

THE MORTGAGE RATE CONUNDRUM

ALEJANDRO JUSTINIANO, GIORGIO E. PRIMICERI, AND ANDREA TAMBALOTTI

ABSTRACT. We study the interest rates of privately securitized residential mortgages during the credit and housing boom of the early 2000s. After controlling for detailed loan and borrower characteristics, we uncover a sharp and persistent drop in the spread between mortgage and Treasury rates starting in the summer of 2003. The emergence of this mortgage rate conundrum immediately followed the collapse of an unprecedented refinancing wave, and it was more pronounced in the regions where that wave had grown faster. These same areas also experienced more originations of the non-conforming mortgages that boosted private label securitization after 2003. This evidence establishes a connection between the end of the refinancing wave and the origin of the well-documented shift in mortgage credit supply that ignited the more explosive phase of the housing boom. We also show that mortgages originated after this shift are the first to show signs of deteriorating quality, as indicated by their delinquency rates.

KEY WORDS AND PHRASES: Credit boom, housing boom, private-label securitization, refinancing, loan-level data.

1. INTRODUCTION

Mortgage and housing markets experienced a massive boom between 2000 and 2006. This paper documents a chain of events concentrated around the summer of 2003 that marked a turning point in the dynamics of this boom, leading to a more explosive phase of credit expansion that laid the groundwork for its disruptive undoing. Crucial among these events was the collapse of an unprecedented refinancing wave that had been surging since 2002. When the refinancing business suddenly dried out, lenders redeployed the infrastructure

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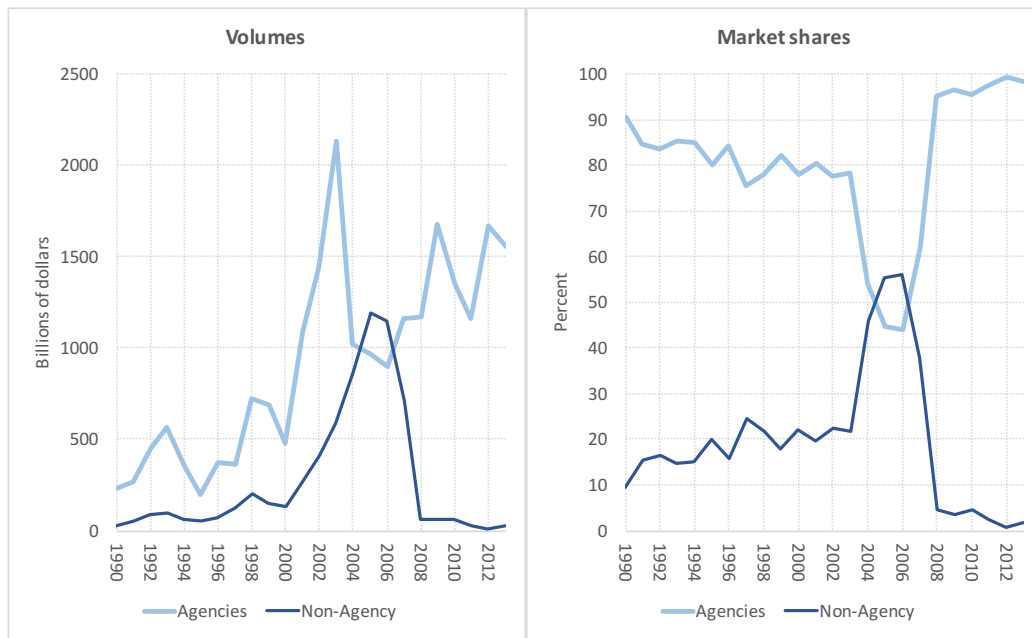


FIGURE 1.1. Securitization of residential mortgages by program: market shares and volumes of origination.

developed to serve the swelling refi wave towards the origination of non-conforming loans. These loans fueled the rise of private-label securitization and were the first to show signs of deteriorating quality, as indicated by their higher delinquency rates down the road.

We are able to pinpoint the timing of this inflection in the credit boom, and to highlight the role of the refi wave as its catalyst, by studying the pricing of privately securitized (PS) loans. Focusing on these loans, which include subprime, jumbo, and Alt-A products, is especially revealing of the underlying drivers of the credit boom because this segment of the market was at the heart of the transformation in mortgage finance that defines that era. As shown in figure 1.1, the market share of private-label (or non-agency) mortgage-backed securities (MBS), which were primarily composed of those non-conforming mortgages, increased from about 20 percent in the early 2000s to more than 50 percent in 2005 and 2006, before evaporating in 2008.

To control for this revolution in the composition of the mortgage market, we take advantage of detailed loan-level data from the Private Label Securities Database, which collects the near universe of privately securitized U.S. mortgages. We use these data to compute a *conditional spread* of mortgage rates over four Treasury market factors that summarize the level, slope, curvature and volatility of the Treasury yield curve. This spread is “conditional”

because it controls for a long list of observable borrower and loan characteristics, such as the borrower's FICO score, the loan-to-value ratio, and the type of mortgage contract, which affect the pricing of the mortgage. To the extent that those observables accurately reflect the well-documented changes in mortgage finance in the early 2000s, this spread will provide a measure of the cost of mortgage credit that is comparable over time and across mortgages. In this respect, the spirit of our analysis is similar to that of corporate bond spreads in [Gilchrist and Zakrajsek \(2012\)](#).

Our first finding is that the aggregate conditional mortgage spread for PS loans fell by about 80 basis points in the summer of 2003, recovering only gradually over the course of the subsequent years. This decline in the conditional spread was more pronounced for subprime mortgages and in poorer geographical areas.¹ We refer to this large, abrupt and persistent decoupling of mortgage interest rates from the prevailing conditions in the Treasury market as the mortgage rate conundrum, since it shares some characteristics with the well-known Greenspan conundrum (2005). Greenspan was puzzled by the fact that long-term Treasury rates did not rise in response to the Federal Reserve's tightening campaign between 2004 and 2006, when the federal funds rate (FFR) increased from 1 to 5.25 percent. Similarly, we show that conditional mortgage rates did not react to the significant steepening of the Treasury yield curve over the weeks following the FOMC meeting of June 24-25, 2003. At that meeting, the Committee lowered the FFR from 1.25 to 1 percent, which marked the end of that monetary policy easing cycle.

The emergence of this conundrum, by itself, does not shed light on the factors that drove mortgage rates significantly below their historical relationship with Treasury yields. However, the sharp identification of the timing of this discontinuity provides some important clues, in light of several other notable events that followed the June FOMC meeting in quick succession. Most notably, the massive refinancing wave that had been surging over the previous two years crashed in July 2003, once it became clear that the FFR was unlikely to fall below 1 percent. Yet, employment in the mortgage sector did not decline, in sharp contrast with the experience of the previous two refinancing cycles in 1994 and 1999. In fact, instead of shrinking, the mortgage industry redirected the infrastructure developed to take advantage of the refi boom towards the origination of non-conforming purchase mortgages,

¹[Antinolfi et al. \(2016\)](#) also use loan-level data to study the evolution of mortgage interest rates during the housing boom as a function of loan and borrower characteristics. They focus on the systematic part of this relationship and its evolution over time, rather than on the conditional mortgage spread as we do.

which swelled the private-label MBS market. This is when non-agency securitization took off, even as the issuance of agency MBS slowed down.

This connection between the refinancing wave and the surge in the origination of PS purchase loans with low (conditional) spreads can already be inferred from the aggregate time series. Our second main finding is that it is also strong across regions. We show that counties that experienced a bigger refi boom saw a larger increase in the volume of PS purchase loans after the summer of 2003. In addition, these loans were originated at a lower conditional spread. This negative cross-sectional correlation between the quantity of PS loans and their interest rate, conditional on the magnitude of the refi wave, is indicative of a shift in the supply of non-conforming credit following the summer of 2003.

Non-conforming loans issued during the credit boom eventually defaulted in large numbers, as shown by [Mian and Sufi, 2009](#), [Demyanyk and Van Hemert, 2011](#), [Foote et al., 2012](#), [Palmer, 2015](#), [Santos, 2015](#) and [Ospina and Uhlig, 2017](#), among others. We contribute to this literature by documenting that this deterioration in loan performance started immediately after the emergence of the conundrum in mid 2003. To establish this third main result, we show that the incidence of delinquencies, as a function of the time of mortgage origination, was flat through the summer of 2003 and started rising immediately afterwards. This is true in the raw data, as well as after controlling for the evolution of borrower and loan characteristics, and for the intervening economic conditions.

The rest of the paper is organized as follows. Sections 2 and 3 describe the loan-level data used in our paper and the empirical model used to extract a measure of conditional spread from Treasuries. Section 4 documents the abrupt fall of the estimated spread in the summer of 2003, while section 5 relates these findings to the end of an unprecedented refinancing wave. Section 6 studies the consequences of the conundrum in terms of loan quality and delinquency rates, and section 8 concludes highlighting the main takeaways from the paper.

2. DATA

This paper pulls information from two loan-level datasets, the Private Label Securities Database (PLSD) and the confidential version of the Home Mortgage Disclosure Act (HMDA) database. We supplement this information with macroeconomic and other data as further described below.

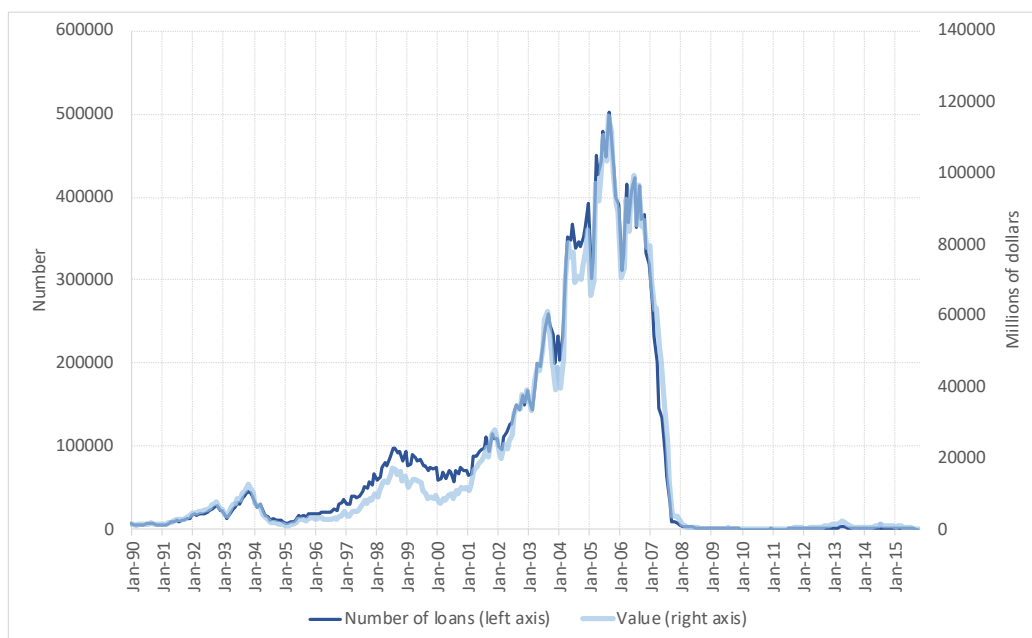


FIGURE 2.1. Mortgage origination in the PLSD.

The PLSD (sometimes referred to as ABS/MBS) covers the near universe of mortgages in non-agency securitization pools. The database includes publicly available information collected by CoreLogic Loan Performance, including details about the characteristics of the loans and of the borrowers. For example, we observe the date of origination, the borrowing rate and other loan characteristics, as well as the value of the collateral backing the loan, the loan-to-value ratio, the credit score of the borrower, and whether she provided income documentation. Section 3 provides summary statistics on these and other variables used in our analysis. In addition, the dynamic version of the dataset follows the life of each loan, also recording its performance status every month.

