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ABSTRACT

In the U.S. mortgage market, private mortgage insurance (PMI) is mandated for high-leverage mortgages purchased by Fannie Mae and Freddie Mac to serve as a private market check on GSE risk-taking. However, we document that PMI firms dramatically expanded insurance on high-risk mortgages at the tail-end of the housing boom, contradicting the industry's own research regarding house price risk. Using three detailed sources of mortgage and insurance data, we examine PMI application denial rates, default rates on PMI-backed loans, and growth rates of high-leverage lending around the GSE conforming loan limit, along with information extracted from company, industry and regulatory filings and reports. We conclude that PMI behavior during the housing boom in part reflects a "moral hazard" incentive inherent to insurance companies in general to underprice risk and be undercapitalized. Our results suggest that rather than providing discipline, private mortgage insurers facilitated GSE risk-taking.

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> "Mortgage insurers were designed to be review underwriters. Because they are in the first loss position on insured mortgages, they are the second set of eyes looking at potential loans to check and see if it is safe for both the investor and the borrower."
> –Mortgage Insurance Companies of America (MICA) 2008–2009 Factbook

I Introduction

In banking and financial markets, the government often plays a role as a guarantor to help ensure market stability and confidence. One well-known example is federal deposit insurance. Another example is in residential mortgage markets, where the government implicitly and explicitly guarantees investments in certain mortgage-backed securities (MBS). While these guarantees can provide essential countercyclical liquidity support, the presence of a guarantee can also blunt the incentives of market participants to monitor intermediaries and accurately price risk. To help restore market discipline, the government may require a significant involvement of private capital that does not receive government protection.

Two giants of the U.S. mortgage market that have benefited from implicit government backing are Fannie Mae and Freddie Mac, collectively known as Government-Sponsored Enterprises, or GSEs. The GSEs purchase loans from lenders, bundle them into MBS, and provide a credit guarantee that protects investors against losses. Investors perceived the GSEs' credit guarantee to be as good as a government guarantee because of the tight link between the GSEs and the federal government (Acharya, Richardson, Van Nieuwerburgh and White 2011). Given this guarantee, investors had little incentive to monitor the GSEs or constrain profit-driven risk-taking. To help overcome these incentive incompatibilities, Congress requires the GSEs to obtain a private market "credit enhancement" for high-leverage mortgage loans.

The most common form of credit enhancement is private mortgage insurance, or PMI. Private mortgage insurers partially cover the losses incurred from a mortgage default. When a high loan-to-value ($LTV > 80\%$) mortgage is securitized through Fannie Mae or Freddie Mac, PMI takes a first-loss position in front of the GSEs. PMI companies are independent firms, and can set their own underwriting standards and review loans prior to origination. If PMI companies were unwilling to insure a high-LTV loan, it would be ineligible for purchase by the GSEs. The PMI industry frequently touts its role in providing market discipline as a "second set of eyes," as in the above

quote (MICA 2009).

In this paper we show that, rather than providing restraint, PMI companies facilitated a dramatic expansion of risky lending by the GSEs in 2007. Employing rarely used data on the universe of PMI applications, along with loan-level data reported under the Home Mortgage Disclosure Act (HMDA) and from mortgage servicers, we document several troubling facts about PMI activity during the housing boom. First, PMI issuance grew sharply — by nearly 50 percent — in 2007, at the tail-end of the housing boom when fears of a housing downturn were elevated. This surge in issuance pushed the fraction of home purchase loans covered by PMI to historic levels.

Second, PMI issuance grew disproportionately in cities where the PMI industry's own published research indicated the highest levels of housing risk. Moreover, PMI issuance grew disproportionately in 2007 in the riskiest types of loans, such as those with zero down payment, and for the riskiest types of borrowers, with both low FICO scores and small down payments (high LTV ratios).

Third, we demonstrate that PMI growth in 2007 was closely connected to declines in "piggyback" lending — junior liens combined with standard 80 percent LTV first liens at the time of origination. In 2005 and 2006, piggyback lending became heavily used, with these loans usually going into private-label (non-GSE) MBS. The piggyback lending market dried up in late 2006, indicative of other private participants being no longer willing to bear high-LTV risk. Indeed, the PMI industry research noted above argued that areas with high concentrations of piggyback loans were the places most likely to experience near-term house price corrections (Calhoun 2005). Nonetheless, PMI growth occurred precisely when piggyback lending retrenched, and we document a strong negative correlation at the neighborhood (census tract) level between PMI and piggyback growth from 2006 to 2007.

Fourth, this sharp increase in risk exposure in 2007 was not associated with any change in insurance premiums. Based on rate sheets obtained from this time period, we confirm that insurance premiums were based largely on LTV, with constant pricing within LTV bins across much of the credit score distribution, and that prices based on leverage were essentially unchanged from 1996 to 2008. Notably, PMI firms did not price regional risk, despite the industry's awareness of substantial differential likelihoods of house price declines across metro areas.

Rapid expansion in issuance at the height of the boom contributed to a dramatic collapse of

the PMI industry. Loss ratios ballooned starting in 2008, and three of the eight firms in the market failed and were unable to fully pay out their insurance claims. Other PMI companies sharply increased their rescission rates, denying claims at a rate of 20 to 25 percent in 2008 and 2009. Elevated use of rescissions, along with regulatory forbearance from state-level regulators and the GSEs, were crucial for the remaining PMI firms to survive the Great Recession.

The first half of the paper documents this set of facts, while the second half of the paper explores potential explanations for why the PMI industry took on so much risk (and facilitated GSE risk-taking) in 2007 despite having the tools to discipline the market. We believe that the unraveling of the mortgage insurance industry likely reflects a general moral hazard issue associated with many types of insurance providers, coupled with market structure deficiencies peculiar to the GSE portion of the mortgage market.

The moral hazard problem stems from the fact that insurance companies collect premiums today, while payments on claims are not due until sometime in the future (Thompson 2010, Bohn and Hall 1999). With this "inverted production cycle," competition for premiums may lead insurers to take on excessive risk, especially given their limited liability (Plantin and Rochet 2009), a market feature we explore in our model of mortgage lending and insurance (presented in Section II.C). In many insurance markets, regulation and/or sophisticated counterparties (i.e. insurance beneficiaries) may help keep these "race to the bottom" competitive pressures in check (Henderson 2009). However, private mortgage insurers were lightly regulated at the state level, and the primary beneficiaries of mortgage insurance, the GSEs, had distorted incentives due to their implicit government backing. In sum, PMI companies had an inherent and largely unrestrained incentive to take excessive risk, potentially reinforcing rather than checking the risk-seeking incentives of the GSEs.

We provide several pieces of evidence in support of this interpretation. To begin, we show that as the housing market heated up in the early 2000s, denial rates on mortgage insurance applications plummeted to nearly zero. Despite promoting their role as review underwriters with a "second set of eyes," PMI companies sharply curtailed their ex-ante review of loan applications to speed up the approval process. Moreover, they also appear to have aligned their underwriting with the GSEs', ceding their independence. As described in an annual filing of one of the largest mortgage insurers, some PMI companies began automatically approving any loan that the GSEs were willing

to purchase, despite the fact that PMI companies were taking the most risk as first-loss holders.[1]

While the alignment of the PMI companies with the GSEs could conceivably reflect the market power of the GSEs, rather than moral hazard on the part of PMI companies, we also observe a reduction over time in denial rates for insuring "jumbo" loans — larger loans ineligible for purchase by the GSEs. In addition, we see little difference in the performance of loans with PMI just above and below the jumbo loan size threshold (conforming loan limit). These findings suggest that PMI companies loosened their standards considerably even for non-GSE loans.

Nonetheless, the vast expansion of PMI in 2007 reflects the combined willingness of the PMI companies and the GSEs to take on additional risk. Our data show that the PMI expansion of 2007 came almost entirely from an expansion of insurance on GSE loans. PMI issuance for home purchase loans increased by nearly 50 percent in 2007 from 2006, with 90 percent of that increase going towards insuring GSE-purchased loans. The link between the GSEs and PMI growth in 2007 can be seen most clearly around the conforming loan limit, where the data reveal a large, discontinuous drop in PMI growth above the loan limit.

Moreover, we provide evidence that the overall supply of high-LTV loans collapsed in 2007 for non-GSE-eligible loan sizes. In 2007, high-LTV lending shifted back from piggybacks to PMI, but only below the GSE conforming loan limit. In contrast, above the conforming limit, we find that there was a sharp reduction in the use of piggybacks and no offsetting increase in the use of PMI. Taken together, these results imply a tightening of credit from the private market in the face of heightened housing market risk in 2007, while the GSEs and PMI companies together sharply expanded their high-risk lending. We explore a number of alternative explanations and interpretations of these patterns, including the role of the GSEs' Congressionally-mandated Affordable Housing Goals, managerial mistakes, lender market power, and possible "gambling for resurrection" motives of PMI firms.

