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Regional Heterogeneity and Monetary Policy

Martin Beraja
Department of Economics
University of Chicago

Erik Hurst
Booth School of Business
University of Chicago
NBER

Andreas Fuster
Federal Reserve Bank of New York

Joseph Vavra
Booth School of Business
University of Chicago
NBER

Summary

In this paper, the authors conclude that expansionary monetary policy helped stimulate the U.S. economy overall during the Great Recession, but may have widened the disparities among regions.

The authors show that mortgage originations almost tripled, in dollar terms, after the Fed announced its first round of quantitative easing (QE1). They also find a strong relationship between refinancing induced by QE1 and an increase in consumer spending, as measured by car purchases. However, mortgage refinancing increased the *most* in places with the fewest underwater homeowners, defined as borrowers who owed more than 80% of the value of their home. This occurred because it is more difficult and expensive for borrowers with little equity to refinance. In addition, the areas with little equity (which had experienced the largest declines in housing prices) tended to also suffer from the largest declines in employment. Collectively, their empirical results imply that QE1 provided the least amount of monetary stimulus to the metro areas hit hardest by the recession.

The authors offer a theoretical model in which a household's decision to refinance when interest rates decline depends on the interaction of two variables: the value of their collateral (their houses) and their income. Homeowners with positive home equity will refinance; underwater homeowners usually cannot. Additionally, high income households are more likely to refinance when interest rates decrease than low income households. Their model suggests that monetary policy will amplify regional inequality when there is a strong correlation between income and home prices, as there was in 2008. Furthermore, the aggregate stimulative effect of low rates is likely also lower in such a situation. In contrast, the authors point out that in 2001, borrowers that faced a negative income or employment shock weren't also underwater, meaning they were better able to benefit directly from the Fed's monetary policy by refinancing.

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INTRODUCTION

It has long been recognized that the presence of heterogeneous regional shocks within a monetary union will lead to challenges in monetary policy making. Under the classic Mundell criterion for an ideal monetary union, member states should experience synchronized business cycles so that the same monetary policy action can simultaneously mitigate all states' business cycles.[1] However, while fully synchronized business cycles are a feature of an ideal monetary union, this condition is not met within actual monetary unions. For example, recent years have seen large disparities in regional economic activity within the U.S. (e.g., Nevada vs. Texas) and Europe (e.g., Spain vs. Germany).

Should monetary policy pay attention to these regional disparities? While there is a growing body of work exploring the extent to which fiscal policy can be used to mitigate the dispersion of regional shocks, there is little work discussing both the aggregate and regional effects of a common monetary policy when member regions of the monetary union receive heterogeneous shocks.[2] The goal of this paper is to fill that gap. In particular, we ask two questions: (1) Does monetary policy have similar effects on regions experiencing different economic conditions? and (2) Are the aggregate effects of monetary policy affected by the presence of regional heterogeneity?

The fact that the monetary policy (e.g., the target interest rate) pursued by the Central Bank is common across all regions may suggest that changes in monetary policy would have similar effects across member regions. However, even if interest rates are common across regions,[3] this does not mean that the strength of the mechanism by which monetary policy is transmitted to real activity is the same across the regions. For example, if lenders make lending decisions based in part on local collateral values, heterogeneity in these values could result in heterogeneous effects of monetary policy across the regions. Regions with low collateral values may see less of an increase in borrowing in response to a monetary expansion than regions with higher collateral values.

This paper focuses specifically on the collateralized lending channel associated with monetary policy. Business and commercial collateral values often evolve differentially across regions within monetary unions over the business cycle. For example, within the European Union, countries such as Spain, Portugal, and Ireland experienced very large declines in housing values in 2008 and 2009 relative to countries such as France and Germany. Likewise, within the United States, California, Florida, Arizona, and Nevada experienced very large declines in housing values in 2008 and 2009 relative to Massachusetts and Texas. The places within both the E.U. and the U.S. that experienced the largest housing busts also experienced the largest declines in real economic activity.[4]

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[1] See Mundell (1961).

[2] See, for example, Farhi and Werning (2012) and the citations within. Additionally, Sala-i-Martin and Sachs (1991) and Asdrubali, Sorensen, and Yosha (1996) explore the role of an integrated fiscal system in smoothing income across U.S. states.

[3] This paper focuses on the effects of monetary policy on mortgage refinancing. See Hurst et al. (2015) for evidence that mortgage rates are constant across regions.

[4] For discussions of the link between real activity and housing prices during the Great Recession see, for example, Mian and Sufi (2014b), Dynan (2012), and Mehrotra and Sergeyev (2015).

The goals of this paper are twofold. First, we seek to assess under what conditions monetary policy mitigates or exacerbates regional shocks. For example, during the 2008 recession, which did monetary policy help more: the regions with relatively lower economic activity and collateral values (e.g., Nevada or Spain) or the regions with relatively higher economic activity and collateral values (e.g., Texas or Germany)? Further, in determining whether monetary policy mitigates or exacerbates regional shocks, does it matter whether there is a strong or weak correlation between the underlying regional shocks and the extent to which collateral values evolve in response to the shock? If monetary policy resulted in more local lending in the places with relatively high real activity and collateral values, then expansionary monetary policy would actually increase dispersion in economic activity across regions within the union.

Our second goal centers on whether the aggregate effect of monetary policy is different in a currency union with regional heterogeneity than in a currency union where all regions are identical. If monetary policy has different effects on different regions, and if these effects are not perfectly symmetric, then regional heterogeneity can affect the aggregate response to monetary policy. We explore the conditions under which regional heterogeneity is likely to affect the aggregate response to monetary policy. Does this depend on the particular shocks that are driving regional dispersion? And does it depend on whether the shocks driving regional economic activity are correlated with local collateral values?

To help answer these questions, we explore the regional response within the United States to the first round of the Federal Reserve's large-scale asset purchase programs (LSAPs). This program is commonly known as quantitative easing (QE), and we will henceforth refer to it as QE1. On November 25, 2008, the Federal Reserve announced that it would initiate a program to purchase $500 billion of agency mortgage-backed securities (MBS) as well as $100 billion of direct obligations of housing-related government-sponsored enterprises (GSEs).[5] Given that short-term interest rates were close to zero, the Federal Reserve action was designed to lower long-term interest rates. In particular, the stated goal of QE1 was to promote mortgage activity. In its announcement of the purchase of mortgage securities, the Fed said "[The policy] is being taken to reduce the cost and increase the availability of credit for the purchase of houses, which in turn should support housing markets and foster improved conditions in financial markets more generally." Thirty-year fixed-rate mortgage rates, as measured by the Freddie Mac Primary Mortgage Market Survey, hovered between 6.0 percent and 6.4 percent from July 2008 through late November 2008. The week before the QE1 announcement, the mortgage rate was at 6.04 percent. However, by the first week of December 2008—a week after QE1 was announced—the headline mortgage rate had fallen to 5.53 percent. By December 31, 2008, the mortgage rate had fallen even further, to 5.1 percent. The 30-year fixed-rate mortgage rate remained around 5 percent through May of 2009.[6]

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[5] Agency MBS include those guaranteed by the GSEs Fannie Mae and Freddie Mac, as well as those guaranteed by the government agency Ginnie Mae. The GSEs securitize a large portion of conforming mortgages within the United States. Conforming mortgages are those with a size below a fixed amount (the "conforming loan limit") made to borrowers who meet certain quality and loan-to-value thresholds. Borrowers who do not meet the quality and loan-to-value thresholds may in some cases get a loan insured through government programs such as the Federal Housing Administration (which are then securitized in Ginnie Mae MBS).

[6] QE1 was extended on March 18, 2009, by another $750 billion in agency MBS and $100 billion in agency debt to be purchased through the end of 2009. Over 2010 to 2014, additional rounds of asset purchases, including both MBS and Treasury securities, were conducted by the Federal Reserve. We focus on the beginning of QE1 because it was largely unanticipated, thus allowing an "event study," and it arguably had the largest effect in terms of leading to a rapid drop in mortgage rates.

Using a variety of loan-level data sources, we document four facts with respect to mortgage originations in response to QE1. First, we show that QE1 did lead to a boom in mortgage originations. Using data collected under the Home Mortgage Disclosure Act, we document a large rise in mortgage applications starting immediately after QE1 was announced. Between May and November of 2008, at the national level there were roughly $57 billion of monthly mortgage applications leading to originations. However, in December 2008, the volume of applications leading to subsequent originations jumped to $153 billion nationally. The level of applications remained at that high level from January to April 2009 ($156 billion on average).

We also document that essentially all of the increase in mortgage activity occurred with households refinancing their existing mortgage, as opposed to originating new mortgages for home purchases. While the Federal Reserve asset purchases may eventually have spurred new home purchases, in the immediate aftermath of the QE1 announcement they promoted mortgage activity by stimulating household refinancing.

Our second empirical contribution is to explore the response to refinancing across different regions. We begin by documenting a large variation across regions in the extent to which mortgage holders had an estimated loan-to-value ratio (LTV) above 0.8 and above 1.0 on the eve of QE1. During the Great Recession and its immediate aftermath, it was difficult and/or expensive for borrowers to obtain a mortgage if their LTV was above 0.8, and generally impossible if their LTV was above 1.[7] In November 2008, for example, only about 30 percent of mortgage holders in Philadelphia had an LTV above 0.8. Conversely, 60 percent of mortgage holders in Miami and 80 percent of mortgage holders in Las Vegas had LTVs above 0.8. Even though residents in Philadelphia and Las Vegas faced the same decline in mortgage rates, fewer residents would have been able to refinance their mortgage in Las Vegas unless they added substantial equity in their home during the refinancing process.[8] We then formally document our key empirical finding. We show that in the aftermath of QE1, refinancing activity increased most in the places where there were few mortgage holders with an LTV above 0.8. We document that the places with the most mortgage owners who had LTVs above 0.8 in November of 2008 were the places that had the largest decline in house prices between January 2007 and November 2008. These are also the same places were the unemployment rate increased the most between January 2007 and November 2008. In other words, the smallest refinancing response to QE1 took place in the locations that were hit hardest by the recession.

Our third fact documents that the amount of equity removed from a borrower's house during the refinancing process also varied spatially. For those regions with the most mortgage owners who had LTVs above 0.8, the amount of equity removed during the QE1 induced refinancing boom was the lowest. The low amount of equity removed in regions with the largest house price declines in 2007 and 2008 was driven by the fact that mortgage owners in those regions were less likely to refinance. It also meant that

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[7] The Home Affordable Refinance Program (HARP), introduced by the government in 2009, eased LTV restrictions for borrowers with mortgages guaranteed by the GSEs, but for various reasons the program had little effect until it was enhanced (to "HARP 2.0") in late 2011.

[8] Throughout the paper, we assume that conventional mortgage rates do not vary spatially. This assumption is backed up empirically. Hurst et al. (2015) document that conventional mortgage rates do not vary spatially with any local measures of predicted default risk. They also discuss how political constraints prevent the GSEs from engaging in pricing policies that vary spatially.

there was less equity to remove conditional on refinancing. If cash-out refinancing lead to local spending responses, QE1 generated more economic activity in regions that were doing relatively better. In other words, QE1 increased the dispersion in economic activity across regions. The regions that benefited the most were the regions that were doing relatively better prior to QE1 taking place. These regions had lower house price drops and smaller employment declines prior to the policy.

Our fourth fact directly measures the spending response to QE1. Using data on new car purchases, we show that areas where borrowers refinanced the most in early 2009 were the same areas in which car purchases increased the most. This pattern suggests a direct relationship between local spending and the refinancing boom induced by the Federal Reserve. The spending response that we document is in the form of tradable goods as a result of the high frequency data to which we had access. However, two things make us confident that the spending response of a tradable good will translate to broader measures of local consumption. First, even for tradables like car purchases, there is a nontrivial local component associated with the selling of tradable goods. In other words, a boom in car purchases is associated with a boom in the local retail sector that sells the cars. Second, other researchers have documented a strong positive correlation between car purchases at the local level and employment responses in local nontradable sectors.[9] Much of this literature is focused on periods surrounding the Great Recession. The fact that this other literature finds a strong positive link between local employment and local car spending suggests that QE1 indeed led to more economic activity in regions that were doing relatively well prior to the intervention.

What are the implications of our empirical results for the conduct of monetary policy? First, our results suggest that though expansionary monetary policy likely stimulated the economy overall, it may have amplified regional inequality in the U.S. during the Great Recession.[10] Additional refinancing dollars and local spending largely flowed toward the regions that were doing relatively well, rather than the regions that were hardest hit during the recession. In the theoretical section of this paper we argue that this is likely to be the case when local economic activity and local house prices are highly dispersed and when they are highly correlated with each other. We demonstrate this in a quantitative spatial model of collateralized lending, but the results can be explained using intuition from a simple four-region model.

Regions can be divided broadly into four types: those with positive housing equity and high current income (*PH*), those with negative equity and high current income (*NH*), those with positive equity and low current income (*PL*) and those with negative equity and low current income (*NL*). The households most likely to refinance will always be the households with positive equity, since households with negative equity have to put additional cash into the house in order to meet LTV requirements. Thus, as the spatial dispersion of housing equity increases, so does spatial variation in refinancing and spending in response to interest rate reductions: high housing equity locations have larger and larger responses, while locations with more negative housing equity do not refinance at all.

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[9] See, for example, Mian and Sufi (2014a).

[10] Refinancing mortgages into lower rates benefits the borrower, but at a cost to the lender. One may think that the two cancel out at the macro level. However, it is very likely that borrowers have a higher marginal propensity to consume; furthermore, a large portion of U.S. mortgages are owed to foreign investors and U.S. governmental institutions (see libertystreeteconomics.newyorkfed.org/2012/01/why-mortgage-refinancing-is-not-a-zero-sum-game.html).

Similarly, high-income households are more likely to refinance in response to interest rate reductions than are low-income households. This is because when interest rates fall, some *NH* refinance even though they have to put additional cash into their house to do so. However, *NL* will never refinance since they are liquidity constrained and cannot afford to meet the LTV requirement to refinance. Thus, high-income households with negative equity respond more to interest rate declines than low-income households with negative equity. Perhaps more surprisingly, *PH* households also respond more to interest rate declines than do *PL* households. One might think that *PL* would be more likely to refinance since they are liquidity constrained and want to access their positive housing equity. While this is true, it is also true that these households can access their positive housing equity even if interest rates do not decline, and they have strong incentives to do so. Indeed, in our theoretical model we find that many of the refinancing decisions of *PL* households occur independently of monetary policy. Conversely, *PH* households do not need to access their housing equity, and only refinance when interest rates fall. Thus, they respond strongly to monetary policy.

Putting these implications together delivers our conclusion that monetary policy amplifies regional differences in spending when regional dispersion rises. As the difference between *P* and *N* regions widens, so will their spending decisions. Similar effects occur as the difference between *H* and *L* regions widens. Quantitatively we find that these effects are quite strong and that they amplify each other. The regions with the lowest consumption responses are *NL* and the regions with the highest consumption responses are *PH*. Thus, the more income and house prices are correlated, the greater the amplification in inequality induced by monetary policy. This can have important implications for how monetary policy affects regional inequality in different recessions.

To illustrate, we compare the refinancing response across regions during the 2008 recession with the refinancing response across regions during the 2001 recession. We show that during the 2001 recession there was essentially no correlation between local unemployment changes and local house price changes. We also show that between 2001 and 2003 refinancing activity was slightly stronger in places with high increases in unemployment rates. This stands in stark contrast to the 2008 recession, during which refinancing activity was lower in places with weak labor markets. The key difference driving the results is the underlying correlation during the recession between changes in the unemployment rate and changes in collateral values at the local level. These results imply that if one wants to understand the consequences of monetary policy for regional inequality, it is crucial to take account of the nature of the shocks driving regional differences. Both the variance of these shocks across regions and their correlations with each other will change the regional consequences of monetary policy, and there is evidence that the correlation of these shocks changes across time.

These differences in regional responses have potential implications for the aggregate effects of monetary policy. Most importantly, the median level of housing equity matters. If house prices fall, and more regions slip over the threshold to negative equity, then aggregate spending responses through the refinancing channel are likely to be dampened dramatically. In addition, for the same reasons mentioned above, the aggregate response to an interest rate reduction will change as the amount of heterogeneity within a monetary union changes. This heterogeneity induces different responses in different regions, and to the extent that these differential responses do not exactly cancel each other out, this will induce aggregate effects. Our quantitative model suggests that when shocks are highly correlated across space, the aggregate effect of monetary policy may be dampened. From an optimal policy perspective, this would imply that maintaining the same target for inflation and output gaps requires larger changes in interest rates.

Our work relates to many separate existing contributions in the literature. First, there is a vast New Keynesian literature emphasizing intertemporal substitution as the main reason why unanticipated interest rate changes affect household consumption behavior.[11] While we also emphasize the response of household spending to interest rate changes, we depart from this literature in our modeling of household capital markets. In particular, standard New Keynesian models assume frictionless household capital markets, which feature only one-period borrowing and lending. This standard modeling abstraction stands in stark contrast to the reality of the bulk of actual household borrowing.

The vast majority of household borrowing occurs through the mortgage market. Loans in this market are subject to collateral requirements, are typically long term with fixed nominal payments (in the U.S.), and can only be refinanced subject to a costly adjustment process. Each of these features differentiates this borrowing from that in the standard model. Together they give rise to what we call a "collateralized lending channel" of monetary policy. While this channel shares many features with the standard transmission mechanism, it also has several important differences. First, the collateralized aspect of these loans means that regional dispersion in collateral will have direct consequences for the aggregate monetary transmission mechanism (for the reasons discussed above). Furthermore, the fixed costs of refinancing affect the relationship between regional income and refinancing propensities.

In addition, even in an environment with no regional heterogeneity, the long-dated fixed nominal payments imply that nominal interest rate movements will affect spending and refinancing decisions even if inflation expectations adjust so that the real interest rate is unchanged. This is because a household considering refinancing from nominal interest rate i^{old} to i^{new} will face the same expected inflation whether they keep their old loan or refinance into the new loan, so that changes in nominal interest rates are directly relevant, even if there is no other wage or price-stickiness in the economy.[12] That is, fixed nominal mortgage contracts introduce a nominal friction, which is absent from standard New Keynesian analysis.

Our focus on the implications of realistic modeling of household borrowing and how it interacts with heterogeneity in the economy makes our theoretical analysis most similar to Auclert (2015). The main insight in Auclert is that the covariance of the marginal propensity to consume with interest rate exposures in the cross-section of agents influences the aggregate consumption response to interest rate changes. He shows that this channel has quantitatively important implications for monetary policy in an environment where most people hold adjustable-rate mortgages. We instead focus on regional variation in collateral values and its interaction with households' abilities to refinance, which is central in an economy such as the U.S. where households mainly hold fixed-rate mortgages. The correlation of collateral values with local income in turn has implications for the aggregate spending response to monetary policy. Thus, while our motivation is similar in spirit to Auclert, we focus on a different source of heterogeneity, which we argue is particularly relevant for economies with fixed-rate mortgages. Similarly, McKay and Reis (2013) introduce household borrowing restrictions into a New Keynesian environment, but do not explore the role of fixed-rate mortgages, collateral, or regional heterogeneity.

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[11] See Woodford (2005) and Galí (2009) for canonical expositions.

[12] This will be exactly true for a nonamortizing loan, which is paid in perpetuity, and will be approximately true for any loan with substantial remaining maturity.

In addition to the vast New Keynesian literature, our work also contributes to the literature that focuses on collateral constraints and the "credit channel" of monetary policy. For example, Iacoviello (2005) shows that adding collateral constraints tied to real house values to a "financial accelerator" model similar to the one in Bernanke, Gertler, and Gilchrist (1999) amplifies the output response to a decrease in nominal interest rates by increasing collateral values and relaxing these constraints for net borrowers. Third, our work contributes to the literature on the balance-sheet channel of monetary policy. Gertler and Karadi (2011) study unconventional monetary policy in a world where financial intermediaries face balance-sheet constraints. Adrian and Shin (2010) and Brunnermeier and Sannikov (2014) emphasize the revaluation of nominal assets and the redistribution of wealth that results from monetary interventions.[13] We add to this literature by (1) highlighting a different theoretical channel—the "collateralized lending channel" and its interaction with the properties of the idiosyncratic shocks hitting households—and (2) quantifying its importance using regional data to estimate the household consumption response to monetary policy.

More broadly, we contribute to the literature studying regional stabilization in currency and fiscal unions. The theoretical side includes the pioneering work on optimal currency areas (e.g., Mundell, 1961; and McKinnon, 1963) and the more recent efforts by Galí and Monacelli (2008) and Farhi and Werning (2012). On the empirical side, Nakamura and Steinsson (2014) and Suarez-Serrato and Wingender (2010) concentrate on local fiscal multipliers. Beraja (2015) studies federal transfer rules in fiscal unions. Hurst et al. (2015) focus on regional redistribution through the mortgage market. Lustig and Van Nieuwerburgh (2010) study how regional risk-sharing varies with local housing collateral values.

Finally, we relate to studies investigating the pass-through of monetary policy through the mortgage market. Fuster and Willen (2010) measure the effects of QE1 on the primary U.S. mortgage market and emphasize differential effects on borrowers with different levels of creditworthiness. In contrast, we emphasize regional disparities.[14] Chen, Michaux, and Roussanov (2013) investigate the link between macroeconomic uncertainty and cash-out refinancing. Bhutta and Keys (2014) show that low interest rates increase the likelihood and magnitude of home equity extraction. Rubio (2011); Calza, Monacelli, and Stracca (2013); and Garriga, Kydland, and Sustek (2013) study the transmission of monetary policy in adjustable-rate mortgage (ARM) and fixed-rate mortgage (FRM) environments. Di Maggio, Kermani, and Ramcharan (2014) and Keys et al. (2014) study the effects of ARM resets on durable consumption, following work by Fuster and Willen (2012) and Tracy and Wright (2012) studying the effects of resets on mortgage defaults. Perhaps closest to the empirical portion of this paper, Caplin, Freeman, and Tracy (1997) emphasize how in the early 1990s, drops in housing values in some regions impeded the ability of homeowners to refinance, thereby deepening regional recessions. Also related, Fratantoni and Schuh (2003) propose a heterogeneous-agent VAR model that incorporates regional heterogeneity in housing markets to study time variation in the pass-through of monetary policy.