The PLSD contains observations on approximately 25 million individual mortgages issued since the 1980s, but our analysis concentrates on the period between 2000 and mid 2007, which corresponds to the most intense phase of the housing boom. Moreover, the private-label MBS market was very thin outside of this period, as show in figure 2.1. Origination of non-agency loans took off around the turn of the millennium, and essentially disappeared at the onset of the financial crisis in 2007.

The PLSD provides a classification of each mortgage as *prime*, *Alt-A* or *subprime*, based on a flag assigned to the loan by the issuer of the MBS. Approximately two thirds of

the dataset consists of subprime mortgages. This relatively large share of subprime loans reflects the fact that the GSEs cannot securitize them, which is why most of them ended up in private-label pools. However, it would be too simplistic to identify private-label MBS with subprime mortgages, since a substantial fraction of the loans in the PLSD are prime (11 percent) or Alt-A (25 percent).

The HMDA database collects data reported by financial institutions with an office within metropolitan statistical areas, as required by law. It includes records on mortgage applications and originations, including the loan amount and purpose (home purchase, home improvement, or refinancing). We use this information to construct a detailed picture of the size and geographic reach of the refinancing wave that swept the mortgage market in the middle of our period of analysis. Given the abrupt collapse of the refi wave in the middle of 2003, doing so requires the confidential version of the database, which includes the exact date of origination for each mortgage, rather than only the year as in the public file.

3. THE CONDITIONAL MORTGAGE RATE SPREAD: METHODOLOGY AND EMPIRICAL IMPLEMENTATION

This section illustrates the details of the empirical model that we use to construct the conditional mortgage rate spread. The properties of the estimated spread are then presented in section 4, where we also discuss why those properties give rise to a mortgage rate conundrum in the summer of 2003. Subsequent sections investigate the connection of the conundrum with other important events that occurred around the same time, most notably the sudden end of a refinancing wave that had been surging to unprecedented highs over the previous two years.

3.1. Methodology. We begin our investigation of the behavior of interest rates on mortgages in private label securitizations—PS mortgages for short—with a preliminary look at the PLSD data between 2000 and 2007. Figure 3.1 plots the spread between the average interest rate of PS mortgages and the 10-year Treasury yield. This spread is more informative than the level of mortgage rates themselves because Treasury securities provide a simple benchmark for overall credit conditions. This spread declines steadily from above 4.5 percentage points in 2001 to around 2.5 percentage points after 2004, with a particularly pronounced, abrupt and persistent fall in the middle of 2003.

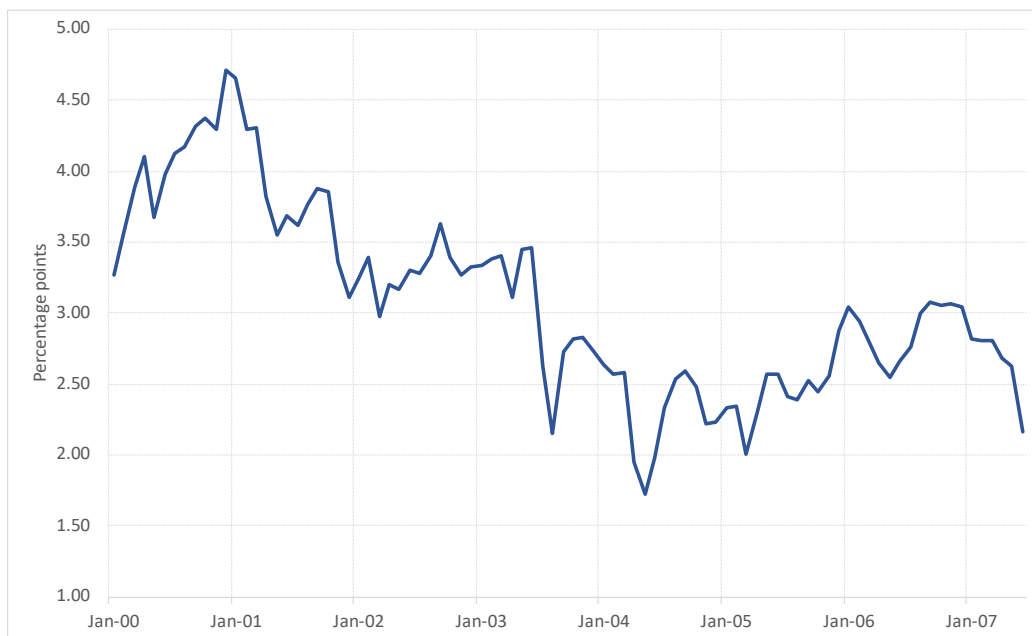


FIGURE 3.1. Spread between the average mortgage rate in the PLSD and the 10-year Treasury yield.

There are many reasons why the spread in figure 3.1 is only a rough first pass at illustrating the evolution of mortgage credit conditions. An especially relevant one is that the spread is constructed using the average interest rate of PS loans, thus ignoring the well-documented changes in mortgage finance that characterized this era, especially as reflected in the evolution of typical loan terms and borrower types. For example, suppose that average mortgage rates were constant over time. This observation would not imply that the price of credit is unchanged, because banks might be offering loans at the same interest rate to customers with different relevant characteristics, such as higher or lower credit worthiness. This simple consideration highlights the importance of controlling for the observed evolution of loan and borrower characteristics when studying the price of mortgage credit during the housing boom. Loan-level data such as those in the PLSD are essential to this task.

Motivated by this simple reasoning, we estimate the following empirical model of the evolution of mortgage rates

$$(3.1) \quad r_{i,t} = c + f'_{t-1}\beta + x'_{i,t}\gamma + \text{other controls} + \varepsilon_{i,t}.$$

In this expression, $r_{i,t}$ denotes the interest rate on loan i at time t (the month of the deal closing date), c is a constant, $x_{i,t}$ is a vector of loan-specific variables, including those pertaining to the borrower, f_t denotes aggregate variables, and *other controls* are additional geographic and time controls, such as dummies for the month and the state in which the loan was issued.²

The vector $x_{i,t}$ is a comprehensive set of controls for loan and borrower characteristics, which we expect a priori to be reflected in mortgage interest rates. As a guide to determine what explanatory factors to include in $x_{i,t}$, we rely on loan-rate sheets. These documents list different mortgage products offered by lenders and their interest rates, as a function of variables such as the borrower’s credit score, the LTV ratio, whether the loan is a jumbo mortgage, if it is intended for purchase or refinancing, and more. A list of the variables included in $x_{i,t}$ can be found in table 1, along with some summary statistics to which we return in the next subsection.

Turning to the aggregate variables, the vector f_t contains four term-structure factors for Treasuries. These factors control for the comovement between mortgage and Treasury rates in a more comprehensive manner than by simply taking the difference from any single Treasury yield, as done in figure 3.1. Therefore, we interpret the residual of the regression of mortgage rates on Treasury factors as a “spread” that captures the extent to which each mortgage is cheaper, or more expensive, than what is suggested by the historical correlation with the Treasury market. More specifically, we extract the first three principal components from a panel of Treasury yields of maturities ranging from 3 months to 10 years. These principal components have the interpretation of level, slope and curvature factors, which effectively summarize the observed variation in Treasury rates over time. In addition, f_t includes a volatility factor, computed as the realized volatility of the daily 2-year Treasury yield over a rolling 60-day window. We include this measure of interest rate volatility in the regression as a simple way to capture the effect of interest rate uncertainty on the prepayment option value embedded in mortgage rates (Gilchrist and Zakrajsek, 2012). These aggregate factors are included in the regression with a lag, to account for the fact

²We omit a geographic subscript on the interest rate to lighten the notation.

that mortgage rates are typically “locked in” a few weeks in advance of closing, which is the point at which we observe $r_{i,t}$.³

We focus on the residuals of equation (3.1). We interpret them as a spread between actual mortgage rates and their predicted value based on aggregate factors, as summarized by the evolution of the four Treasury factors, after controlling for the loan and borrower characteristics included in $x_{i,t}$. Given their construction, we refer to these residuals as *conditional mortgage rate spreads*. They provide a measure of what happened to the underlying cost of mortgage credit over the housing boom, once we take into account the changes in the types of loans being originated, and in the kinds of borrowers that took out those loans, as well as in the macroeconomic and monetary policy environment as reflected in the Treasury market. Persistent negative realizations of these spreads indicate that mortgage rates are systematically lower than expected, based on their historical correlation with idiosyncratic and aggregate risk factors. We examine the time-series behavior and the geographic characteristics of these spreads in section 4.

3.2. Empirical implementation. We estimate equation (3.1) on a subset of the PLSD that includes first-lien mortgages with a maturity of 30 years, originated for the purchase or refinancing of owner-occupied housing between 2000 and mid 2007. These restrictions produce a relatively more homogeneous sample, which nonetheless captures the main changes observed in the mortgage market over the period of interest.⁴

3.2.1. Summary statistics in the PLSD. Table 1 presents summary statistics for this sample by year, providing some basic information on the loan-level variables used in the estimation.

About two thirds of mortgages in the sample are subprime, with the remaining third approximately equally split between prime and Alt-A. The share of Alt-A mortgages exhibits a marked upward trend after 2003, while the fraction of prime and subprime loans declines.

³Antinolfi et al. (2016) study the evolution of the sensitivity of mortgage interest rates to risk factors. To this end, they estimate an equation similar to (3.1), including a subset of our loan and borrower characteristics and an aggregate factor capturing the level of Treasury rates.

⁴Second-lien mortgages usually have a substantially lower claim on the collateral, and mortgages backed by investment properties are more likely to default, since the borrower does not live in the house and thus has less at stake. Together with mortgages with maturity lower than 30 years, these loans have a substantially different risk profile among them and with respect to the those included in our sample, and hence are likely to be priced quite differently.

	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Interest rate (p.p.)	10.1	8.8	7.8	7.0	6.6	6.7	7.7	7.4
Loan and Borrower								
Loan-to-value ratio (%)	78.5	77.9	77.8	78.6	78.9	77.9	78.3	77.1
Borrower's FICO score	625	645	649	650	649	657	653	673
Origination amount (log)	11.7	12.1	12.1	12.1	12.2	12.3	12.3	12.6
Full documentation (%)	73	71	67	60	58	52	47	43
Prepayment penalty (%)	58	53	58	59	60	58	59	46
Jumbo (%)	24	36	32	25	21	22	20	35
Collateral Type (%)								
Prime	16	25	22	18	11	8	7	16
Alt-A	12	15	16	15	24	33	34	41
Subprime	72	60	62	67	65	59	59	42
Purpose (%)								
Purchase	47	38	34	34	41	44	44	34
Refinance w/cash-out	41	43	44	46	46	46	46	47
Refinance	12	20	22	20	12	10	10	19
Contract Type (%)								
Fixed Rate	41	48	39	36	22	20	22	28
ARM (not back loaded)	33	25	30	27	28	25	18	12
Interest Only (IO)	1	1	5	9	22	31	27	35
Balloon	0	0	0	0	0	3	17	14
Option ARM	2	0	1	0	5	10	8	7
Other	23	26	25	26	23	11	9	3
N (thousands)	320	541	792	1,315	2,152	2,833	2,403	706

TABLE 1. Summary statistics for 30-year, first-lien mortgages on owner-occupied housing in the PLSD for the period from January 2000 to June 2007. Averages or share of total (%), per year.

Another striking feature of the data is the trend in the share of standard fixed-rate mortgages, which falls from approximately one half to one fourth of the sample. Progressively more and more loans are instead either interest-only or balloon mortgages. Combined, these unconventional products account for about 50 percent of the sample in 2007.⁵

⁵Interest-only mortgages are loans requiring only the payment of the interest on the principal, for a set term. Balloon mortgages are loans that require a final large payment (the so-called “balloon payment”) at the end of the amortization period.

Perhaps surprisingly, both the FICO score of the average borrower and the LTV ratio of the loans are approximately constant over time. Instead, the fraction of borrowers presenting full income documentation drops quite substantially from 73 percent in 2000 to 43 percent in 2007, consistent with the findings of [Keys et al. \(2012\)](#) and [Mian and Sufi \(2015\)](#). Overall, [table 1](#) paints the picture of a transforming mortgage finance industry, in which non-traditional mortgage products become gradually more popular, at least until 2007. Some of these loans are riskier than more traditional products, and thus involve relatively higher interest rates. Others, such as adjustable-rate mortgages (ARM), might instead be associated with lower “teaser” rates at origination. Therefore, failing to control for these changes might lead to a misrepresentation of the behavior of mortgage rates for given loan and borrower characteristics.

