Online Appendix for

House Prices, Home Equity-Based Borrowing, and the U.S. Household Leverage Crisis

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Appendix Figure 1

Appendix Figure 1 graphs house price growth from 2002 to 2006 against the Saiz (2010) elasticity measure for the 68 MSAs in our final sample.

Appendix Figure 2

Appendix Figure 2 presents the non-parametric plot of the effect of house price growth on debt growth across the full distribution. It shows the second stage of the IV estimate in column 2 of Table II in the paper by plotting total debt growth from 2002-2006 against predicted house price growth over the same period. As Appendix Figure 2 shows, the effect is close to linear with a slight convexity near the middle of the distribution. The pattern is also robust across almost the entire distribution, although the statistical precision is lower at the low end of the house price growth distribution.

Appendix Tables 1 and 2

Appendix Tables 1 and 2 present summary statistics for the sample of renters that do not move from 1997 to 1999 and the sample of homeowners that move from 1997 to 1999, respectively.

Within-MSA Empirical Specification

Appendix Tables 3 and 4

This section of the appendix presents an alternative IV strategy that exploits within- MSA variation at the level of zip codes to identify the effect of house prices on homeowner borrowing. The motivation for this test comes from Mian and Sufi (2009). They present evidence of a securitization-driven shift in the supply of mortgages for new home purchase from 2002 to 2005 toward zip codes that have a high fraction of subprime borrowers. Column 1 of Panel A in Appendix Table 3 replicates the basic finding, which shows a strong positive correlation between new home purchase mortgage growth from 2002 to 2006 and the fraction of borrowers with a credit score below 660 as of 1997.

Mian and Sufi (2009) show that higher credit growth for home-purchase mortgages occurs in subprime zip codes despite declining relative, and in some cases absolute, income growth in these areas. Furthermore, 2002 to 2005 is the only period in the last 18 years in which mortgage origination for home purchase growth is higher in areas with lower income growth.

In columns 2 to 5 of Appendix Table 3, Panel A, we replicate another finding of Mian and Sufi (2009): the relative shift in the supply of mortgage credit for home purchase toward high subprime share zip codes occurs even in the most elastic MSAs where there is no significant house price growth. However, the shift in the supply of mortgage credit is stronger in more inelastic housing supply MSAs that experience strong house price growth. Based on these findings, Mian and Sufi (2009) argue that house price appreciation cannot fully explain the shift in the supply of mortgage credit to high subprime areas, but house price growth strengthens the effect through a collateral feedback mechanism (as in Kiyotaki and Moore (1997)).

Column 1 of Appendix Table 3, Panel B presents evidence that the shift in the supply of credit toward subprime share zip codes leads to higher house price growth in subprime zip codes relative to prime zip codes within the same MSA. Columns 2 through 5 show that this effect is only present in inelastic MSAs, as we would expect given the intuition on house prices and supply elasticity in Glaeser, Gyourko, and Saiz (2008). Mian and Sufi (2009) present evidence that the relative house price appreciation in high subprime share zip codes within inelastic MSAs is *credit-induced*: they find that house price growth and income growth are negatively correlated from 2002 to 2006 and that high subprime share zip codes experience relative house price growth despite relatively negative income growth.

Our instrumental variable strategy is designed to exploit credit-induced house price appreciation in high subprime share zip codes within inelastic MSAs to estimate the effect of house price appreciation on homeowner borrowing. The exact thought experiment is as follows. Take two homeowners *IP* and *IS* with the same credit score as of 1997. The homeowners live in the same inelastic MSA, but differ in the neighborhood of residence. Homeowner *IP* lives in a prime neighborhood, while *IS* lives in a subprime neighborhood. We know from Mian and Sufi (2009) that *IS* experiences a larger house price increase than *IP* as a result of the aggregate credit supply expansion. Let ΔB_{IS} and ΔB_{IP} be the change in household borrowing for *IS* and *IP* respectively during the price boom period. Then the double difference (ΔB_{IS} - ΔB_{IP}) provides one possible reduced form measure of the effect of house prices on homeowner borrowing.