Our paper represents the first empirical examination of PMI market issuance and its interaction with the GSEs during the housing boom. Surprisingly, there has been little attention paid to the mortgage insurance market, despite its size and importance. Thomas and Van Order (2011) argue that the main cause of the GSEs' failure was the risky loans they purchased and guaranteed in

[1] See MGIC's 2007 10-K filing to the SEC.

2006 and 2007, as opposed to their subprime investments or retained portfolios, but they do not analyze the role played by PMI firms. Agarwal, Ambrose and Yao (2016) and Park (2016) compare the performance of PMI-covered loans to high-LTV Fannie Mae loans and FHA loans, respectively, finding that PMI performed relatively more poorly, on average, in both cases. Concurrent work by Liu (2017) argues that the GSEs were more conservative in their underwriting than PMI companies in 2006, but this argument assumes that the GSEs were not exposed to risk on PMI-insured loans. As we describe later, PMI only partially insures the GSEs against default losses, and the GSEs faced substantial counterparty risk if the insurers failed. Another concurrent paper by Kahn and Kay (2017) compares the pre-crisis and post-crisis pricing models of the PMI industry to document that insurance was substantially underpriced during the boom, consistent with our evidence that pricing was largely constant over time in this market. Our paper provides new empirical evidence on the quantity side of the market, concretely establishes the ex-ante cross-sectional expectations held by these firms, and connects issuance patterns in 2007 to the collapse of the industry.

Our work provides some of the first analysis of the distorted incentives faced by insurers. Unlike traditional insurance discussions where policyholders may take on excessive risk, (e.g. health or auto insurance), in this paper we emphasize that insurers themselves face incentives to generate business by underpricing risk, and to be undercapitalized for future potential claims (see, e.g., Bohn and Hall 1999, Thompson 2010, Acharya et al. 2009). Similar phenomena have been documented in the underpricing of catastrophe risks such as floods (Froot 1999, Jaffee and Russell 1997, Michel-Kerjan 2010).[2] Notably, the risky insurer behavior that we document occurs in the absence of any state-level guaranty funds or implicit bailouts for these private firms.

Our findings also have implications for GSE reform and optimal risk sharing in the $10 trillion U.S. residential mortgage market. Many recent proposals attempt to remove the GSEs from the center of the market and encourage entry of private participants.[3] PMI is currently protected under the GSE charters, but the recent episode we document calls into question whether risk in the mortgage market is being shared optimally (Borch 1962), especially in the presence of moral hazard (Doherty and Smetters 2005). We show that instead of serving as a check on GSE risk-taking, PMI

[2]In corporate finance, this issue is similar to the treatment of free cash flow raised by Jensen (1986), Stein (1988), and Blanchard, Lopez-de Silanes and Shleifer (1994), among others.

[3]See, for instance, Parrott, Ranieri, Sperling, Zandi and Zigas (2016), as well as recent proposals by the Treasury/HUD in 2011 and the Mortgage Bankers' Association in 2017.

companies introduce counterparty risk and require costly monitoring. Moreover, they are not necessarily better able to diversify or underwrite risk relative to the GSEs, which are traditional arguments for the benefits of reinsurance (Plantin 2006). In contrast, an alternative approach to private participation is for the GSEs to sell risk outright through derivatives contracts known as credit risk transfers (CRT). In Section VI, we discuss the tradeoffs between these two approaches for private participation in the mortgage finance market in light of our findings on PMI.

In the next section, we provide background on the microstructure of the mortgage insurance market and the incentives of market participants, as well as a stylized model of mortgage lending and insurance. In Section III, we describe the loan-level datasets we use to analyze PMI issuer decision-making, while Section IV documents the expansion of PMI issuance in 2007, along with the consequences of the concomitant increase in firms' risk exposure. In Section V, we explore potential mechanisms that drove the increase in risk-taking. Section VI concludes with implications for the structure of the mortgage market.

II Background on Private Mortgage Insurance

II.A The Basics of Private Mortgage Insurance

Mortgage lenders often require prospective borrowers to pay for mortgage insurance if they do not make a down payment of at least 20 percent of the cost of their home. Loans with relatively small down payments have a higher risk of default and are more likely to generate losses in the event of default. Mortgage insurance protects lenders against these default losses. Both private mortgage insurance (PMI) companies and the Federal government, primarily through the Federal Housing Administration (FHA), sell mortgage insurance. PMI companies stand in a first-loss position, usually insuring 20 to 30 percent of the loan balance against default-related costs such as any unpaid principal balance, legal fees, accumulated taxes and interest, and potential home maintenance costs.[4]

Most private mortgage insurance policies are issued on a "flow" basis — that is, loan by loan as they close — and premiums are charged directly to borrowers, on top of monthly principal and

[4]In contrast, FHA insurance covers 100 percent of losses.

interest payments. To a lesser degree, PMI companies may sell "bulk" and "pool" insurance for groups of existing mortgages in portfolios or mortgage-backed securities. Under the Homeowners Protection Act of 1998, PMI coverage can be canceled once borrower equity reaches 20 percent, and must be automatically terminated at 22 percent equity for borrowers in good standing.

When a loan is originated, the PMI policy covers the party that bears the default risk – lenders for loans kept in portfolio; MBS investors for loans sold into private label securities; and the GSEs for loans sold into agency MBS. A large fraction of the core, flow-basis PMI policies insure loans purchased by the GSEs. The close connection between PMI companies and the GSEs stems from the fact that the charters of the GSEs mandate the use of PMI (or another type of external credit enhancement) on loans that have LTV ratios over 80 percent. From 2001 to 2007, about 60 to 70 percent of PMI policies issued supported GSE-insured loans.[5]

The PMI industry is composed of just a few large private institutions — eight during the period we study — which must meet certain financial requirements to be eligible to insure GSE-purchased loans. Prior to the financial crisis, the GSE eligibility requirements included levels of capitalization, risk-to-capital ratios, and maintaining certain credit ratings. In addition to GSE eligibility standards, the PMI firms are regulated by state insurance departments. PMI companies are required to operate on a "monoline" basis, providing insurance coverage for a single risk, and all mortgage insurance premiums must be used to cover mortgage default-related losses (Jaffee 2006).

States generally require firms to have a maximum risk-to-capital ratio of 25-to-1 (not risk-weighted), reserve 50 percent of premiums (if possible) for ten years, and place restrictions on extraordinary dividend payments. Firms are also subject to periodic examinations and accounting audits by state insurance regulators. Based on data from the Mortgage Insurance Companies of America, the industry's risk-to-capital ratio was close to 10-to-1 at the end of 2006 (MICA 2009). Examining loss given default for PMI in the early 1990s when there was another sizable housing downturn, Qi and Yang (2009) find that for loans with LTV ratios of 95 percent or higher, average losses exceeded 30 percent of unpaid balance, thereby exhausting PMI coverage.

Maintaining a 10-to-1 unweighted risk-to-capital ratio, while well within most states' statutory requirement, put the PMI firms in a highly levered position and exposed the GSEs to substantial

[5]See Appendix Table A-1 for detailed summary statistics.

losses in the event of a downturn.[6] Rather than building up large reserves during the housing boom, when loan performance was relatively strong, industry reports suggest that about 60 to 65 percent of premium revenue went to total expenses, including claims. For instance, in 2006, the industry's loss ratio (claims divided by net premiums earned) was 41 percent, while the expense ratio (all other expenses divided by net premiums earned) was 24 percent (MICA 2009). These values imply that PMI firms could reserve, at most, just 35 percent of premiums, well below the regulatory target of 50 percent. In fact, we estimate from the data reported by MICA (2009) that only about 18 percent of premiums went into reserves.[7] Most of the remaining 17 percent of premiums likely went to shareholders via dividends and stock buy-back programs.

Insurance premiums in this market were based largely on leverage, with price and coverage varying for LTV ranges (e.g. 81-85 percent, 86-90 percent, etc.). During the period we study, available information indicates that annual PMI premiums ranged from 30 to 120 basis points of the loan amount. While some PMI firms differentiated premiums based on credit score or other loan or borrower attributes, others priced their flow policies based almost exclusively on the LTV ratio. For example, in Appendix Figure A-1, we reproduce the rate sheet for the monthly premiums charged by mortgage insurer MGIC as of March 2006.[8] In 2006, for standard full-documentation borrower-paid mortgage insurance, MGIC did not differentiate their pricing by FICO score for scores between 620 and 800, despite the large differences in risk across the credit score spectrum.[9]

Most notably, prices based on leverage were essentially unchanged from 1996 to 2008, despite large changes in underwriting technology, competition from second liens, and tax equalization with the introduction of deductibility of insurance premiums over this time period. Over this period, as shown by Kahn and Kay (2017), PMI firms sharply expanded the range of borrowers and products which they were willing to insure over the 2000s. In addition, similar to the GSEs, PMI firms did

[6] See also the discussion in United States Federal Housing Finance Agency (2009).

[7] MICA (2009) reports that from 2005 to 2006, net risk in force increased from $150 billion to $158 billion, while the risk-to-capital ratio went up slightly from 8.91 to 9.04. These numbers imply that capital increased by about $600 million, or 18 percent of the $3.6 billion in net premiums earned in 2006. We estimate a similar percentage reserved for 2005.

