our estimation procedure, but the coefficients in the first stage default model are little changed when the weights are applied.[29] Accordingly, in Table V, our estimates of the median walk-away value (174 and 174) accounting for heterogeneity are basically identical to the baseline estimate. This similarity supports our assumption that, while houses in a ZIP code might differ, their appreciation rates are likely to be highly correlated.

We also run the analysis using just the subset of condominium buyers, as condos could be easier to price as the units are more homogenous.[30] As

[28] The ZIP code standard deviation in the price of homes sold is estimated from the recorded sales price for mortgages originating in 2006 according to LPS/Applied Analytics and CoreLogic. The ratio of the 75^{th} percentile of home values to the 25^{th} percentile in a ZIP code is from the American Community Survey.

[29] Coefficient estimates are provided in columns (2) and (3) of Internet Appendix Table IAII.

[30] We are grateful to an anonymous referee for this suggestion.

seen in Table V, the median walk-away CLTV threshold for condo buyers in California and Nevada is quite similar to the single-family estimates shown in Table IV.

A final issue is that for the baseline estimates we use an "all-in" HPI that includes distressed sales (e.g., short sales). If distressed sales transactions are not representative of the average home sale in the same ZIP code, the all-in HPIs may not be appropriate to use. So we also use CoreLogic's HPIs excluding distressed sales and re-estimate the parameters using only loans in ZIP codes where the house price appreciation rates between 2006 and 2009 for the two indexes are within 10 percentage points of each other. Approximately one-quarter of sample ZIP codes are excluded, but the results are little changed (Table V).

(ii) *Omitted Variables*: Another potential identification concern might be omitted variable bias because we have very little borrower-specific information regarding liquidity shocks.[31] However, we believe that the scope for such bias is fairly narrow. First, individual heterogeneity in our sample is limited because all borrowers put no money down and bought in similar areas of the country at roughly the same time. Moreover, only those liquidity shocks uncorrelated with loan-age, calendar-time, and county-time-level economic conditions but correlated with the timing of ZIP-code–level house price changes would confound our estimates of negative equity's effect on default decisions. When we control for ZIP code–level foreclosure rates in the first half of 2006 using data from RealtyTrac in the first-step hazard regression to help capture ex ante underlying economic conditions across ZIP codes, the estimated median threshold hardly rises (Table V). Finally, to reiterate a point made earlier, our controls for liquidity shocks turn out to be quantitatively important and unobserved confounding liquidity shocks simply suggest that the median walk-away threshold is even further below zero than we have estimated.

D. External Validity

Is it possible that the nonprime borrowers we study above are among the least ruthless borrowers, and that more typical, prime borrowers would be far more responsive to negative equity? To explore this possibility, we turn to loan-level data from Lender Processing Services (LPS) to infer the behavior of a broader group of borrowers, rather than just that of subprime borrowers.

[31] To be clear, we are referring to omitted variables that are correlated with equity, as opposed to the issue of independent unobserved heterogeneity in the estimation of hazard models. Unobserved heterogeneity, which we do not attempt to account for, can bias estimates of duration dependence (e.g., Lancaster (1990)). But we are not interested in duration dependence. Moreover, Monte Carlo results from Nicoletti and Rondinelli (2010) suggest that one can ignore unobserved heterogeneity in discrete duration models and still obtain unbiased estimates of expected survival probabilities, especially in large samples, which is the key for this paper.

Table VI

Estimated Distribution of Default Costs in a Broader Sample of Loans

This table shows descriptive statistics for various estimated distributions of default costs, or walk-away threshold LTV values, using loan performance data from Lender Processing Services (LPS).

	(1) 25th	(2) Median	(3) 75th	(4) *N*
Baseline result (using privately securitized subprime loans from CoreLogic data)	148	174	209	128,248
LPS samples:				
Initial LTV of 85% to 95%	136	162	197	7,593
Initial LTV of 85% to 95%, excluding privately securitized loans	144	174	214	3,889
Initial LTV of 70% to 90%, excluding 80% LTV loans	133	156	186	33,272
Initial LTV of 70% to 90%, excluding 80% LTV loans and PLS loans	141	165	199	14,302

We first focus on those whose initial CLTV was between 85 and 95; this sample consists of borrowers who, on average, put about 10% down, and over half of these loans were not privately securitized but instead were sold to Fannie Mae or Freddie Mac or were held in bank portfolios (in contrast, recall that all CoreLogic loans are privately securitized). That said, the average credit score in this sample is roughly the same as in our baseline CoreLogic sample, at just over 670 (not shown). We next try dropping the privately securitized loans from this sample, which raises the average credit score to a level closer to the national average at just over 690. Finally, we also try using an LPS sample comprised of even higher quality loans with initial CLTVs between 70 and 90, but exclude initial CLTVs of exactly 80 due to the high prevalence of "piggyback" loans, that is, junior liens taken out simultaneously with the first lien to help fund the home purchase.[32] In this sample, the average FICO score is about 704, and when we drop privately securitized loans, the average FICO rises to over 717.

As shown in Table VI, our estimates of the walkaway CLTV threshold using the LPS data are similar to, or just slightly lower than, our estimates using the subprime loan data. These results help provide some confidence that a high walk-away CLTV threshold is not limited to subprime borrowers or to borrowers with privately securitized loans.