However, a concern with this estimate is that despite IS and IP having the same initial credit score, the fact that they live in different neighborhoods potentially makes them different on

unobserved dimensions. The unobserved dimensions could also affect the borrowing decisions in a way that makes (ΔB_{IS} - ΔB_{IP}) a biased estimate of the direct house price effect.

How does one control for the unobserved neighborhood effect of subprime versus prime neighborhoods? The triple-difference strategy exploits the additional variation in housing supply elasticity. In particular, as mentioned earlier, the difference in house prices of subprime versus prime neighborhood disappears in elastic MSAs due to easily adjustable housing supply. However, the unobserved dimension of neighborhood effects is still operating on homeowners living in elastic MSAs. Let *ES* and *EP* be two homeowners with the same initial credit scores as *IS* and *IP*. *ES* and *EP* live in subprime and prime neighborhoods of an elastic MSA respectively. Then we can control for the unobserved neighborhood effect of homeowners living in subprime areas by computing the triple difference: [$(\Delta B_{IS} - \Delta B_{IP}) - (\Delta B_{ES} - \Delta B_{EP})$].
This idea translates into estimating the following reduced form regression equation:

$$y_{izmt} - y_{izm,1998} = \alpha_m + \delta^t * X_{izmt} + \gamma^t * Subprime_{zm,1997} +$$
$$\beta^t * Subprime_{zm,1997} * Inelasticity_{m,1997} + \varepsilon_{izmt} \quad for\ t = 1999, 2000, \dots, 2008$$

which examines the growth in *y* from the base year 1998 to *t* for individual *i* living in zip code *z* within MSA *m*. We relate the growth in *y* to MSA fixed effects, individual and zip code level control variables (*X*), the fraction of subprime borrowers (*Subprime*) in zip code *z* within MSA *m* in 1997, and the interaction between the zip code fraction of subprime borrowers and the housing supply inelasticity (*Inelasticity*) of MSA *m*. The coefficient of interest is β.
Figure 4 in the paper presents the estimate of β for years 1999 to 2008, where inelasticity is measured as 4 – the Saiz measure to help interpret the coefficients. The top panel examines the

relative growth in house prices for high subprime share zip codes in highly inelastic MSAs. Consistent with the estimates in Panel B of Appendix Table 3, house price growth is strongest in subprime zip codes of inelastic MSAs. In terms of magnitudes, the coefficient estimate for 2006 implies that in the most inelastic MSA, a one standard deviation increase in the 1997 subprime share of the zip code leads to a 15% increase in house prices from 2002 to 2006.

The bottom two graphs of Figure 4 in the paper show a relative increase in debt growth and debt to income ratios for homeowners living in high subprime share zip codes within highly inelastic MSAs. Once again, these graphs are based on a triple-difference estimate which compares homeowner leverage in high subprime share zip codes within inelastic MSAs to both homeowners in high subprime share zip codes in elastic MSAs and homeowners in low subprime share zip codes in the same MSA. In terms of magnitudes, the coefficient estimate for 2006 implies that in the most inelastic MSA, a one standard deviation increase in the 1998 subprime share of the zip code leads to a 9% increase in debt and a 1/2 standard deviation increase in the homeowner debt to income ratio from 2002 to 2006.

Figure 4 suggests that a potential instrument for house prices is the zip code level share of subprime borrowers as of 1997 interacted with MSA housing supply inelasticity. In Panel C of Appendix Table 3, we examine how this instrument is correlated with debt and debt to income levels in 2002. As Panel C shows, homeowners' debt amounts and debt to income ratios in high subprime share zip codes within elastic MSAs are not significantly different than homeowners in high subprime share zip codes within inelastic MSAs prior to the house price acceleration in 2002.

The results in Appendix Table 3 and Figure 4 of the paper together with the results in Mian and Sufi (2009) motivate the following within-MSA instrumental variables specification:

(A1) $$LeverageGrowth0206_{izm} = \alpha_m + \theta X_{izm} + \mu Subprime_{zm,1997} + \beta \widehat{HousePriceGrowth0206_{zm}} + u_{izmt}$$

(A2) $$HousePriceGrowth0206_{zm} = \alpha_m + \delta * X_{izmt} + \gamma Subprime_{zm,1997} + \rho Subprime_{zm,1997} * Elasticity_{m,1997} + \varepsilon_{izmt}$$

Equation (A2) represents the first stage in which house price growth from 2002 to 2006 is instrumented with the interaction of zip code level subprime share as of 1997 and MSA level housing supply elasticity. Equation (A1) represents the second stage in which we examine the growth in leverage for homeowners as a function of predicted house price growth. The control variables in *X* include median home value in the zip code and individual credit score, income, debt to income ratio, sex, and age. The control variables imply that we are comparing two homeowners with the same age, same credit score, same sex, same income, and same debt to income, but one resides in a high subprime share zip code within an inelastic housing supply MSA.