[13] There is also a growing literature specifically studying the effects of QE. Most of this work focuses on financial market reactions. See, for instance, Gagnon et al. (2011); Hancock and Passmore (2011); Krishnamurthy and Vissing-Jorgensen (2011, 2013); Stroebel and Taylor (2012). Chen, Cúrdia, and Ferrero (2012) study the effects of QE on the macroeconomy through the lens of a DSGE model.

[14] From a broader perspective, Coibion et al. (2012) and others study the effects of monetary policy on individual inequality.

DATA

To help document the extent to which refinancing patterns differed spatially in the aftermath of QE1, we use a variety of different data sources. We briefly discuss each of these data sources below. We discuss each data source in greater detail in the Appendix that accompanies this paper.

We use measures of refinancing activity computed from two different data sources. Our first measure of refinancing activity uses data made available under the Home Mortgage Disclosure Act (HMDA), which requires mortgage lenders to report information on mortgage applications and originations. The HMDA data is generally perceived to be the most comprehensive and representative source of information on mortgage applications and originations, with market coverage estimated to be around 90 percent.[15] For each application, HMDA reports the geographic location of the property, the desired loan amount, the loan purpose (purchase or refinance), and whether the loan application led to an origination, was rejected by the lender, or was withdrawn by the borrower.[16] While the public-use HMDA data only contains calendar year indicators, the private-use version of the dataset (available to users within the Federal Reserve system) also contains the exact application date and the exact action date. The action date is the date on which one of these occurs: the loan is originated, the application is rejected, or the application is withdrawn. These exact dates make the data suitable for high-frequency event studies (see, for example, Fuster and Willen, 2010). We use the high-frequency data to explore the extent to which refinancing activity differed across locations in the months surrounding QE1.

While the HMDA data is ideal for measuring the flow volume of mortgage origination activity across locations, it has two prominent limitations. First, for refinance loans, the HMDA data does not include any information on the loan that is paid off. As a result, we cannot use the HMDA data to estimate the extent to which households are removing cash from their mortgage during the refinancing process. Second, the HMDA data does not include any information on the loans after they are originated. Thus, HMDA is not informative about how many outstanding mortgages there are in a metropolitan statistical area (MSA), which is the level of local aggregation we use throughout the empirical part of the paper.[17] The stock of outstanding mortgages is necessary to measure a refinancing propensity.

To overcome the limitations of the HMDA data, we supplement our analysis with additional data sources. First, to obtain an estimate of the number of outstanding mortgages in each MSA, we use data from the 2008 American Community Survey (ACS), which reports the number of outstanding mortgages (but not their amount) and number of households for fine geographic areas. Since the ACS only samples a fraction of the population, we scale up the number of households based on Census information on the overall number of households in the U.S. in 2008. We use the same scaling factor for the number of mortgages in each location. By combining ACS data with HMDA data, we can compute the number of loan originations per number of outstanding mortgages for each location within the United States.

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[15] See, for instance, Avery et al. (2010) or Dell'Ariccia, Igan, and Laeven (2012).

[16] There are actually three designated loan types within the HMDA: origination, refinancing, and home improvement. We combine the home improvement loans with the refinancing ones in this analysis.

[17] For large MSAs that are subdivided into Metropolitan Divisions, we use the latter. Many of our control variables are defined at the public use microdata area (PUMA) level. We aggregate the PUMA data to MSAs using the cross-walk available at http://mcdc.missouri.edu/data/georef/zcta_master.Metadata.html.

To obtain measures of cash-out refinancing and to create a second measure of local refinancing propensities, we supplement our analysis with data from Equifax's Credit Risk Insight™ Servicing McDash (CRISM) dataset. This dataset merges McDash Analytics mortgage-servicing records (from Black Knight Financial Services, previously known as Lender Processing Services) with credit bureau data (from Equifax). To our knowledge, this is the first paper to use these data. The structure of the dataset makes it possible to link multiple loans by the same borrower together—something that is not possible with servicing data alone—and thus allows us to accurately measure refinancing activity.[18]

The CRISM data allow us to study cash-out refinancing much more accurately than with servicing data alone. Since we know the outstanding amount of the old loan (as well as any second liens that get paid off around the same time) and the principal amount of the new loan, we can measure the dollar amount of equity that is removed from the home during the refinancing process. Finally, unlike the HMDA data, the CRISM data provides us with a natural denominator to scale the refinancing activity, given that we can measure the stock amount of loans outstanding in a given area in the previous month.[19] That said, CRISM has somewhat lower coverage than HMDA (it is estimated to cover roughly 65 percent of the market during the period we study), and does not contain loan application dates. Given that both datasets have different limitations, we use both the HMDA and CRISM data to explore refinancing activity around QE1 and during the broader 2000s.

We also use the CRISM dataset to estimate the fraction of mortgages in different MSAs that have combined loan-to-value (CLTV) ratios above certain thresholds (80 or 100; we denote these fractions by *CLTV_80* and *CLTV_100*, respectively). A CLTV ratio combines the outstanding balances on all mortgages outstanding relative to the home value attached to the loans. To estimate a mortgage's CLTV, we combine the balances of first mortgages and matched second liens (closed-end second liens or home equity lines of credit; see Lee, Mayer, and Tracy, 2012), and divide it by the estimated property value (given by the appraisal value at the time the mortgage was granted, updated using a house price index from CoreLogic).[20] Additional details are provided in the Appendix. The CLTV is a key determinant of homeowners' ability and incentive to refinance their mortgage. Obtaining a new mortgage with a CLTV above 0.8 is generally more expensive than if the CLTV is below this threshold, because the borrower needs to take out mortgage insurance (through a private mortgage insurance company for loans securitized through Fannie Mae or Freddie Mac, or by paying insurance premia to FHA). Furthermore, due to tightening of underwriting standards in 2008–09, some lenders were simply unwilling to make high-CLTV loans—even for borrowers who were otherwise creditworthy. Mortgage financing with no down payment (that is, a CLTV of 100), which was relatively easy to obtain during the housing boom, has been practically nonexistent since 2007, except through special programs such as the Home Affordable Refinancing Program (HARP). HARP was introduced in March 2009 to help borrowers with mortgages guaranteed by Fannie Mae or Freddie Mac refinance, even if they are underwater (or nearly so). However, due to various implementation issues (see, for instance, Goodman, 2012) the program initially did little to

[18] Servicing data alone indicates whether an existing loan is paid off, but there is no way of knowing whether the borrower refinanced the mortgage or moved to another home.

[19] A detailed description of how we use CRISM to measure origination and refinance propensities, as well as how we measure cash-out refinancings, is provided in the Appendix.

[20] We use the zip-code-level index if available, and otherwise the MSA-level index.

increase refinancing volumes among such borrowers.[21]

Finally, we supplement our analysis with five other types of data. First, we use the Census Bureau's 2007 and 2008 American Community Survey to define local demographic controls for each U.S. sublocation. We merge the 2007 and 2008 data to ensure the sample sizes are large enough to minimize measurement error. In terms of demographics, we measure the age composition of each area, the education composition of each area, the percentage of homeowners in each area, the racial composition of each area, local employment (and unemployment) rates, and the percentage of naturalized citizens in each area.[22] Second, we also show aggregate refinancing trends within the U.S. using published statistics from the Mortgage Bankers Association (MBA) Refinance Index, which is based on refinancing applications. Third, as stated above, we use MSA-level house price data from CoreLogic to measure local house price appreciation. Fourth, we measure employment and unemployment rates for each MSA using data from the Bureau of Labor Statistics (BLS) Local Area Unemployment Statistics. Finally, we use data purchased from R.L. Polk and Company to measure new car purchases at the MSA level. The data are collected from new auto registrations at the zip code level and can be combined to measure total new car purchase activity for individuals residing in a given location.

THE SPATIAL VARIATION IN MORTGAGE ACTIVITY IN RESPONSE TO QE

AGGREGATE TRENDS IN MORTGAGE ACTIVITY AROUND QE1

Figure 1a shows the time-series patterns in the monthly MBA Refinance Index from 2000 to 2012 (solid line). The figure also includes the difference between the average 30-year fixed-rate mortgage rate (also from MBA) in month *t* and the average of the 30-year mortgage rate over the prior 5 years (dashed line). This metric indicates periods when the 30-year mortgage rate changes discretely in a given month relative to average rates over the prior 5 years. A few things are noticeable from Figure 1. First, there is a very strong relationship between refinancing activity and 30-year mortgage rates. The simple correlation between the two series is -.77. When mortgage rates fall relative to the average over the prior few years, refinancing activity increases. Second, mortgage rates fell sharply and refinancing activity expanded sharply when QE1 was announced in late November 2008, marked as a vertical line in the figure. As seen from the figure, 30-year mortgage rates fell sharply in December of 2008 (relative to the months before) and refinancing application activity increased sharply in December of 2008. The refinancing boom in December 2008 through April of 2009—as measured by the MBA Refinance Index—was larger than in any period since mid-2003. Finally, we note that since refinancing activity essentially increases whenever mortgage rates fall, the applicability of our results extends to any period where Federal Reserve policy moves mortgage rates. We primarily focus on the QE1 announcement simply because it was largely

[21] Changes to the program in late 2011, often referred to as HARP 2.0, substantially increased the volume of refinancings through the program. One of the main changes was to remove the cap on admissible LTV ratios, which was initially set at 105, then extended to 125 in summer 2009. See the Federal Housing Finance Agency refinance report, http://www.fhfa.gov/AboutUs/Reports/ReportDocuments/May-14-Refi_Report.pdf, for statistics on HARP.

[22] We restrict the ACS data to those individuals between the ages of 21 and 75 (inclusive) that were not living in group quarters (e.g., dorms, prisons, or medical facilities).

unexpected and led to such a sharp drop in mortgage rates.

In Figure 1b we plot the time-series of monthly mortgage origination activity within the HMDA data over the same 2000 to 2012 period, by month in which the borrower applied for the mortgage (not the month in which the loan was ultimately originated, which is usually 1 to 3 months later). The dark shaded area measures the national monthly dollar volume of refinancing originations. The light shaded area measures the national monthly dollar volume of purchase mortgage originations. The sum of these two areas is total mortgage origination activity. Three things are of interest from this figure. First, like in the MBA Refinance Index, refinancing originations and also total new mortgage originations are highly correlated with 30-year mortgage rates within the HMDA data. The simple correlation of the HMDA refinancing originations (total mortgage originations) with the 30-year mortgage rate relative to its 5-year average is -.59 (-.41).[23] Second, like the MBA Refinance Index, mortgage originations increased sharply in December 2008 after the announcement of QE1. Finally, from December 2008 through early 2009 the vast majority of originations were due to refinancing. There were very few mortgage originations for new home purchases during this time period, partly due to seasonality. For this reason, we focus much of our analysis in this paper on refinancing.

SPATIAL VARIATION IN LOAN-TO-VALUE RATIOS PRIOR TO QE1

Before exploring the spatial variation in loan originations around QE1, we begin by documenting the extent to which cumulative loan-to-value ratios (CLTVs) evolved differentially across different regions during the 2007 to 2008 period. Figure 2 shows the distribution of households with different CLTVs for five different MSAs: Chicago, Las Vegas, Miami, Philadelphia, and Seattle. We pick these MSAs to show examples of MSAs that had housing price declines between 2007 and 2008 that were large (Miami and Las Vegas), medium (Chicago), and small (Philadelphia and Seattle). The distributions we show are balance-weighted within MSA.

Figure 2a shows the CLTV distribution for our five example MSAs in January of 2007. We restrict our analysis to only those individuals within the MSA that have a mortgage during that period. We choose January 2007 because it is a period prior to when house prices started declining nationally. The CLTV distributions are quite similar for all five MSAs. To summarize the distribution, we define two variables: *CLTV_80* is the fraction of mortgage owners within the MSA that have a CLTV greater than 0.8. Likewise, *CLTV_100* is the fraction of mortgage holders within the MSA that have a CLTV greater than 1. Returning to Figure 2a, in January of 2007, the *CLTV_100* was below 5 percent, and *CTLV_80* was around 20 percent for four of the five highlighted MSAs. Borrowers in Las Vegas were highly levered, and also experienced some local property price declines prior to 2007. As a result, by January 2007 roughly 10 percent of mortgage owners had a CLTV above 100 percent, and roughly 40 percent had a CLTV above 80 percent.

By November of 2008, when QE1 was implemented, there was much larger variation in the CLTV distribution across MSAs. This can be seen in Figure 2b. For example, about 50 percent of mortgage holders in Miami had a CLTV above 1, while 70 percent of mortgage holders in Las Vegas had a CLTV

[23] Our HMDA series is a slightly different construct than the MBA Refinance Index. The MBA Refinance Index measures refinance application activity, while in HMDA we only retain applications that ultimately lead to originations. Also, the MBA series does not include broker/correspondent/wholesale origination channels.

greater than 1. The comparable number for mortgage owners in Philadelphia and Seattle was only around 10 percent. Chicago was in the middle, with roughly 20 percent of its mortgage holders having a CLTV above 1. Also seen from Figure 2b, there was large variation in the number of households with a CLTV above 0.8 between Miami/Las Vegas (70 to 85 percent) and Philadelphia/Seattle (35 to 40 percent). In other words, a majority of homeowners in cities like Miami and Las Vegas were underwater at the time of QE1, and even more had high CLTVs that would have made it difficult and expensive to refinance. In cities like Philadelphia or Seattle, a much larger proportion of homeowners had sufficient collateral to easily refinance.

Table 1 shows descriptive statistics for all 381 MSAs in our analysis sample. The table shows the distribution of *CLTV_80* and *CLTV_100* in both January 2007 and November 2008 across all the MSAs. Table 1 also shows the distribution of house price changes (in percent) and the change in the unemployment rate (in percentage points) between January 2007 and November 2008 across the MSAs. Finally, the table also shows the fraction of households who own their own home and the fraction of homeowners with a mortgage in 2008.[24] In January of 2007, essentially all mortgage owners within each MSA had a CLTV below 1, and the vast majority had a CLTV below 0.8. For example, in the mean MSA, only 5 percent of all mortgage holders had a CLTV greater than 1. The standard deviation across the MSAs with respect to the share of mortgage owners underwater was also small (3.8 percent). This is consistent with the five MSAs we highlighted in Figure 2. However, by November 2008 there was a large variation across MSAs in their CLTV distributions. Averaging across the MSAs, the mean MSA had 52.7 percent (21.2 percent) of mortgage owners with a CLTV above 0.8 (1), with standard deviations of 13.4 percent and 16.3 percent, respectively. The 90th percentile MSA had 71 percent of mortgage owners with a CLTV above 0.8, while the 10th percentile only had 38 percent of mortgage owners with a CLTV above 0.8. This variation is key to the regional differences in refinancing that we highlight below.

The variation in CLTV across the regions prior to QE1 is driven by the fact that house prices evolved differentially across MSAs during 2007 and 2008. Table 1 shows the distribution in house price changes during this period for the MSAs in our sample. As has been documented by many in the literature, there was large variation across MSAs in the extent to which housing prices declined during the Great Recession. Unsurprisingly, these house price declines were the main determinant of high-LTV shares. Figure 3 shows a simple scatter plot of house price changes in the MSA between January 2007 and November 2008 against *CLTV_80* in November of 2008. As seen from the figure, there is a strong relationship between change in house price between January 2007 and November 2008 and the fraction of mortgage owners with a CLTV above 0.8. On average, a 10 percent decrease in house prices during that period was associated with an 8.8 percentage point higher fraction of mortgage owners with a CLTV above 0.8 in November 2008.

Likewise, there is a large body of literature showing that house price declines are associated with a weakening labor market (Charles et al., 2013; Mian and Sufi, 2014b). Figure 4 shows a simple scatter plot of the percentage point change in the unemployment rate within the MSA between January 2007 and November 2008 against *CLTV_80* in November 2008. The places with the largest increases in local

[24] To compute the fraction of households who own a home and the fraction of homeowners who have a mortgage, we use data from the 2008 American Community Survey (ACS). Because the ACS cannot be used to compute monthly statistics we show statistics averaged over the entire year.

unemployment rates were also associated with having relatively more mortgage owners with a CLTV above 0.8.

SPATIAL VARIATION IN MORTGAGE ACTIVITY AROUND QE1

In the months after QE1 was announced, refinancing activity was much higher in regions where individuals had sufficient equity in their home. As seen in Figure 4, these are the same places where the unemployment rate was relatively lower. To summarize the amount of equity individuals have in their home within a region, we use our measures of *CLTV_80* and *CLTV_100* (defined above). Throughout this section, we will primarily focus on *CLTV_80* as our measure of the state of the local housing market prior to QE1. However, it makes little difference whether we use *CLTV_80* or *CLTV_100* because they are so highly correlated with each other (as shown in Appendix Figure A-1).

Figure 5 shows different refinancing activity measures for MSAs in the top and bottom *CLTV_80* quartiles as of November 2008. These quartiles are population-weighted (based on 2008 Census population numbers) to ensure each has the same number of people. The top quartile of *CLTV_80* in November 2008 includes MSAs like Las Vegas and Miami, where the vast majority of mortgage owners had a CLTV greater than 0.8. The bottom *CLTV_80* quartile includes MSAs where most mortgage owners had CLTVs below 0.8. These MSAs include, for example, Philadelphia and Seattle. The appendix lists the MSAs within each of the *CLTV_80* quartiles.

Figure 5a shows the raw monthly refinancing volume (in billions of dollars) in the HMDA data between January 2008 and December 2009. To better capture the high-frequency response to QE1, we are focusing on refinancing application dates for originated mortgages in the HMDA data.[25] Figure A-2 in the Appendix shows that patterns are nearly identical if we focus on total originations rather just refinancing originations (which is not surprising, given that most mortgage origination activity during this period is refinancing activity, as discussed above). Refinancing volumes evolved the same between high and low *CLTV_80* MSAs up to November 2008. Once QE1 was implemented, refinancing activity jumped—but it jumped much more in the low *CLTV_80* MSAs relative to the high *CLTV_80* MSAs.

Figure 5b also uses HMDA to explore the regional variation in refinancing applications to QE1, but looks at refinancing propensities instead of refinancing volumes. We compute refinancing propensities by counting all the refinancing loan applications in the HMDA data during the given month and dividing them by the number of mortgage holders in the MSA (as computed by the 2008 ACS). The patterns in refinancing propensities are similar to the ones in refinancing volumes.

Figure 5c documents the regional difference in refinancing propensities using the CRISM data.[26] The difference between the timing response in the HMDA data and the CRISM data is that the CRISM data

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[25] Although we show the results monthly, we could have explored weekly refinancing totals. Fuster and Willen (2010) show that refinancing applications in HMDA jumped starting the day of the QE1 announcement.

[26] The measures of MSA refinancing propensities in late 2008 and early 2009 are very highly correlated between the HMDA data and the CRISM data, once we account for the lag in CRISM relative to HMDA. The population-weighted, cross-sectional correlation between the HMDA refinance propensity in December 2008 and the CRISM refinance propensity in January (February) 2009 is .86 (.88). Pooling the second half of 2008 and the first half of 2009, the correlation between HMDA and CRISM propensities is .82 for both one-month and two-month forward CRISM propensities.

measures actual refinancing originations as opposed to applications. The HMDA data shows that applications jumped immediately in response to QE1. However, the majority of actual originations did not take place until January and February. This is exactly what one would expect, given that there is a delay of about 4 to 12 weeks between when a mortgage application is initially made and when the actual mortgage origination takes place.[27] The key point from Figure 5 is that, regardless of the metric for measuring local refinancing activity, refinancing activity was significantly higher in MSAs where *CLTV_80* was low.

Figure 6 is a scatter plot of refinancing propensity for November 2008 (black circles) and February 2009 (grey circles) as measured in CRISM against *CLTV_80* in November 2008 for all MSAs in our dataset.[28] In Appendix Figure A-3 we show the same pattern for the HMDA data. There is essentially no relationship between refinancing activity and *CLTV_80* in November of 2008. This is not surprising given that (1) mortgage rates were relatively high and (2) aggregate refinancing activity was very low. However, by early 2009, refinancing activity was highly correlated with our measure of *CLTV_80*. The simple linear regression fitting the February data in Figure 6 shows that a 20 percentage point increase in *CLTV_80* is associated with a 0.35 percentage point decrease in the monthly refinancing rate (relative to a population-weighted average refinancing rate of 1.2 percent).

Table 2 shows the results from the following regression:

$$\Delta refi_{t,k} = \beta_0 + \beta_1 CLTV_{t,k} + \beta_2 \Delta Unemp_{t,k} + \Gamma X_{t,k} + \varepsilon_{t,k}$$

where $\Delta refi_{t,k}$ is the increase in CRISM refinancing propensity between November 2008 and February 2009 in MSA k, $CLTV_{t,k}$ is either *CLTV_80* or *CLTV_100* within the MSA during November 2008, $\Delta Unemp_{t,k}$ is the change in MSA k's unemployment rate between January 2007 and November 2008, and $X_{t,k}$ is a vector of MSA *k* control variables defined from the pooled 2007–08 ACS. The control variables include four variables representing the educational composition of the MSA (e.g., fraction of individuals with schooling equal to 12, 13–15, 16, and 16+), three variables representing the age distribution of the MSA (e.g., fraction of individuals aged 31–45, 46–60, and 61+), the fraction who are African-American, the fraction who are U.S. citizens, the fraction who own their home, and the fraction of homeowners with a mortgage. MSAs are weighted by their 2008 population in all of our regressions.