[8] Accessed through the Internet Wayback Machine at `http://web.archive.org/web/20060603192958/http://www.mgic.com:80/pdfs/71-6704.pdf`. We have also obtained rate sheets covering our sample period from a large anonymous mortgage insurer. Additional pricing evidence can be found in OFHEO's 1997 Annual Report to Congress and data compiled by Jack Guttentag's "Mortgage Professor" website. See `https://www.mtgprofessor.com/A-PMI/sample_mortgage_insurance_premiums.htm` (accessed 2/20/2017).

[9] Kahn and Kay (2017) further explore mortgage insurance pricing, and find that there was no pricing differentiation for FICO scores above 660 prior to the crisis across a range of firms and time periods.

not price regional risk, despite the industry's awareness of differential risk of house price declines across MSAs (Milner 2006a, Hurst, Keys, Seru and Vavra 2016).

PMI companies can set their own underwriting standards and deny insurance applications for loans not meeting those standards. That said, a common practice was the use of "delegated underwriting agreements," whereby PMI firms delegate their underwriting to lenders and agree to insure loans that meet their joint standards. Furthermore, during the housing boom PMI companies generally insured any loan approved by the automated underwriting systems of the GSEs, even if those loans did not meet insurer's published guidelines.[10] For example, MGIC reported that from 2005–2007, over 25 percent of their insured loans were approved through automated underwriting software despite falling outside of their published underwriting guidelines in terms of credit scores, LTV ratios, loan documentation, or other contract or borrower characteristics.[11] This admission that the PMI companies' published underwriting standards were effectively overridden by the beneficiary of the insurance policy through the GSEs' automated software suggests that the incentive structure of the market is worthy of further exploration.

II.B Agency Problems and Informational Frictions in Mortgage Insurance

In this subsection, we examine the potential agency problems and informational frictions inherent in the mortgage insurance market structure. Any discussion of agency problems in the mortgage market necessarily begins with the implicit government guarantee provided to the GSEs, Fannie Mae and Freddie Mac (Acharya et al. 2011). The GSEs do not lend directly to households; rather, they purchase residential mortgages from banks and other lenders. The GSEs then pool these mortgages and issue "agency" MBS, passing along principal and interest payments from homeowners to investors, less a credit guarantee fee. The GSEs were for-profit, publicly traded companies, but were originally created by Congress. Through their government charters, the GSEs enjoy certain regulatory and tax benefits not available to other financial institutions, but also face unique Congressional oversight and expectations (Congressional Budget Office 2010). Because of this tight link

[10] For example, Triad Guaranty's 2006 10-K states, "We also accept loans approved through Freddie Mac or Fannie Mae's automated underwriting systems," and Mortgage Guaranty Insurance Corporation's 2007 10-K says, "From 2000 through January 2007, loans approved by the automated underwriting services of the GSEs were automatically approved for MGIC insurance."

[11] See MGIC's response to request for comments on credit risk retention, August 1, 2011, page B-2.

between the GSEs and federal government, MBS investors perceived the credit guarantee from the GSEs to be as a good as a government guarantee (Congressional Budget Office 2001). This guarantee allowed the GSEs to take on excessive risk and retain insufficient capital to protect against even a relatively small nationwide decline in house prices.

The GSE charter requires some form of credit enhancement from private sources on high-LTV loans, with the intention that other private entities not backed by the government would help discipline GSE behavior. By insuring high-LTV loans, shareholders of PMI companies are exposed to risk in a first-loss position. PMI firms can serve as market gatekeepers by not agreeing to insure overly risky loans, or pricing this risk appropriately, thereby imposing restraint on the market. However, as we discuss in the next subsection, PMI companies' willingness to impose restraint depends on how much capital they have at risk.

The insurance policies of the PMI companies are such that they collect certain premiums now, while facing an uncertain risk of payout in the future. In any insurance arrangement such as this one, firms have an incentive to write a large number of policies, collect substantial premiums, and under-reserve capital for future contingent payments (Bohn and Hall 1999). Moreover, the party with expertise and the most incentive to monitor the PMI companies is the GSEs, and by extension agency MBS investors. However, because MBS investors believed they were shielded from all credit losses by a government guarantee, they ultimately lacked the incentive to scrutinize the financial strength of PMI companies.[12]

The other participants in the market face incentives that generally support risk-taking. Despite paying the monthly premium, borrowers play no role in deciding which PMI company to use and are not beneficiaries of the insurance policy, leaving them unconcerned regarding PMI solvency. Lenders originate loans with the intention to distribute them to securitizers, and do not bear default (or counterparty) risk. Nonetheless, lenders choose which PMI company will provide the policy on a particular loan. Lenders choose PMI firms on the basis of price, speed of origination, and potentially other contract dimensions, as opposed to the financial strength of the PMI company.[13] Our data

[12]In Thompson (2010), lenders are able to incentivize insurers to hold more liquid capital, mitigating counterparty risk. However, lenders only engage in counterparty risk mitigation if they actually face significant costs from not doing so.

[13]In many cases, lenders made a "corporate allocation" at the beginning of the year to determine the volume of loans going to each PMI firm. The CFPB has brought charges against three PMI companies for providing kick-backs in the form of favorable reinsurance opportunities to lenders' captive reinsurance providers in exchange for business,

suggests that lenders typically spread their business across six or seven PMI firms, suggesting that lenders could easily move business from one PMI firm to another.[14]

II.C Stylized Model of Mortgage Lending and Private Mortgage Insurance

In this subsection, we provide a stylized framework of mortgage lending and private mortgage insurance in the (potential) presence of a government guarantee. Rather than modeling an optimally designed approach to sharing risk, we instead attempt to follow the logic of the current market as it exists in practice to help demonstrate where incentive issues arise. The participants are borrowers, lenders, investors, the government, and mortgage insurers. We first describe an equilibrium price and quantity of credit in the absence of government or private insurance, then add a government guarantee, and finally add insurers to the framework.

Borrowers demand for mortgage credit is increasing in the benefits of homeownership, b, and decreasing in the cost of borrowing, which is the sum of the interest rate, i, and insurance premium, m:

$$B^D = b - \mu(i + m) \tag{1}$$

First, consider a setting with no mortgage insurance, $m = 0$. Lenders arrange loans between investors, who provide capital for lending, and borrowers. To keep the model as simple as possible, we think of lenders as full-service intermediaries performing origination, servicing and securities issuance activities. Lenders receive a fee for these services, c, and are thus paid solely on loan volume, $B \times c$. There are two possible states of the world, a bad state where borrowers default and investors receive 0, which occurs with probability ϕ, and a good state where investors are repaid principal+interest in full, which occurs with probability $(1 - \phi)$. Given an outside option to invest in a risk-free bond that pays r^f, risk-averse investors set the mortgage interest rate i to satisfy:

$$r^f + r^p = (1 - \phi)(1 + i) + \phi(0) - (1 + c) \tag{2}$$

see CFPB (2013). Although the exact details of the reinsurance contracts are not publicly available, generally PMI firms were unable to reinsure their first losses. PMI firms distributed roughly 20% of their premium-based income to reinsurance providers.

[14] Panel A of Appendix Figure Figure A-2 indicates that roughly 60 percent of lenders allocate business across 6 or 7 PMI firms.

Where r^p represents an investor's risk premium for a given expectation of ϕ.[15] In this case, the equilibrium interest rate with no guarantee (i^{NG}) is given by:

$$i^{NG} = \frac{r^f + r^p + c + \phi}{1 - \phi} \tag{3}$$

such that interest rates rise when the expectation of the bad state is greater, when lender fees increase, when the risk-free rate increases, or when investors are especially risk averse. Given borrowers downward-sloping demand, this interest rate i^{NG} corresponds with an equilibrium amount of lending, B^{NG}.

Now suppose that a risk-neutral government charters a set of state-sponsored lenders, which provide a guarantee on the principal and interest for the mortgage bonds that the investors are buying.[16] These lenders, due to their connection to the government, can provide a highly credible guarantee such that in any state of the world, investors can be confident that they will receive full payment of principal and interest. This guarantee is similar to that provided by the GSEs. The rationale for such a government guarantee is to eliminate high risk premia (r^p) that lead to high interest rates and thus low levels of credit demanded. In the case of the GSEs, the government guarantee was made implicit rather than explicit, allowing GSE liabilities to remain off of the federal balance sheet (Acharya et al. 2011). However, an implicit guarantee constrains the government from charging a fee for the risk it assumes.

In this setting, the risk premium would be zero, and the equilibrium interest rate is given by:

$$i^G = r^f + c \tag{4}$$

Provided with an implicit government guarantee, investors require only enough return to cover the lenders' fee, so $i^G < i^{NG}$, and the equilibrium amount of lending increases to $B^G > B^{NG}$.[17]

Pricing in the mortgage market no longer reflects risk, ϕ, which will lead to excessive lending

[15] In a richer model that specified investors' utility functions, the risk premium would reflect the curvature of the utility function and the variance in the payoffs. As we do not seek to estimate this premium directly, we pursue a less parametric approach to incorporating it here.