The second stage estimates for both debt growth and the change in debt to income are presented in Appendix Table 4. The estimates from the within-MSA specification are slightly higher than the estimates from the across-MSA analysis presented in the previous sub-section. The inclusion of control variables does not change the debt growth specification estimate. However, the effect

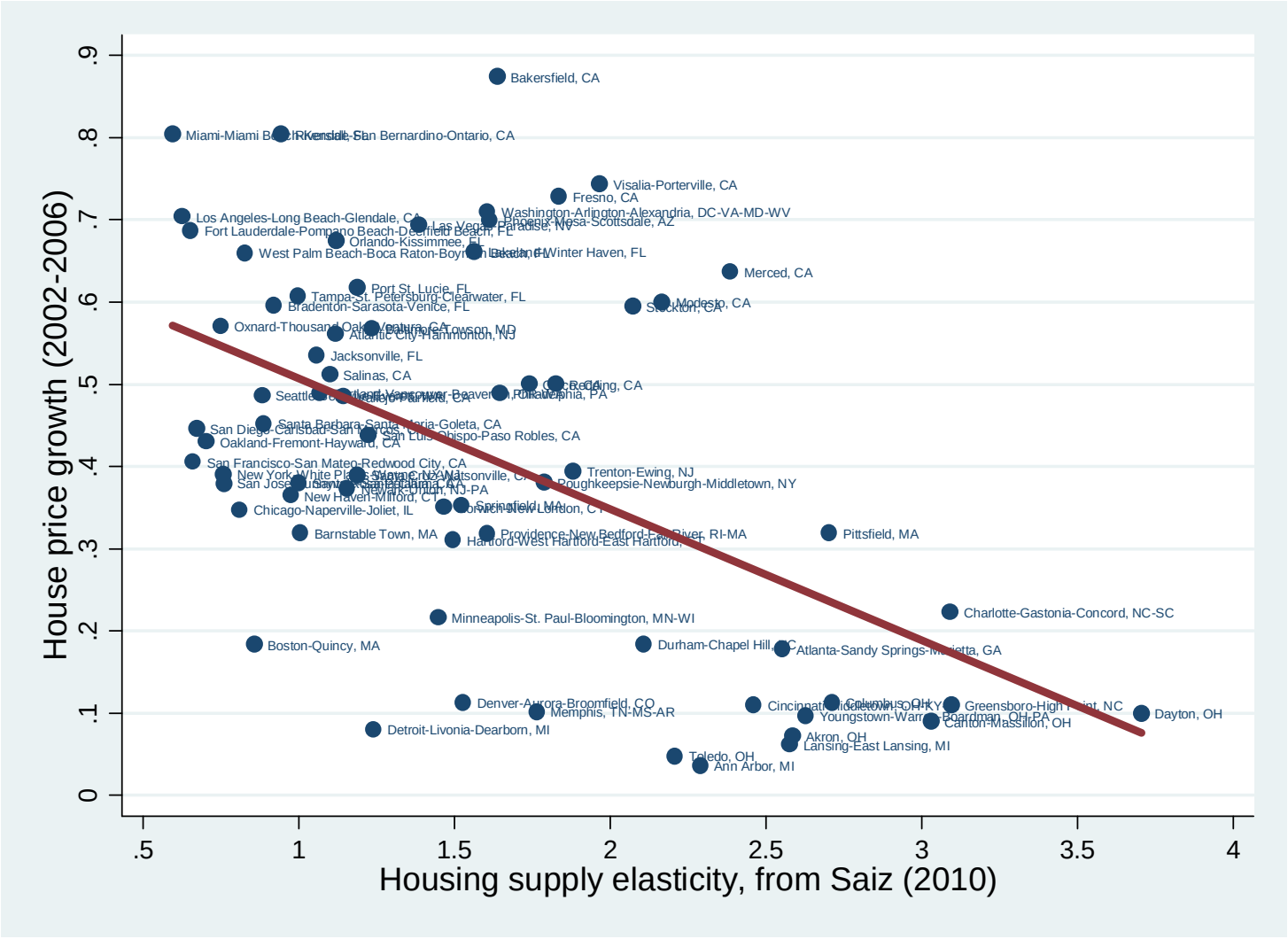
of house price growth on the change in debt to income is more sensitive to the inclusion of control variables.