Column 1 of Table 2 shows the simple relationship between the growth in the MSA refinancing rate after QE1 relative to the month before, and the fraction of mortgage owners with CLTV greater than 0.8. With no additional controls ($\Delta Unemp_{t,k}$ or $X_{t,k}$), our estimate of β_1 is -1.43 (standard error = 0.51). To help interpret the magnitudes, we consider a one-standard-deviation change in *CLTV_80,* which was 13.4 percentage points. The simple linear regression—with no additional controls—implies that a one-standard-deviation change in *CLTV_80* is associated with a 0.19 percentage point decline in the local refinancing rate. Given that the population-weighted mean change in the refinancing rate in the CRISM data was 0.97 percent, a one-standard-deviation change in *CLTV_80* thus represents about a 20 percent difference in refinancing rates. Put another way, if one went from the 10th percentile of the *CLTV_80* distribution

[27] During this time both the loan underwriting and closing procedures take place.

[28] We focus on February 2009 as a comparison because of the time delays in (1) originating a mortgage after an application and (2) posting the mortgage to credit reports. The results are qualitatively similar if we use the January 2009 data instead.

(0.375) to the 90th percentile (0.71), refinancing activity would decline by 0.48 percentage points. Column 2 shows the regression results when $CLTV\_100$ is the only control variable. The simple relationships between CLTV and refinancing rates are even stronger when we use $CLTV\_100$ instead of $CLTV\_80$. For example, a one-standard-deviation increase in $CLTV\_100$ results in 0.27 percentage point decline in refinancing activity within the MSA (corresponding to a 28 percent decrease relative to the mean).

In columns 3 and 4, we add $\Delta Unemp_{t,k}$ to the regressions in columns 1 and 2. The coefficients on CLTV weaken in both specifications, and the coefficient on the change in the unemployment rate comes in with a negative sign and is statistically significant. In places where unemployment grew the most, refinancing was lower; this occurs above and beyond the effect of differences in equity across regions. We note that these two variables alone explain between 25 and 30 percent of the cross-MSA variation in refinancing propensities.

In columns 5 and 6, we add our X vector of controls to columns 3 and 4. Controlling for differences in the local composition of households and differences in local home ownership and mortgage ownership rates increase the magnitude of the coefficients on $CLTV\_80$ and $CLTV\_100$ relative to columns 3 and 4. Going forward, our preferred specification is column 5, using $CLTV\_80$ as our measure of local collateral values. The regression coefficient, and thus the economic magnitude of the effects, is almost exactly the same as in column 1 discussed above.

Finally, in the last column of Table 2 we change the dependent variable so it is the cumulative refinancing rate between January and March of 2009, relative to the September–November 2008 cumulative refinancing rate. (We start in January since Figure 5 suggests that some of the QE1-induced refinancing starts being reflected in CRISM in January already.) Otherwise, the specification is the same as in column 5. The mean of the new dependent variable over this period is 2.5 percent. The coefficient on $CLTV\_80$ implies that a one-standard-deviation increase in $CLTV\_80$ reduces refinancing by about 0.55 percentage points, or about 20 percent of the mean refinancing rate. This size of the response to a one-standard-deviation change in $CLTV\_80$ over 3 months is nearly identical to the 1-month response highlighted in column 5.

Collectively, the results in this section show that there were large spatial differences in refinancing activity in response to QE1. Places that received the largest house price declines and had the largest declines in employment were the least responsive to QE1 in terms of their subsequent mortgage refinancing behavior.

Spatial Variation in Equity Extraction and Consumer Spending around QE1

One natural question is whether the differences in refinancing activity across space resulted in differences in spending differences across space. There are no easily available broad measures of local spending. To overcome the data limitations, we proceed in two ways. First, we explore the extent to which households removed equity from their home at the time of refinancing. Research has shown that households, on average, spend a large amount of the equity they remove during the refinancing process on current consumption and home improvements.[29] Second, as described above, we have data on new car purchases at the MSA level from R.L. Polk. This data has been used recently to measure spending at the local level.[30]

Figure 7 shows the amount of equity removed during the refinancing process around the QE period for both the top and bottom quartiles of the *CLTV_80* distribution. Figure 7a shows estimated dollar amounts, while 7b shows the equity removed through refinancings in a given month relative to the total outstanding mortgage balance in the prior month.[31] We use the CRISM data to measure the total amount of equity removed during the refinancing process. This includes the people who removed no equity during the refinancing, those who put equity into their home during refinancing, and those who extracted equity during the process. In both high and low *CLTV_80* quintiles, borrowers removed equity during the refinancing process. However, in the low *CLTV_80* quartiles, there was a much larger increase in equity removed than in the high *CLTV_80* MSAs. Within the low *CLTV_80* MSAs, more than $7.5 billion of equity was removed during the refinancing that took place in 3 months after QE1 (January–March). Conversely, for the high *CLTV_80* MSAs, only $3.0 billion of equity was removed. In the former case, this was an increase in monthly cash-outs of about 0.08 percent of outstanding mortgage balances, while in the latter case (those MSAs in the top quartile of the *CLTV_80* distribution), the increase in monthly cash-outs was only about 0.025 percent of outstanding mortgage balances. If we integrate the amount of equity removed during the refinancing process over the 6-month period between January 2009 and June 2009, the bottom quartile of the *CLTV_80* distribution removed an estimated $16 billion, while the top quartile only removed $6 billion.

Table 3 shows results from regressions similar to the ones in Table 2, but using the change in equity removed (relative to outstanding balance) between November 2008 and February 2009 as the dependent variable. Column 1 shows the strong relationship between this variable and *CLTV_80* in November 2008; a one-standard-deviation change in *CLTV_80* is associated with roughly a 0.016 percentage point change in cash-out fraction, or roughly 32 percent of the mean of that variable. Column 2 adds $\Delta Unemp_{t,k}$ (defined above) as an additional control. In column 3, we add both $\Delta Unemp_{t,k}$ and our X vector of local controls. If anything, adding controls only strengthens the coefficient on *CLTV_80*. The coefficient on $\Delta Unemp_{t,k}$ comes in negative in both column 2 and column 3. However, it is only significant in column 2; once additional demographic controls are added in column 3, it is no longer significant. How much of the differences in cash-outs are due to the fact that high *CLTV_80* places refinance less and how much is do to the fact that high *CLTV_80* remove less equity conditional on refinancing? To answer this question, in column 4 of Table 3 we additionally control for the change in refinancing propensity over the same period. The coefficient on the change in refinancing propensity and the coefficient on *CLTV_80* are both very statistically significant. This implies that high *CLTV_80* MSAs both refinanced less and removed less equity during the refinancing process conditional on refinancing. This is intuitive, since these places have less equity to remove conditional on refinancing.

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[29] See, for example, Brady, Canner, and Maki (2000); Canner, Dynan, and Passmore (2002); Hurst and Stafford (2004); and Bhutta and Keys (2014).

[30] See, for example, Mian, Rao, and Sufi (2013).

[31] Since the CRISM data does not cover the whole mortgage market, we scale up the dollar amounts we get in CRISM as explained in the Appendix .

Instead of looking at equity removed, and implicitly discussing the potential for differential local spending responses to the QE1-induced refinancing, we now explore more direct measures of spending. Figure 8 shows the normalized auto sales differences across the low and high *CLTV_80* MSAs. There were level differences in auto sales across the different *CLTV_80* quartiles. To facilitate exposition, we normalize auto sales in both quartiles to 1 in November 2008. As a result, the figure shows percent deviation in monthly auto sales from November 2008. A few things are noticeable. First, prior to QE1, the trend in auto sales was nearly identical in percentage terms between the high and low *CLTV_80* quartiles. In both groups of MSAs, new auto sales were 80 percent higher in early 2008 relative to November 2008, showing a dramatic decline in the fall. Second, the trajectory of new auto sales remained constant through February 2009. This is not surprising, given that the refinancing applications that took place in December 2008 did not result in new mortgage originations until January or February 2009. Third, and most importantly, after February 2009, auto sales started diverging sharply between the low and high *CLTV_80* groups. Averaging over March, April, and May 2009, the increase in auto sales relative to November 2008 averaged 32 percent in the low *CLTV_80* quartile MSAs, and only 17 percent in the high *CLTV_80* quartile MSAs (p-value of difference < 0.01). The timing lines up perfectly with the expected spending response of the QE1 policy. Moreover, it shows sizable differences in spending at the local level in response to QE1 that are consistent with the differences in the refinancing behavior.[32]

Table 4 shows MSA-level regressions using the change in new car sales from pre-QE1 (September–November 2008) to post-QE1 (March–May 2009). We take 3-month averages to reduce noise. The first column shows the strong raw relationship with *CLTV_80*. A one-standard-deviation change in the latter is associated with roughly one-third of a standard deviation change in Δlog(auto sales), since the standard deviation of that variable is 0.155. The second column shows that adding unemployment and MSA characteristics as controls lowers the coefficient somewhat, but the coefficient on *CLTV_80* remains statistically significant at the 5 percent level. The coefficient on the change in unemployment also comes in negative, but it is not significant at standard levels. In columns 3 through 5 we instead directly test the link between refinancing, equity extraction, and auto sales, since we are arguing that mortgage refinancing was associated with stronger auto sales over this period. Columns 3 and 4 show that refinancing and cash-out propensities, individually, are significantly correlated with higher growth in auto sales. In the last column, we find that if we control for both factors simultaneously, only the former remains significant; however, a decrease in significance should not be too surprising, given that the two variables are strongly positively correlated (with a population-weighted correlation of above .6).

In sum, the results in this section suggest that (1) QE1 increased spending in the aggregate (in part by inducing households to remove equity) and (2) the amount of spending by households differed across regions in a way that is correlated with house price declines during the 2007 and 2008 period.

[32] In addition to the refinancing differences, other differences in mortgage-related outcomes may have contributed to the variation in consumption behavior across MSAs. For instance, defaults in high-CLTV MSAs were substantially higher, which in turn led to a decrease in credit scores and increased difficulty in profiting from lower interest rates (e.g., on car loans) for affected borrowers.

ADDITIONAL ANALYSES

SPATIAL VARIATION IN ADJUSTABLE-RATE MORTGAGE SHARE

The share of ARMs among outstanding loans in November 2008 was higher in MSAs with higher CLTVs, as shown in Figure 9a. This is due to the fact that the ARM share increased more strongly during the boom years in areas with larger price increases (for affordability reasons, and potentially also due to speculation; see Barlevy and Fisher, 2010), which subsequently experienced the largest bust.

This pattern can partly offset the pattern of refinancing we documented earlier, since payments on ARMs can decrease without requiring refinancing. ARM rates are based on short-term rates (most commonly 6-month or 1-year LIBOR, or 1-year Treasuries), which also fell in late 2008/early 2009 as the Fed lowered its interest rate target. However, the extent to which ARM resets offset the heterogeneity in the effects of refinancing that we have documented depends on what fraction of ARM borrowers received a payment-reducing rate reset between November 2008 and mid-2009 (our main period of interest). There are a number of reasons why not all ARM borrowers benefited from low short-term rates over that period:

1. Most ARMs in the U.S. are hybrids, with initial fixed-rate periods of 3, 5, 7, or 10 years. Borrowers with an ongoing fixed-rate period had to refinance to lower their payment, just like fixed-rate mortgage (FRM) borrowers.

2. The length of the fixed-rate period of hybrid ARMs often coincided with the length of an interest-only (IO) period on the loan (during which the borrower only pays interest but does not amortize principal). When the IO period ends, the required payment jumps up since the borrower now makes payments towards the principal. This could more than offset a decrease in the rate that happens at the same time.

3. ARMs commonly have rate floors that indicate a minimum rate for the loan. For subprime loans, this minimum rate was almost always set at the initial interest rate of the loan (Bhardwaj and Sengupta, 2012), so that borrowers would not benefit from declines in the index rate that would otherwise lead to further decreases.

In Figure 9b we plot the fraction of loans that were ARMs and that experienced an economically significant rate reduction of 1 percentage point or more over the November 2008 to June 2009 period against *CLTV_80*.[33] Since only about 15 percent of ARMs experienced significant downward resets over our main period of interest, the level is much lower than shown in Figure 9a. Differences in ARM resets across MSAs are about half as large as the difference in refinance propensities in early 2009. The regression line in the third figure has a slope of 0.047 ($t = 5.3$). Meanwhile, regressing the 6-month refinancing propensity (January–June 2009) on *CLTV_80* yields a coefficient of -0.10. Thus, overall, decreases in interest rates were still larger in MSAs with low *CLTV_80*.

[33] We furthermore require that the recorded required monthly payment does not increase over the same period (which may indicate that the loan's IO period expired).

In terms of interpretation, two aspects are worth highlighting. First, ARM downward resets can be "induced" directly through conventional monetary policy, while the Fed's QE1 efforts put additional downward pressure on long-term rates, leading to the additional refinancing that we document in earlier sections. Second, it is interesting to note that the higher ARM shares in areas with a larger "bust" in house prices to some extent acted as an automatic stabilizer, although due to infrequent adjustments and other contract features the pass-through of monetary policy still was not very strong during the recession.

BACK-OF-THE-ENVELOPE ESTIMATE OF SPATIAL VARIATION IN TOTAL CHANGES IN DISPOSABLE CASH

In this section we provide a rough estimate of how the total disposable cash coming from mortgage activity increased differentially during the January to June 2009 period for MSAs with high versus low *CLTV_80* MSAs. We noted above that during this period MSAs in the bottom quartile of the *CLTV_80* distribution cashed out approximately $16 billion in the process of refinancing, whereas for the top quartile it was only $6 billion. The middle two quartiles cashed out $30 billion through refinances over the same period. But this does not give the full picture of equity extraction, since borrowers can also access equity through second liens, specifically home equity lines of credit (HELOCs). To get a sense of how much equity might have been extracted through this channel, we look at borrowers in our CRISM dataset that keep the number of open first-lien mortgages constant over this period (which should eliminate most borrowers who either buy an additional home or default on their mortgage) and also do not decrease their number of second liens (as might happen if a borrower consolidates multiple liens during a refinancing). For these borrowers, total second-lien balances, as measured in CRISM, increased by an estimated $36 billion, of which $9.8 billion went to the bottom quartile of the *CLTV_80* distribution and $6.7 billion to the top quartile.[34]

Finally, there is the flow value of the change in monthly payments from interest rate reductions due either to refinancing or ARM resets. We find that the change in average interest rates on outstanding first-lien mortgages between November 2008 and July 2009 was about 0.19 percentage points in the bottom quartile of the *CLTV_80* distribution (and also the middle two quartiles) and 0.15 percentage points in the top quartile.[35] Total outstanding mortgage debt at the end of 2008 is estimated to be $2.06 trillion in the bottom quartile, $2.08 trillion in the top quartile, and $4.9 trillion in the middle quartiles. The reduction in total annual interest expenses on outstanding debt would thus be estimated to be roughly $16.3 billion, of which $3.1 billion went to the top quartile. However, these savings are partly offset by payments on additional balances due to cash-outs. Given that the average mortgage rate over the first half of 2009 was roughly 5 percent, and we estimated total additional balances to be $25.8 billion in the bottom *CLTV_80* quartile and $12.7 billion in the top quartile, the overall interest expenditure savings over the first half of 2009 were roughly $1.3 billion in the bottom quartile, versus $1.2 billion in the top quartile. Thus, at least in the short term, the net differential changes in available cash due to reductions in monthly payments appear small. Adding up the cash from cash-out refinances, second-lien balance increases, and interest rate expenses over the first half of 2009 gives a total across all MSAs of about $94 billion, of which only 15 percent went to the

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[34] This is a lower bound of the total equity extraction through second liens over this period, since we do not capture borrowers who only have a HELOC but no first lien.

[35] For this calculation, we only use mortgages that do not become seriously delinquent (60 days past due or worse) during this period.

MSA quartile with the highest *CLTV_80*. Conversely, roughly 29 percent went to the MSA quartile with the lowest *CLTV_80*.[36]

Spatial Variation in Refinancing During the 2001 Recession

Figure 10 shows the relationship between house price growth and unemployment change across MSAs around the 2001 recession (grey circles) and the 2008 recession (black triangles). The periods chosen for the two recessions are determined not by the official National Bureau of Economic Research (NBER) recession dates, but by (rough) turning points in the overall seasonally adjusted U.S. civilian unemployment rate. In the earlier episode, national unemployment started increasing from a (local) low of 3.9 percent in December 2000 up to a high of 6.3 percent in June 2003. In the latter episode, unemployment increased from 4.7 percent in November 2007 to 10 percent in October 2009.

As discussed above, there was a tight relationship between house price changes and unemployment during the 2008 recession. However, the patterns are very different during the 2001 recession. First, in essentially all MSAs, house prices were growing during that episode. Second, there is no correlation during the recession between local house price changes and local unemployment changes. This suggests that the patterns between local economic activity and refinancing may be different in the 2008 recession relative to the 2001 recession.

Figure 11 illustrates that the pass-through of monetary policy through the mortgage market was much stronger following the 2001 recession, and that regional effects may have been very different as well relative to the 2008 recession. Figure 11a shows the times series of monthly refinancing propensities in HMDA for both the low- and high-unemployment quartile MSAs during the 2008 recession. MSAs are sorted into quartiles based on the unemployment increase between November 2007 and October 2009; the highest unemployment increase quartile experienced unemployment increases of 6.3 percentage points or more over this period. The lowest unemployment increase quartile experienced unemployment increases of 3.8 percentage points or less. Given the high correlation between unemployment changes and house price changes, the unemployment results in Figure 11a are very similar to the pattern shown for *CLTV_80* quartiles in Figure 5.

Figure 11b shows the time series of monthly refinancing propensities in HMDA for both the low and high unemployment quartiles during the 2001 recession.[37] The sorting is again done by total unemployment increases over this period; for the highest unemployment increase quartile the unemployment rate increased by 2.5 percentage points or more. The lowest unemployment increase quartile increased by 1.6 percentage points or less. The results are very different from those shown in Figure 11a; during the entire period studied, refinancing volumes were higher in the MSAs more strongly affected by a surge in unemployment.[38] Also, we note how much higher overall refinancing propensities were in this earlier episode (especially between mid-2002 and mid-2003). There was arguably no single main monetary policy

[36] These calculations do not take into account transaction costs from refinancing.

[37] To obtain propensities, we normalize refinancing counts by the number of outstanding mortgages in 2000 as measured in the ACS. The CRISM dataset only goes back to 2005, so we cannot use it to study refinancing during this episode.

[38] Chen, Michaux, and Roussanov (2013) document that over the 1993 to 2009 period, refinancing activity was relatively higher in states with worse economic conditions (after controlling for aggregate conditions or including quarter fixed effects).

"event" during this episode—rather, the federal funds rate target decreased gradually from 6.5 percent in December 2000 to 1 percent by the end of June 2003.

A QUANTITATIVE MODEL

In this section we provide some quantitative theoretical insights pertaining to the interplay between monetary policy and micro-level heterogeneity. This framework allows us to better interpret the empirical results from previous sections. While the empirical results provide direct high-frequency evidence on the differential response of various regions to quantitative easing, they provide less insight into the particular features of regional heterogeneity, which are important for driving these differential responses. Since our data only exists for a fairly limited time horizon, it is difficult to fully identify the structural features that are most important for the interplay between monetary policy and regional heterogeneity.

The theoretical analysis in this section allows us to provide some answers to a number of important questions that are difficult to answer in the data alone. Do the regional effects of monetary policy change as the spatial dispersion of collateral values becomes more or less compressed? To what extent do monetary policy effects depend on the correlation between regional income and house prices? Do the aggregate effects of interest rate changes vary with the distribution of regional shocks? To answer these questions, we build a model that is consistent with the regional responses to quantitative easing and then use the discipline imposed by this model to explore various counterfactual scenarios.

For clarity of exposition, we separate our discussion into two broad categories. First we explore how reductions in interest rates affect heterogeneity across different regions. Since these results measure the response of regional heterogeneity to changes in interest rates, we refer to these results as *ex post* consequences of monetary policy for regional heterogeneity. Second, we explore the extent to which regional economic activity affects the aggregate response to monetary policy. For example, does the aggregate response to monetary policy change with the dispersion of collateral, or as collateral values decline? Since these results measure the effects of existing regional heterogeneity on monetary policy at the time of an interest rate cut, we refer to these results as the aggregate consequences of *ex ante* regional heterogeneity.

MODEL DESCRIPTION

Our modeling framework introduces collateralized borrowing, fixed-rate mortgages with refinancing, and regional shocks to a Huggett (1993)-style model of household risk. We focus our model on refinancing activity, but we think it applies to collateralized borrowing more broadly. As in Huggett, we assume that households receive exogenous stochastic labor income y_t. Households have access to a risk-free asset a_t paying interest rate r. All borrowing occurs through the mortgage market, so we impose $a_t \geq 0$. Finally, the household receives period utility $u(c_t)$ from consumption c_t and discounts the future using the discount factor β.