3.2.2. Parameter estimates. [Table 2](#) presents the coefficient estimates of equation [\(3.1\)](#). The first column reports the baseline, most comprehensive specification, which includes 11 million observations on fixed and variable interest rate mortgages, for both purchase and refinancing.

According to the regression, Alt-A and, especially, subprime mortgages carry a higher interest rate on average. However, this classification does not capture all dimensions of risk. In fact, even within these groups, riskier borrowers, such as those with higher LTV ratios, lower FICO scores, or without full income documentation, as well as jumbo mortgages, are associated with higher mortgage rates. On the contrary, rates are generally lower when refinancing, regardless of whether this involves equity extraction. Finally, interest-only, ARM and balloon mortgages have substantially lower interest rates at closing, since the main feature of these contracts are smaller initial payments.

To allow for the possibility of varying interest rate sensitivity to risk factors across different broad classes of mortgages, columns II-V in [table 2](#) analyze more restrictive specifications, with smaller, but more uniform samples. In particular, columns II and III distinguish between mortgages intended for purchase or refinancing, while column IV only focuses on fixed-rate mortgages. The last column is the most restrictive specification, with fixed-rate mortgages only intended for purchase. The sign of the estimated coefficients is the same across all these specifications, and their magnitude is also similar.

The primary objective of running the regression in [\(3.1\)](#) is to recover a measure of mortgage rate spreads over the Treasury factors, which controls for the changes in mortgage

	Specification				
	I	II	III	IV	V
	Purchases & Refis	Purchases	Refis	FRM	FRM Purchases
Yield Curve					
Level	1.032**	1.047**	1.028**	1.042**	1.061**
Slope	0.724**	0.711**	0.728**	1.134**	1.208**
Curvature	3.776**	3.347**	3.936**	3.716**	3.354**
Realized volatility	0.139**	0.172**	0.119**	0.098**	0.125**
Loan and Borrower					
LTV ratio	0.016**	0.028**	0.012**	0.014**	0.019**
log(orig. amt.)	-0.553**	-0.489**	-0.575**	-0.667**	-0.517**
FICO score	-0.008**	-0.007**	-0.008**	-0.007**	-0.006**
Low/no doc	0.355**	0.368**	0.338**	0.245**	0.208**
Prepayment penalty	-0.055**	0.023	-0.086**	0.042	0.272**
Jumbo	0.406**	0.355**	0.441**	0.515**	0.390**
Collateral Type					
Prime (base)					
AltA	0.188**	0.262**	0.104**	-0.002	0.187**
Subprime	0.715**	0.848**	0.587**	0.355**	0.646**
Contract Type					
Fixed rate (base)					
IO	-0.374**	-0.421**	-0.359**		
Option ARM	-1.552**	-1.759**	-1.451**		
ARM (not back loaded)	-0.102**	-0.162**	-0.090**		
Balloon	-0.360**	-0.424**	-0.337**		
Other	-0.031*	-0.162**	0.031		
Purpose					
Purchase (base)					
Refi (cash out)	-0.067**		0.045*	-0.064**	
Refi (no cash out)	-0.081**			-0.084*	
R^2	0.621	0.658	0.607	0.637	0.657
N	10990130	4466147	6523983	2815198	942056

TABLE 2. Coefficient estimates in various specifications of equation (3.1). All specifications include a constant, state and month (Jan, Feb, etc.) dummies, as well as dummies for the property type (single family residence, condo, etc.). White standard errors clustered at the state level. Significance levels: (*) 5 percent, (**) 1 percent. FRM refers to fixed-rate mortgages.

finance observed in the early 2000s. Therefore, the exact interpretation of the estimated coefficients is not crucial to the analysis of those spreads. However, the signs of these coefficients are all consistent with the hypothesis that equation (3.1) represents a mortgage supply schedule, along which riskier loan-borrower combinations are charged higher interest rates.⁶ This interpretation is in turn consistent with a model of the mortgage market in which all financial institutions post similar rate sheets, and the borrowers take the conditions in those sheets as given. Under these assumptions, most of the cross-sectional variation in mortgage rates would originate from the observed variability in the characteristics of loan demand, as captured by the covariates included in vector $x_{i,t}$. In any case, this interpretation is not essential to the results that follow.

4. THE MORTGAGE RATE CONUNDRUM

This section presents the first main finding of the paper: The cost of mortgage credit, as measured by the conditional mortgage rate spread, fell abruptly in the middle of 2003 and it only recovered slowly over the course of the subsequent three years. We refer to this phenomenon as the mortgage rate conundrum because it is reminiscent of the decoupling between long-term Treasury yields and policy rates that emerged between 2004 and 2006, Alan Greenspan’s famous conundrum (Greenspan, 2005). Section 7 explores this parallelism further. Here, we begin by illustrating our conundrum in the aggregate time-series. We then explore some of its potential drivers in the cross-section of U.S. counties. Section 5 furthers this cross-sectional analysis by uncovering a link between the conundrum and the refinancing wave that ended in the summer of 2003.

4.1. Aggregate time-series evidence. Figure 4.1 depicts the mean of the distribution of conditional mortgage spreads across the loans in our PLSD sample, grouped by month of origination. The time average of this sequence of cross-sectional means over the entire period is equal to zero by construction. Its time profile, however, exhibits a peculiar pattern: it bounces around a positive average between 2000 and 2003, but it drops sharply in the

⁶The only coefficient that is apparently at odds with this interpretation is the one capturing the relationship between mortgage rates and the (log) size of the loan origination amount. However, closer inspection reveals that the negative estimate in this linear model is entirely due to the effect of small loans. Since the mortgage originator pays a fixed cost to issue each loan, small loans carry relatively higher interest rates to cover that cost.

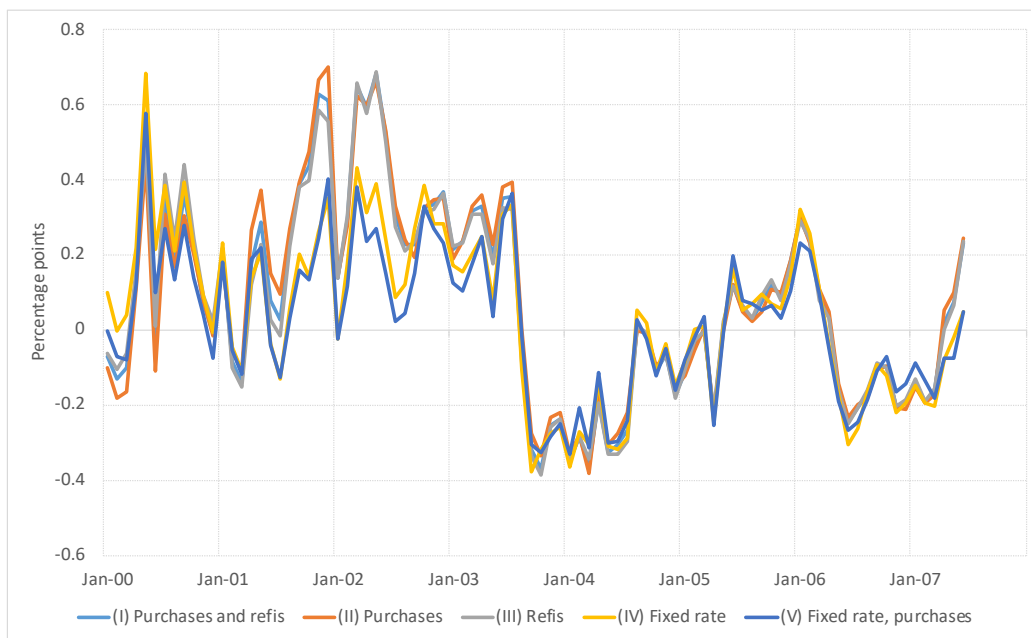


FIGURE 4.1. Average residuals in the five specifications of table 2.

middle of 2003. After this large fall of about 80 basis points, the mean of the residuals moves back towards positive values, but only very gradually.⁷

Figure 4.1 also demonstrates that this phenomenon is not just due to the increasing popularity of products with attractive teaser rates and other exotic features. Rather, it is common to all the specifications of equation (3.1) described in table 2, including the most restrictive that only includes fixed-rate purchase mortgages. In fact, all five specifications agree on the size and timing of the shift in the residuals, even if they often diverge in the period before.

In principle, these persistently low residuals could be due to variation in unobserved borrower characteristics. In practice, however, there are at least two reasons to discount this concern. First, the fall of the conditional mortgage spread in the summer of 2003 is very abrupt. Therefore, we would need an equally sudden change in unobserved borrower characteristics around the same time to explain it. Such a change seems unlikely to have occurred. Second, unobserved borrower quality should have *improved* after 2003 to rationalize the *lower* estimated spreads. This hypothetical improvement is the opposite of what

⁷These results are robust to a number of variants of the baseline model, such as the inclusion as controls of the borrower's combined LTV and debt-to-income ratio, and of a set of originator dummies. Our baseline specification omits these variables because they are only available for a subset of our sample.

was observed. In fact, section 6 documents that unobserved credit quality—as measured by residual ex-post loan performance after controlling for observables—*deteriorated* after the summer of 2003.

The most straightforward interpretation of our finding is that, in the middle of 2003, mortgage credit became significantly and persistently cheaper with respect to the prevailing conditions in the Treasury market, even after controlling for the concomitant evolution of observable loan and borrower characteristics. Section 7 shows that this decoupling reflects a tightening of credit conditions in the Treasury market, as captured by changes in the factors included in f_t , rather than an abrupt fall in mortgage interest rates. It also shows that the conundrum is larger for subprime mortgages, and that it is not due to a sudden shift in the product composition of our sample.

4.2. Cross-sectional evidence. This subsection explores the behavior of the conditional mortgage spread across geographical areas around the summer of 2003. This analysis yields two main findings. First, the spread fell more in poorer areas. Second, its decline is neither correlated with past and future income growth in the area, nor with local housing supply elasticity, and hence with the potential for significant house price appreciation. These findings on the evolution of the *price* of mortgage credit complement the evidence on *quantities* in Mian and Sufi (2009).

To illustrate the geographical patterns of the mortgage rate conundrum, we compute a value of the conditional mortgage rate spread at the county-month level, by averaging the loan-level spreads computed in section 4 over all the mortgages issued in a county in any given month. For every county, we then compute the difference in this spread between its time-series average over the twelve months of 2004 and the first six months of 2003. This change from the first half of 2003 to 2004 is a summary measure of the extent of the conundrum in each county. We refer to it as the county-conundrum indicator, or CCI.⁸

The first panel in figure 4.2 visualizes the dispersion of the CCI across all counties for which we have data. The distribution is centered around negative values, as expected given the findings in the previous subsections. Its mean and median are close to -50 basis points. This number is lower than the 80 basis points decline observed in the aggregate

⁸We build the CCI by taking time-series averages over 2004 and the first half of 2003 to reduce the noise in the county-month spreads. This calculation ignores the second half of 2003 to capture the decline in the spread in all counties more fully, including those where the decline happened more gradually after June 2003.