[16] It is not necessary that the government be risk-neutral, but simply less risk-averse than investors, who may be more sensitive to short-term macroeconomic fluctuations, for instance.

[17] Note that our underlying assumption is that lenders do not charge extra for providing the guarantee, in large part because the state does not require them to hold substantial reserves that would be at risk. Indeed, at the time they were taken into conservatorship, the GSEs had essentially no meaningful reserves (Acharya et al. 2011).

from the perspective of a risk-neutral government. One way to address this concern would be for the government to set an explicit price for this guarantee, thereby recovering the risk-neutral price of credit. However, as noted above, charging a fee would require making the guarantee explicit. In addition, the government may want to avoid risk-based pricing becoming a political issue (see, e.g. Hurst et al. (2016)).

As an alternative, the government can mandate the use of PMI to provide partial coverage, $0 \leq \sigma \leq 1$, with the idea that putting some private capital at risk will lead to more appropriate pricing. Insurers put their capital, W, at stake, and can flexibly set premiums to reflect their risk exposure. The insurance industry is competitive, and risk-neutral insurers set their premiums, m, such that they make zero profits in expectation:

$$(1-\phi)mB - \phi \min\{\sigma B, W\} = 0 \tag{5}$$

In the good state of the world, insurers receive m in premiums for each dollar loaned, while in the bad state, insurers pay out their covered portion of the lost principal, σB, up to the amount of wealth the firm has. Thus, insurers have limited liability. For a given premium rate, m, lenders with less capital can earn a higher expected return. In a more dynamic model, less-capitalized insurers could offer insurance at lower prices and capture market share, unless buyers of insurance value well-capitalized insurance providers or regulators set stringent capital standards. In the U.S., state insurance regulators set minimum capital-to-risk ratios for mortgage insurers of just 1:25, while credit rating agencies set somewhat higher standards for PMI companies to obtain minimum ratings generally required by the GSEs. Given a setting where firm wealth is less than the amount of insured risk, $W < \sigma B$, then the equilibrium insurance premium is given by:

$$m = \frac{\phi W}{(1-\phi)B} \tag{6}$$

As long as insurers have some capital at stake, premiums will be non-zero and the equilibrium amount of lending will be B^{MI}, where $B^G > B^{MI} > B^{NG}$. With higher levels of capital for a given amount of insured risk, premiums will rise. If insurers are sufficiently capitalized such that

$W \geq \sigma B$, then premiums would be:

$$m = \frac{\sigma\phi}{1-\phi} \tag{7}$$

Thus, with sufficient capital and significant risk coverage, σ, the cost of credit, $i+m$, would approach the "correct" risk-neutral price that fully reflects market risk ϕ.

This simple framework provides several intuitive implications. First, in the presence of a government guarantee, the equilibrium amount of mortgage credit with private insurance will be less than the equilibrium without private insurance.[18] The degree to which mortgage insurance helps price risk more appropriately depends on how much capital insurers have at stake, and the amount of risk they assume. Competition between insurers tends to drive capital and premiums lower, minimizing the value of insurance and pushing B^{MI} closer to the fully guaranteed equilibrium amount of mortgage credit B^G — the "excess-lending" case that the government wanted to avoid. Thus, the framework highlights a standard problem with limited liability in insurance markets and incentives for undercapitalization on the part of insurers (Bohn and Hall 1999, Thompson 2010).

Next, when lenders are compensated solely based on volume with a fixed fee and no risk exposure, lenders prefer insurers with very little capital. This keeps the overall cost of borrowing $i + m$ low and increases borrower demand. A similar intuition holds if we consider the incentives of the GSEs, who are observationally equivalent to the lenders in this framework. If the GSEs do not bear the government guarantee costs directly, they too have no incentive to encourage sufficient capital on the part of the mortgage insurers, and instead would prefer keeping premiums low to drive up volume.

Finally, this framework highlights a principal-agent problem between taxpayers—who provide the guarantee—and the GSEs. The GSEs have little incentive to monitor their counterparties, the mortgage insurers; if anything, they have the opposite incentive to increase loan volume by seeking undercapitalized insurers who underprice the true market risk. In a 2007 report to Congress, OFHEO, the GSEs' regulator at the time, noted exactly this pattern: "The program to identify, aggregate and communicate counterparty risk is ineffective." This behavior is not surprising in a

[18] This conclusion is reached under the assumption that insurers are risk neutral. Of course, if insurers are risk-averse, the associated risk premium would push premia upward, leading to an ambiguous relationship between equilibria.

setting where the GSEs set their own standards, and are expected to monitor the insurers, but because of their implicit guarantee do not face any consequences for failing to do so. In the next section, we describe the data we use to examine the implications of this insurance framework.

III Data

In this paper, we use three sources of loan-level data. First, we use mortgage loan-level data reported by mortgage lenders in the U.S. under the Home Mortgage Disclosure Act (HMDA). The HMDA data cover the vast majority of home purchase and refinance mortgage lending in the U.S. (Bhutta, Laufer and Ringo 2017b). These data include details such as the name of the lender, loan amount, loan purpose (home purchase, refinance, or home improvement), census tract of the property, borrower characteristics such as race and income, and the date of origination.[19] Throughout the paper, unless otherwise indicated, we focus on home purchase mortgages.

Under HMDA, lenders must report all first and junior lien closed-end mortgages used to purchase a home. Prior to 2004, although junior liens were reported, the HMDA data lacked any indicator of the lien status of a given loan. In order to create a consistent time series of "piggyback" home purchase loans — that is, a junior lien taken out simultaneously with a first lien to finance a home purchase — we identify all instances where exactly two home purchase loans match on closing date (to the day), lender, census tract, and borrower income. In addition to obtaining a long time series of the prevalence of piggyback lending, matching junior liens to their first lien counterpart also allows us to compare their respective loan amounts and infer the combined loan-to-value (CLTV) ratio. For example, if the smaller of the two loans is one-quarter the size of larger, it implies a zero down payment, 100 percent CLTV: an 80 percent first lien coupled with a 20 percent second lien. In 2006, when piggyback lending was at a peak, we estimate that nearly two-thirds of piggyback loans were the 80/20 variety.[20]

[19] We use the confidential version of the HMDA data. Origination date is not available in the public version of the HMDA data.

[20] For these data, see Appendix Table A-1. This table also shows the total number of piggyback loans each year that we identify through our matching procedure. Starting in 2004, lien status was reported in HMDA, allowing us to examine our success in identifying junior liens. For 2004–2006, the number of piggyback junior liens we identify through matching hovers around 80 percent of the number of junior liens actually reported, with very few false positives. For example, in 2006, less than 3 percent of inferred piggybacks were not reported as junior liens. One reason not all juniors can be matched is that the same lender may not have originated both the first and junior liens.

Second, we use comprehensive microdata on insurance applications submitted to PMI companies (PMIC data). Although not required by law, from 1993 through 2013 private mortgage insurers made microdata available to the public on PMI applications with basically the same set of fields as the HMDA data.[21] These data allow us to observe when, where, and by which insurers mortgage insurance policies were written, and measure denial rates on applications for mortgage insurance.[22]

Third, we draw on loan-level mortgage servicing data from McDash Analytics. While the HMDA and PMI datasets provide the most comprehensive information of mortgage lending and PMI activity, these datasets do not include important underwriting variables such as LTV ratio or credit score, nor do they provide indicators of loan performance. For more loan characteristics and performance measures, we turn to the McDash data. These data also provide important details such as whether a loan has PMI and whether it has been purchased by the GSEs. The McDash data are limited to the largest mortgage servicers in the country and the sample of loans may not be not be fully representative of all mortgages. From 2005 through 2007, we find that the number of first lien home purchase mortgages reported in the McDash data was about 80 percent of the number reported in the HMDA data. Similarly, the number of first lien home purchase mortgage with PMI reported in the McDash data during this time span was about 85 percent of the number of policies reported in the PMIC data.[23]

In addition to these loan-level datasets on mortgages and mortgage insurance, we draw on publicly available local house price data from Zillow, local labor market data from the Bureau of Labor Statistics (BLS), and firm stock price data from The Center for Research in Security Prices (CRSP). We also draw on PMI firms' annual reports and 10-K filings to the SEC, transcripts of executives' quarterly conference calls with analysts (stored with Factiva), and industry reports.

[21] The annual Federal Reserve Bulletin articles summarizing trends in the HMDA data frequently mentioned and summarized the PMI data. See, for instance, Canner and Passmore (1994) and Avery, Bhutta, Canner and Gibbs (2010). Otherwise, these data have been largely neglected by academic research. One recent exception is Park (2015).

[22] Although most of our analysis relies on each dataset separately, we are able to match roughly 66 percent of the PMI policies on year, location (census tract), loan amount, loan purpose, loan type, and borrower income to a loan in the HMDA dataset for matched policy-loan analysis.