We extend the household's problem in one key direction by endowing the agent with an asset of value h_t, which can be used as collateral for issuing long-term debt. For simplicity, we do not allow the agent to trade this asset, and assume that debt is infinite maturity, requiring a constant payment $r^m_{\tau_0} m_{\tau_0}$ every period, which is determined at the moment of debt issuance τ_0. This can be interpreted as a fixed-rate mortgage on a house. Hence, at any point in time, the agent is endowed with a house and owes the corresponding sequence of mortgage payments. However, we allow some fraction of agents to refinance their mortgage at time $\tau > \tau_0$ by paying a fixed cost K. In order to match the fact that refinancing responds persistently to declines in interest rates (that is, not everybody refinances instantaneously after rates drop), we also introduce a Calvo probability of refinancing.[39]

When refinancing, the household secures the market interest rate r_τ^m and a new mortgage payment $r_\tau^m m_\tau$. In order to reduce the complexity of the computational solution, we assume that agents always cash out any equity built in the house when refinancing. That is, households always borrow the maximum amount possible subject to maximum LTV requirements when refinancing. This implies that the new mortgage balance when refinancing in period τ is given by $m_\tau = \gamma h_t$ where γ is the constant loan-to-value ratio. To summarize, the agent's sequential budget constraint for any time $\tau_0 < t < \tau$ is:

$$c_t + a_t = (1+r)a_t + y_t - r_{\tau_0}^m m_{\tau_0}$$

and at the time of refinancing $t = \tau$:

$$c_\tau + a_\tau = (1+r)a_{\tau-1} + y_\tau - r_\tau^m m_\tau \quad - K.$$

These equations show the incentives to refinance, or not. When the current interest rate r_τ^m is below the interest rate at which the household last refinanced $r_{\tau_0}^m$, the household can secure a lower mortgage payment forever, even if house prices are unchanged. Conversely, if the value of the house has increased since the agent last refinanced, the household can obtain a larger loan when refinancing, at the cost of future increased mortgage payments when the interest rate has not changed.

In addition to introducing collateralized housing and refinancing to the Huggett model, we also introduce regional shocks. In particular, we assume that households are grouped into regions with similar values of income and house price shocks.

Calibration

For simplicity, we calibrate our model annually. We pick an interest rate r=0.03 to match the long-run real interest rate between 1990 and 2015 and set a discount factor of β=0.93 to target the median asset-earnings ratio in the U.S. economy. The flow utility of consumption is given by

$$u(c_t) = \frac{{c_t}^{1-\sigma}}{1-\sigma},$$

We calibrate

$\sigma = 2$

to match standard values on risk aversion. We assume that mortgage rates follow an autoregressive (AR) process, which we calibrate to match the behavior of 30-year conventional fixed-rate mortgages from 1990

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[39] This means that a household only has the option to refinance with a certain probability less than one in each period. This can be rationalized with some attention cost or for behavioral reasons.

to 2015. Similarly, we assume that regional house prices also follow an AR process, which we calibrate to match house price indices produced by CoreLogic. The stochastic income process follows an AR process, which is matched to Panel Study of Income Dynamics earnings data as computed in Floden and Linde (2001). We calibrate the fixed cost of refinancing K such that refinancing in response to a 1 percent decline in interest rates has on average a 2-year break-even horizon. Finally, the LTV ratio γ is set to 0.80.

EFFECTS OF MONETARY POLICY ON REGIONAL INEQUALITY

How does regional heterogeneity in income and housing equity affect the response of consumption to monetary policy through the refinancing channel?

Effects of Monetary Policy on Regions with High and Low House Prices

We begin by showing the effects of heterogeneity in equity. Both the empirical evidence as well as our quantitative model suggests that this is the most important source of inequality that interacts with monetary policy through refinancing decisions. Our model predicts that differences in housing equity have dramatic effects on the propensity to refinance, as well as on the resulting consumption responses. To provide a stark illustration of results, we use a version of the model with three regions. In the “Low Equity” region, households are one house price standard-deviation underwater. In the “Mid Equity” region, households hold no equity above the required downpayment, but they are not underwater. Thus, they have no equity to extract when refinancing, but also do not have to put additional cash into their house in order to refinance. Finally, the “High Equity” region households have one house price standard-deviation of positive equity, so that they can cash out approximately 25 percent of their outstanding balance when refinancing.

Figure 12 shows how refinancing changes across time in response to a 1 percentage point reduction in mortgage rates, roughly in line with the reduction observed in the 6 months after QE1 was announced. Consistent with the empirical evidence, there are sharp differences in refinancing propensities with housing equity. In the region where households are underwater, substantially fewer households choose to refinance than in the other two regions, since refinancing requires injecting substantial cash into the house to meet the LTV requirement.

Figure 13 shows that there are also striking differences in the consumption responses to the interest rate decline across the three regions. Again, the low-equity region has the smallest response. This is because fewer households choose to refinance, and even conditional on refinancing, these households must inject substantial equity into their house, which reduces their potential to consume today. In fact, consumption in the low-equity region actually falls very mildly on impact. This is because these households pay the fixed cost of refinancing—and inject equity into their house today—but receive the benefit of lower mortgage payments in the future. To the extent that some of the low-equity households are liquidity constrained, this tends to reduce consumption today in exchange for higher future consumption.

Thus, together these results imply that in the presence of heterogeneity in regional house prices, monetary policy is likely to exacerbate consumption inequality. Households in regions with low house prices cannot take advantage of interest rate cuts, so there is little increase in refinancing or in consumption. This was likely to be particularly important during the Great Recession in general, and for the consequences of QE1 in particular. In our baseline results, we calibrate regional house price shocks to data from 1990 to 2015. However, our empirical evidence shows that dispersion in equity rose to unprecedented levels during the Great Recession. To assess the role of this unusually large heterogeneity, Figures 14 and 15 redo the previous calculations in a model where the standard deviation of house price shocks doubles relative to the previous baseline. Again, this is in line with the increase in dispersion observed in the Great Recession, and it further amplifies the effects of monetary policy on regional inequality. With greater dispersion in house prices across regions, the locations with low house prices are even less likely to refinance than before, and have even more muted consumption responses. In contrast, the regions with high equity experience an even larger consumption boom in response to the interest rate decline.

Effects of Monetary Policy on Regions with High and Low Income

We next look at how regional dispersion in income affects the response of local refinancing and consumption to monetary policy. As before, we split our sample into three regions. For computational tractability, we do not introduce regional income shocks—which are separate from idiosyncratic income shocks—and instead just break households into groups by their idiosyncratic income. The lowest income "region" is then defined as households with income 1 to 2.5 standard deviations below average, the middle income region includes households with income within 1 standard deviation of the average, and the highest income region includes households with income 1 to 2.5 standard deviations above average.

Figure 16 shows that the level of income has some effect on the propensity to refinance in response to an interest rate decline. Households with the highest income are most likely to refinance because the interest rate falls. Similarly, Figure 17 shows that high-income households have the largest consumption response when interest rates fall. This might initially seem surprising, since households in the low-income region are more likely to be liquidity constrained, and thus have a higher marginal propensity to consume. However, it is important to remember that much of the benefit of refinancing comes in the future, and if households are liquidity constrained, then the lower mortgage payments in the future do not help them increase consumption today. In addition, these households still have to pay the fixed cost of refinancing today, which also reduces their consumption today if they are liquidity constrained. Finally, some fraction of these liquidity-constrained households will have positive equity, while other households will have negative equity. If a liquidity-constrained household is underwater, then they do not want to refinance since this substantially hurts their consumption today because they have to add money into the home in order to refinance. In contrast, if a liquidity-constrained household has positive equity, then there are strong incentives to refinance, but this is true even if the interest rate does not fall. Thus, these households' refinancing decisions are less sensitive to interest rate movements than the decisions of higher income households, who are not liquidity constrained. We return to this point in the following sections when discussing the role of correlated income and house price shocks.

Finally, it is worth noting that our model abstracts from the effects of household income on mortgage qualification. As long as households have enough cash on hand to meet the LTV requirement, they can always obtain a mortgage, even if they have low income. In practice, unemployed households are less likely to be approved for a given mortgage. Introducing this feedback into the model would only amplify the effects of regional income on refinancing and consumption responses to monetary policy.

Correlation Between Income and House Prices

The previous results showed that regional dispersion in house prices and in income both independently affect the propensity to refinance and the resulting consumption responses to interest rate declines. How do these shocks interact with each other? To assess the extent to which these shocks either amplify or counteract each other, we now turn to a version of our model with nine regions. In particular, we interact the three previous regions defined by house prices (-1 Standard Deviation (SD) Equity, 0 Equity, +1 SD Equity) with the three regions defined by income (-2.5 to -1 SD Income, -1 to +1 SD Income, +1 to +2.5 SD Income).

Figure 18 shows that when splitting simultaneously by income and equity, it becomes clear that the regions that respond most differently to monetary policy from average are those that are underwater and have average or below-average income. In these regions, it is extremely difficult to refinance; households have to put additional cash into their house if they want to meet maximum LTV requirements, yet they have little income with which to do so.

Even larger spatial variation is observed in consumption responses, as shown in Figure 19. Again, the regions with low income and low housing equity have the smallest consumption responses to interest rate declines. Thus, the regions with the worst economic conditions receive the smallest benefit from monetary policy. In contrast, it is the regions with the best economic conditions that respond most strongly to the interest rate reduction. The regions with high equity all exhibit the largest consumption responses. Furthermore, the highest income regions conditional on having high housing equity exhibit the largest overall response. That is, the high housing equity/low income regions have smaller consumption responses than the high housing equity/high income regions. Thus, the worst overall region responds least to monetary policy and the best overall region responds most.

Again, it might seem counterintuitive that for regions with high equity, the regions with higher income respond more strongly to monetary policy than the regions with low income. Since households extract the positive equity when refinancing, they both receive a positive "transfer" today when refinancing and can increase consumption. Since low-income households have a higher marginal utility of consumption, one might expect consumption to increase more for these households. However, this intuition ignores the fact that households have the option to refinance even if interest rates do not fall. Households living in regions with both low income and high housing equity have strong incentive to refinance, even if there is no monetary policy action that lowers interest rates. For example, if a household is hand-to-mouth but has lots of housing equity then it does not make sense to wait for a decline in interest rates to refinance—they are potentially willing to refinance even if interest rates go up. As long as households have the option to refinance independent of monetary policy, then the response of low-income households to interest rate declines is smaller than the response of high-income households.

To demonstrate that this refinancing that occurs independently of monetary policy is what causes low-income households with positive equity to respond less to interest rate reductions than high-income households with positive equity, one can shut off this channel. In particular, if we add an additional restriction that households can only refinance if interest rates fall, then monetary policy that reduces interest rates allows poor households to access housing equity that they otherwise could not. Figure 20 shows that in this case there are much larger responses to interest rate decline for the low-income households than for the high-income households. So in principle, monetary policy can potentially reduce consumption inequality across regions with positive equity, but households endogenously move away from this situation if they have the option to refinance at all times. Households with lots of equity who are hand-to-mouth don't wait around for monetary policy to refinance. In contrast, unconstrained households only refinance when interest rates actually fall, so monetary policy largely benefits these households.

Thus, some of the differential effects of monetary policy on different regions are sensitive to the institutional features of refinancing. Nevertheless, it is always the case that low-housing-equity regions respond less to interest rate cuts than high-housing-equity regions. Furthermore, in the data some amount of refinancing occurs even when interest rates do not decline, and there are no constraints in the real world against refinancing to a constant or higher interest rate, so we believe the baseline model is the more empirically realistic specification. While the fraction of households choosing to do so in both the model and the data is low, it is not zero and has quantitatively important effects. In our baseline model, monetary policy amplifies consumption inequality between high equity/low income regions and high equity/high income regions.

Thus, our model is consistent with the broad regional patterns in response to QE, and the implications for regional inequality are quite striking: the refinancing channel of monetary policy largely exacerbates inequality. Refinancing and consumption respond least in places with low house prices and low income and respond most in places with high house prices and high income.

AGGREGATE IMPLICATIONS OF REGIONAL INEQUALITY

Figure 19 shows that consumption in different regions responds differently to monetary policy in ways that are not perfectly symmetric. That is, the additional consumption responses in some regions are not perfectly offset by reduced consumption responses in other regions. This suggests that if the prominence of different regions changes across time, then the aggregate consumption response to monetary policy may depend on the distribution of regional shocks. In this section, we turn from the implications of monetary policy for *ex post* regional inequality and now consider whether changes in *ex ante* regional inequality have aggregate consequences for monetary policy.

While such aggregate effects are of obvious policy relevance, we should emphasize here that our current model makes a number of abstractions for computational simplicity. While we do not believe these simplifications are important for the previous results showing that monetary policy amplifies regional inequality, these simplifications are more important for analyzing aggregate implications, so the model's aggregate implications should be viewed as suggestive rather than as ready for policy action.

In particular, our current model is partial equilibrium in nature and so does not account for the fact that when households refinance to reduce their mortgage payments, these reduced payments lower someone else's income. As long as holders of mortgage debt are regionally diversified, this is irrelevant for the results in the previous section, but it may matter for aggregate interpretations. If every household that increases consumption by $1 is offset by some other household reducing consumption by $1, then the refinancing channel has no aggregate effects. However, even if all mortgage debt is held domestically, creditors are likely to be wealthier and have lower MPCs than debtors, so that refinancing can still have aggregate effects. Furthermore, a substantial fraction of mortgage debt is held by foreigners, so even if their income is reduced this will not show up as reduced U.S. consumption.

In addition to these general equilibrium considerations, it is also important to note that the current model does not have any shocks that change the regional distribution of economic activity across time. While we can exogenously change the relative prominence of different regions, households may adjust their behavior in a fully consistent forward-looking model as the regional correlation of shocks changes. That is, the response of the economy to one-time unanticipated changes in the distribution of regions may be different than the response to anticipated correlation in regional shocks. Finally, even in a steady state with no aggregate shocks, the current model summarizes regional heterogeneity in a very coarse manner, and so does not closely match the actual distribution of activity in the United States.

Nevertheless, we now show that the current model has a number of interesting aggregate implications. We believe these results suggest that further attention to regional heterogeneity is warranted and that exploring the robustness of these conclusions in a richer model is an important task for future research.

Effects of Equity on Aggregate Responses to Monetary Policy

Figure 21 compares the aggregate consumption response to a reduction in interest rates under two different scenarios. The blue line shows the aggregate response in our baseline model. The green line recomputes the aggregate response after a 20 percent decline in house prices. There is a strong reduction in the aggregate response to interest rate movements when house prices fall. This is because many of the regions that previously had positive equity now have negative equity and are unlikely to refinance. This suggests that the effects of monetary policy working through refinancing and collateralized borrowing are likely to be especially low during periods of time when collateral values are low. Thus, there are large effects of average house price values on monetary policy.

To what extent does the variance of housing equity matter, holding the mean level of equity constant? We evaluate this by comparing the baseline model with low, medium, and high equity to two alternative scenarios. In the first, there is no variance in house prices across space, and in the second there is increased house price variance, but in all cases, the mean level of equity is unchanged. That is, we consider mean preserving changes in house price variance. Figure 22 shows that increasing the variance of house prices mildly dampens the response to monetary policy, but these effects are substantially smaller than the effect of shifting the mean of the distribution in Figure 21.

Figures 23 and 24 show the same experiments using variation in regional income rather than house prices. Again, the refinancing channel has smaller aggregate effects when income declines, and there are more modest effects of mean preserving income spreads.

Figures 22 and 24 show that mean preserving changes in income or in house prices have some aggregate effects, but that these effects are relatively mild. However, the Great Recession was associated with an increase in the correlation between income and house prices across space, in addition to an increase in their variance. That is, the Great Recession was not just an increase in dispersion. Since the regions that experienced the largest house price declines also experienced the worst employment outcomes, the Great Recession amplified the correlation between house prices and income. Figure 25 evaluates the consequence of this increased correlation and shows that it may have dampened the strength of the refinancing channel in this recession, independently of the mean shifts documented in Figures 21 and 23.

CONCLUSION

There is a growing body of literature assessing the heterogeneous impacts of monetary policy. One underexplored aspect is the extent to which monetary policy differentially affects regions within a monetary union. As regions get hit with shocks that are not perfectly correlated, the effects of a given monetary policy could differ across the regions. Our paper makes a step toward filling this gap. Specifically, our goals were twofold. First, we set out to assess whether monetary policy mitigates or exacerbates regional dispersion in economic activity. Second, we set out to ask whether regional heterogeneity affects the aggregate effects of monetary policy.

The paper begins by empirically exploring the local effects of Federal Reserve policy during the 2008 recession and its aftermath. Using a variety of data sources, we document that Fed policy during the Great Recession had a much larger stimulus effect in regions that were doing relatively well, as opposed to regions that were doing relatively poorly. Our focus is on the collateralized lending channel, illustrating that while interest rates may be similar across all regions within a monetary union, the variables that determine the monetary transmission mechanism can differ markedly.

One of the stated goals of the Federal Reserve's large-scale asset purchase program, or "quantitative easing," was to stimulate mortgage activity. As the program started, some areas (e.g., Las Vegas) had sharply declining residential property values, high unemployment rates, and most homeowners were underwater. Other areas (e.g., Seattle) had more modest residential property price declines, a more modest increase in the local unemployment rate, and relatively fewer homeowners underwater. As the Federal Reserve announced its large-scale asset purchases, mortgage rates fell, spurring a national refinancing boom. However, we document large regional disparities in the extent to which the refinancing boom took place. Places where most homeowners were underwater saw relatively little refinancing increase (compared to places where most homeowners were not underwater). Likewise, relatively little equity was removed in these regions during the refinancing process. Finally, given the lack of equity removed, the consumption response to the refinancing boom was also small in these regions. Given that during this recession the regions where most borrowers were underwater were also the regions with the highest unemployment rate, this suggests that monetary policy during the Great Recession exasperated regional dispersions.

In the second part of the paper, we developed a quantitative heterogeneous agent macro model to explore the relationship between regional heterogeneity and a national monetary policy. Regions differ in both the extent to which they receive a local income shock and the extent to which house prices (collateral values) evolve. Within the model, agents pay a fixed cost to refinance their mortgage. During the refinancing process they can lock in the current market mortgage rate and—if local house prices have increased since they took out their existing loan—they can remove equity from their home. In this sense, housing collateral can be used as an asset to smooth the marginal utility of consumption. As we illustrate in the model, the level of collateral in the economy at the time of the monetary stimulus affects the aggregate responsiveness of monetary policy. If households want to tap into their home equity to smooth local income shocks as interest rates fall, they must have a sufficient amount of housing collateral. Additionally, the model shows that areas with more housing collateral respond more to a monetary policy innovation than do areas with less collateral. This latter prediction is consistent with our data.

At this stage of our research process the model is mostly illustrative. Going forward, we plan to expand the theoretical work in four important ways. First, as mentioned already, the model must incorporate the owners of the mortgage debt. As mortgage rates decrease and households refinance, their mortgage payments get reduced. In the model this generates a refinancing and consumption boom. However, for our aggregate analysis we need to examine the consumption response of the owners of the mortgage debt, given that they are now receiving lower payments. We do not feel that this will alter our regional results, but will likely dampen the aggregate effects of the monetary policy transmission through collateralized lending. Second, the model has not conducted a serious quantitative analysis of the welfare effects of monetary policy across regions. How much did "good" regions gain relative to "bad" regions during QE1? How would the results differ if housing prices were equated across regions? Our model was calibrated to provide an illustrative quantitative analysis, but a more thorough model and calibration is needed to talk about welfare effects. Third, the paper in its current form does not talk about optimal monetary policy. Studying optimal monetary policy in a world with heterogeneous local shocks and the collateral channel we have emphasized is an important topic for future work. Finally, while we have emphasized only residential mortgage borrowing and refinancing, we think our mechanism applies to any collateralized lending channel. In future work, it would be useful to see whether the regional patterns we identified in mortgage lending during the Great Recession showed up in other forms of collateralized lending.

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TABLES

Table 1: Descriptive Statistics

Data on 381 MSAs; statistics are unweighted.

		Mean	Std. Dev.	p10	p25	p50	p75	p90
CLTV_80	**Jan. 2007**	0.316	0.106	0.194	0.238	0.305	0.380	0.460
CLTV_80	**Nov. 2008**	0.527	0.134	0.375	0.419	0.508	0.617	0.710
CLTV_100	**Jan. 2007**	0.054	0.038	0.020	0.029	0.044	0.064	0.100
CLTV_100	**Nov. 2008**	0.212	0.163	0.057	0.095	0.162	0.275	0.480
Homeownership rate		0.779	0.053	0.712	0.751	0.785	0.813	0.839
Fraction of owners with mortgage		0.698	0.077	0.583	0.656	0.707	0.755	0.791
Δ(House Price Index), Jan 2007–Nov 2008		-0.111	0.113	-0.286	-0.161	-0.086	-0.033	0.010
Δ(Unemployment), Jan 2007–Nov 2008		2.297	1.370	0.700	1.400	2.100	3.000	4.100

Table 2: The Responsiveness of Local Refinancing Activity to Local Collateral and Unemployment around QE1

Column 1 shows the results of a regression of the change in the local monthly refinancing propensity (balance weighted) between November 2008 and February 2009 on the fraction of local borrowers with a CLTV greater than 0.8 in November of 2008. Both variables are measured using the CRISM data. Column 2 is the same regression as in column 1, except the independent variable is the fraction of borrowers with a CLTV greater than 1.0 in November 2008. Columns 3 and 4 replicate columns 1 and 2 with the addition of the percentage point change in the unemployment rate between January 2007 and November 2008. Columns 5 and 6 replicate columns 3 and 4 with the addition of a detailed set of local controls (measured in 2008). These controls include variables representing the education, age, citizenship, and racial composition of the MSA, as well as the fraction of households that are homeowners within the MSA, and among those, the fraction that has a mortgage. Column 7 is the same as column 5 except the dependent variable is the change in the local 3-month refinancing rate between January to March 2009 relative to September to November 2008. MSAs are weighted by their 2008 population. Robust standard errors in parentheses. Significance: $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CLTV_80	-1.433***		-0.447		-1.430***		-4.114***
	(0.510)		(0.527)		(0.240)		(0.576)
CLTV_100		-1.679***		-1.014***		-1.473***	
		(0.250)		(0.333)		(0.216)	
D UR			-0.207***	-0.136***	-0.071***	-0.044	-0.163**
			(0.036)	(0.036)	(0.027)	(0.027)	(0.068)
Constant	1.738***	1.375***	1.727***	1.554***	0.542	-1.159	2.450
	(0.307)	(0.099)	(0.257)	(0.092)	(2.027)	(1.972)	(4.796)
Other Controls	No	No	No	No	Yes	Yes	Yes
N	381	381	381	381	381	381	381
Adj. R^2	0.122	0.266	0.269	0.312	0.578	0.598	0.605
Mean(dep. var.)	0.973	0.973	0.973	0.973	0.973	0.973	2.498

Table 3: The Responsiveness of Cash-Out Refinancing Activity to Local Collateral and Unemployment around QE1

Column 1 shows the results of a regression of the change in cash-out amount relative to outstanding balance between November 2008 and February 2009 on the fraction of local borrowers with a CLTV greater than 0.8 in November of 2008. We measure the cash-out amounts using the CRISM data and divide it by the previous month's mortgage balance outstanding (see Appendix for details). Column 2 replicates the results from column 1 with the addition of the percentage point change in the unemployment rate between January 2007 and November 2008 as an additional control. Column 3 further adds controls for local demographics and mortgage ownership rates. Column 4 also adds the change in local refinancing propensity between November 2008 and February 2009 as an additional control. The change in refinancing propensity is defined using the CRISM data (and is the same as the dependent variable in columns 1 to 6 of Table 2). MSAs are weighted by their 2008 population. Robust standard errors in parentheses.