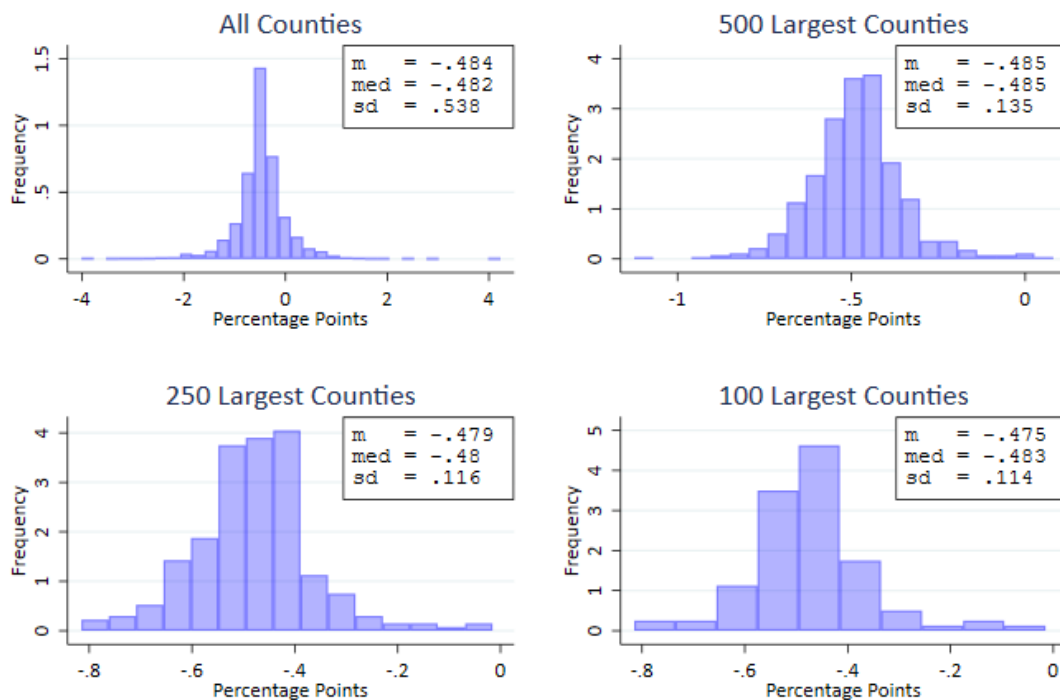


FIGURE 4.2. County-conundrum indicator for purchase and refinancing mortgages (CCC-I): Distribution across counties, including mean (m), median (med) and standard deviation (sd). County size is based on population in 2000.

around the summer of 2003, due to the time-series averaging underlying the construction of the CCI. This averaging reduces the magnitude of the conundrum compared to its peak around mid 2003 in the average county, but it produces a less noisy measure in the cross-section. Nevertheless, the CCI across all counties in the sample is quite volatile, with a standard deviation of more than 50 basis points and long tails below -2 percent and above +1 percentage points. Most of this volatility, though, is attributable to small counties, as demonstrated in the remaining panels of the figure. As we restrict attention to the 500, 250, and 100 most populous counties in the sample, the average and median of the CCI distribution remain close to -50 basis points, but its standard deviation drops closer to 10 basis points.

What are some of the key characteristics of the counties in which the conundrum was most pronounced? Table 3 addresses this question by presenting regressions of the CCI on several county characteristics. The first column shows that the CCI was lower (i.e. the conditional mortgage spread fell more) in poorer counties, as measured by their per-capita

	CCI-I Purchases & Refis				CCI-II Purchases		CCI-III Refis	
Log-income, 2000	0.12** (3.00)	0.12* (2.49)	0.17** (3.71)	0.17** (4.14)	0.23** (5.40)	0.22** (4.62)	0.18** (3.52)	0.20** (5.13)
Income growth, 2000-2002		-0.11 (-1.22)	0.01 (0.08)	-0.01 (-0.04)	0.05 (0.26)	-0.03 (-0.15)	-0.07 (-0.36)	0.04 (0.24)
Income growth, 2002-2004		0.06 (0.28)	-0.04 (-0.15)	-0.36* (-2.05)	0.28 (0.82)	-0.13 (-0.52)	-0.22 (-0.82)	-0.48* (-2.49)
Housing supply elasticity			-0.00 (-0.37)	0.01 (0.91)	-0.02 (-1.80)	-0.00 (-0.11)	0.01 (1.08)	0.01 (1.95)
N	2754	2754	754	752	751	749	754	752
R^2	0.02	0.02	0.11	0.49	0.13	0.33	0.09	0.49
State F.E.	No	No	No	Yes	No	Yes	No	Yes

TABLE 3. Cross-county regressions of the county-conundrum indicators (CCI). All specifications include a constant. Observations are weighted by population in year 2000. Standard errors are clustered at the state level. t -stats are in parentheses. Significance levels: (*) 5 percent, (**) 1 percent.

personal income in the year 2000.⁹ Moving from the 10th to the 90th percentile of the per-capita income distribution by county—i.e. from around 18 to 30 thousand dollars, for a difference of 0.53 log points—results in a 6 basis point decline in the CCI. This effect is small in absolute terms, but economically significant from at least two perspectives. First, the CCI is the change over time in the residuals of a very rich loan-level regression, which already accounts for most of the predictable variation in mortgage rates. Therefore, the bar for explaining the cross-county variation in the CCI is much higher than for “regular” county-level economic variables and closer to that of asset prices, for which low predictability is the norm. Second, and related to the asset pricing comparison, competition in the provision of mortgage credit pushes towards the equalization of *conditional* mortgage rates across loans, and hence across counties. In fact, when we exclude the smaller counties with noisier CCI estimates, the cross-sectional standard deviation of the CCI is only about 10 basis points, as shown in the fourth panel of figure 4.2.

These results complement those of Mian and Sufi (2009). They document that the unprecedented expansion in the quantity of mortgage credit between 2002 and 2005 was more pronounced in areas with a higher share of subprime borrowers, which they show are also the ones with lower income. The results in table 3 add to this evidence by demonstrating that, following 2003, the price of that credit fell more in poorer areas. The fact that the quantity of credit extended to the poorer counties grew, at the same time as its cost was

⁹Data on personal income per capita at the county level are from the Bureau of Economic Analysis.

falling, is consistent with a shift in the supply of credit that was especially concentrated in these areas. Moreover, this change in credit conditions in low income counties does not appear to be related to positive economic developments either before or after 2003. As shown in the second column of table 3, the relationship between the CCI and per-capita income is robust to controlling for the growth rate of income between 2000 and 2002, as well as between 2002 and 2004.

A possible explanation for the facts presented so far is that the observed credit expansion to more marginal areas that kicked into high gear around 2003 was driven by the expectation that house prices would eventually rise enough to justify bigger and cheaper mortgages (e.g. [Landoigt, 2017](#) and [Kaplan et al., 2020](#)). This hypothesis is difficult to test directly, since detailed data on house-price expectations are hard to find for the period under consideration.¹⁰ As an alternative, we build an indirect test using Saiz’s (2010) measure of local housing supply elasticity, as first proposed by [Glaeser et al. \(2008\)](#). They argue that house prices cannot be expected to rise much more than building costs in areas with a very elastic housing supply. Therefore, if the house price expectations-based hypothesis is correct, counties with low housing supply elasticity should have experienced a more pronounced credit boom. The third column in table 3 shows that this is not the case: the correlation between our CCI—a price-based measure of the shift in credit supply around 2003—and Saiz’s (2010) measure of housing supply elasticity is statistically zero. This estimate implies that the drop in mortgage spreads occurred even in counties with an elastic housing supply, where house price growth was muted, casting doubt on expectations-based explanations of the credit boom.¹¹

The fourth column in table 3 shows that the results described above are robust to the introduction of state fixed effects, although income growth from 2002 to 2004 is now borderline significant. This within-state correlation, however, is confined to mortgages issued for refinancing, as shown in the remaining columns of the table. Here, we distinguish between refinancing and purchase mortgages, in the same way as in the time-series plot of figure 4.1. When focusing on purchases alone, as in the column labeled CCI-II, the coefficient

¹⁰[Piazzesi and Schneider \(2009\)](#) document that the share of respondents in the Michigan Survey who think that now is a good time to buy a house starts declining in the middle of 2003. On the face of it, this evidence would seem inconsistent with an expectations-based explanation of the conundrum, even though these survey data are only available at the aggregate level.

¹¹We are grateful to Marco Di Maggio, Amir Kermani, and Maxim Pinkovsky for sharing the county-level data on the elasticity of housing supply based on [Saiz \(2010\)](#) used in [Di Maggio and Kermani \(2017\)](#) and [DiMaggio et al. \(2016\)](#).

on per-capita income is larger than among refinancing mortgages. The coefficient on the elasticity of housing supply remains statistically zero across the board, as is the one on the growth rates of income for purchase mortgages. The next section demonstrates that the distinction between purchase and refinancing mortgages is crucial to understanding the factors that led to the emergence of the mortgage rate conundrum in the summer of 2003.

5. THE SUMMER OF 2003: A TURNING POINT IN THE CREDIT BOOM

The evidence introduced in the previous section suggests that mortgage rates disconnected from those on Treasuries in mid 2003, and that this gap closed only around 2006. In this section, we discuss the relationship between this disconnect and the end of the refinancing wave that had been surging since 2002. We document that the size of this wave was unprecedented in U.S. history, and that counties where refinancing grew larger subsequently experienced a more pronounced conundrum and higher originations of PS purchase mortgages. We conclude that the summer of 2003 was a crucial turning point in the development of the credit boom.

As a preliminary step, it is useful to narrow down the timing of the sharp fall in the conditional mortgage rate spread illustrated in section 4. Recall that we model mortgage rates observed in the month of closing as a function of lagged Treasury factors. This lag accounts for the fact that the loan terms are typically “locked in” a few weeks before the actual closing, and thus reflect conditions at that time. Based on these considerations, we infer that the initial decoupling between mortgage and Treasury rates must have occurred in July 2003.

This dating of the emergence of the mortgage conundrum is notable because it immediately follows the FOMC meeting of June 24-25, 2003. At that meeting, the Committee decided to cut the federal funds rate by 25 basis point, from 1.25 to 1 percent. This was going to be the lowest level reached by the policy rate over the course of that cycle, a fact that became progressively clearer to market participants in the following days and weeks. As a result, the Treasury yield curve steepened significantly over the course of July, as shown in figure 5.1. On the day of the policy decision, the 10-year Treasury yield increased by 15 basis points. This is a large change, more than twice the standard deviation of the daily change on FOMC meeting dates between 1994 and 2007. Rates continued to rise in the subsequent weeks. By the end of July, long-term Treasury yields had increased by more

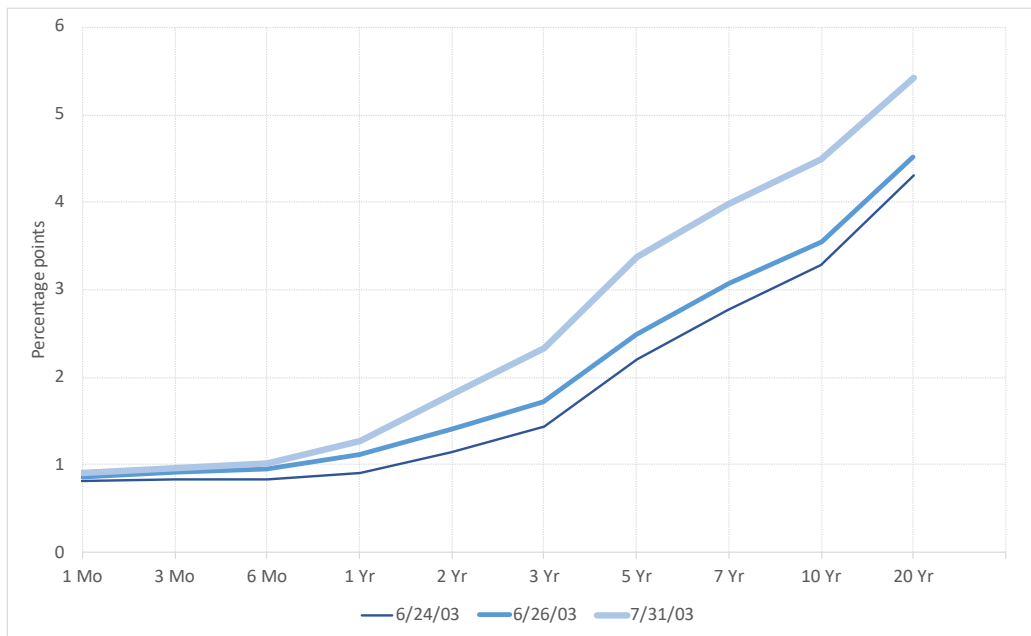


FIGURE 5.1. Treasury yield curve in June and July 2003.

than 100 basis points, mostly reflecting upward revisions to the expected future path of the policy rate. However, mortgage rates barely reacted to this significant tightening in Treasury market conditions, as shown in the previous section and further documented in section 7. As a result, their conditional spread over the Treasury factors dropped.