[23] See Appendix Table A-1 for data on the number of loans and PMI policies reported in each data set from 2001–2009. Perhaps the most important source of bias in the McDash data is the limited coverage of loans held in the portfolios of small banks and credit unions.

IV Mortgage Insurers Increased Risk Exposure in 2007

In this section, we explore the housing market context that the private mortgage insurers faced in late 2006 and their subsequent expansion of risk in 2006 and 2007. We then compare their decision-making with how other private actors responded to similar information about risk in the market, especially across different regions of the U.S., and the consequences of this expansion in PMI issuance.

IV.A Competition and the Risk of Piggyback Lending

During the housing boom years of 2004–2006, the primary alternative to private mortgage insurance was the use of a "piggyback" loan, a second lien taken out simultaneously with a first lien at the time of home purchase. For example, instead of taking out one 90 percent or higher LTV mortgage and paying PMI, a borrower could instead take out two mortgages, with the first covering 80 percent of the purchase price and the second covering 10, 15 or, quite frequently, 20 percent (thus producing a CLTV ratio of 100 percent). A likely reason for the increased use of piggyback loans in 2005 and 2006 is that for many borrowers, the overall cost of the two loans became relatively cheap as investor appetite for junior liens increased, making them widely available and pushing down their interest rates (see, e.g. LaCour-Little, et al. 2011).[24]

Figure 1 shows the share of loans with PMI and with a piggyback from 2000 to 2009.[25] As described above, to infer the presence of a piggyback loan we identify pairs of loans reported in the HMDA data that were originated on the same day, from the same lender, in the same census tract, and to borrowers with identical incomes. The figure shows that the use of piggyback loans sharply increased from 2004 to 2006, and increased disproportionately in the sand states (AZ, CA, FL, NV). At the same time, the share of PMI loans declined from a market share of around 25 percent to less than 15 percent over a similar period.

In 2005, consultants within the PMI industry provided the first internal forecasts (to our

[24] In addition, until 2007, mortgage insurance payments were not tax deductible, whereas interest payments on second mortgages were deductible, further contributing to the perceived advantage of piggyback loans. That said, the available data on the relative costs of PMI versus piggybacks suggests that piggybacks were often cheaper even without the tax advantage during the peak years of the housing boom. Lenders may also have encouraged borrowers to junior liens rather than PMI because of the fee revenue and opportunity to earn interest on the loan (Calhoun 2005).

[25] Appendix Table A-1 presents summary statistics from our three data sources showing detailed trends in the usage of PMI and piggybacks from 2001 to 2009.

knowledge) that some markets were more likely than not to experience a decline in house prices, and that the price declines could be widespread given the recent increases in high-LTV lending (Calhoun 2005). One industry consultant's report ranked MSAs based on their risk to mortgage insurance providers as of June 2005. Eight of the top 13 markets were in California, and many metro areas that subsequently suffered the largest price declines were prominently featured in the top 25 markets. The report highlighted increased "risk layering," where borrowers not just with low FICO scores or high LTVs were receiving loans, but borrowers with *both* low FICO scores and high LTVs were able to qualify for mortgages. The report concluded that house price risk was greatest in regions where piggyback lending in particular, and weakened lending discipline in general, was most prevalent.

By the end of 2006, there was substantial public evidence that the housing boom was coming to a close. Homeownership rates peaked in 2004, homebuilder share prices peaked in 2005, and house prices peaked in most MSAs by mid-2006.[26] Mortgage defaults on riskier loans were rising, vacancy rates were reaching record highs, and new home construction effectively halted in the markets that had boomed most sharply from 2001–2005, especially in the sand states.[27] In their Fall 2006 "Economic & Real Estate Trends" report, the Chief Risk Officer of PMI Mortgage Insurance Company wrote, "There's no longer any doubt that the housing market is cooling" (Milner 2006b).

By this point, house prices had begun to decline disproportionately in the sand states. In Figure 2, we show that year-over-year house price changes in the sand states were negative from January 2006 to January 2007, and close to zero in the rest of the country, on average.[28] In August 2006, mortgage insurance industry representatives publicly expressed fears of an acceleration of price declines, driven by a "contagion effect from poorly underwritten or unsuitable mortgages and home equity loans."[29]

Transcripts from PMI firms' quarterly earnings calls with market analysts support the view

[26]See, for instance, Haddad, Annette. 2006. "Glum Outlook is Offered by Home Builders." *Los Angeles Times*, September 7. `http://articles.latimes.com/2006/sep/07/business/fi-kb7` and Izzo, Phil. 2006. "Housing Slowdown Takes its Toll." *Wall Street Journal*, September 8. `www.wsj.com/articles/SB115756077868455240`.

[27]Simon, Ruth. 2006. "Late Payments on Mortgages Rise." *Wall Street Journal*, May 18. `www.wsj.com/articles/SB114791579478456175`.

[28]Indeed, based on the Zillow house price database, of the 75 MSAs located in the sand states, 88 percent had a price peak prior to January 2007, and the average decline from peak to early 2007 in these markets was 5.6 percent.

[29]Downey, Kirstin. 2006. "Insurers Urge Action on Risky Mortgages; Firms Want More Loan Restrictions." *Washington Post*, August 19. `https://www.washingtonpost.com/archive/business/2006/08/19/insurers-urge-action-on-risky-mortgages`.

that the industry was aware of the increasing risks in the housing market, especially in the sand states. For example, in their 2007Q1 earnings call, the CEO of Genworth said "We're also seeing a pick-up in delinquencies in California and Florida. These two markets have had rapid home price appreciation that is now ending, and have higher concentrations in Alt-A and adjustable rate mortgages."[30]

IV.B PMI Expansion to Ex-Ante Observably Risky Markets

IV.B.1 PMI Industry Growth

Despite the negative signals from the housing market suggesting heightened default risk, and specifically the extensive regional variation in that risk, we next show that private mortgage insurance firms nonetheless expanded insurance issuance dramatically in 2007. It is important to emphasize here the inherent riskiness of the PMI business, as it takes a first-loss position on mortgages with LTV ratios over 80 percent. One key reason that high-LTV loans are risky is that modest declines in home prices can push borrowers into negative equity, increasing the incentive to default (Deng, Quigley and Van Order 2000) and increasing the need to default when coupled with a liquidity shock (Bhutta, Dokko and Shan 2017a, Gerardi, Herkenhoff, Ohanian and Willen 2017). Naturally, default risk rises as LTVs rise toward 100 percent and also as other metrics of credit quality, such as FICO scores, deteriorate. Below, we document not just an overall expansion in PMI as house price risk was rising, but also a disproportionate expansion toward the riskiest borrowers and the riskiest housing markets.

Going back to Figure 1, the share of home purchase loans with PMI spiked in 2007 to historically high levels, for the U.S. as a whole and in the sand states. Figure 3A shows the time series (monthly frequency) of year-over-year growth in the level of PMI issuance from 2005 to 2009. During the boom years of 2005 and 2006, there was essentially no growth in PMI issuance, but the industry grew by more than 50 percent on a year-over-year basis in 2007. Figure 3B shows that the growth was disproportionately located in the sand states. The figure's dashed red line presents the growth in the sand states, while the solid blue line represents the growth in the non-sand states. At its peak, PMI issuance was growing at an annual rate of over 50 percent in mid-2007, but at a rate of

[30] Genworth 2007Q1 earnings call transcript (accessed through Factiva).

over 100 percent by the end of 2007 in the sand states.

The rise in PMI market share coincided closely with the drop in piggyback lending, as indicated in Figure 1 and further documented in Table I. The first three columns show results from regressions of the form:

$$y_{ic} = \alpha + \beta x_{ic} + \eta_c + \epsilon_{ic} \tag{8}$$

Where y_{ic} is the change in PMI issuance (or log PMI issuance) in census tract i of county c between 2006 and 2007; x_{ic} is a measure of piggyback lending; and η_c is a county-specific fixed-effect.

Column 1 of Table I indicates that for every 10 piggyback mortgages lost between 2006 and 2007, there was a gain of nearly three PMI policies in the same census tract. Column two shows an even stronger relationship between increases in PMI and declines in the highest leverage 80/20 combination loans.[31] Finally, column 3 shows the relationship between the growth rate in PMI and the 80/20 share of first lien mortgages in 2006. The point estimate suggests that a 10 percentage point increase in the 80/20 share was associated with higher PMI growth of about 12 percent.