Significance: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	(1)	(2)	(3)	(4)
CLTV_80	-0.121***	-0.091**	-0.159***	-0.106***
	(0.032)	(0.037)	(0.021)	(0.019)
D UR		-0.006**	-0.001	0.002
		(0.002)	(0.002)	(0.002)
Δ refinance prop.				0.037***
				(0.004)
Constant	0.114***	0.114***	0.137	0.117
	(0.019)	(0.018)	(0.175)	(0.163)
Other Controls	No	No	Yes	Yes
N	381	381	381	381
Adj. R^2	0.160	0.183	0.318	0.422
Mean (dep. var.)	0.050	0.050	0.050	0.050

Table 4: The Responsiveness of New Vehicle Spending around QE1

Columns 1 and 2 show the results of a regression of the change in log auto sales (from R.L. Polk) between the 3-month period between February and April 2009 relative to the 3-month period between September and November 2008 at the MSA level on the fraction of local borrowers with CLTV greater than 0.8. Column 1 includes no other controls, while column 2 also controls for the change in unemployment between January 2007 and November 2008 and for local demographic and homeownership controls. Columns 3 through 5 remove as a control the fraction of local borrowers with CLTV greater than 0.8. Instead, column 3 includes the change in cash-out share (dependent variable in Table 2) as an additional control. Column 4 includes the change in the refinancing propensity (dependent variable in Table 3) as an additional control. Column 5 includes both the change in the cash-out share and the change in refinance propensity as additional controls. MSAs are weighted by their 2008 population. Robust standard errors in parentheses.

Significance: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

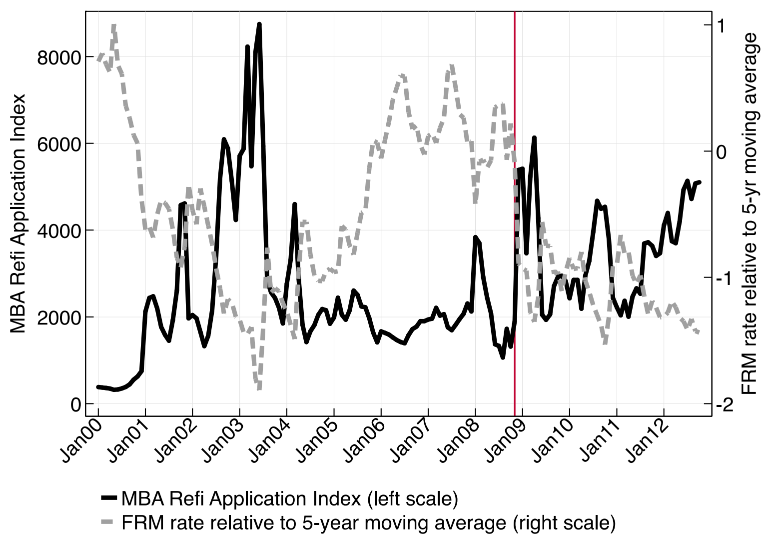
	(1)	(2)	(3)	(4)	(5)
CLTV_80	-0.407***	-0.237**			
	(0.095)	(0.106)			
D UR		-0.023	-0.022	-0.028*	-0.022
		(0.016)	(0.014)	(0.017)	(0.014)
Δ refinancing prop.			0.073**		0.065**
			(0.030)		(0.030)
Δ (cashout/balance)				0.488**	0.167
				(0.228)	(0.186)
Constant	0.207***	2.182**	2.048**	2.302***	2.116**
	(0.048)	(0.868)	(0.892)	(0.838)	(0.875)
Other controls	No	Yes	Yes	Yes	Yes
N	381	381	381	381	381
Adj. R^2	0.119	0.274	0.286	0.268	0.286
Mean (dep. var.)	-0.010	-0.010	-0.010	-0.010	-0.010

FIGURES

Figure 1: Mortgage Activity in the U.S., 2000–2012

Figure 1a shows monthly average of Mortgage Bankers Association (MBA) Refinancing Index (seasonally adjusted; March 1990 = 100) and the 30-year fixed-rate mortgage rate (relative to 5-year moving average), also from MBA. Figure 1b shows mortgage originations on 1- to 4-unit homes in HMDA, by month in which the borrower applied for the loan. In both panels, the vertical line indicates the month of the QE1 announcement (November 2008).

(a) MBA Refinancing Index and Mortgage Rate



(b) HMDA Origination Volume

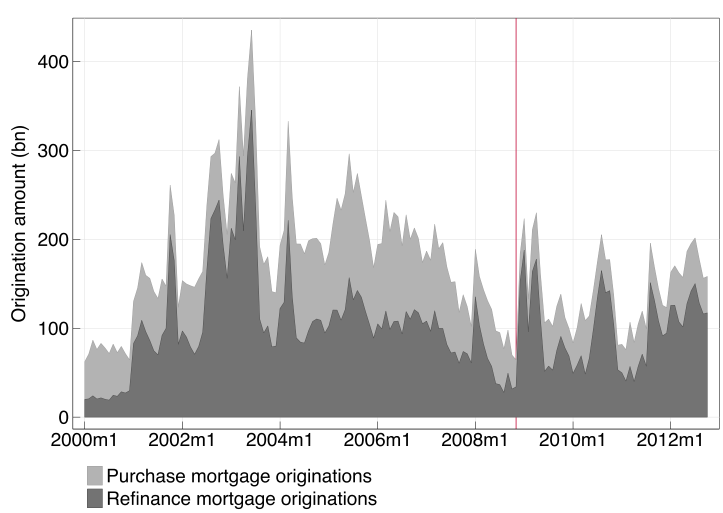
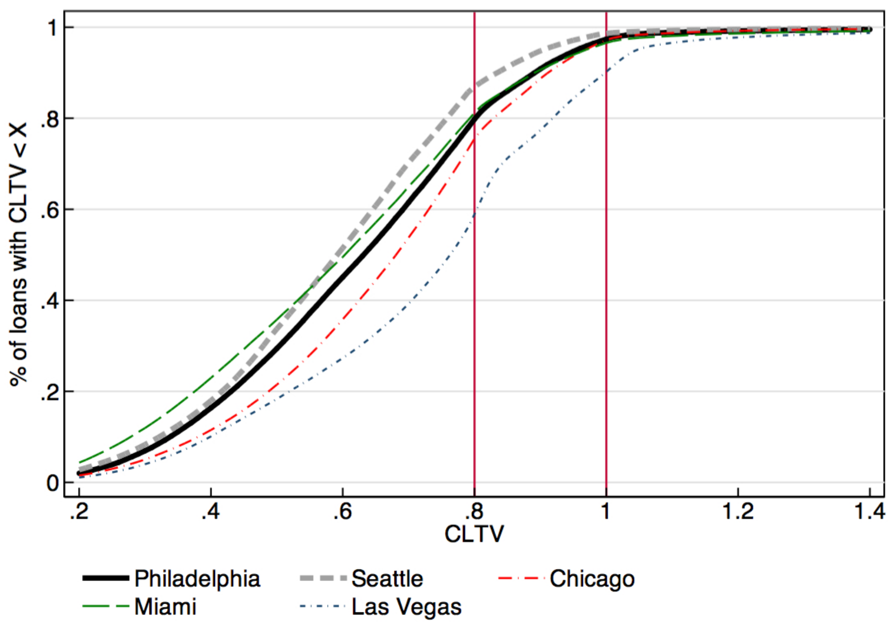


Figure 2: CLTV Distributions of Borrowers in 5 MSAs

Figure 2 shows the cumulative distribution function of the CLTV distribution of borrowers in five illustrative MSAs in January 2007 (panel a) and November 2008 (panel b). CLTV is measured for each household in the MSA using data on total current mortgage debt from the CRISM data. To compute CLTV we divide current mortgage debt for each borrower by an estimate of their current house value (see text for details). The vertical lines represent CLTV values of 0.8 and 1.0.

(a) January 2007



(b) November 2008

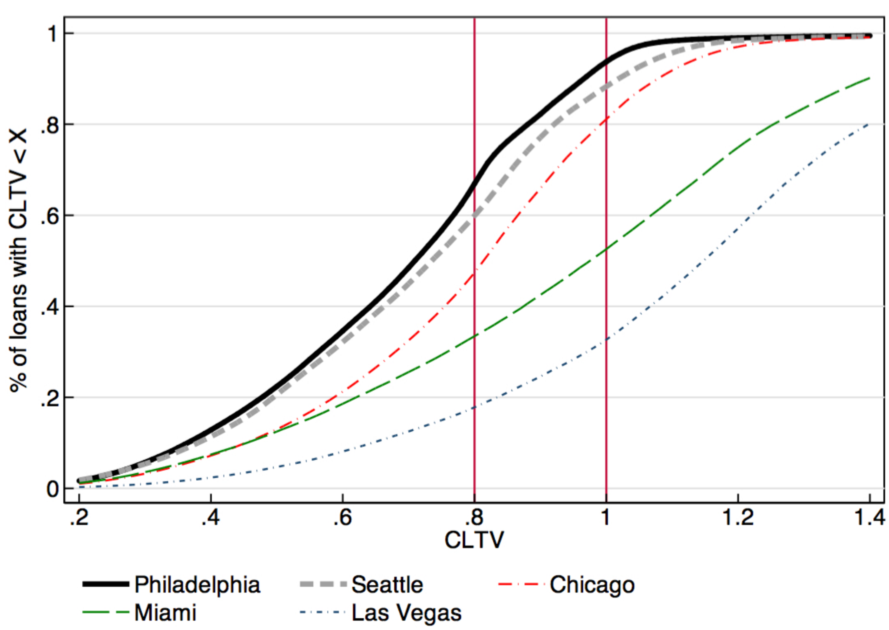


Figure 3: House Price Growth January 2007–November 2008 vs. *CLTV_80* in November 2008

Figure 3 shows the relationship between MSA house price growth between January of 2007 and November 2008 (x-axis) vs. the share of loans in the MSA in November 2008 with estimated CLTV greater than 0.8 (*CLTV_80*). Each observation in the figure is an MSA (381 MSAs in total). The size of the circle represents the 2008 population of the MSA. The figure also shows the simple (population weighted) regression through the scatter plot. The regression shows that a 1 percent decline in house prices is associated with a 0.88 percentage point increase in the fraction of borrowers within the MSA with a CLTV over 0.8 (standard error 0.07). The R-squared over the simple regression is 0.61.

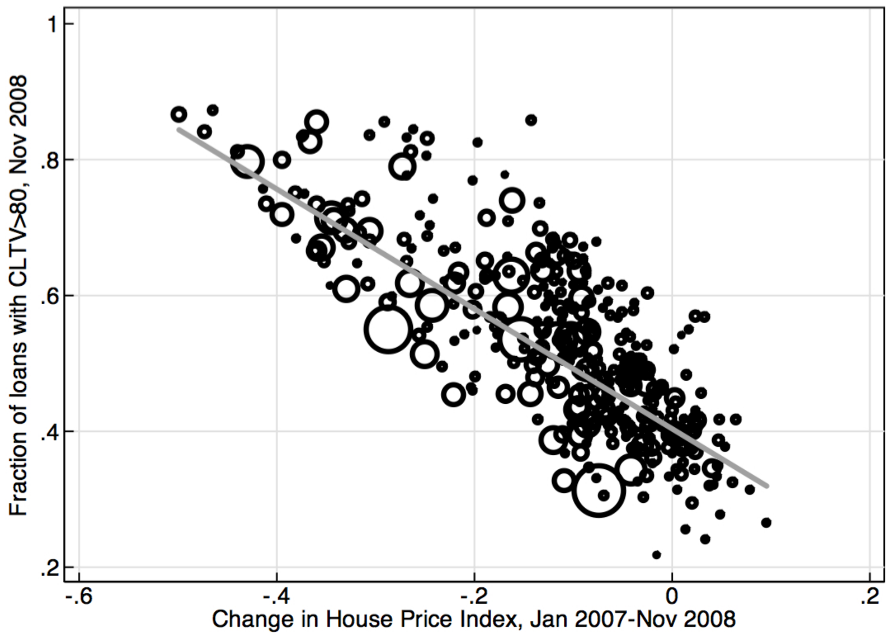


Figure 4: Percentage Point Change in the MSA Unemployment Rate, January 2007–November 2008 vs. *CLTV_80* in November 2008

Figure 4 shows the relationship between the percentage point increase in the MSA unemployment rate between January of 2007 and November 2008 (x-axis) vs. the share of loans in the MSA in November 2008 with CLTV greater than1.8 (*CLTV_80*). Each observation in the figure is an MSA (381 MSAs in total). The size of the circle represents the 2008 population of the MSA. The figure also shows the simple (population weighted) regression through the scatter plot. The regression shows that a 1 percentage point increase in the unemployment rate is associated with a 0.060 percentage point decline in the fraction of borrowers within the MSA with a CLTV over 0.8 (standard error 0.008). The R-squared over the simple regression is 0.29.

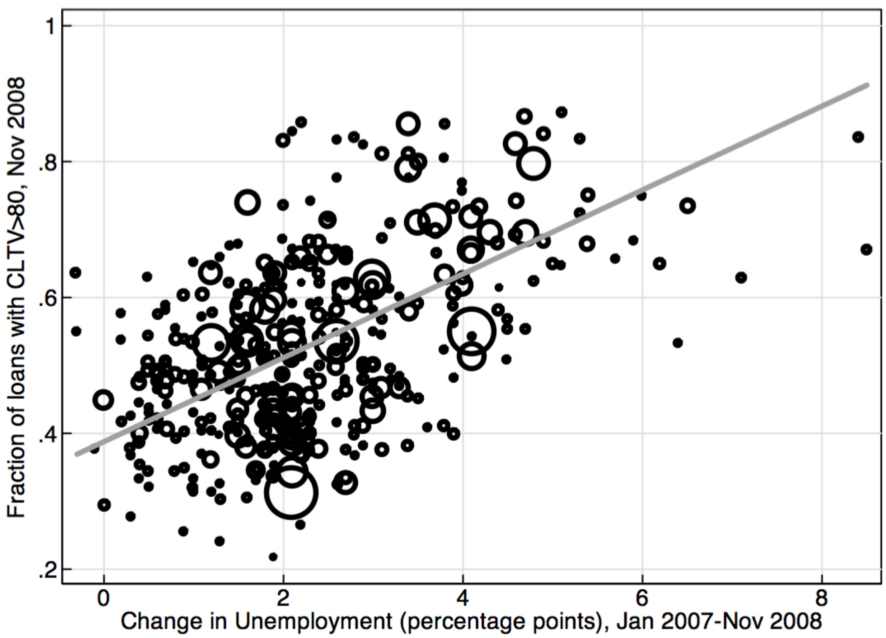
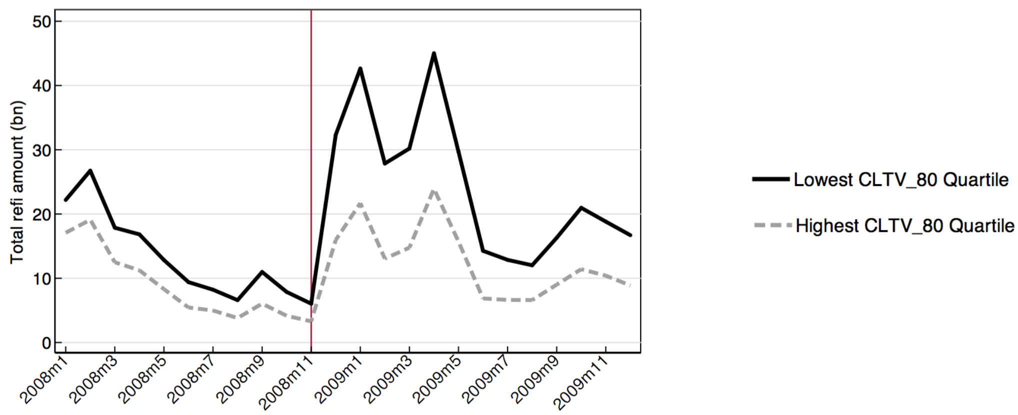


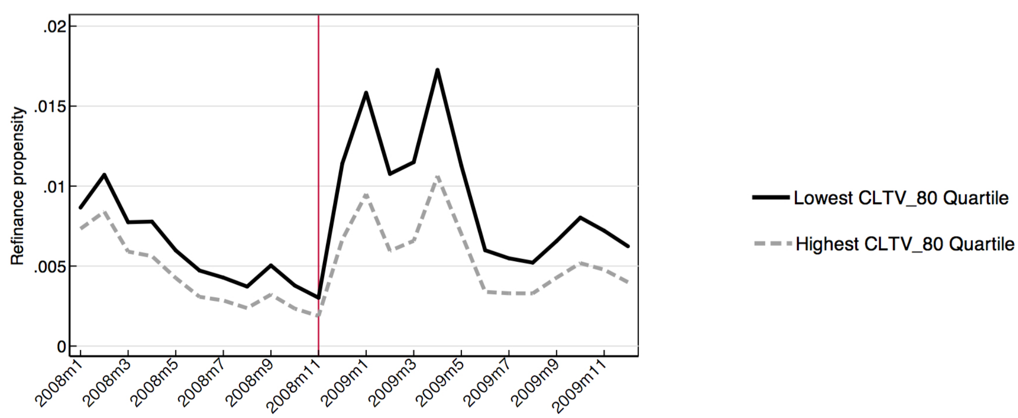
Figure 5: Mortgage Refinance Activity 2008–2009 in Top and Bottom Quartiles of MSAs Defined by *CLTV_80* in November 2008

Figure 5a shows total mortgage refinance volume in HMDA by month in which borrower applied for the mortgage, where months are redefined such that they start on the 25th day of the prior month. Figure 5b shows corresponding refinance propensities, defined as the number of refinance originations in HMDA divided by the total number of mortgages outstanding as measured in the 2008 American Community Survey. Figure 5c shows refinance propensities in CRISM, defined as the dollar amount of new refinance mortgage originations divided by the outstanding amount of mortgages in the previous month. In all three panels, calculations are done at the level of MSA quartile groups. We calculate the fraction of loans with CLTV above 0.8 (*CLTV_80*) for each MSA in November 2008. Each MSA is placed into quartiles based on this measure, where the quartiles are defined such that there is equal population in each quartile. In all panels, the vertical line indicates the month of the QE1 announcement (November 2008).

(a) HMDA: Refinance Origination Volumes



(b) HMDA: Refinance Propensities



(c) CRISM: Refinance Propensities

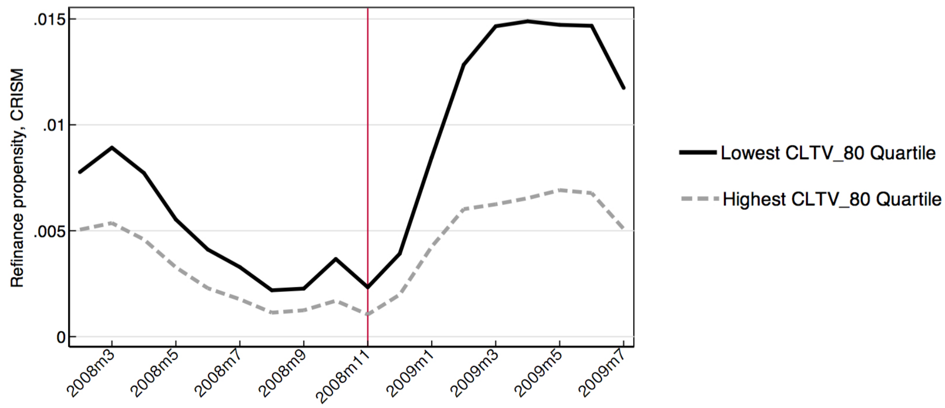

Refinance propensity, CRISM
.015
.01
.005
0
2008m3
2008m5
2008m7
2008m9
2008m11
2009m1
2009m3
2009m5
2009m7
Lowest CLTV_80 Quartile
Highest CLTV_80 Quartile

Figure 6: CRISM Refinancing Propensity, November 2008 and February 2009 vs. *CLTV_80* in November 2008

Figure 6 shows the simple scatter plot of the refinancing propensity in a given MSA, as measured in the CRISM data, vs. the fraction of loans within the MSA with CLTV greater than 0.8 (*CLTV_80*) in November 2008. The dark circles represent the refinancing propensity in November 2008. The light circles represent the refinancing propensities in February 2009. The size of the circle represents the 2008 population of the MSA. The two lines represent simple regression lines fitting the scatter plot (population weighted).