5.1. An unprecedented refinancing wave. The realization after the June FOMC meeting that policy rates were unlikely to fall further had another important consequence. It led to the abrupt end of the refinancing wave that had been ongoing since 2001, and had substantially accelerated since 2002. The size of this refinancing boom is unique in U.S. history, as illustrated in figure 5.2. The top panel plots the Mortgage Bankers Association (MBA) refinance index, which tracks applications to refinance an existing mortgage. This indicator reached an all-time high in June 2003, from which it dropped precipitously immediately following the FOMC meeting. Focusing on originations, rather than applications, refis reached 73 percent of the total in the first half of 2003, according to HMDA data. The bottom panel of figure 5.2 presents the evolution of both the dollar value and the number of refinancing mortgages originated monthly between 1990 and 2019. The value of refi originations peaked at around \$325 billion in July 2003, following the peak in applications one month earlier. Afterwards, refi originations dropped quickly and steadily towards a value

of \$85 billion in January 2004. Over the course of 2004, the average value of newly issued refinancing mortgages was about \$120 billion per month. This level of activity is still quite elevated by pre-2003 historical standards, but less than half of the flow during 2002 and the first half of 2003. Very similar considerations hold for the number of refinancing mortgages, which co-moves closely with their value.

The refinancing wave in 2002 and 2003 was not only massive, but also widespread around the U.S. Figure 5.3 illustrates its geographic reach by reporting the distribution across counties of the growth rate of the dollar value of refinancing originations between 2002 and the first half of 2003. As shown in the first panel, refinancing activity climbed over that period in the vast majority of counties, with a median increase of 60 percent. As shown in the remaining panels, the largest counties experienced an even higher median increase in refinancing, with less dispersion.

Overall, the refinancing data paint the picture of a sustained and widespread boom peaking in the summer of 2003 at levels of refinancing activity twice as large, by most metrics, as anything seen before and since. For comparison, that refi wave was much larger than the one currently under way amid the COVID-19 housing boom, which is taking place with 10-year Treasury rates close to 1 percent and the expectation that short-term rates will be at the effective lower bound for several years. Even in this very favorable environment, the MBA refinance index has been hovering around a value of 4,000 in the third quarter of 2020, with total refinancing originations at approximately 200 billion monthly, according to data from the New York Fed’s Consumer Credit Panel (CCP). Both these numbers are well below their levels in the first half of 2003.¹²

5.2. From refinancing to purchase loans in private-label securitizations. How did the mortgage industry react to the abrupt end of the refi wave in June 2003? This section shows that answering this question provides a novel perspective on one of the switches that boosted the credit and housing boom towards unsustainable highs later in the decade.

Figure 5.4 provides a first clue about the answer. It plots two measures of employment in the mortgage industry from the Bureau of Labor Statistics, along with one of the indicators

¹²Mortgage originations in the New York Fed’s Consumer Credit Panel are split between purchase and refis by looking at address changes around the time that a new mortgage loan appears on credit reports. The resulting totals tend to lag comparable measures based on the origination date of the loans, such as those obtained from HMDA and PLSD, by about a quarter. We thank Danghoon Lee and Joelle Scally of the New York Fed CCP team for sharing this information.

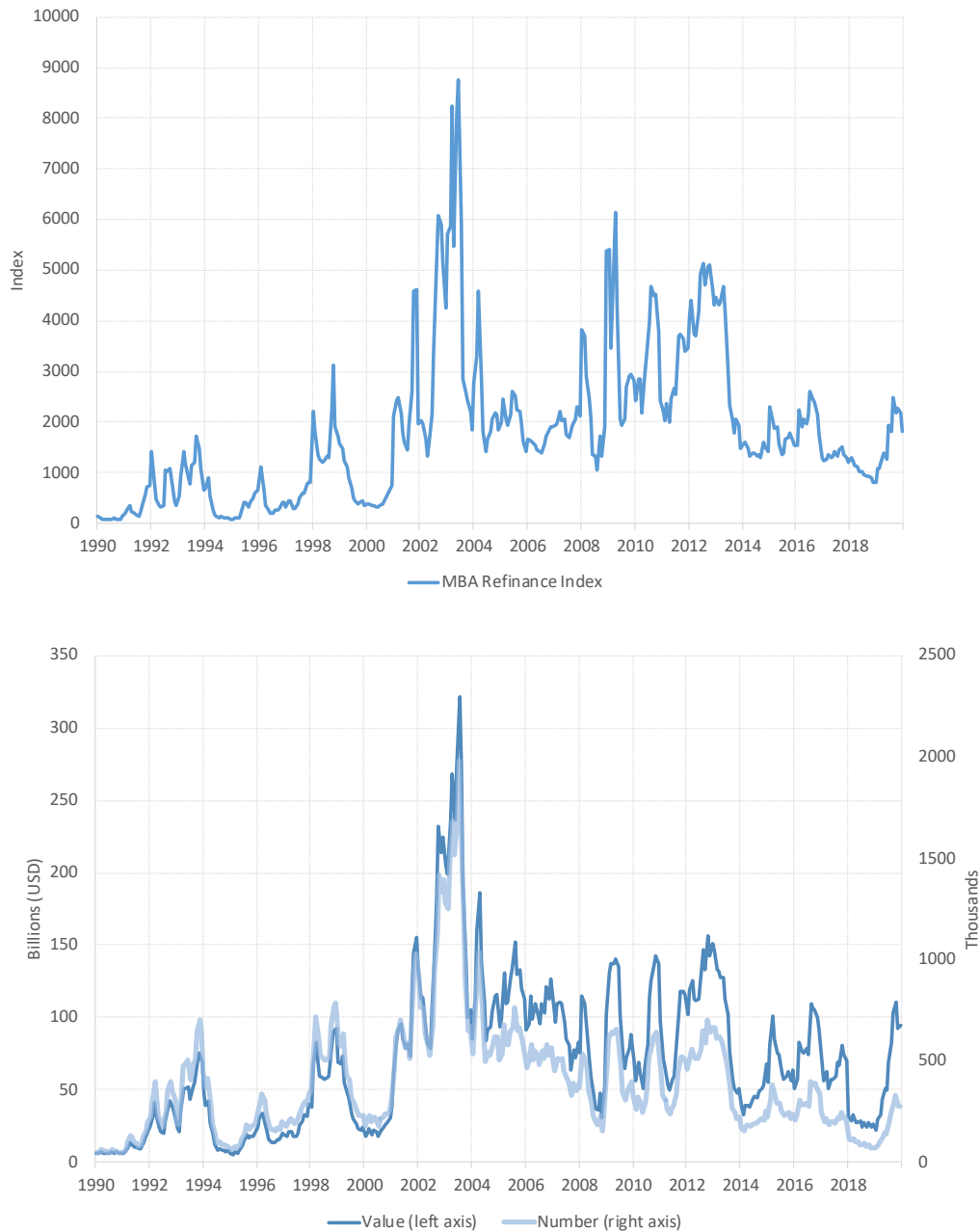


FIGURE 5.2. Top panel: Mortgage Bankers Association (MBA) refinance index covering mortgage applications for refinancing (seasonally adjusted, Mar-16-1990=100). Bottom panel: Total value and number of monthly originations of refinancing mortgages from the HMDA database.

of refinancing activity introduced above. Employment among loan brokers and in real estate credit did not fall after the end of the refinancing boom. This stability of employment in the mortgage industry, stands in contrast with the pattern observed in the two previous

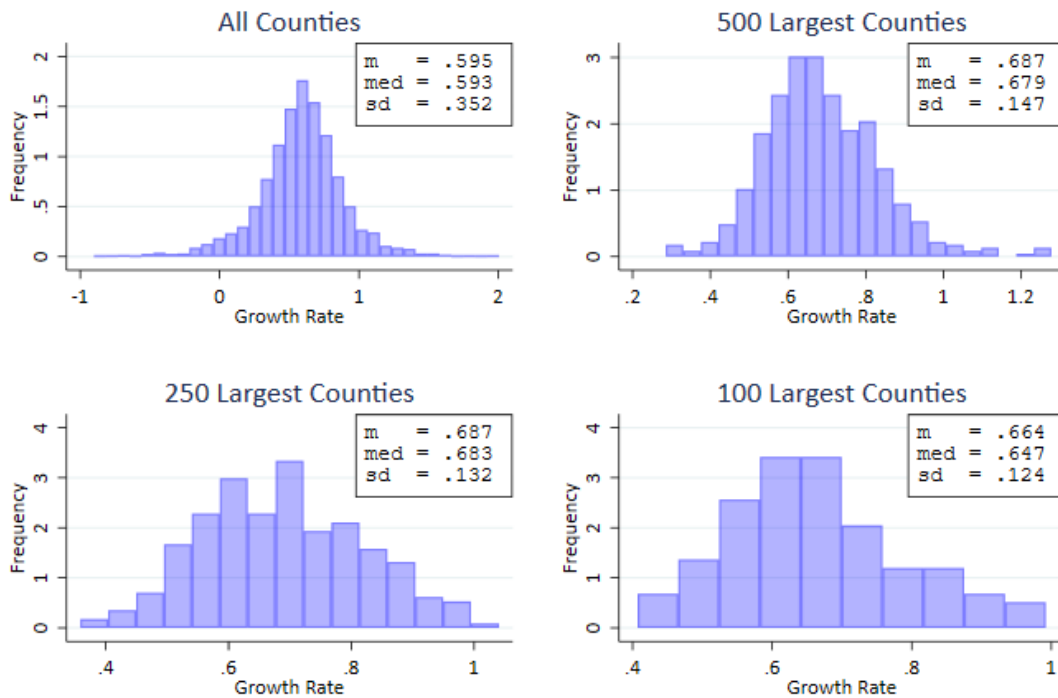


FIGURE 5.3. Growth rate of the dollar value of refinancing originations between 2002 and the first half of 2003. Distribution across counties, including mean (m), median (med) and standard deviation (sd). The growth rate in each county is computed between the average monthly originations in the entire year 2002 and in the first six months of 2003. County size is based on population in 2000. In the first subplot, all observations larger than 2 (0.5 percent of the total) have been trimmed to aid visibility. However, the mean, median and standard deviation are computed using the original, untrimmed sample.

refinancing cycles around 1994 and 1999, when employment fell together with the level of refinancing activity. This discontinuity in the correlation between employment and activity in the summer of 2003 is especially notable given the large and sudden drop in the latter, which dwarfs the two previous episodes.