Appendix Table 5

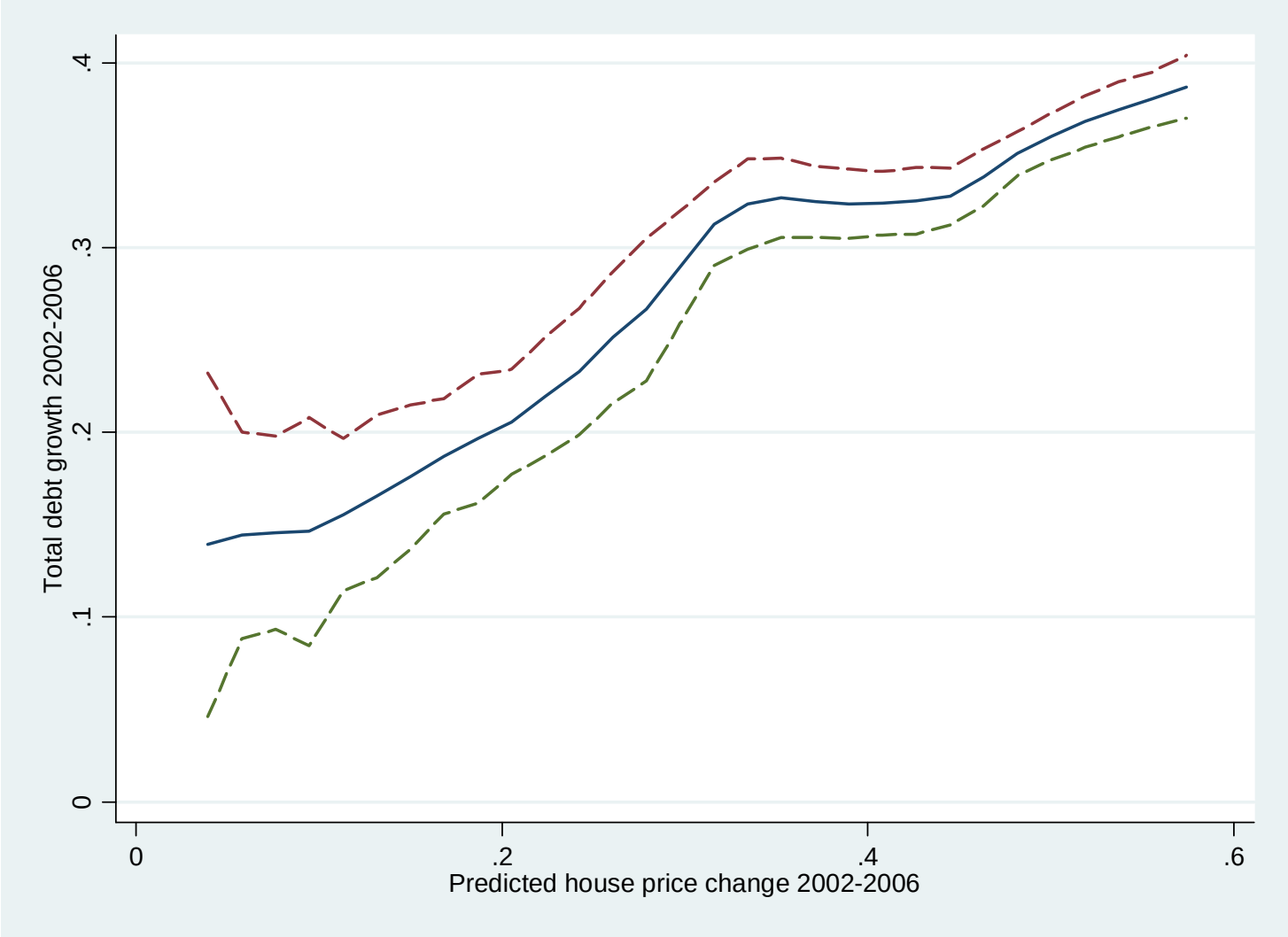
Appendix Table 5 presents the regressions that correspond to Figure 5 in the paper. In columns 1 through 3 of Appendix Table 5, we examine how house price growth from 2002 to 2006 affects default rates. Columns 2 and 3 present estimates how this effect differs for low credit score and high credit card utilization individuals. As the results show, default rates decrease for homeowners with high house price growth, and this effect is strongest among low credit score and high credit card utilization individuals. These are precisely the homeowners that borrow most aggressively during the house price boom.