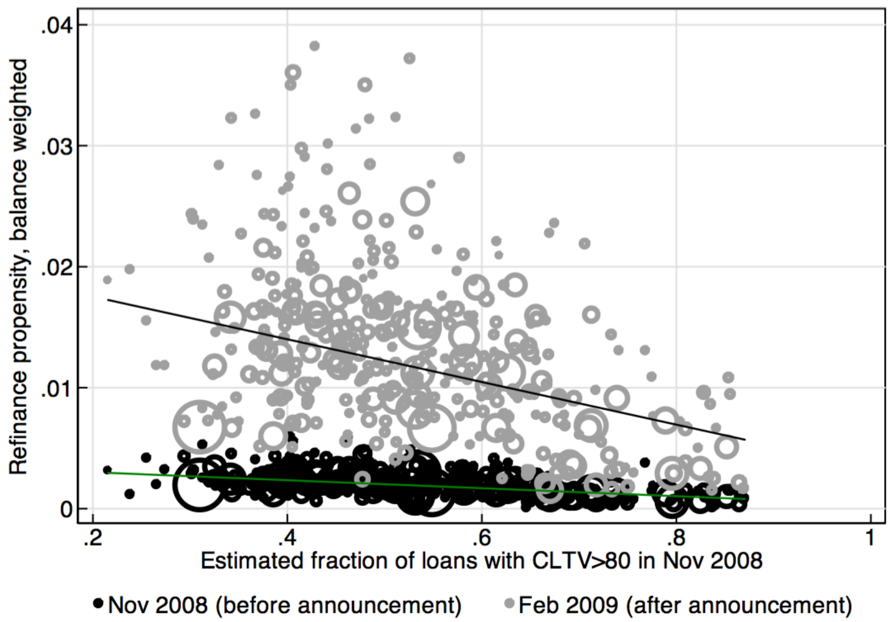
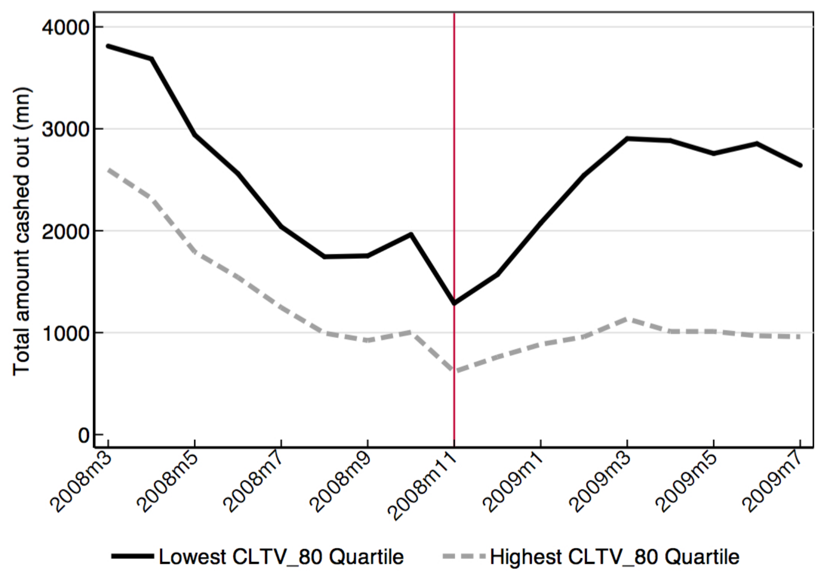


Figure 7: Cash-Out Refinancing Activity in Top and Bottom Quartiles of MSAs Defined by *CLTV_80* in November 2008, CRISM Data

Figure 7 shows the total cash removed from the mortgage during the refinancing process for the top and bottom quartiles of MSAs with respect to *CLTV_80* in November 2008. Figure 6a shows dollar volumes, which are calculated by scaling up amounts from the CRISM data to the market level, as explained in the Appendix. Figure 6b shows cash-out amounts in percent relative to outstanding mortgage balances (all lien types) in the previous month. MSA quartile groups are defined the same way as in Figure 5. In both figures the vertical line indicates the month of the QE1 announcement (November 2008).

(a) Cash-out Volumes in Dollars



(b) Cash-out Relative to Outstanding Balance

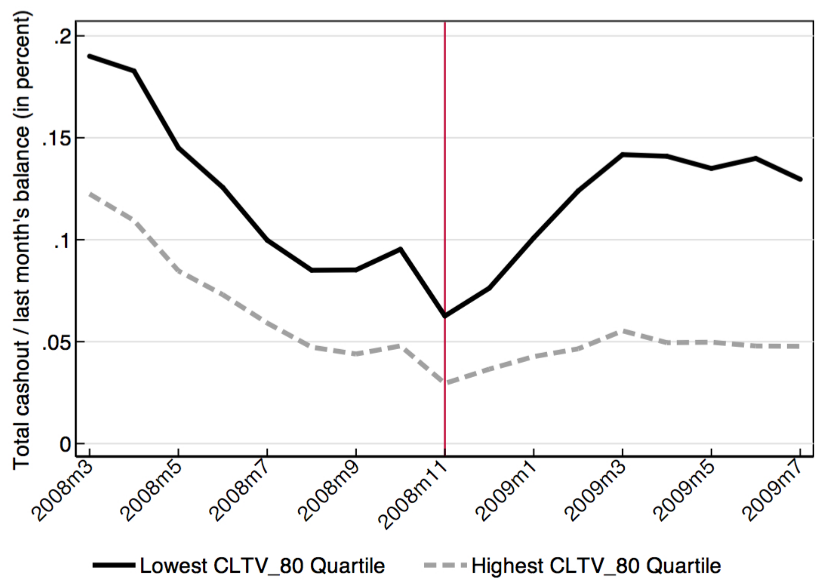


Figure 8: New Auto Sales in Top and Bottom Quartiles of MSAs Defined by *CLTV_80* in November 2008

Figure 8 shows the total volume of new car purchases (relative to November 2008) for the top and bottom quartiles of MSAs with respect to *CLTV_80* in November 2008. Car purchase volumes are from R.L. Polk and Company. MSA quartile groups are defined the same way as in Figure 5. The vertical line indicates the month of the QE1 announcement (November 2008).

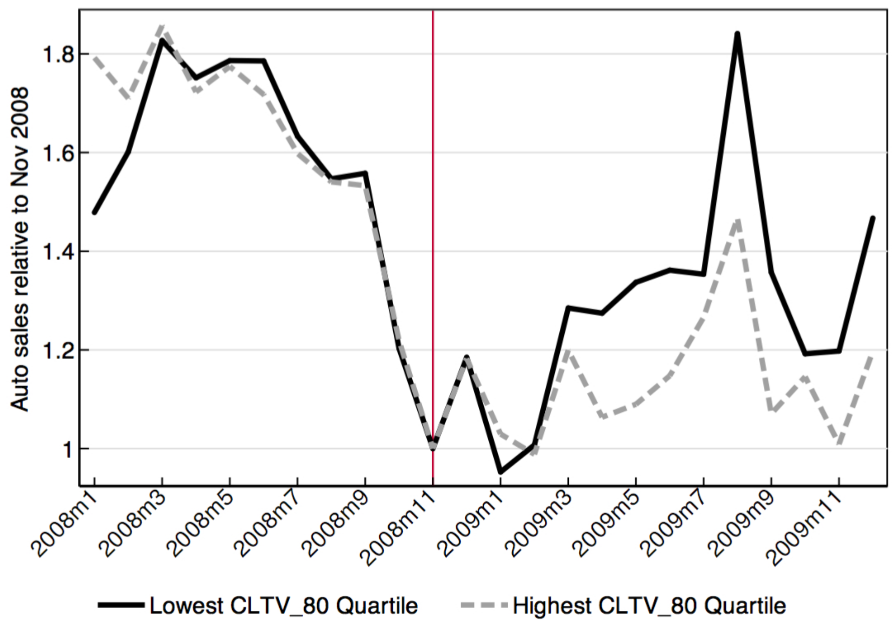
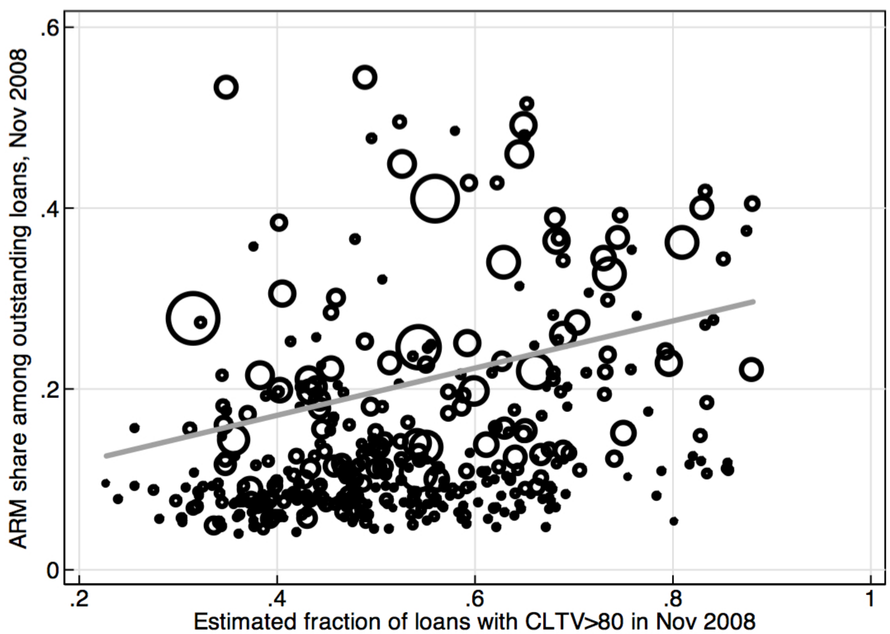


Figure 9: Adjustable-Rate Mortgage Shares Pre-QE1 and Payment Reductions, November 2008–June 2009

Figure 9 shows scatter plots of the balance-weighted fraction of ARMs in a given MSA (9a) or the balance-weighted fraction that are ARMs and experience a rate reduction of 1 percentage point or more from November 2008 to June 2009, as measured in the CRISM data, versus the fraction of loans within the MSA with CLTV greater than 0.8 (*CLTV_80*) in November 2008. The circles represent the 2008 population of the MSA and the grey lines represent simple regression lines fitting the scatter plot (population weighted).

(a) ARM Shares vs. *CLTV_80* in November 2008



(b) Sizeable ARM Payment Reductions vs. *CLTV_80* in November 2008

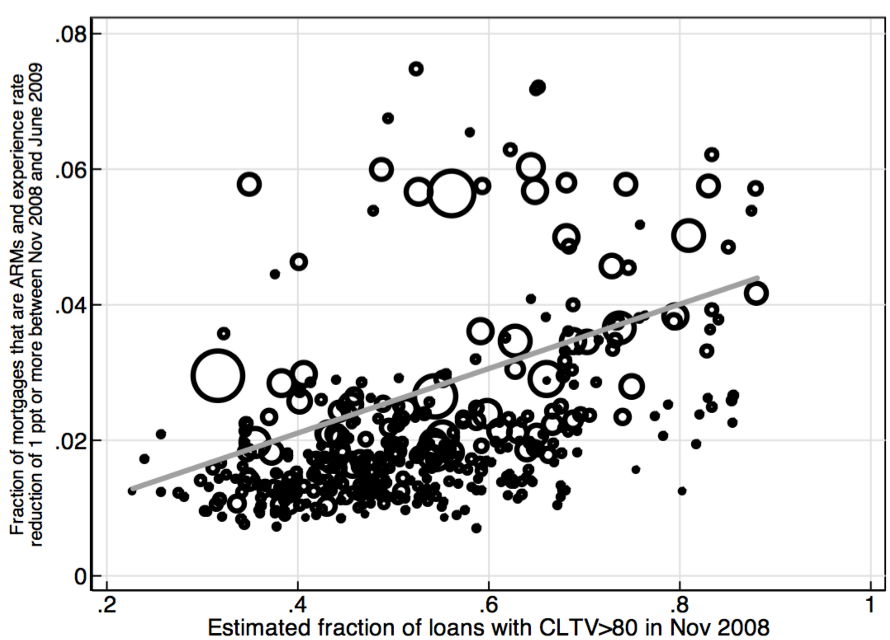


Figure 10: MSA-Level Unemployment Change and House Price Growth, 2001 Recession vs. 2008 Recession

Figure 10 shows the change in MSA-level house price index (in percent) and the change in the MSA-level unemployment rate (in percentage points) during the last two recessions. Specifically, for the 2001 recession (circles), we measure the changes between December 2000 and June 2003. For the 2008 recession (triangles), we measure the changes between November 2007 and October 2009.

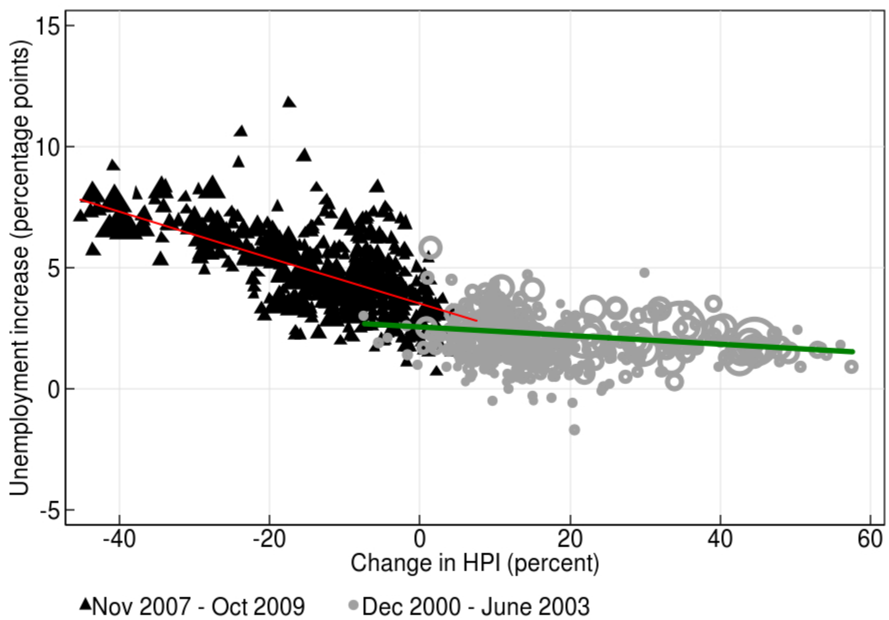
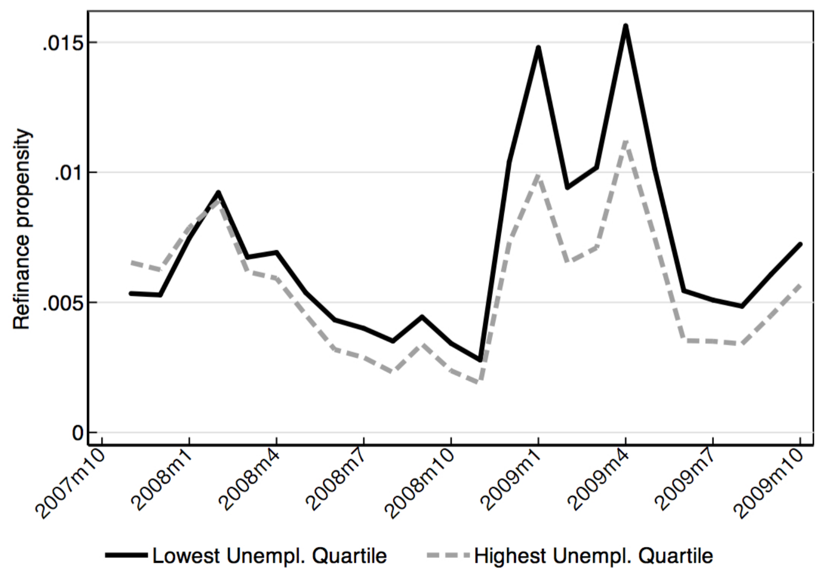


Figure 11: Refinancing Propensities for High and Low Unemployment Change Quartiles, 2008 Recession vs. 2001 Recession

Figure 11 shows monthly refinancing propensities for the top and bottom quartiles of MSAs with respect to their unemployment change over the period shown. Specifically, for each MSA we compute the change in unemployment between November 2007 and October 2009 (11a) and December 2000 to June 2003 (11b). Each MSA is placed into quartiles based on this measure. The quartiles are defined such that there is equal population in each quartile. Refinancing propensities are computed using the HMDA data on origination volumes (by month of the loan application) divided by the total number of mortgages in MSA quartiles from the American Community Survey in 2008 (11a) or 2000 (11b).

(a) Refinance Propensities, 2007–2009



(b) Refinance Propensities, 2001–2003

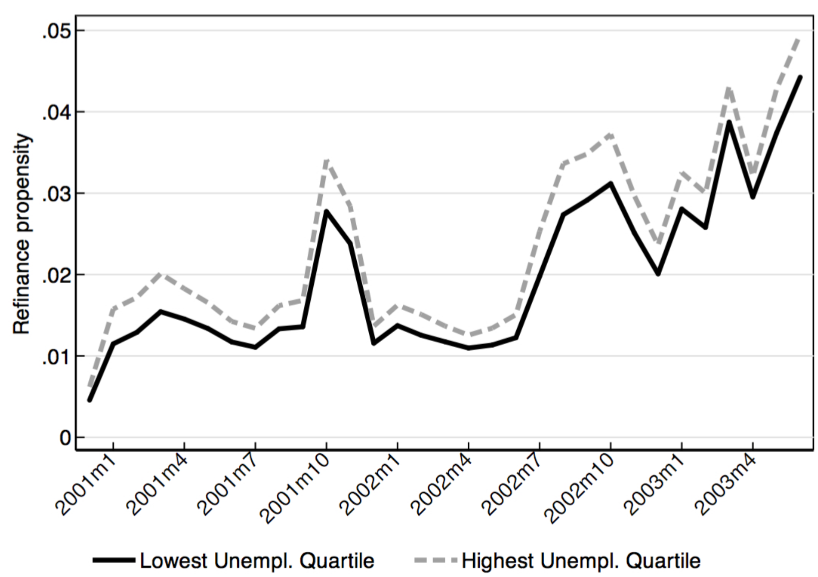


Figure 12: Impulse Response of Refinancing to Interest Rate Decline by Equity Level

Figure 12 shows the change in the share of households refinancing in response to a 1 percent decline in mortgage rates. Low Equity is 1 house price standard deviation underwater (roughly 20 percent of the value of the mortgage). Middle Equity just meets the LTV requirement, so gets no cash out when refinancing. High Equity has 1 positive standard deviation of equity so can extract roughly 20 percent of mortgage in cash when refinancing. See text for additional details.

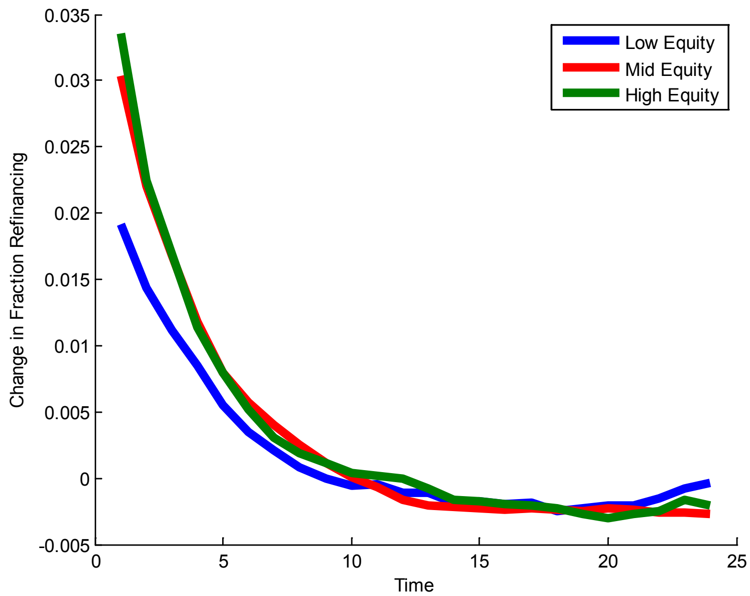


Figure 13: Impulse Response of Consumption to Interest Rate Decline By Equity Level

Figure 13 shows the change in consumption in response to a 1 percent decline in mortgage rates. See text and Figure 12 for additional description.

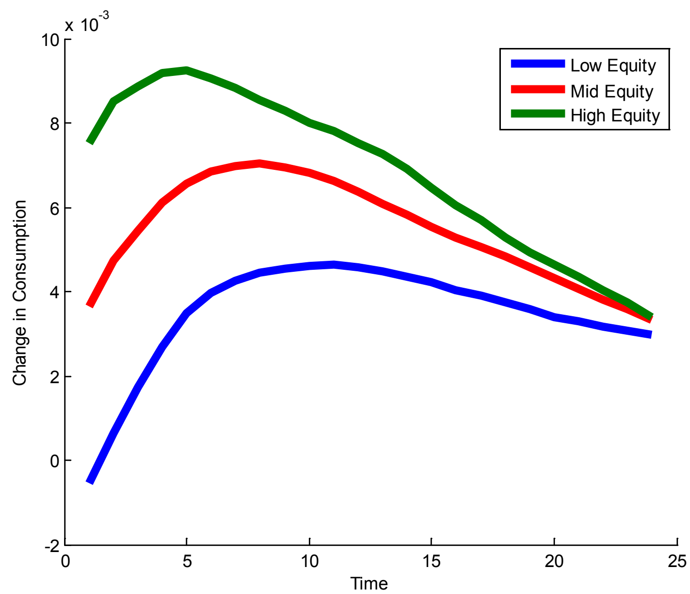


Figure 14: Impulse Response of Refinancing to Interest Rate Decline by Equity Level, High House Price Dispersion

Figure 14 repeats the experiment in Figure 12, but with a standard deviation of house prices and equity, which is twice as large.