In response to the disappearance of refinancing opportunities in the summer of 2003, the mortgage industry did not curtail employment and overall activity as in previous cycles. Instead, lenders appear to have redirected some of the significant resources that they had accumulated to serve the refi boom towards the origination of new *purchase* mortgages for private label securitization. To test this hypothesis more directly, table 4 augments the cross-sectional regressions of the CCI for *purchase* mortgages in table 3 with the measure of growth in refinancing activity presented in figure 5.3. The fifth column of the table shows that this simple measure of the intensity of the refi wave at the county level is negatively

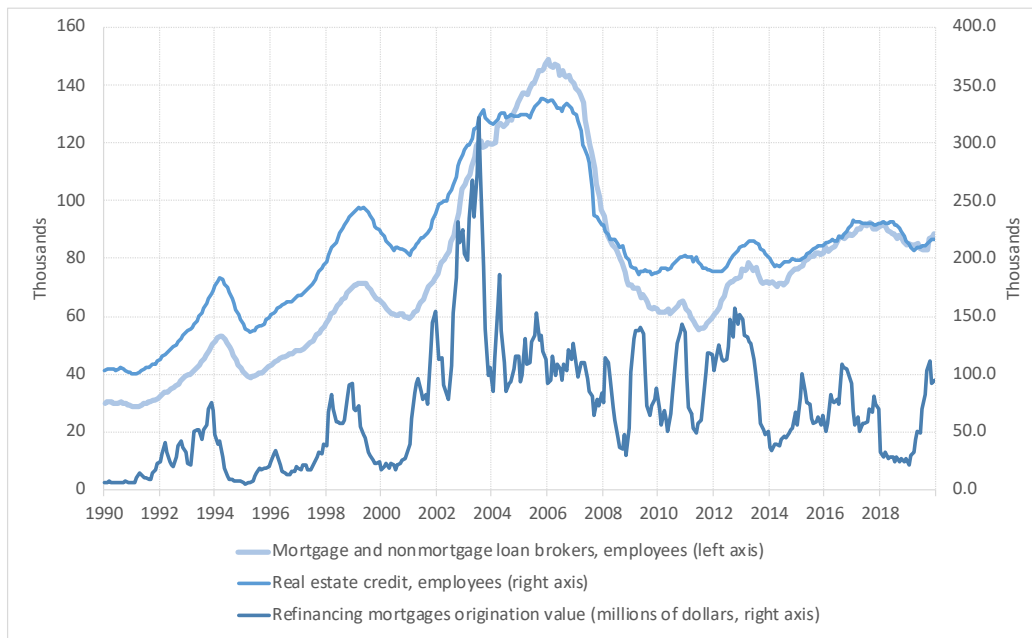


FIGURE 5.4. Employment of mortgage and nonmortgage loan brokers (NAICS code 522310) and in the real estate credit sector (NAICS code 522292), seasonally adjusted. The figure also plots the total monthly value of originations of refinancing mortgages from HMDA.

associated with the size of the conundrum. The coefficient is statistically and economically significant: an increase in refinancing growth of 71 percentage points—corresponding to the difference between the 90th and the 10th percentile of the refi growth distribution—is associated with a 15 basis point decline in the CCI. This is robust to including state fixed effects in the regression. In economic terms, this conditional correlation is of the same order of magnitude as that associated with the level of per-capita income, indicating that the intensity of the refi wave is an important economic factor behind the conundrum.

Table 4 shows that the conditional mortgage spread on purchase mortgages in the PLSD fell more after the summer of 2003 in counties that experienced a bigger refinancing boom. This is not the case for refis, suggesting that the “discount” practiced on purchase mortgages reflects a shift in the supply of funds away from the former and towards non-conforming loans originated for purchase.¹³ This relative supply shift is consistent with the patterns in the MBS market highlighted in figure 1.1 in the introduction. At the end of the refi wave, agency MBS fell significantly in response to a dearth of conforming raw material to

¹³The same regression with the county-conundrum indicator for refis (CCI-III) as a dependent variable has an estimated coefficient on refi growth of -0.05 , as opposed to -0.17 , with a t statistic of -1.13 .

	CCI-II Purchases						PS Purchase Mortgage Growth, 2003:H1-2004					
Log-income, 2000	0.23** (5.68)	0.23** (5.15)	0.23** (5.40)	0.22** (4.62)	0.23** (5.12)	0.21** (4.19)	-0.30 (-1.25)	-0.15 (-0.63)	-0.66** (-3.31)	-0.97** (-4.34)	-0.60** (-3.87)	-0.84** (-5.43)
Income growth, 2000-2002		-0.00 (-0.03)	0.05 (0.26)	-0.03 (-0.15)	0.18 (0.90)	0.03 (0.13)		1.62* (2.38)	1.76 (1.89)	-0.11 (-0.16)	0.87 (0.89)	-0.59 (-0.81)
Income growth, 2002-2004		0.24 (0.70)	0.28 (0.82)	-0.13 (-0.52)	0.38 (1.16)	-0.12 (-0.45)		1.10 (1.19)	1.73 (1.46)	-0.52 (-0.56)	1.05 (0.81)	-0.64 (-0.69)
Housing supply elasticity			-0.02 (-1.80)	-0.00 (-0.11)	-0.02* (-2.07)	0.00 (0.06)			-0.02 (-0.51)	0.03 (0.49)	-0.03 (-0.77)	0.01 (0.28)
Refi growth, 2002-2003:H1					-0.21** (-2.73)	-0.17** (-2.98)					1.40** (2.84)	1.53** (3.61)
N	2359	2359	751	749	751	749	2388	2388	752	750	752	750
R ²	0.03	0.04	0.13	0.33	0.15	0.33	0.01	0.02	0.11	0.36	0.18	0.41
State F.E.	No	No	No	Yes	No	Yes	No	No	No	Yes	No	Yes

TABLE 4. Cross-county regressions of the county-conundrum indicator and the growth rate of the origination value of privately securitized purchase mortgages (CCI-II and PS purchase mortgage growth). All specifications include a constant. Observations are weighted by population in year 2000. Standard errors are clustered at the state level. *t*-stats are in parentheses. Significance levels: (*) 5 percent, (**) 1 percent.

securitize. In contrast, non-agency securitization grew rapidly in 2003 and 2004, gaining a sizable market share. It follows that the majority of newly originated loans after the summer of 2003 were in the form of the non-conforming products that fed private-label MBS.

Indeed, the effect of refi growth on conditional mortgage spreads has a counterpart in terms of quantities, as shown in the right section of table 4. Counties in which the refinancing boom was stronger also experienced higher issuance of non-conforming purchase mortgages that landed in private-label MBS after the refi boom ended. We measure this quantity variable as the growth rate in the average monthly value of purchase mortgage originations in the PLSD between the first half of 2003 and 2004—PS mortgage growth, for short. This is an indicator of the penetration of non-conforming products in the county-level mortgage market during the crucial year of 2004. The loans used in the construction of this quantity variable are the same as those underlying CCI-II, the price indicator used in the regressions in columns 1 to 6 of table 4.

The marginal effect of refi growth on PS mortgage growth is statistically significant and economically large, as shown in the last two columns of table 4. An increase in refinancing growth of 71 percentage points, the interdecile range, is associated with an increase in PS mortgage growth of about 100 percentage points. This marginal effect, which is robust to the inclusion of state fixed effects, corresponds to either one or two standard deviations of

the cross-county distribution of PS mortgage growth, depending on whether we consider all counties or just the largest ones. In addition, PS mortgage growth is higher in areas with lower income, while it does not appear to be related to income growth or the housing supply elasticity.

In summary, the cross-sectional evidence presented in this section indicates that counties in which the refi boom before June 2003 was more pronounced ended up with more non-conforming purchase mortgages to feed private label securitizations in 2004. Moreover, these mortgages were priced more favorably in those same counties. The negative correlation between quantity and price of these new mortgages, conditional on the size of the refi wave, leads us to conclude that booming refinancing activity was one of the sparks behind the shift in credit supply towards non-conforming mortgages that reached its apex in 2005. The effect of refinancing in our regressions is additional to the already well-documented one associated with the level of income. One hypothesis consistent with this evidence is that the shift in the relative supply of mortgages reflected the desire of mortgage lenders not to reduce the scale of operations reached during the refi boom, as suggested for instance by [Levitin and Wachter \(2012\)](#).

Our analysis leaves open the question of why mortgage lenders waited to originate non-conforming loans on a large scale until the summer of 2003. If that market was profitable, why not push into it earlier? One possibility is that the surge in business generated by refinancing over the previous two years was more than sufficient to keep them occupied and profitable. As the refinancing wave surged, issuing non-conforming loans became gradually more attractive and accessible, for reasons that have already been explored in the literature (e.g. [Shin, 2012](#), [Bernanke et al., 2011](#), [Foote et al., 2012](#)). By the time the refi wave crushed and the need for alternative sources of revenue became more urgent, lending to borrowers that did not qualify for conforming mortgages had become a more viable option than it was before the refi boom. This push into new markets is also confirmed by the findings of [Scharfstein and Sunderam \(2015\)](#), who document a sharp increase in competitive pressures in local mortgage markets between 2003 and 2004 (see figure 1 in their paper).

6. CONSEQUENCES FOR LOAN QUALITY

The evidence presented so far suggests that the summer of 2003 witnessed a shift in the supply of credit towards marginal borrowers, marking a crucial turning point in the

evolution of the mortgage boom. One of the most significant implications of this shift is the eventual deterioration in the performance of mortgages originated over the period, as documented for instance by [Demyanyk and Van Hemert \(2011\)](#), [Foote et al. \(2012\)](#), [Santos \(2015\)](#) and [Palmer \(2015\)](#).¹⁴ This section contributes to this literature by demonstrating that this process of progressive deterioration in the quality of originations started in the middle of 2003, right after the emergence of the mortgage rate conundrum.

Figure 6.1 offers a preliminary look at the raw loan performance data, from the dynamic version of the PLSD. The figure plots the fraction of mortgages becoming delinquent within 2, 3 and 4 years of origination, as a function of their date of origination. In this analysis, we define a mortgage as delinquent if its payments are sixty or more days late, or if it is reported as being in foreclosure, real-estate-owned, or in default. The figure shows that delinquency rates were on a declining trend for loans originated through the first half of 2003, but this trend reversed in the summer of 2003. Mortgages issued around 2006 performed especially poorly, as is well known, also due to the subsequent plunge in property values and deep recession.

To control for the impact of these time-varying economic conditions, we follow [Demyanyk and Van Hemert \(2011\)](#) and study the frequency of mortgage delinquencies by estimating a proportional odds model of the form

$$(6.1) \quad p_{i,t,a} = \Lambda \left(d_a + d_t + z'_{i,t} \theta + w'_{i,t,a} \xi \right),$$

where Λ is the cdf of the standard logistic distribution. In this equation, $p_{i,t,a}$ denotes the probability that loan i , originated in quarter t , becomes delinquent for the first time at age a ; $z_{i,t}$ and $w_{i,t,a}$ are two sets of controls that include all the loan and borrower characteristics listed in table 1, as well as the percent changes in income and house prices between t and $t + a$ in the county where the mortgage was issued; d_a and d_t are the coefficients on age and origination dummies. Our baseline estimation of model (6.1) uses a 40 percent random sample of the PLSD mortgages, rather than focusing only on one million subprime loans as in [Demyanyk and Van Hemert \(2011\)](#). In addition, we track mortgage performance for up to four years after origination, since we have now been able to observe the loans for longer.

¹⁴[Ospina and Uhlig \(2017\)](#) study the implications of this deterioration in mortgage performance on the losses sustained by private-label MBS, based on a carefully constructed dataset that includes the near universe of non agency securitizations up to 2013. They find that MBS losses were roughly stable up to 2003, but started increasing for securities issued after 2004, especially for the lower rated tranches (see their Figure 6).

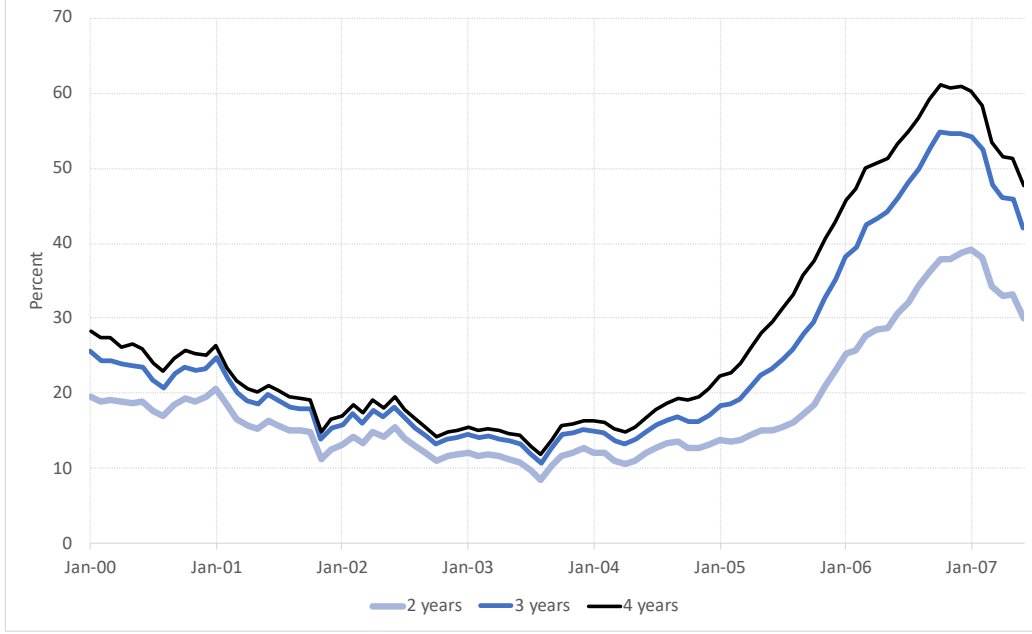


FIGURE 6.1. Delinquency rates within 2, 3 and 4 years of origination, as a function of the origination date.