In columns 4 through 6, we examine default rates from 2006 to 2008. We find that house price growth from 2002 to 2006 has a strong positive effect on default rates from 2006 to 2008, and this effect is much stronger among low credit score and high credit card utilization individuals. The magnitude of the difference is very large. Among homeowners one standard deviation below the mean 1997 credit score, a one standard deviation increase in house prices from 2002 to 2006 leads to a full standard deviation increase in default rates from 2006 to 2008. In contrast, among homeowners one standard deviation above the mean 1997 credit score, a one standard deviation increase in house prices from 2002 to 2006 leads to 1/6 standard deviation increase in default rates from 2006 to 2008.

Appendix Figure 1
House Price Growth (2002 to 2006) and Saiz (2010) Housing Supply Elasticity



Appendix Figure 2
The Effect of House Price Growth on Homeowner Borrowing



Appendix Table 1
Summary Statistics for Renters

This table presents summary statistics for 88,730 individuals who we classify as renters. There are 2,315 zip codes and 68 MSAs that are represented in the sample.

	N	Mean	Median	St. Dev.
Equifax individual level data				
Total debt, 1997, $thousands	16837	5	4	5
Home debt, 1997, $thousands	16837	0	0	0
Growth in total debt, 1998-2002	16837	0.873	0.733	1.275
Growth in total debt, 2002-2006	16837	0.610	0.425	1.387
Growth in home debt, 1998-2002	16837	1.174	0.000	1.859
Growth in home debt, 2002-2006	16837	0.875	0.000	2.025
Total debt to income ratio, 1997	16282	0.150	0.106	0.155
Change in debt to income ratio, 1998-2002	16833	0.443	0.136	0.704
Change in debt to income ratio, 2002-2006	16833	0.692	0.134	1.295
Total debt default rate, 1997	16804	0.127	0.000	0.266
Change in default rate, 1998-2006	16286	-0.033	0.000	0.293
Change in default rate, 2006-2008	15991	0.039	0.000	0.274
Credit score, 1997	16837	716	716	106
Credit card utilization fraction, 1997	16813	0.447	0.403	0.348
Age, 1997	16796	45	42	14
Male	15898	0.469	0.500	0.357
Income, 1997, $thousands	16680	57	51	33
Fiserv Case Shiller Weiss zip level data				
House price growth, zip level, 1998-2002	16758	0.416	0.439	0.142
House price growth, zip level, 2002-2006	16837	0.492	0.490	0.228
Saiz (2010) MSA level elasticity measure				
Housing supply elasticity	16837	1.189	0.975	0.634
Median home value, 1997, $thousands	16606	122	110	61
IRS zip level income data				
Per capita wage growth, 2002-2006	16833	0.117	0.111	0.059
Census business statistics zip level data				
Per capita payroll growth, 2002-2006	16356	0.118	0.118	0.121
Employment growth, 2002-2006	16356	0.063	0.053	0.185
Equifax zip level aggregate data				
Fraction of zip code with credit score under 659, 1997	16832	0.331	0.317	0.123

Appendix Table 2
Summary Statistics for Homeowners that Move Between 1997 and 1999

This table presents summary statistics for 14,620 individuals who are homeowners that move from their original zip code between 1997 and 1999. There are 1,397 zip codes and 66 MSAs that are represented in the sample.