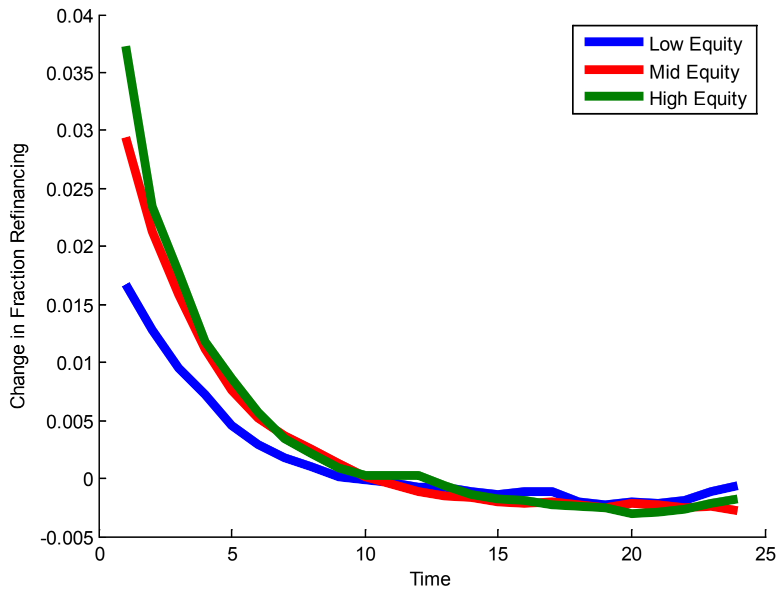


Figure 15: Impulse Response of Consumption to Interest Rate Decline by Equity Level, High House Price Dispersion

Figure 15 repeats the experiment in Figure 13, but with a standard deviation of house prices and equity, which is twice as large.

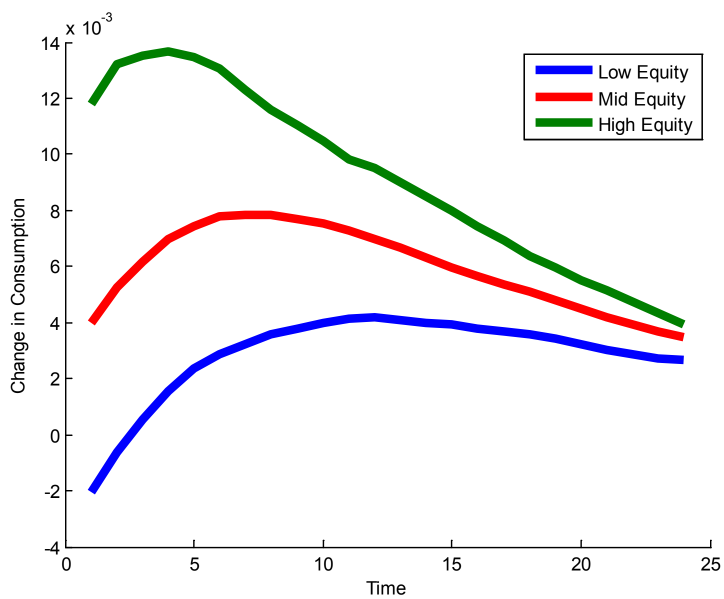


Figure 16: Impulse Response of Refinancing to Interest Rate Decline by Income Level

Figure 16 shows the change in the share of households refinancing in response to a 1 percent decline in mortgage rates. Plots break regions into thirds by income level. See text for additional details.

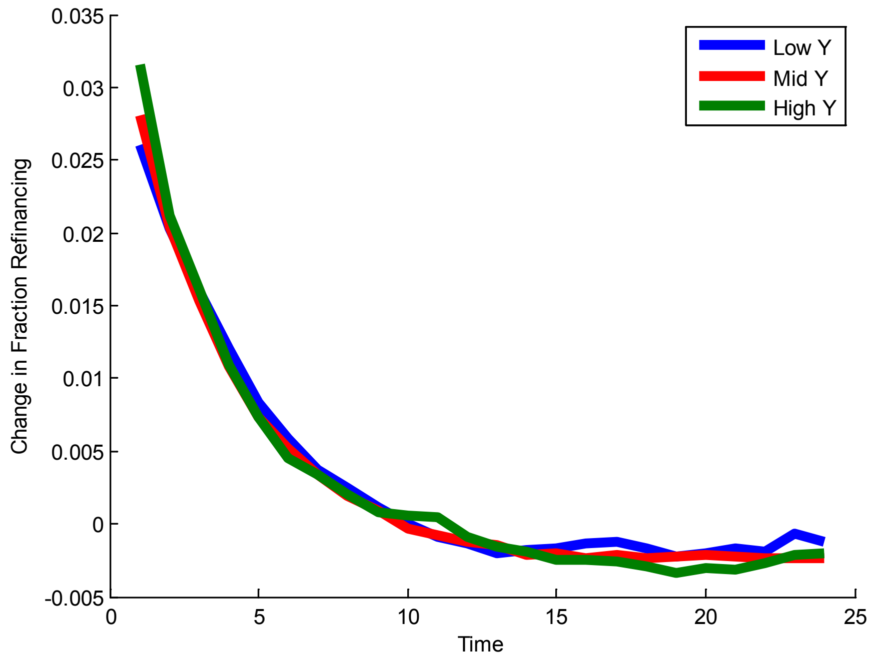


Figure 17: Impulse Response of Consumption to Interest Rate Decline by Income Level

Figure 17 shows the change in consumption in response to a 1 percent decline in mortgage rates. Plots break regions into thirds by income level. See text for additional details.

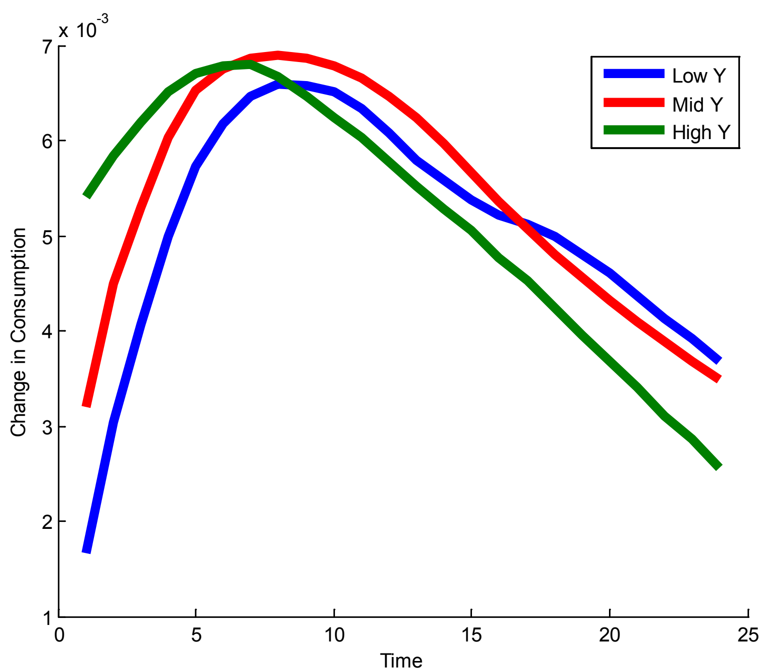


Figure 18: Impulse Response of Refinancing to Interest Rate Decline by Equity and Income

Figure 18 shows the change in the share of households refinancing in response to a 1 percent decline in mortgage rates for different combinations of equity and income levels. See previous figures and text for description of low, middle, and high equity and income.

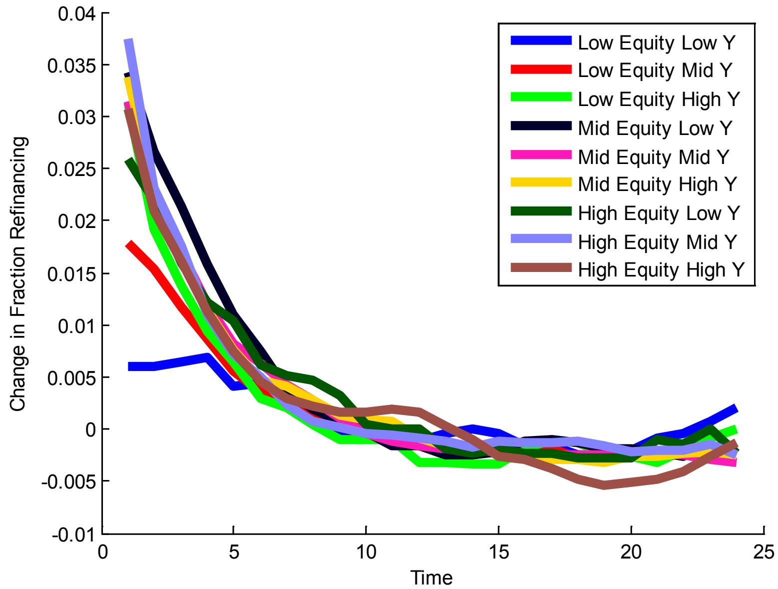


Figure 19: Impulse Response of Consumption to Interest Rate Decline by Equity and Income

Figure 19 shows the change in consumption in response to a 1 percent decline in mortgage rates for different combinations of equity and income levels. See previous figures and text for description of low, middle, and high equity and income.

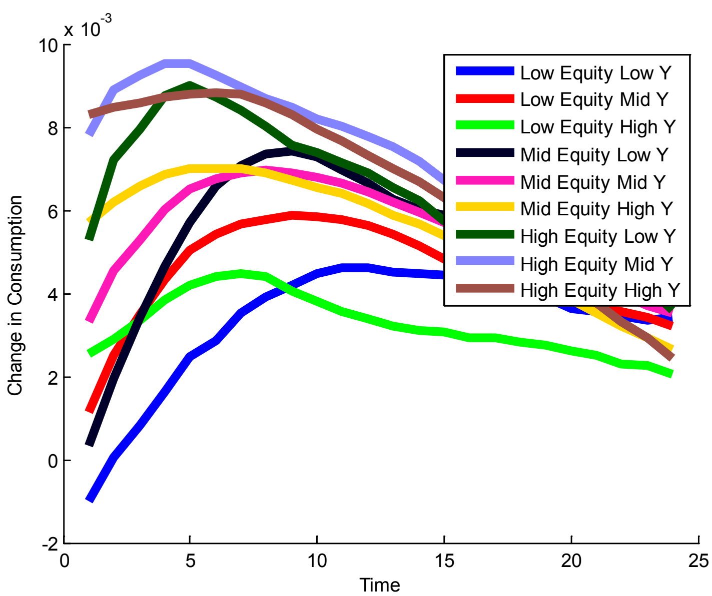


Figure 20: Impulse Response of Consumption to Interest Rate Decline with Additional Restrictions on Refinancing

Figure 20 repeats the analysis in figure 19 in a model where households are only allowed to refinance when interest rates fall. In this restricted model, households with positive equity can only extract that equity when interest rates fall and are not allowed to refinance into the same or increased interest rate.

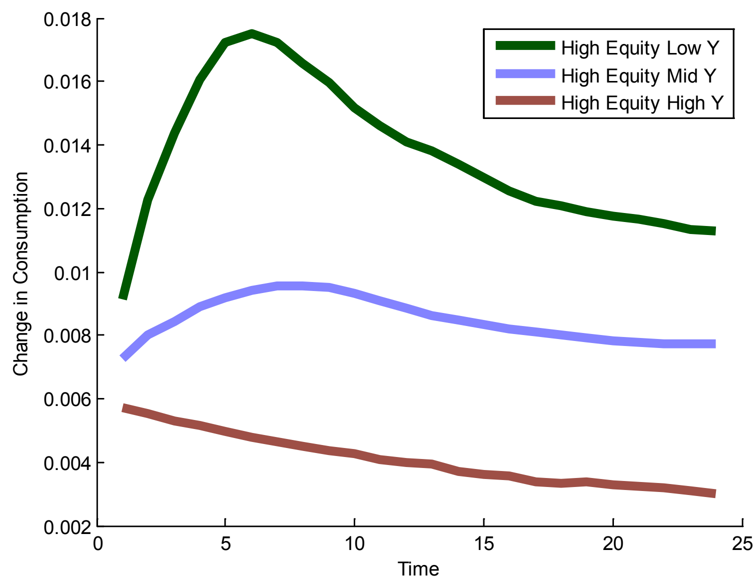


Figure 21: Impulse Response of Aggregate Consumption to Interest Rate Decline After Aggregate House Price Decline

Figure 21 shows how the consumption response to monetary policy changes after an aggregate house price decline of 20 percent.

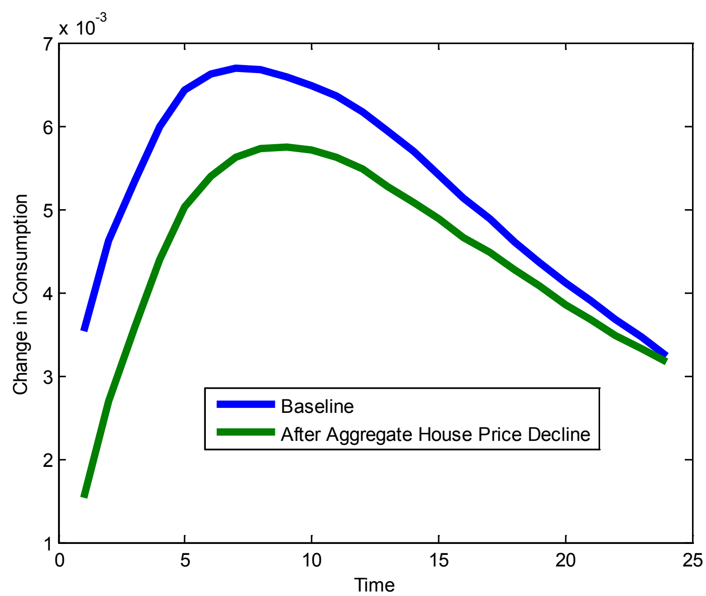


Figure 22: Effects of Regional House Price Dispersion on Aggregate Consumption Impulse Response to Interest Rate Declines

See text for description of baseline model. In the No Variance scenario, all regions have house price values so that there is no regional variance. In the High Variance scenario, regions only take on high and low values.

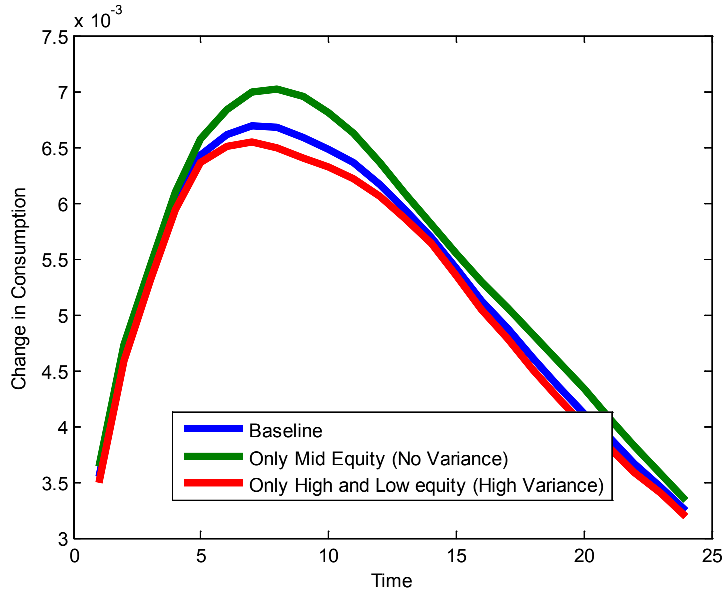


Figure 23: Impulse Response of Aggregate Consumption to Interest Rate Decline after Aggregate Income Decline

Figure 23 shows how the consumption response to monetary policy changes after an aggregate income decline.

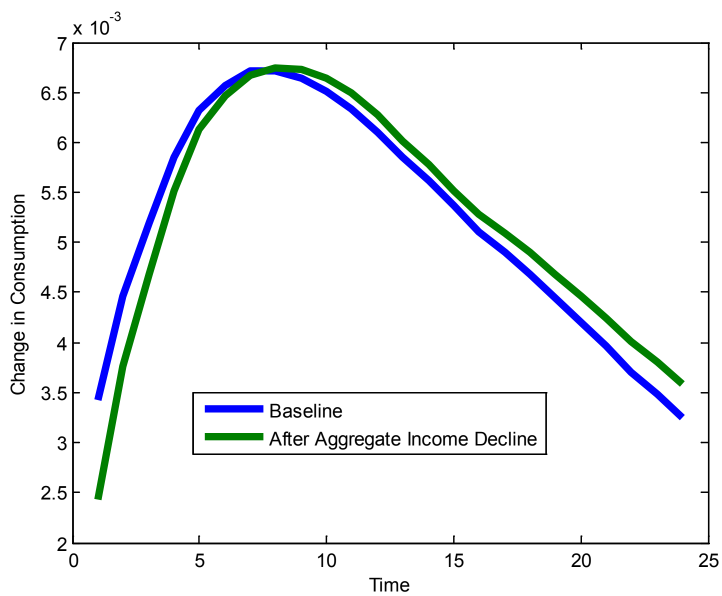


Figure 24: Effects of Regional House Price Dispersion on Aggregate Consumption Impulse Response to Interest Rate Declines

See text for description of baseline model. In the no variance scenario, all regions have middle income values so that there is no regional variance. In the high variance scenario, regions only take on high and low values.

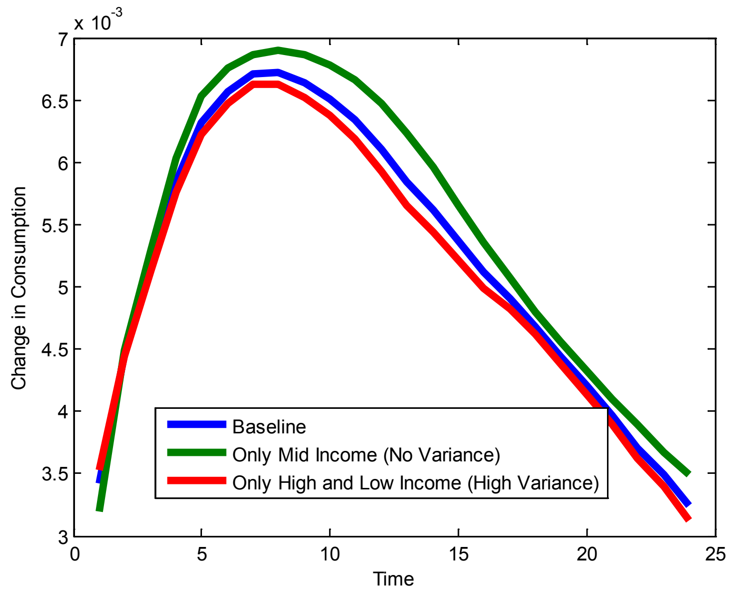
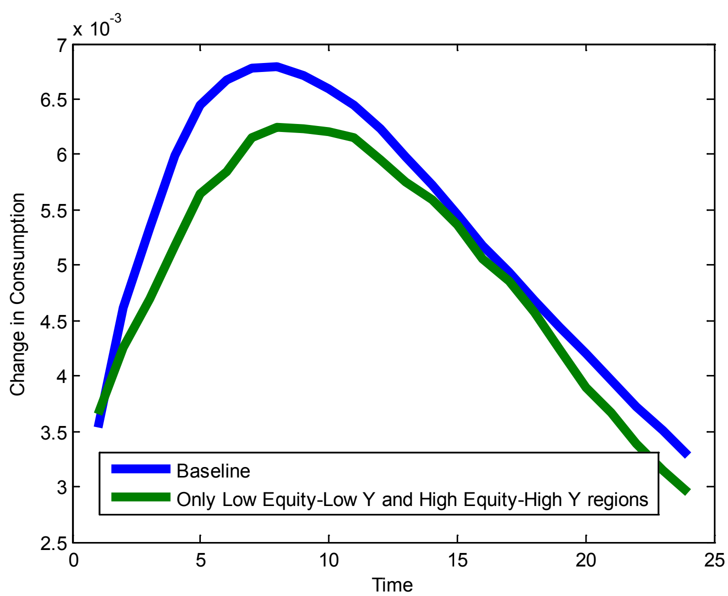


Figure 25: Aggregate Consumption Impulse Response in Baseline Compared to Model Where Income and Equity Are Highly Correlated

In baseline, there is no correlation between income and equity so that all regional shocks are equally likely. In the alternative scenario, equity shocks and income shocks are perfectly correlated so that there are only two types of regions. See text for additional description.



APPENDIX

DATA

HMDA

In all our analysis using HMDA data, we only retain applications that led to originations (action code = 1); however, rather than using the action date, we always use the application date. We drop multifamily properties and mortgages with an origination amount >$3 million (about 0.015 percent of loans).

CRISM

We start with a 50 percent sample of all McDash Analytics mortgages linked to Equifax credit records that were outstanding for at least one month between January 2007 and December 2010. The credit records in the dataset cover the lifetime of the loan, including an additional 6 months before origination and after termination. Equifax is reported as a panel at the consumer level, providing total outstanding debt amounts in different categories (first-lien mortgages, second-lien mortgages, home equity lines of credit, etc.). Additionally, in any month, Equifax provides the origination date, amount, and remaining principal balance of the two largest (in balance terms) first mortgages, closed-end seconds, and HELOCs outstanding for a given consumer.

We convert these records into a loan-level panel with each loan's type, origination month, origination amount, termination month, and remaining principal balance for all months that the loan is outstanding. We restrict our sample to those consumers who start our sample with two or less loans in each category and never have more than three of any of these types of loans outstanding.[40] This amounts to about 94 percent of the population of loan IDs, and about 91 percent of the total loan balance. In creating this loan-level dataset, we assume that the month that the loan stops appearing in Equifax is the month that it was terminated.