Thus, PMI issuance grew most in markets where piggyback loans, which were often funded through private-label securitization, dried up. These geographies were precisely those in which the PMI industry raised concerns around flawed underwriting and fear of contagion in mid-2006 (Downey 2006). This negative relationship suggests that the expansion of PMI-backed lending occurred where private secondary mortgage markets viewed new lending as exceedingly risky in 2007. As documented in Mason and Rosner (2007), the price of risk for home equity loans began to rise in August 2006, making MBS issuance more expensive. In addition, Gorton, Metrick and Xie (2015) estimate that the subprime ABX index experienced a time series break in January 2007. The CEO of MGIC explained to investors in a 2007Q1 earnings call, "As far as [PMI] pricing, nothing has changed. What's happening is a lot of that business that was done with 80/10s and 80/15s and 80/20s is now flowing back to our industry as 95s or 100s. So you're just seeing the change back given our product is a much more favorable product relative to those, *because they're not available.*"[32]

[31] As described earlier, 80/20 combination loans refer to the 80 percent first lien combined with a 20 percent second lien for a 100 percent CLTV ratio. See Section III for details on how we identify 80/20 loans in the HMDA data.

[32] MGIC earnings call from 2007Q1 (accessed through Factiva), emphasis added.

In Figure 4A, we show that PMI expanded disproportionately in markets where prices were leveling off or even had begun to decline by 2007. The y-axis measures the percent change in PMI issuance at the county level from 2006 to 2007, while the x-axis shows the change in house prices from June 2006 to June 2007.[33] We can also look at the relationship between ex-ante known patterns of house appreciation and PMI growth, as shown in Figure 4B. This figure shows that PMI issuance grew more so in counties where price growth was slowing, as defined by the second derivative of house price changes (the difference-in-differences from 2006–2005 vs. 2005–2004). House prices do not follow a random walk, but instead show substantial and predictable short-term momentum, as shown in Shiller (2007) and Piazzesi and Schneider (2009). Thus, based solely on house price trends, PMI issuance expanded disproportionately in ex-ante risky markets.

In Table I, we establish that these relationships persist after controlling for county wage growth, county employment growth and state fixed effects. In columns 4 and 5, we run regressions similar to those in columns 1–3, but now at the county level:

$$y_{cs} = \alpha + \beta x_{cs} + \gamma z_c + \eta_s + \epsilon_{ic} \tag{9}$$

Where y_{cs} is the change in log PMI issuance in county c of state s between 2006 and 2007; x_{cs} is a measure of county house price growth (column 4) or pre-2007 price acceleration (column 5), using prices from June of each year; z_c is a vector of controls for county wage and employment growth; and η_s is a state-specific fixed-effect. The house price growth and acceleration variables have been normalized by their standard deviation.

Column 4 of Table I indicates that one standard deviation weaker house price growth was associated with almost 8 percent higher PMI growth from 2006 to 2007. Column 5 shows PMI growth was about 10 percent higher in counties with declining house prices compared to counties with stable or rising prices. Finally, columns 6 and 7 show a more modest relationship between PMI growth and pre-2007 slowdowns in house price growth. In sum, rather than shifting issuance away from the riskiest markets in 2007, Table I shows that PMI firms grew even more aggressively in markets where a decline in prices was more likely, imperiling high-LTV insurance protection.

[33]The results look nearly identical if we use price changes from January 2006 to January 2007.

IV.B.2 Growth in PMI on Riskier Loans

Next, we examine whether insurers' shift to riskier markets coincided with a shift away from riskier loan types. Annual filings by PMI firms suggest that they were increasingly issuing policies on riskier loans in 2006 and 2007. For example, the PMI Company's 2007 10-K filing reports that from 2005 to 2007, the share of their issuance on alt-A (low or no documentation) loans rose from 17.2 percent to 22.8 percent, on interest-only loans rose from 6.2 percent to 14.2 percent, and on loans with LTV ratios above 97 percent rose from 14.3 percent to 24.6 percent over this two-year period.

We use the McDash data to systematically examine PMI growth in 2007 for the riskiest types of loans, defining risky loans as those having both a FICO score below 680 and an LTV of 95 percent or higher.[34] The top panel of Figure 5 indicates that growth in riskier loans led the surge in PMI issuance during 2007. PMI on riskier loans nearly doubled in 2007 from 2006, and was dramatically above historic levels going back to 2001.[35] In contrast, growth in PMI on lower risk loans (that is, all other PMI) grew much more modestly in 2007.

The bottom panel of Figure 5 shows that the higher-risk share of PMI issuance peaked at over 20 percent in 2007, before plummeting in 2008. Note that because either FICO or LTV information are missing for nearly a quarter of loans with PMI in McDash, the solid line in this bottom panel provides a lower bound on the share of riskier loans in any given year by simply including all loans with missing information in the PMI total (i.e. assuming all of them are lower-risk). The true higher-risk share may be closer to the dashed line, which drops loans with missing information and thus assumes loans with missing information have the same FICO and LTV distributions as the loans with available information.[36] Both approaches show a sharp relative increase in high-risk issuance in 2007.

Columns 9–13 of Table I examine how growth in higher-risk PMI issuance from 2006–2007

[34] Other risk characteristics like interest-only and alt-A status not reliably reported in the McDash data.

[35] Note that we adjust PMI counts from the McDash data using an annual inflation factor equal to the number of PMI contracts reported in the PMIC data relative to the number reported in McDash for a given year. Because the coverage in McDash rose steadily from 2001–2005, unadjusted counts in McDash likely overstate PMI growth considerably prior to 2005. See Table A-1 for raw counts and coverage ratios.

[36] Comparing delinquency rates for loans with missing information versus those with available information suggests missing information loans tend to be somewhat less risky. Thus, the dashed line is likely an upper bound on the higher-risk share.

correlates with the housing market risk factors discussed earlier. These columns show regression results from running the same county-level specification described above (equation 9), but now with higher-risk PMI growth measured from the McDash data as the outcome. As in columns 3–7, the coefficients in columns 9–13 indicate that growth in higher-risk PMI policies was positively correlated with market risk indicators. Moreover, the coefficients in these columns tend to exceed those in columns 3–7, suggesting an even stronger relationship between market risk and higher-risk PMI growth compared with the relationship between market risk and overall PMI growth.

Overall, the results of this and the previous subsections establish that PMI disproportionately expanded issuance to consumers, products, and markets that were ex-ante riskier based on widely observable measures. As discussed above, this expansion in risk was not associated with any corresponding change in insurance premia. We next turn to examining how changes in PMI issuance correlated with a summary measure of market-level risk published by the industry itself.

IV.B.3 PMI Industry's Ex-Ante Housing Market Risk Measure

As discussed earlier, industry consultants recognized these patterns and the high risk of house price declines in certain markets. The PMI Mortgage Insurance Company's "Market Risk Index" was designed to predict the likelihood of a house price decline within the next two years. The MSA-level score used information regarding house price growth, local unemployment, and an affordability measure based on local house prices, local incomes, and the cost of mortgage credit. Table II shows the estimated likelihood of price declines for the top 25 riskiest MSAs as defined by their measure in 2005 as found in Calhoun (2005). Our subsequent analysis focuses on the summer 2006 risk score found in Milner (2006a) because it pre-dates any issuance decisions made in 2007. While these materials were produced by industry consultants and by PMI Co.'s chief risk officer, discussions with industry participants indicate that these MSA-based indices were widely distributed and replicated at other firms.

We first show that the PMI industry's estimates of market risk were accurate ex-post. In Table II, the names of metro areas line up well with some of the markets that had the largest declines, and the rank ordering became more accurate over time. Figure 6 formally shows the relationship between the summer 2006 risk score and the magnitude of the subsequent house price decline (from

mid-2006 to the market-specific trough). This strong relationship suggests that the PMI industry's own risk forecast was quite accurate, especially for extremely high-risk markets in California and Florida.[37]

We next document that rather than limiting their exposure, PMI firms expanded their issuance disproportionately in these high-risk markets in 2007. Figure 7A shows that on average, higher-risk markets had larger expansions of PMI issuance in 2007 than markets that were lower risk. Moreover, Figure 7B indicates that higher-risk (low-FICO, high-LTV) policies expanded more so in high risk markets than in low risk markets. These relationships are also documented in columns 8 and 14 of Table I. Most notably, these regression results indicate an even stronger relationship between the market risk index and growth in higher-risk PMI (column 14) than with overall growth in PMI (column 8).

IV.B.4 Did All PMI Firms Act Similarly?

One possible explanation for the industry-level patterns we have documented is that just one or two PMI firms may have taken an contrarian position vis-a-vis house price expectations and pricing in an effort to expand market share. However, as we discussed above, all PMI firms set very similar, or identical, prices for coverage. Here we provide evidence of similar issuance behavior across all firms in the industry, as opposed to the overall industry trends potentially reflecting just one or two highly aggressive firms.

The top two panels of Figure 8 show that all insurers had very similar low-FICO and high-LTV shares of policies issued in 2007.[38] The bottom left panel indicates that early delinquency rates — a summary measure of risk, which we define as 90 days or more past due within 15 months of origination — on 2007 mortgages with PMI were quite similar across all firms. Finally, the bottom right panel shows issuance growth from 2006 to 2007. Four of the seven firms posted growth in excess of 0.4 log points, while the other three firms grew by over 0.25 log points. Overall, the similarity of the behavior across firms is consistent with each facing similar incentives and responding in largely the same fashion.