This yields a sample of 95 million quarterly performance records. Finally, we estimate the effect of quarterly, rather than annual, origination dummies, to gain some insights into what happened in 2003.

The first panel of figure 6.2 visualizes the estimated impact of loan and borrower characteristics ($z_{i,t}$) on the probability of delinquency within 2 to 4 years, for mortgages issued since 2000. The evolution of these observable traits leads to a decline in delinquency rates up to the middle of 2003, and to a slow increase afterwards. Towards the end of 2006, observable characteristics again contribute to push delinquency rates down, since the onset of the financial crisis led originators to tighten their standards. The process of progressive deterioration in credit quality starting in the middle of 2003 is even more evident when focusing on the unobservable factors, captured by the origination dummies (d_t). This is illustrated in the second panel of 6.2, which plots the estimated vintage effect on the cumulative delinquency rates. This effect is constant for the early origination vintages, but it starts increasing steadily right after the summer of 2003.¹⁵

¹⁵As described in equations (10)-(12) of [Demyanyk and Van Hemert \(2011\)](#), the cumulative probability of delinquency within A quarters of origination is equal to one minus the survival rate, i.e. $P_{t,A}^j \equiv 1 - \prod_{a=0}^A (1 - \pi_{t,a}^j)$. To visualize the role of observable characteristics and the vintage effect, figure 6.2 plots $P_{t,A}^o$ and $P_{t,A}^u$, computed using $\pi_{t,a}^o = \Lambda \left(\Lambda^{-1}(\bar{\pi}_a) + \bar{z}_t' \hat{\theta} - \bar{z}' \hat{\theta} \right)$ and $\pi_{t,a}^u = \Lambda \left(\Lambda^{-1}(\bar{\pi}_a) + \hat{d}_t - \bar{d} \right)$ respectively. In these expressions, $\bar{\pi}_a$ is the unconditional frequency of experiencing a first-time delinquency

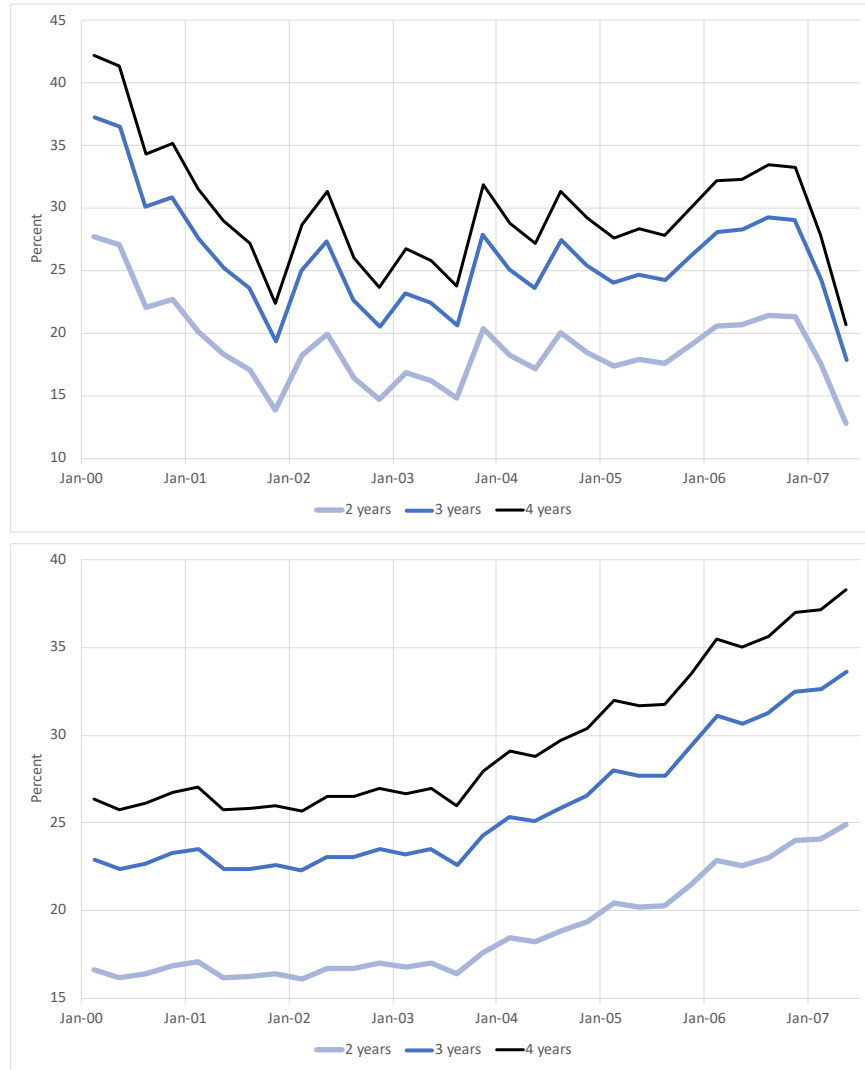


FIGURE 6.2. Estimated effect of observable loan/borrower characteristics (upper panel) and vintage dummies (lower panel) on 2, 3 and 4-year cumulative delinquency rates.

These findings suggest that the (conditionally) cheaper mortgages originated after the summer of 2003 were of progressively lower average quality, as measured by their ex-post performance. This lower quality was partly reflected in some of their observable characteristics included in equation (6.1). For instance, there was an increase in the incidence of mortgages with no documentation and with non-traditional features such as low amortization. In addition, figure 6.2 indicates that a notable deterioration in credit quality happened

at age a , $\hat{\theta}$ is the estimate of θ , $\bar{z}_t$ is the time- t average of the observable loan and borrower characteristics, $\bar{z}$ is the mean of $\bar{z}_t$ over time, $\hat{d}_t$ are the estimated coefficients on the origination dummies, and $\bar{d}$ is their mean over time.

along dimensions that are not spanned by the controls, and that are captured instead by the origination dummy.¹⁶

In summary, the sharp and persistent decline in conditional mortgage rates underlying the conundrum was accompanied by a worsening of the observable and unobservable quality of the credit being extended. A natural interpretation of these facts is that the summer of 2003 witnessed a shift in the supply of credit that ultimately resulted in the origination of mortgages with lower interest rates and of worse overall quality. As shown in section 5, a majority of these mortgages were non-conforming and were thus absorbed by private-label securitization pools. The fact that an important dimension of these loans' lower quality was not publicly observable helps to explain why these MBS performed especially poorly.

7. THE MORTGAGE RATE CONUNDRUM: ADDITIONAL RESULTS

This section provides some additional results on the behavior of the aggregate conditional mortgage rate spread. In particular, we show that the conundrum (i) reflects a tightening of credit conditions in the Treasury market, as captured by changes in the factors included in f_t , rather than an abrupt fall in mortgage interest rates; (ii) is robust to an alternative forecast-based estimation strategy; (iii) is common to prime, Alt-A and subprime mortgages, but more pronounced for the latter; and (iv) was not due to a sudden composition shift in the pool of mortgages in our dataset.

7.1. Credit conditions in the Treasury and mortgage markets. This subsection documents that the abrupt fall in the average conditional spread in the middle of 2003 was not primarily due to a sudden reduction in mortgage rates, but to changes in the conditioning factors. To illustrate this result, we re-estimate equation (3.1) in two steps. In the first step, we estimate the model substituting the aggregate factors, f_t , with a set of monthly time dummies instead. By construction, these dummies force the cross-sectional average of the regression residuals to be zero in each month. Figure 7.1 plots the coefficients on the time dummies in the baseline specification that includes all mortgages

¹⁶The vintage effects plotted in the lower panel of figure 6.2 could also be interpreted as reflecting a disconnect between the ex-ante pricing of the mortgages and their ex-post performance. This mispricing may have been due to outright fraudulent reporting by originators, of the kind documented by Griffin and Maturana (2016) and Mian and Sufi (2017), under-estimation of the true credit riskiness by lenders, as in Landvoigt (2016), or overly optimistic beliefs about future home price appreciation, as in Landvoigt (2017) and Kaplan et al. (2020). However, the results in section 4.2 on the role of the housing supply elasticity in the conundrum cast doubts on this latter possible source of mispricing.

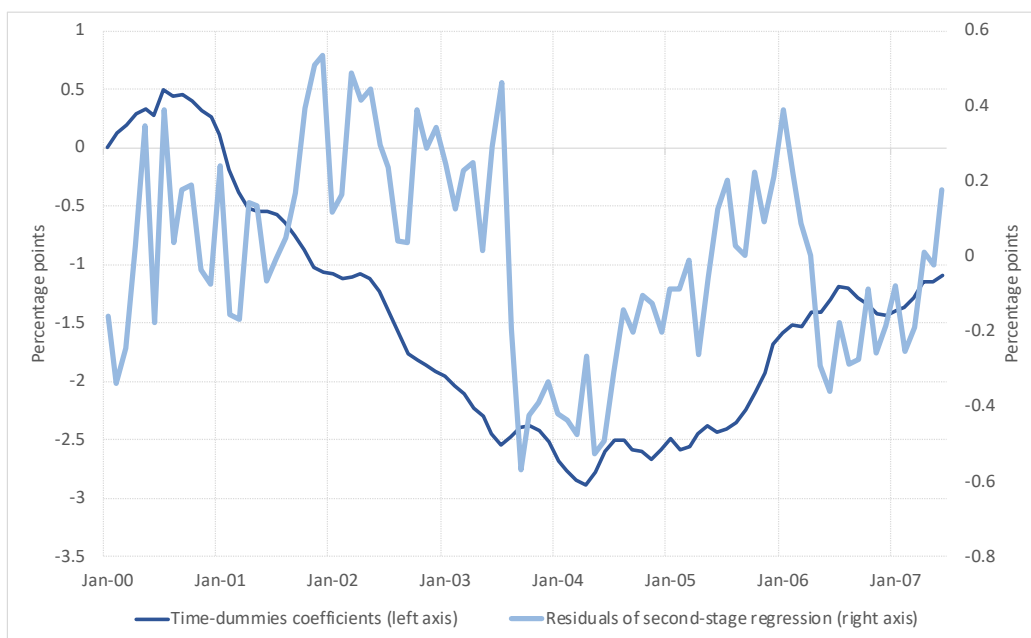


FIGURE 7.1. Estimated coefficients on monthly time dummies and residuals of second-stage regression on Treasury and volatility factors.

in our sample. This time series captures the evolution of average mortgage rates (up to a constant term), after controlling for all the loan and borrower characteristics included in $x_{i,t}$. This average conditional mortgage rate falls steadily between mid 2001 and mid 2004, by about 3.5 percentage points in total, consistent with the idea that mortgage credit became significantly cheaper over this period.

Of course, conditions in the Treasury market were also changing at the same time, which accounts for the bulk of the movements in the time-dummy coefficients. To control for the effect of these changes in the Treasury market, the second step of the procedure is to regress the time effect on the term-structure and volatility factors f_t .¹⁷ Figure 7.1 plots the residuals of this second-stage time series regression, which look very similar to the average residuals of the baseline regression reported in figure 4.1.