[32] While information about junior liens is not available in the LPS data alone, the Federal Reserve recently obtained a data set of LPS loans matched to credit record data of the mortgage borrowers. The matched credit records allow us to observe junior liens taken out at the same time as the first lien observed in the LPS data. Using these data, we find that while piggybacks were extremely common in 2006 when the first lien was exactly 80% of the purchase price, they appear to have been virtually nonexistent for loans where the first lien exceeded 80% of the purchase price.

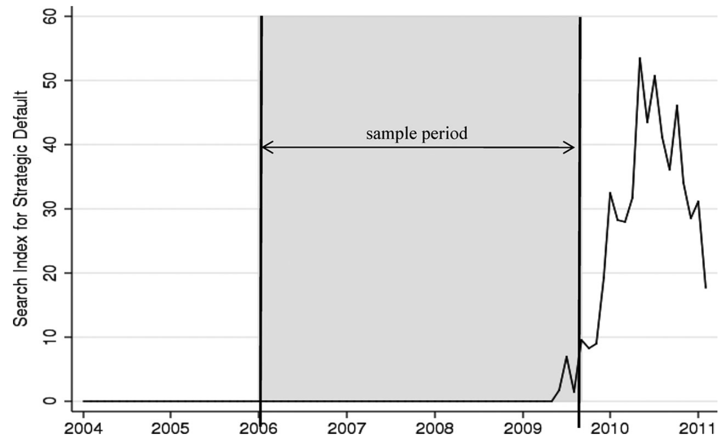

Figure 8. Google Trends Search Index for the term "strategic default," 2004–2011. This figure shows data from Google Insights on the volume of web searches for the term "strategic default."

E. Has Ruthless Default Increased over Time?

Using data from Google Trends, Figure 8 shows that few people searched for "strategic default" online during our observation period. The search index increased significantly during 2010, however. Interestingly, Google Trends also indicates that California, Arizona, and Florida were among the states with the highest volume of searches of "strategic default" or "walk away from mortgage."[33] As more people learn about other borrowers strategically defaulting on their mortgages or about legal and counseling resources to help one "walk away" in the most cost-minimizing manner, the cultural environment may have shifted to make strategic default less stigmatizing and more acceptable.[34] Thus, the distribution of default costs among borrowers may have changed after our sample period. On the other hand, as the number of defaults and foreclosures reached record high levels, lenders may have found it increasingly worthwhile to pursue deficiency judgments, where permitted, which would have changed the potential legal liabilities of default.[35]

[33] See Internet Appendix Figure IA1.

[34] Shiller (2010) has argued that, over time, strategic defaults are likely to have grown "substantially. . . The sense that 'everyone is doing it' is already growing and will continue to grow. . . because of a building backlash against the financial sector, growing populist rhetoric, and a declining sense of community with the business world. Some people will take another look at their mortgage contract, and note that nowhere did they swear on the bible that they would repay."

[35] A more direct way to assess whether borrowers have become more strategic is by testing for a time-varying effect between default and equity. As seen in columns (2) and (3) of Internet Appendix Table IAIII, the coefficients on the interaction terms suggest that the effect of equity actually declined over time for our sample. However, we caution that this may reflect borrowers surviving to later stages of the sample period having a stronger commitment to repay their mortgages than those who default early. Testing more thoroughly whether the implied costs of default have changed

V. Conclusions

This paper uses the precipitous decline in house prices in Arizona, California, Florida, and Nevada from 2007 through 2009 as well as better measures of housing equity than have typically been available to researchers to estimate the level of indebtedness and negative equity that triggers ruthless mortgage default. Our empirical analysis has two parts. In the first part, we estimate the relationship between equity and default based on a flexible hazard model and show that CLTV *alone* does not drive mortgage defaults until it exceeds 120. These results feed into the second part, where we assume a simple theoretical framework where borrowers walk away from their houses when the financial benefits of doing so exceed the costs, and we estimate the distribution of default costs among our sample borrowers. The results suggest that the median sample borrower did not walk away until his CLTV exceeded 174. To the best of our knowledge, this is the first paper to quantify the walk-away values of mortgage borrowers using real-world data.

We find it difficult to reconcile how deeply underwater borrowers are when they decide to walk away with a standard financial default cost story. Even in nonrecourse areas with historically low house price volatility, borrowers still exhibit a very high walk-away threshold that would imply that relocating and reduced future access to credit cost well in excess of $50,000 for most borrowers.

We therefore think that nonfinancial costs and behavioral factors must be playing a role. Moral aversion to default is probably one important factor, given recent survey evidence. An additional factor might be overstated fear of the consequences of default, although many of the borrowers we study probably have experience defaulting on some type of credit account, which might make them relatively less fearful than the typical homebuyer. A final contributing factor may be that some borrowers grossly overestimate their home's value. That said, we provide evidence from survey data that a large majority of those who acknowledge being deeply underwater continue to pay their mortgage, which suggests there is more to the story than just biased home value estimates.

While it is difficult to pin down precisely why borrowers do not walk away more readily, we still draw two important conclusions from our work. First, while convenient and elegant, the frictionless neoclassical model of ruthless default appears to be an insufficient description of actual borrower behavior. Second, a standard transaction costs story is not enough to explain large walk-away equity thresholds. Rather, some collection of noneconomic and behavioral factors is probably at play. Gaining a more precise understanding of these factors is worthy of future research.

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over time is challenging and beyond the scope of this paper but would be an interesting direction for future research.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.