[37] We are not aware of any publicly available data on the PMI firms' forecasts of the relationship between house price declines and default rates, or the relationship between these declines and loss severities.

[38] The figure presents results for the seven largest PMI firms. The 8th firm, CMG, was a small participant in the market, focusing on insuring loans originated by credit unions.

IV.B.5 Defaults and the Consequences of Expansion

The increase in high-risk lending contributed to a wave of mortgage defaults impacting the solvency of PMI firms. While much has been written about the poor performance of subprime privately-securitized mortgage loans during 2004–2006 (e.g. Mayer, Pence and Sherlund 2009; Keys et al. 2010), PMI-backed loans in 2007 performed almost as poorly. In Figure 9A, we plot within-county-by-quarter-of-origination severe delinquency rates for loans with PMI (in blue) and privately securitized loans (in red), relative to the performance of other loans (mostly lower-LTV GSE loans as well as loans backed by the FHA and Veteran's Administration).[39] The figure shows that loans with PMI originated in 2007 performed almost as poorly as the very worst vintages of privately-securitized loans relative to concurrent safer originations.

Defaults on PMI-backed loans were significant in the aggregate. The blue bars in Figure 9B provide an estimate from the McDash data of the overall number of serious delinquencies (90+ DPD) across all types of home purchase loans by quarter of origination. The number of delinquent loans arising from the 2007 cohorts rivals the number from 2006, and the red line shows that by mid-2007, half of all delinquent loans had private mortgage insurance associated with the loan.

These delinquencies led to large numbers of claims. According to PMI industry reports, loss ratios for 2008 (losses divided by premiums) exceeded 200 percent (MICA 2009). Three of the eight firms in the PMI industry failed and were unable to fully pay out claims, and, based on our calculations, the overall market cap of the industry fell by over 90 percent. The loss severities not only punished the PMI companies, but also the GSEs. Goodman and Zhu (2015) use Freddie Mac data and estimate severity at liquidation for loans with LTV>80 percent originated in 2007 at 28.7 percent, even after taking into account the mortgage insurance coverage. This result implies that, on average, mortgage insurance was more than exhausted (in part because of their inability to fully pay claims), and that Freddie Mac bore significant risk for the 2007 cohort in particular.[40]

It is important to note that the default rates on PMI-backed loans that we show include loans

[39] Figure 9A plots coefficients from a loan-level regression of an indicator of going 90+ days past due within 36 months on indicators for PMI status and PLS status interacted with quarter of origination, controlling for county-by-quarter-of-origination fixed effects. These fixed effects account for local economic shocks common to each vintage. Some PLS loans also have PMI, but most PLS loans do not have PMI, allowing separate identification of the correlations between default and PMI versus PLS status.

[40] For more on GSE mortgage loss severities during the crisis, see An and Cordell (2017).

where PMI firms may have ultimately rescinded the policy.[41] PMI firms have emphasized that lenders increasingly approved mortgage insurance — on behalf of insurers through delegated underwriting agreements, which we discuss in more detail below — that were outside the insurers' guidelines, or potentially fraudulent (Kilgore 2010). There is no available data that we know of on rescission activity, but the Financial Crisis Inquiry Commission (FCIC) reported that as of October 2010, rescission rates for the seven largest PMI firms were around 25 percent of all claims, totaling $6 billion.[42]

However, representatives of lenders have argued that rescissions often were not well-justified, and that PMI firms' guidelines were unclear (see, e.g. Orin and Hans 2009). PMI firms rescinded many allegedly "ineligible" policies on mortgages in default, while continuing to collect premiums from "ineligible" policies on mortgages not in default, creating a "heads I win, tails you lose" strategy. Some insurers have acknowledged that the delegated underwriting model with ex-post review was flawed (England 2012). Moreover, if it is indeed the case that insurers would have rejected these loans if they had done ex-ante review, consistent with their "second set of eyes" mantra, the costs to society of the additional foreclosures could have been avoided.

In sum, we have established that PMI issuance grew sharply in 2007, was driven by insuring relatively high-risk loans, and that this behavior was widespread across all industry players. No PMI firm deviated from either pricing norms or issuance patterns at the tail-end of the housing boom. Issuance grew most in the riskiest geographies where house prices were most likely to decline – where piggyback lending was previously heavily concentrated, where home prices were already declining by 2006 or early 2007, and where the industry itself forecasted that house prices were highly likely to decline. This expansion contributed to a surge in defaults and heavy losses among the PMI firms. In the next section, we explore potential mechanisms for the PMI firms' willingness to take on so much risk (without adjusting premiums) during the waning stages of the housing boom.

[41] In the case of a rescission, insurers are not liable for default costs, but also must return any premiums that have been paid. If the loan was purchased by the GSEs, the GSEs would require the lender to buy back the loan, if the lender was still in business.

[42] See also the discussion in Weiss, Rosso and Clymer (2012).

V Potential Mechanisms for Risk-Taking

Despite public signals regarding the risk at this point in the housing cycle, the industry's own risk index, and the concentration of risk in the sand state MSAs, PMI issuance grew dramatically in 2007 and most sharply to the riskiest borrowers in the riskiest markets. In this section, we explore potential explanations for this behavior, focusing on the incentives of mortgage insurers and their counterparties, particularly Fannie Mae and Freddie Mac.

V.A Moral Hazard of Insurers

Insurance contracts share many similarities with loan contracts: Insurers take in money today in the form of premiums, and in return they promise to make claim payments in the future (Bohn and Hall 1999). The differential timing between when premiums are earned and when claims need to be paid leads to moral hazard incentives to generate premium revenue during good times, underprice risk to capture market share, and under-prepare for bad times. The incentive to underprice risk is exacerbated by the limited liability of insurers, who have only their insufficient capital at stake.

One way to push back against these incentives is through regulation. However, mortgage insurers were only lightly regulated at the state level prior to the crisis. States set maximum risk-to-capital ratios of just 25-to-1 despite insuring high-risk mortgages, and these ratios were not adjusted for variation in risk within that higher-risk pool. There is little incentive for states to tightly regulate the PMI industry: Unlike other forms of insurance, states do not provide a backstop if PMI companies fail, and citizens of the state are not beneficiaries of the insurance policies (although they do benefit from lower premiums). Indeed, state regulators allowed many PMI firms to buy back shares and expand dividends, even in 2006 and 2007 when defaults were rising and PMI firms were reserving well below the targeted 50 percent of premiums (see our earlier discussion in Section II.A).[43]

Market forces may also be able to push back against the risk-taking incentives of insurers. Concentrated counterparties may be able to restrict the behavior of insurers (Henderson 2009). Indeed, the GSEs did have eligibility requirements in place for PMI companies. However, as discussed in our

[43]For example, based on 10-K filings, MGIC's dividends increased tenfold, from 2.5 cents per share from 1998–2003 to 25 cents per share in 2006 and 2007.

theoretical framework, the implicit guarantee of the GSEs by the federal government weakens the incentives of the GSEs to monitor and regulate the PMI companies. Just as the implicit guarantee encourages the GSEs to take credit risk, it also encourages them to take counterparty risk. And if the GSEs wanted to expand their market share into the riskiest type of loans, they would need the PMI companies to insure those loans due to their charter requirement for credit enhancement on high-LTV loans.

Consistent with competitive pressures on mortgage insurers to give up their role as "review underwriters," Figure 10 shows that PMI denial rates on applications plummeted from over 10 percent in 1996 to less than 3 percent by the mid-2000s. This decline in denial rates was reflected across all firms active in the industry, and pre-dates the rise of piggyback lending.[44]

The decline in denials likely reflects increased use of "delegated" underwriting, where PMI firms allowed lenders to approve mortgage insurance on their behalf, but still reserved the right to impose additional standards or scrutiny of insurance applications. At least to some extent, PMI firms appear to have ceded their underwriting independence outright. For instance, MGIC notes in a 10-K filing that "Beginning in 2000, loans approved by DU or LP [the GSEs' automated underwriting programs] were automatically approved for MGIC mortgage insurance...even if the loans were outside of MGIC's published guidelines."

Figure 11 documents the growing prevalence of the use of delegated underwriting during the housing boom. We collected information from various PMI firms' 10-K filings regarding the share of new insurance written through delegated underwriting agreements. Firms report this information inconsistently across SEC filings. The figure shows that by 2003, the majority of new insurance written was through a delegated process, a trend that continued to rise through the remainder of the boom. If anything, this figure understates the level of detachment from the underwriting process, as loans that were automatically processed through the GSE software may not have been included in all of these reported statistics.

As one industry executive put it, the goal was to provide lenders with an up-or-down decision on providing MI within two to three minutes.[45] Such a goal, of course, necessarily implies minimal

[44] In results not shown, we further show that the decline in the PMI denial rate was not a function of improving observable characteristics of borrowers; if anything, the risk-adjusted denial rate falls even further.