	N	Mean	Median	St. Dev.
Equifax individual level data				
Total debt, 1997, $thousands	2407	121	115	79
Home debt, 1997, $thousands	2407	105	100	77
Growth in total debt, 1998-2002	2407	0.151	0.139	0.601
Growth in total debt, 2002-2006	2407	0.426	0.412	0.627
Growth in home debt, 1998-2002	2407	0.149	0.124	0.843
Growth in home debt, 2002-2006	2407	0.487	0.455	0.843
Total debt to income ratio, 1997	2263	3.000	2.936	1.642
Change in debt to income ratio, 1998-2002	2334	0.166	0.077	1.069
Change in debt to income ratio, 2002-2006	2389	1.146	0.836	1.576
Total debt default rate, 1997	2407	0.055	0.000	0.118
Change in default rate, 1998-2006	2407	-0.013	0.000	0.137
Change in default rate, 2006-2008	2407	0.052	0.000	0.173
Credit score, 1997	2407	763	766	78
Credit card utilization fraction, 1997	2406	0.351	0.308	0.214
Age, 1997	2407	43	43	6
Male	2407	0.562	0.571	0.243
Income, 1997, $thousands	2407	86	82	32
Fiserv Case Shiller Weiss zip level data				
House price growth, zip level, 1998-2002	2402	0.394	0.413	0.138
House price growth, zip level, 2002-2006	2407	0.501	0.513	0.219
Saiz (2010) MSA level elasticity measure				
Housing supply elasticity	2407	1.174	0.943	0.615
Median home value, 1997, $thousands	2277	130	119	63
IRS zip level income data				
Per capita wage growth, 2002-2006	2389	0.114	0.109	0.065
Census business statistics zip level data				
Per capita payroll growth, 2002-2006	2289	0.124	0.122	0.125
Employment growth, 2002-2006	2289	0.118	0.088	0.227
Equifax zip level aggregate data				
Fraction of zip code with credit score under 659, 1997	2346	0.321	0.305	0.131

Appendix Table 3
Motivation for Within-MSA Test Based on 1997 Subprime Share of Zip Code Population

Panel A shows the effect of subprime fraction in the zip code on mortgage origination growth for home purchase at the zip code level by MSA housing supply elasticity. The zip code level mortgage origination growth data come from HMDA. Panel B shows the effect of the 1997 fraction of subprime individuals in the zip code on house price growth from 2002 to 2006 by MSA housing supply elasticity. Panel C shows the correlation between the instrument, subprime share of total population interacted with housing supple elasticity, and measures of debt as of 2002. Individual dummy variables are quintile indicator variables for 2% bins of the 2002 median home value in the zip code, 1997 credit score, 2008 income, and 1997 age variables. All specifications include MSA fixed effects and standard errors are clustered at the MSA level.

Panel A: Mortgage origination growth for new home purchase (HMDA), 2002-2006

	(1) Full	(2) Most elastic	(3) 2nd quartile	(4) 3rd quartile	(5) Most inelastic
Fraction in zip code with credit score under 660, 1997	1.397**	0.500*	0.973*	0.883**	1.886**
	(0.175)	(0.161)	(0.329)	(0.270)	(0.152)

Panel B: House price growth, 2002-2006

	(1) Full	(2) Most elastic	(3) 2nd quartile	(4) 3rd quartile	(5) Most inelastic
Fraction in zip code with credit score under 660, 1997	0.287**	-0.020	0.093	0.183**	0.419**
	(0.055)	(0.019)	(0.149)	(0.035)	(0.061)

Panel C: Correlation of instrument with measures of debt as of 2002

	(1)	(2)	(3)	(4)
Dependent variable	Ln(total debt, 2002)		Total debt to income ratio, 2002	
Fraction in zip code with credit score under 660, 1997	0.054	-0.002	-0.417+	-0.123
*Housing supply elasticity	(0.131)	(0.111)	(0.243)	(0.285)
Fraction in zip code with credit score under 660, 1997	-1.507**	0.059	2.815**	2.707**
	(0.234)	(0.178)	(0.428)	(0.648)
Additional control variables		Individual dummy variables		Individual dummy variables