Comparing the two series in figure 7.1, we see that the abrupt fall in residuals that occurs in mid 2003 was not due to a sudden fall in average conditional mortgage rates. The time effect briefly stops falling around that time, and even rises somewhat for a few months, but this movement is swamped by the drop in the residuals. Therefore, from this evidence we

¹⁷The R-squared of this regression is 92 percent. In principle, this procedure suffers from a generated-regressor problem, but we have so many observations that the standard errors of the coefficients on the time dummies are effectively zero.

conclude that credit conditions tightened significantly in the Treasury market, as a response to the end of the monetary policy easing cycle in June 2003. But mortgage rates barely moved in response, giving rise to the conundrum.

7.2. A counterfactual exercise. We now use a counterfactual experiment to show that the evidence of a disconnect between mortgage and Treasury rates after the summer of 2003 is robust to alternative estimation strategies. This exercise is motivated by the fact that the estimated model (3.1) fits the data better between 2000 and mid 2003 than afterwards. In particular, the average residuals over the pre-2003 period appear to fluctuate around a constant without any clear pattern. This discontinuity in mid 2003 suggests that the peculiar dynamics in the second part of the sample might be due to a break in the coefficients of equation (3.1).

To investigate this possibility, we first estimate our baseline specification with data from 2000 to June 2003. We then project mortgage rates after mid 2003 conditional on the estimated coefficients and the realizations of the regressors after mid 2003. Figure 7.2 plots the average difference between the actual and projected values of the mortgage rates. In the first part of the sample, this difference is just the average of the regression residuals, which fluctuates around a roughly zero mean. After mid 2003, however, a large and persistent discrepancy between actual and projected rates emerges. This discrepancy has a similar magnitude and time series pattern as the residuals plotted in figure 4.1. It hovers between 60 and 80 basis points into 2005, and it reverts to positive territory only in 2006. This result confirms that mortgage rates after the summer of 2003 were substantially lower than what would have been predicted based on the behavior of aggregate factors, and of observable loan and borrower characteristics.

7.3. Prime, Alt-A and subprime mortgages. Our next take on the extent of the conundrum in the time-series consists of distinguishing among the main types of mortgages in our sample: prime, Alt-A, and subprime mortgages. This cut of the data is partly motivated by the focus on subprime mortgages as an important conduit of the boom. Figure 7.3 plots the evolution of the average conditional mortgage rate spread in alternative specifications of equation (3.1), which separate the three kinds of mortgages. The drop in residuals in the summer of 2003 is evident in all these specifications. However, it is more

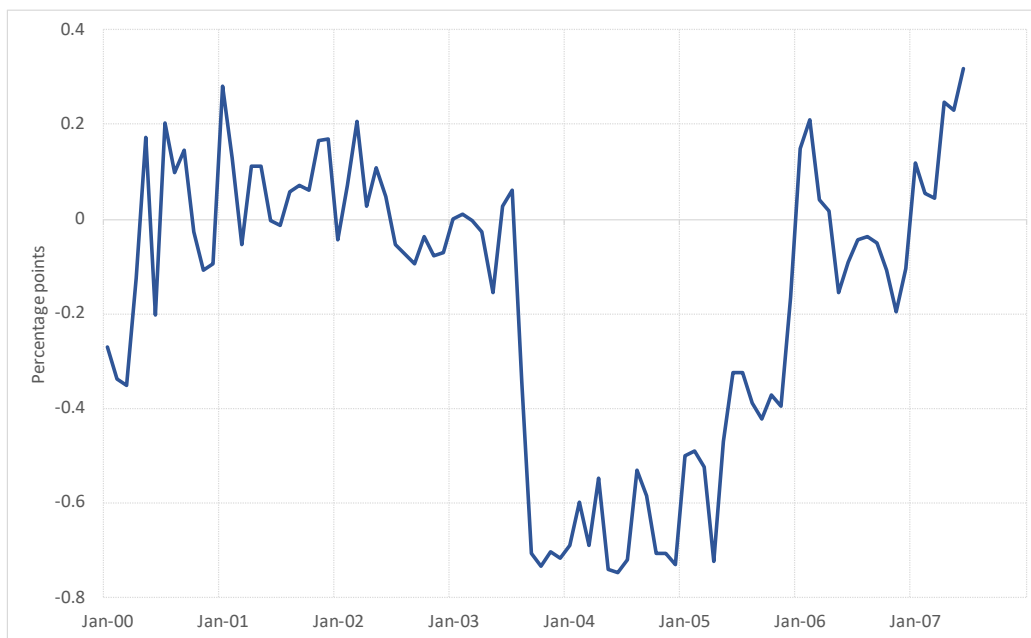


FIGURE 7.2. Average difference between actual and counterfactual mortgage rates.

pronounced for subprime mortgages, consistent with the evidence in [Demyanyk and Van Hemert \(2011\)](#).¹⁸

7.4. Composition shifts. Our last exercise addresses the concern that the rapid fall in residuals around the summer of 2003 might in part reflect shifts in the composition of the pool of mortgages in our dataset. To this end, we construct an alternative measure of the conditional mortgage rate spread, obtained as a monthly weighted average of the mean residual across eighteen mortgage bins, with weights corresponding to the sample share of each of these categories between January 2000 and May 2003. These mortgage bins are defined by interacting prime, subprime and alt-A indicators with the six contract types listed in table 1. These are the dimensions in which the sample composition appears to be changing the most around 2003, albeit smoothly. Figure 7.4 compares this alternative version of the spread with our baseline. The very small differences between these two measures indicate that compositional changes are unlikely to be a major driver of the evolution of the conditional spread in the summer of 2003 and afterwards.

¹⁸In a previous version of this paper, we used data from the Residential Mortgage Servicing Databases to study the existence of a mortgage rate conundrum also among mortgages sold to the GSEs or held in banks portfolios ([Justiniano et al., 2017](#)). We found that the conditional spread on agency and portfolio loans also declined in 2003, but by a smaller amount and less abruptly than for mortgages in the PLSD. This finding suggests that the conundrum was primarily a feature of mortgages in private-label securitizations.

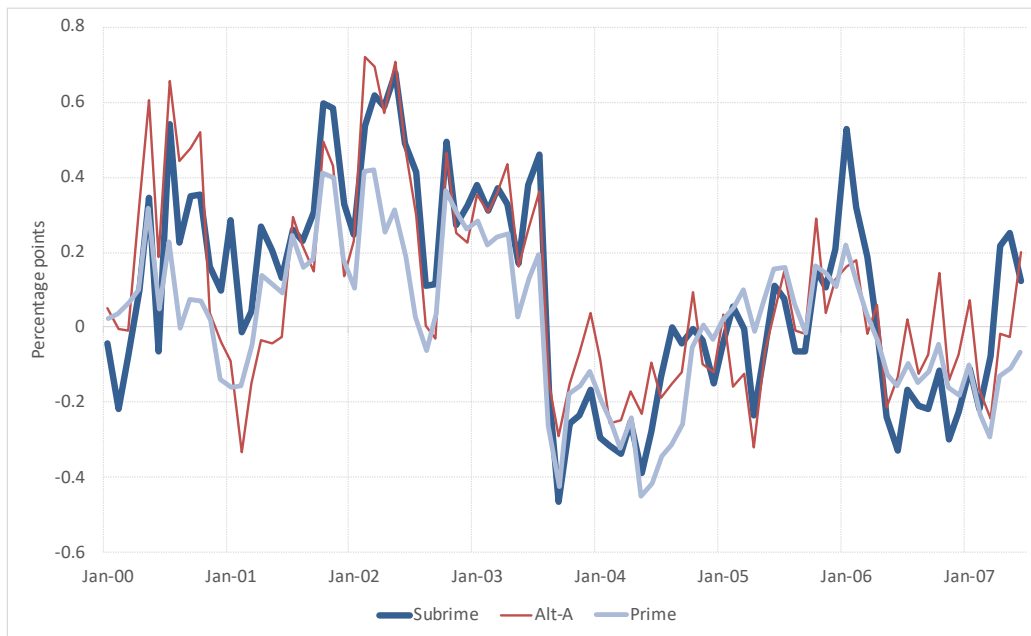


FIGURE 7.3. Average residuals by collateral type.

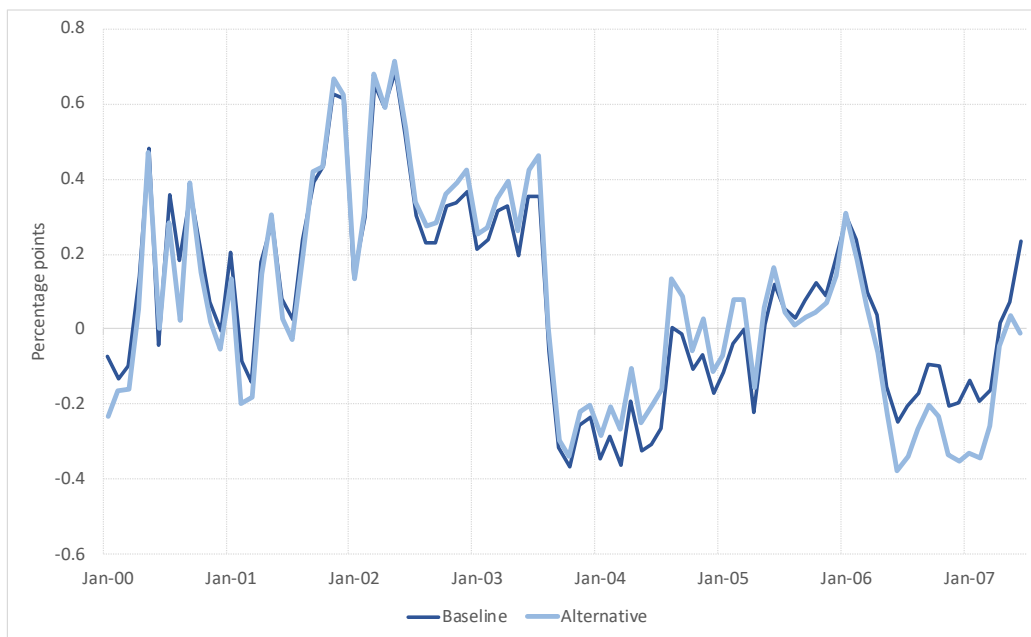


FIGURE 7.4. Average residuals: baseline and alternative measure using the pre-June-2003 weights of eighteen mortgage categories.

8. CONCLUDING REMARKS

This paper contributes to the literature documenting the shift in the supply of credit towards marginal borrowers during the U.S. housing boom. By focusing on loan-level interest rates, our contribution to this literature is a sharper identification of the timing of this discontinuity, and of an important factor behind it. In terms of timing, we pinpoint the emergence of a mortgage rate conundrum—a sharp and persistent disconnect between mortgage and Treasury interest rates—in the summer of 2003. In terms of drivers, we empirically link the conundrum, and the accompanying shift in the supply of credit towards privately securitized mortgages to the attempt of originators to sustain their level of activity following the collapse of their refinancing business. We also show that this shift was associated to a progressive deterioration in the quality of new mortgages, as indicated by their subsequent worsening performance.

Given its focus on interest rates, our analysis also provides a new perspective on the role of monetary policy during the credit boom. According to a popular narrative (e.g. [Taylor, 2007](#)), the Federal Reserve enabled the boom by keeping the policy rate “too low for too long” after the recession of the early 2000s, especially during the “measured” tightening cycle that started in June 2004. According to our results, this narrative misses a crucial element: after the summer of 2003, mortgage rates fell by up to 100 basis points *relative* to Treasuries. This observation suggests that further reconstructions of the chain of events that drove the most disruptive phase of the credit boom should focus more on the incentives of the mortgage industry around the summer of 2003, as it reacted to the end of the easing cycle.

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FEDERAL RESERVE BANK OF CHICAGO

Email address: ajustiniano@frbchi.org

NORTHWESTERN UNIVERSITY, CEPR, AND NBER

Email address: g-primiceri@northwestern.edu

FEDERAL RESERVE BANK OF NEW YORK

Email address: a.tambalotti@gmail.com