The variables that McDash provides are already in the form of a loan-level panel, and include origination date, origination amount, remaining principal balance, termination date, termination type, lien type, interest type, property zip code, and purpose type. We match these to our Equifax panel. We consider an Equifax loan/McDash loan pairing a match if the origination date of the Equifax loan is within 1 month and the origination amount is within $10,000 of the McDash loan. If more than one loan is matched, we use the origination amount, date, termination date, zip code, and termination balance as tiebreakers. We are able to match more than 93 percent of McDash loans using these restrictions, with more than 80 percent matching the origination information perfectly (up to $1 in balances due to rounding).

We use the set of Equifax/McDash matched loans as our universe in our analysis. Due to the restrictions above, this amounts to about 82 percent of the McDash universe. We also verify that we are correctly

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[40] This restriction allows us to infer the origination month, origination balance, and balance of the third largest loan of any loan type, even though this information does not appear explicitly in Equifax. If the third largest loan is also the newest, we assume its origination month to be the first month it appears in Equifax. We also drop loans that do not have complete consecutive Equifax records.

measuring the termination date and termination balance using the Equifax records by checking these variables against their McDash counterparts for the matched loans.

Measuring Refinancing Propensities

Our goal is to measure the proportion of outstanding loans in an MSA that were refinanced in a given month. For the denominator, we start with all outstanding first liens (where lien type is measured using the McDash variable) in our Equifax/McDash matched universe, but exclude in each month loans that terminate in the next month because they were transferred to another servicer or terminate for unknown reasons (since we will be looking at the proportion of loans that are voluntarily paid off and refinanced).

We count a loan as being refinanced if (1) its McDash termination type is a "voluntary payoff" and (2) for that consumer, there is another loan that is opened around the time of the first loan's termination on the same property (i.e., the new loan is a refinance rather than a new purchase loan). More specifically, the most clear indicator that the new loan was a refinance is if the loan has a matching McDash loan (about 70 percent), and that McDash loan is marked as a refinance loan (in McDash's purpose type variable). On the other hand, the loan is clearly a new purchase loan if the purpose type is marked as such. However, about 25 percent of McDash loans have purpose type "Unknown" or "Other," and about 30 percent of the new loans are not matched in McDash (they only appear in Equifax, since McDash does not cover the entire market) and thus have no purpose type attached.

We thus use the following rules to identify refinances. We start by looking for any loan in the Equifax dataset that has an open date within 4 months of the McDash loan's termination date. We find at least one such loan for about 81 percent of the voluntary terminations in 2008 and 2009. We classify these new loans as a refinance if one of these is true:

- the loan also appears in McDash and is tagged as a refinance in the purpose-type variable (61 percent of the McDash-matched loans),
- the loan also appears in McDash and is tagged as an "Unknown" or "Other" purpose type, and has the same property zip code as the original loan, or
- the loan appears only in Equifax but the borrower's Equifax address does not change in the 6 months following the termination of the original loan.

This allows us to compute our measure of interest, the balance-weighted refinance propensity, as (balance outstanding in t-1 of loans that were refinanced in month t) / (balance outstanding in McDash in month t-1 that does not terminate for unknown reason in month t).

As a check, we also calculate the refinance propensities separately for the three different cases above (McDash, known purpose; McDash, unknown purpose; Equifax), and find that these refinance propensities are very similar.

Measuring Cash-outs

To measure cash-out refinancing we need to both identify refinances and how the balance of the new loan compares to the outstanding balance of the loan(s) paid off in the process. We begin with Equifax/McDash first liens (again using the McDash lien type variable), and keep only those loans that have a McDash purpose type of Refinance or Unknown/Other. Our algorithm to identify whether or not our new loan is a refinance is similar to the algorithm above. This time, we look for a loan (or loans) in Equifax that terminate(s) around the time when the new loan is originated and check that this loan looks like it was refinanced. We use McDash refinances rather than outstanding loans as our point of reference for these statistics so that we can better represent all refinances, rather than introducing potential bias through only seeing refinances of McDash loans. Specifically, we call any loan in the Equifax dataset that terminates between -1 and 4 months from our new loan's close date a "linked" loan, including first mortgages as well as closed-end seconds and HELOCs, and we call the new loan a refinance if one of the following applies:

- The loan is a known refinance in McDash. (For 86 percent of these we find a linked loan in either McDash or Equifax. For the remaining 14 percent, we would consider these refinances where there was no previous loan on the property.)
- The loan has an "Unknown" or "Other" purpose type in McDash and a linked loan in McDash that has a matching property zip code.
- The loan has an "Unknown" or "Other" purpose type in McDash and a linked loan that appears only in Equifax, but the consumer's Equifax address does not change in the 6 months after the new loan was opened.

For each of these cases we can thus calculate the cash-out amount as the difference between the origination amount on the refinance loan and the balance of the linked loan(s) at termination. In order to capture the correct origination amount on the refinance loan, we want to ensure that we are also including any "piggyback" second liens that are opened with the refinance loan that we find in McDash. Thus, we look for any loan in the corresponding Equifax record to our refinance loan that has the same Equifax open date and an origination balance of less than 25 percent of the refinance loan's origination balance, and add the balance of these piggyback second liens to the refinance origination amount when calculating cash-out amounts. To eliminate outliers, we also drop cash out and "cash in" amounts that are greater than $1,000,000. These amount to less than 0.05 percent of the refinance loans.

At the MSA level, this allows us to calculate the amount cashed out relative to the total outstanding balance in month t-1. To estimate total dollar amounts cashed out, we scale up the amount cashed out by the ratio of total housing debt outstanding in an MSA according to the Federal Reserve Bank of New York Consumer Credit Panel (CCP) relative to the total outstanding balance in our CRISM sample. (The CCP amounts are available as end-of-quarter snapshots, so we interpolate between them to get a monthly series.)

In Figure A-4 we compare the total estimated quarterly cash-out amounts to those estimated on prime conventional loans by Freddie Mac.[41] The figure shows that the two series co-move closely and also show similar levels. The higher level in CRISM is expected since the Freddie Mac series does not include subprime/Alt-A as well as FHA and VA loans.

[41] To make the two comparable, we multiply our CRISM total by 1/0.9175, where 0.9175 is the share of mortgage balances in CRISM that is in MSAs (as opposed to micropolitan statistical areas or rural areas) as of November 2008.

Measuring CLTVs

We start with all matched first-lien McDash loans. For a given month, we take the corresponding Equifax record and assign all outstanding second liens to the outstanding first liens in Equifax using the rule that each second lien is assigned to the largest first lien (in balance terms) that was opened on or before the second lien's opening date. We then add the assigned second lien balance(s) to the McDash balance of our original loan and use this combined balance to compute CLTVs. We then compute *CLTV_X* (where *X* is either 80 or 100) at the MSA level as (balance [first-lien only, from McDash] of loans with CLTV > *X*%) / (balance of all matched first-liens outstanding in McDash).

ADDITIONAL FIGURES AND TABLES

Figure A-1: *CLTV_100* vs. *CLTV_80* in November 2008

Based on CRISM data. Size of circles is proportional to MSA 2008 population.

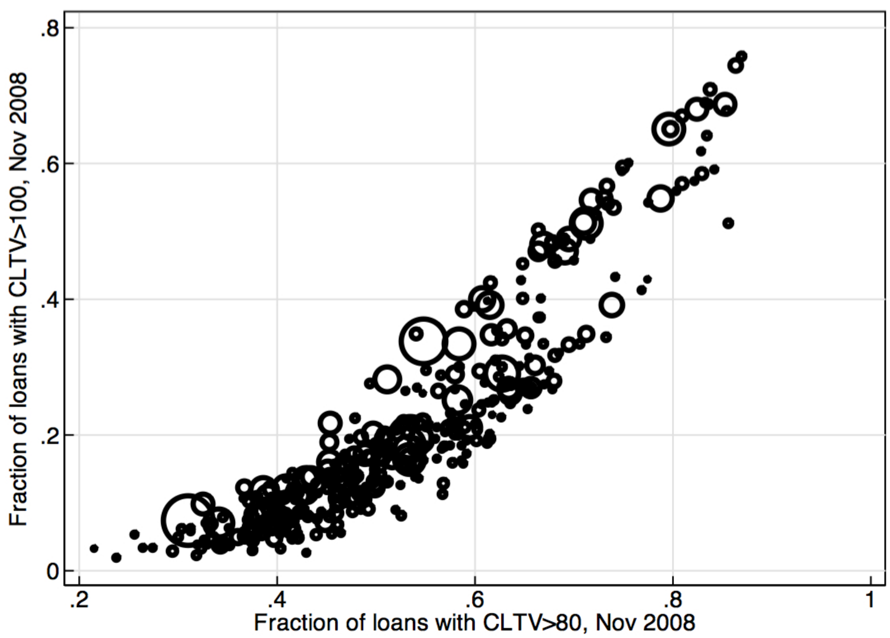


Figure A-2: Total Mortgage Origination Activity, 2008 and 2009 in Top and Bottom Quartiles of MSAs Defined by *CLTV_80* in November 2008

Figure A-2 shows total mortgage origination volume (purchase and refinance) in HMDA by the month in which the borrower applied for the mortgage, where months are redefined so they start on the 25th day of the prior month. MSA quartile groups are defined the same way as in Figure 5. The vertical line indicates the month of the QE1 announcement (November 2008).

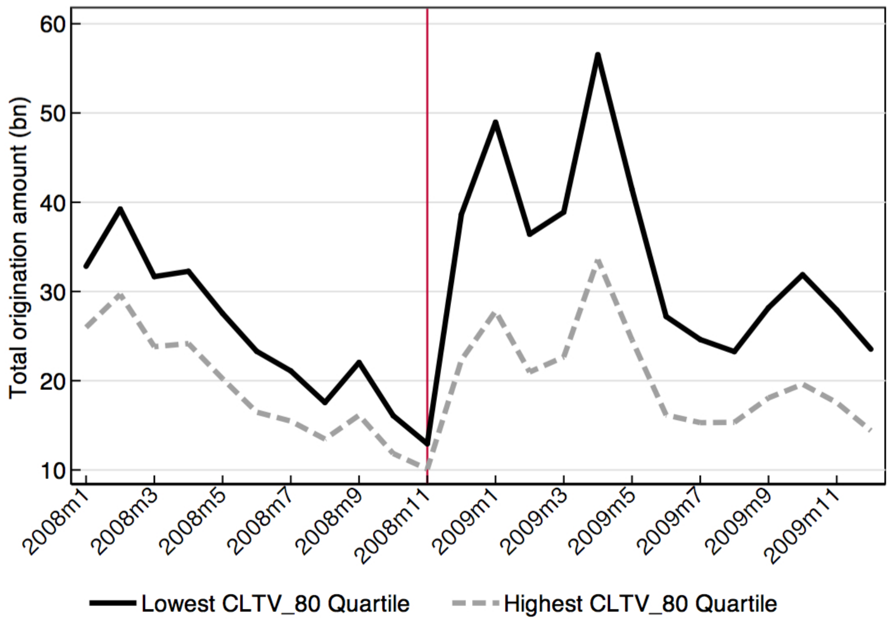


Figure A-3: HMDA Refinancing Propensity, November 2008 and December 2008 vs. *CLTV_80* in November 2008

Figure A-3 shows the simple scatter plot of the refinancing propensity in a given MSA, measured as (number of new refinancing originations by application month in HMDA) / (number of mortgages in MSA in 2008 from ACS), versus the fraction of loans within the MSA with CLTV greater than 0.8 (*CLTV_80*) in November 2008. The dark circles represent the refinancing propensity in November 2008 and the light circles represent the refinancing propensities in December 2008. Months are redefined so they start on the 25th day of the prior month. The size of the circle represents the 2008 population of the MSA. The two lines represent simple regression lines fitting the scatter plot (population weighted).

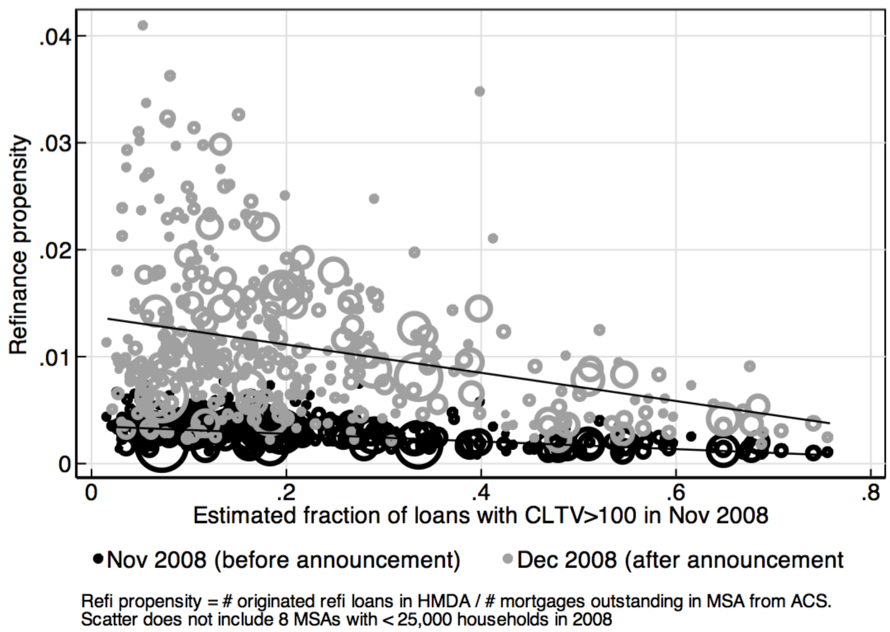
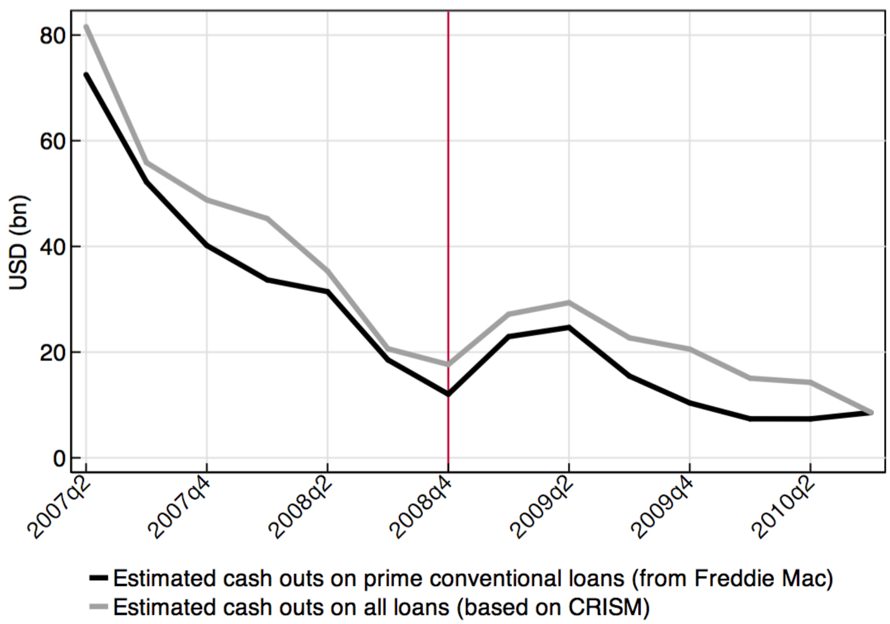


Figure A-4: Estimated Cash-out Amounts from Freddie Mac vs. CRISM Data

Figure A-4 shows estimated quarterly cash-out volumes on prime conventional (nongovernment) mortgages estimated by Freddie Mac (obtained from http://www.freddiemac.com/finance/docs/q4_refinance_2014.xls), as well as those we obtain based on the CRISM data (which also includes FHA/VA loans) after scaling up as explained in "Measuring Cashouts" section of the Appendix.



MSA Groups Used in Figures 5, 7, and 8

MSAs in the quartile with highest *CLTV_80* in November 2008:

Akron, OH; Anderson, IN; Ann Arbor, MI; Bakersfield, CA; Bangor, ME; Battle Creek, MI; Bay City, MI; Bradenton- Sarasota-Venice, FL; Canton-Massillon, OH; Cape Coral-Fort Myers, FL; Cleveland-Elyria-Mentor, OH; Columbus, OH; Dalton, GA; Danville, IL; Dayton, OH; Deltona-Daytona Beach-Ormond Beach, FL; Detroit-Livonia-Dearborn, MI (Metro Div.); El Centro, CA; Elizabethtown, KY; Elkhart-Goshen, IN; Fairbanks, AK; Flint, MI; Fort Lauderdale- Pompano Beach-Deerfield Beach, FL (Metro Div.); Fort Walton Beach-Crestview-Destin, FL; Fort Wayne, IN; Fresno, CA; Grand Rapids-Wyoming, MI; Greeley, CO; Gulfport-Biloxi, MS; Hagerstown-Martinsburg, MD-WV; Hanford-Corcoran, CA; Holland-Grand Haven, MI; Indianapolis-Carmel, IN; Jackson, MI; Jacksonville, FL; Jefferson City, MO; Johnstown, PA; Kalamazoo-Portage, MI; Kankakee-Bradley, IL; Kansas City, MO-KS; Lake Havasu City- Kingman, AZ; Lakeland-Winter Haven, FL; Lansing-East Lansing, MI; Las Vegas-Paradise, NV; Madera-Chowchilla, CA; Mansfield, OH; Memphis, TN-MS-AR; Merced, CA; Miami-Miami Beach-Kendall, FL (Metro Div.); Modesto, CA; Monroe, MI; Muskegon-Norton Shores, MI; Naples-Marco Island, FL; Niles-Benton Harbor, MI; Ocala, FL; Orlando-Kissimmee, FL; Palm Bay-Melbourne-Titusville, FL; Palm Coast, FL; Panama City-Lynn Haven-Panama City Beach, FL; Pascagoula, MS; Pensacola-Ferry Pass-Brent, FL; Phoenix-Mesa-Scottsdale, AZ; Port St. Lucie, FL; Punta Gorda, FL; Reno-Sparks, NV; Riverside-San Bernardino-Ontario, CA; Sacramento–Arden-Arcade–Roseville, CA; Saginaw-Saginaw Township North, MI; Salinas, CA; Sebastian-Vero Beach, FL; Springfield, OH; St. George, UT; Stockton, CA; Sumter, SC; Tampa-St. Petersburg-Clearwater, FL; Terre Haute, IN; Toledo, OH; Vallejo-Fairfield, CA; Visalia-Porterville, CA; Warren-Troy-Farmington Hills, MI (Metro Div.); Weirton-Steubenville, WV-OH; West Palm Beach-Boca Raton-Boynton Beach, FL (Metro Div.);

Wheeling, WV-OH; Winchester, VA-WV; Worcester, MA; Youngstown-Warren-Boardman, OH-PA; Yuba City, CA; Yuma, AZ.

MSAs in the quartile with lowest *CLTV_80* in November 2008:

Albany-Schenectady-Troy, NY; Alexandria, LA; Anderson, SC; Asheville, NC; Athens-Clarke County, GA; Austin-Round Rock, TX; Baltimore-Towson, MD; Barnstable Town, MA; Baton Rouge, LA; Beaumont-Port Arthur, TX; Bellingham, WA; Billings, MT; Binghamton, NY; Bismarck, ND; Blacksburg-Christiansburg-Radford, VA; Bloomington- Normal, IL; Boulder, CO; Bridgeport-Stamford-Norwalk, CT; Buffalo-Niagara Falls, NY; Burlington-South Burling- ton, VT; Cedar Rapids, IA; Charleston, WV; Charlottesville, VA; Cleveland, TN; College Station-Bryan, TX; Corvallis, OR; Cumberland, MD-WV; Davenport-Moline-Rock Island, IA-IL; Dubuque, IA; Duluth, MN-WI; Durham-Chapel Hill, NC; Edison-New Brunswick, NJ (Metro Div.); Elmira, NY; Erie, PA; Eugene-Springfield, OR; Fargo, ND-MN; Florence, SC; Fort Collins-Loveland, CO; Fort Smith, AR-OK; Glens Falls, NY; Grand Forks, ND-MN; Grand Junction, CO; Great Falls, MT; Green Bay, WI; Greenville-Mauldin-Easley, SC; Harrisburg-Carlisle, PA; Harrisonburg, VA; Hartford-West Hartford-East Hartford, CT; Hickory-Lenoir-Morganton, NC; Honolulu, HI; Hot Springs, AR; Houma-Bayou Cane-Thibodaux, LA; Huntsville, AL; Iowa City, IA; Jacksonville, NC; Johnson City, TN; Jonesboro, AR; Kingsport-Bristol-Bristol, TN-VA; Knoxville, TN; La Crosse, WI-MN; Lafayette, LA; Lake Charles, LA; Lancaster, PA; Lawrence, KS; Lebanon, PA; Longview, WA; Lubbock, TX; Lynchburg, VA; Madison, WI; Midland, TX; Missoula, MT; Mobile, AL; Monroe, LA; Mount Vernon-Anacortes, WA; Nassau-Suffolk, NY (Metro Div.); New Orleans-Metairie-Kenner, LA; New York-White Plains-Wayne, NY-NJ (Metro Div.); Ocean City, NJ; Oshkosh-Neenah, WI; Philadelphia, PA (Metro Div.); Pittsburgh, PA; Pittsfield, MA; Pocatello, ID; Raleigh-Cary, NC; Rapid City, SD; Reading, PA; Roanoke, VA; Rochester, NY; Salem, OR; San Angelo, TX; San Francisco-San Mateo-Redwood City, CA (Metro Div.); Scranton–Wilkes-Barre, PA; Seattle-Bellevue-Everett, WA (Metro Div.); Sheboygan, WI; Sioux City, IA-NE-SD; Sioux Falls, SD; Spokane, WA; State College, PA; Syracuse, NY; Trenton- Ewing, NJ; Tulsa, OK; Victoria, TX; Waterloo-Cedar Falls, IA; Wenatchee-East Wenatchee, WA; Williamsport, PA; Wilmington, NC; Yakima, WA; York-Hanover, PA.