**,*, + coefficient statistically distinct from 0 at the 1, 5, and 10% level, respectively.

Appendix Table 4
The Effect of House Prices on Household Borrowing for 1997 Homeowners
Using Within-MSA Variation

This table presents second stage estimates from a within-MSA instrumental variables specification where the first stage instrument for house price growth from 2002 to 2006 is the fraction in the zip code with a credit score under 660 as of 1997 interacted with MSA level housing supply elasticity. Individual dummy variables are quintile indicator variables for 2% bins of the 2002 median home value in the zip code, 1997 credit score, 2008 income, 1997 debt to income, and 1997 age variables. All specifications (both first and second stage) include MSA fixed effects and standard errors are clustered at the MSA level.

Dependent variable	(1)	(2) Total debt growth 2002-2006	(3)	(4)	(5) Change in total debt to income 2002-2006	(6)
Instrumented house price growth, 2002-2006	0.931**	0.964**	0.926**	4.190**	3.150**	2.201**
	(0.327)	(0.294)	(0.251)	(1.147)	(0.880)	(0.646)
Fraction in zip code with credit score under 660, 1997	-0.235**	0.071	0.115	0.292	0.660**	1.120**
	(0.089)	(0.094)	(0.102)	(0.267)	(0.229)	(0.264)
Median home value, 2002		-0.000			-0.001**	
		(0.000)			(0.000)	
(Credit score, 1997)/100		-0.037**			-0.146**	
		(0.009)			(0.022)	
Ln(household income, 2008)		0.181**			0.527**	
		(0.025)			(0.046)	
Debt to income ratio, 1997		-0.042**			0.019*	
		(0.005)			(0.010)	
Age, 1997		-0.011**			-0.027**	
		(0.001)			(0.002)	
Male dummy variable		0.023	0.022		0.110*	0.106*
		(0.024)	(0.022)		(0.053)	(0.047)
Additional control variables			Individual dummy variables			Individual dummy variables
N	13334	13016	13016	13333	13016	13016
R^2	0.01	0.04	0.07	0.05	0.11	0.14

**,*, + coefficient statistically distinct from 0 at the 1, 5, and 10% level, respectively.

Appendix Table 5
Default Rate Regressions

This table presents the effect of house price growth from 2002 to 2006 on default rates from 2002 to 2006 (first three columns) and default rates from 2006 to 2008 (second three columns). In columns 2,3,5 and 6, we interact house price growth with the variable in the top of the column. The instruments in the first stage are MSA level housing supply elasticity and MSA level housing supply elasticity interacted with the interaction variable listed in the top of the column. In all columns, we use the data sorts that maximize variation in the interaction variable. All standard errors are clustered at the MSA level.

	(1)	(2)	(3)	(4)	(5)	(6)
Interaction variable		Credit score, 1997	Credit card utilization, 1997		Credit score, 1997	Credit card utilization, 1997
Left hand side variable	Change in default rate, 2002-2006			Change in default rate, 2006-2008		
Instrumented house price growth, 2002-2006	-0.048**	-0.325**	-0.008	0.114**	0.711**	0.028+
	(0.008)	(0.097)	(0.013)	(0.018)	(0.155)	(0.016)
Instrumented house price growth, 2002-2006		0.036**	-0.112*		-0.078**	0.244**
*Interaction term (listed at top of column)		(0.012)	(0.043)		(0.019)	(0.062)
(Credit score, 1997)/100	0.010**	-0.007	0.009**	-0.024**	0.018*	-0.017**
	(0.002)	(0.007)	(0.003)	(0.002)	(0.008)	(0.003)
Ln(household income, 2008)	0.001	0.001	0.001	-0.006+	-0.007*	-0.007+
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Debt to income ratio, 1997	0.002	0.001	0.002	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age, 1997	0.000	0.000	0.000	-0.001**	-0.001**	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male dummy variable	0.001	0.001	0.001	-0.001	-0.001	-0.001
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
Credit card utilization, 1997		-0.000	0.051*		0.025+	-0.087**
		(0.011)	(0.022)		(0.013)	(0.029)
N	13025	13024	13024	13021	13020	13020
R^2	0.01	0.02	0.02	0.04	0.05	0.04

**,*, + coefficient statistically distinct from 0 at the 1, 5, and 10% level, respectively.