[45] Memorandum for the Record, September 23, 2010, Interview with Jeffrey H. Lane, accessed at the FCIC Resource Library, `https://fcic-static.law.stanford.edu`, March 20, 2017.

review underwriting. Thus, rather than serving as a "second set of eyes," private mortgage insurers passively accepted the underwriting standards of the GSEs and other lenders, driving denial rates to historic lows when market risk was at its peak. A summary of testimony by the general counsel of MGIC to the Financial Crisis Inquiry Commission supports this view, saying "Instead of doing underwriting upfront they relied on the automated underwriting systems of the lenders. MGIC took on the view that 'if it is good for them, it is good for us' ", implying a focus on current revenue generation as opposed to managing future claims risk.[46]

V.B Moral Hazard of PMI or GSE Influence?

Instead of a limited liability-based explanation for why PMI companies might take on excessive risk, one alternative explanation for the observed behavior of PMI companies during the housing boom and particularly in 2007 is that the GSEs, as the dominant users of mortgage insurance, may have been able to exercise undue influence on PMI firms. As documented by Acharya et al. (2011), the GSEs sought to expand riskier mortgage lending from the early 2000s through 2007. As they did, they may have put pressure on PMI firms to insure riskier loans and cede underwriting to the GSEs.

In the data, we observe a tight connection between the expansion of GSE lending and PMI issuance. Figure 12 shows that the surge in PMI market share in 2007 was almost entirely driven by growth on the GSE side of the business. The overall share of home purchase loans with PMI jumped from 15 to 27 percent, or 12 percentage points, and the GSE portion of this growth accounts for about 11 of those 12 percentage points.

The relationship between the GSEs and PMI companies during 2007 is even clearer in Figure 13. We plot coefficients from non-parametric regressions around the GSEs' conforming loan limit, or CLL:

$$y_{ls} = \alpha + \gamma_l + \delta_s + \epsilon_{ls} \tag{10}$$

where y_{ls} is the change in log number of loans with PMI, or the change in the log number of

[46] Memorandum for the Record, September 23, 2010, Interview with Jeffrey H. Lane, accessed at the FCIC Resource Library, `https://fcic-static.law.stanford.edu`, March 20, 2017.

high-LTV loans, in state s and in loan size category l, γ_l are fixed effects for each loan size category and δ_s are state fixed effects. We plot the loan size category fixed effects on either side of the CLL. The CLL is the loan amount threshold above which loans are ineligible for purchase by the GSEs. This limit is Congressionally determined and varies over time, although it was static between 2006 and 2007 at $417,000. We include state fixed effects to ensure that state-specific factors are not driving any observed differences in lending growth across the CLL.

The connection between PMI growth in 2006–2007 and the GSEs can be seen clearly in the top-left panel of Figure 13.[47] The figure shows that while there was strong growth in insurance below the CLL, there was sharply less growth to the right of the CLL for "jumbo" loans.[48]

The top right panel shows how growth in total high-LTV lending differed across the CLL. We measure total high-LTV lending as PMI issuance plus the number of first-lien home purchase loans that had a piggyback where the first-to-junior lien size ratio implies a CLTV of at least 95 percent (and total loan amount on the x-axis refers to the first lien plus junior lien amounts). This figure indicates that total high-LTV lending dropped dramatically to the right of the CLL. In other words, as junior lien lending dried up between 2006 and 2007, the expansion of PMI helped offset the loss of piggybacks, but only to the left of the CLL where loans could have been funded by the GSEs.

As a "placebo" test, we examine the same relationship around the conforming loan limit for changes between 2004 and 2005, when the non-agency secondary mortgage market was active.[49] As shown in the bottom two panels of Figure 13, in this market environment, we document no significant differences around the conforming loan limit. This comparison from an earlier date supports the view that a key aspect of growth in 2007 was differential liquidity of the GSE market, which the PMI industry helped to maintain.

While Figure 13 may be consistent with GSE influence over PMI firms, two pieces of evidence suggest that mortgage insurers behaved similarly even in the absence of GSE influence. First, Figure 14 shows that denial rates for jumbo loans declined over time in parallel with the decline for conforming loans. Denial rates on jumbo loans did rise in 2007 relative to conforming loans,

[47] Column (1) of Appendix Table A-2 provides the regression coefficients that correspond to the figure.

[48] We use the second-to-the-left loan size category ($10,000 to $20,000 below the CLL) as the reference category in these regressions. To provide a sense of the level of growth rates, we set the reference growth rate to the growth rate for loans between $250,000 to $300,000. The first point to the left of the CLL likely captures some shifting of loans in 2007 from just above the CLL to just below as liquidity in the jumbo market dried up.

[49] Columns (3) and (4) of Appendix Table A-2 provide the corresponding regression coefficients.

suggesting some introduction of differential decision-making, but the change was modest.

Second, Figure 15 indicates that the delinquency rates of PMI-insured loans originated in 2007 above the CLL were very high and similar to delinquency rates for loans below the CLL. This finding suggests that the PMI companies were willing to insure high-risk loans even outside the GSE space.[50]

Putting it all together, the evidence suggests that PMI companies were willing to take risk even when the GSEs were not involved, but private willingness to participate in high-risk loans dissipated in 2007, leading to a sharp contraction in lending above the CLL. Below the CLL, the joint willingness of PMI companies and the GSEs to take risk helped sustain high-risk lending in 2007. As we hypothesized earlier, PMI companies had strong incentives to take excessive risk because, as lightly regulated insurers, they could write policies without having to put much capital at stake.

V.C Alternative Explanations

In this brief section, we explore a number of alternative interpretations and explanations for the patterns we have documented in the PMI market. In turn, we examine the GSEs' Affordable Housing Goals, managerial mistakes, lender market power, and gambling for resurrection motives.

V.C.1 Effects of the Affordable Housing Goals?

A natural question is whether the GSEs were pushed to lend in 2007 because of the Congressionally mandated Affordable Housing Goals. These goals have been studied elsewhere, but previous research has focused on GSE purchases and investments prior to 2007 (Bhutta 2011, Ghent, Hernandez-Murillo and Owyang 2015). The expansion of GSE purchase activity in 2007, and simultaneous rise in PMI, may have been a response to the lack of investment opportunities in "goal-rich" subprime PLS in 2007 (Adelino, Frame and Gerardi 2017). In years just prior to 2007, the GSEs had been prominent investors in subprime PLS. Dwindling issuance of PLS in 2007 may have put pressure on the GSEs to directly fund riskier loans and increased their demand for PMI. However,

[50] Appendix Figures A-3A and B show even smoother performance across the CLL when we utilize additional data on refinance loans and loans originated in 2006, respectively.

in Appendix Figure A-4, we find little difference in PMI issuance growth around the sharp income thresholds where loans would be counted toward the goals. Thus, we do not find any evidence that the expansion in 2007 can be attributed to the Affordable Housing Goals.

V.C.2 Managerial Incompetence

Were the managers of PMI firms simply incompetent in assessing the risks of the housing market, in contrast to other private actors? A number of pieces of evidence suggest that this is unlikely. First, the forecasts of PMI Company were publicly available, and industry representatives were expressing public concern as of August 2006. At the very least, the chief risk officers appear to have accurately anticipated a downturn in house prices, although forecasts of severity and loss given default have not been made public.

Next, a similar degree of managerial incompetence would have had to have affected all PMI firms at same time, given the similarity in risk-taking we have shown and parallel drops in firms' share prices (Appendix Figure A-6). Instead, we think a more likely explanation given the similarity of behavior across all firms is that each firm acted on the same set of incentives to take excessive risk, as described earlier in Section II.C.

V.C.3 Market Power of Lenders

In discussions we have had with industry representatives and observers, one alternative explanation that has been put forth is that lenders' market power influenced PMI firms to continue to insure risky loans as house prices began to fall. The logic of this explanation rests on the idea that lenders, and not borrowers or the GSEs, choose which PMI firm will receive the opportunity to insure a particular loan. However, this story aligns closely with the competitive dynamics described in Section II.C. In particular, lenders are not exposed to the counterparty risk of PMI firms, creating a "race to the bottom" dynamic whereby lenders, regardless of their size, naturally steer business to the easiest and most affordable—and least capitalized—mortgage insurer. This competitive dynamic is present whether there are a few concentrated lenders or many small lenders, and also regardless of the housing cycle.[51]

[51] Note that this dynamic would also be present if borrowers chose which PMI firm to acquire their insurance policy from, as they similarly have no incentive to monitor the financial health of PMI firms.

Our data suggests that lender concentration and market power was not a driving force behind the risky behavior of PMI firms in 2007. First, we find that PMI issuance was widely distributed across hundreds of lending organizations, and the top four lenders (Wells Fargo, Bank of America, Countrywide, and J.P. Morgan Chase) accounted for less than one-quarter of PMI issuance in 2006 and 2007.[52] In addition, we find that lender concentration in a county is generally uncorrelated with the extent of PMI expansion in 2007, and the correlation between PMI growth and the Housing Market Risk Index shown in Table I is robust to controlling for the county mortgage origination market share of top two or top four lenders.[53]

V.C.4 Were PMI Firms Gambling for Resurrection?

One potential interpretation of the growth in PMI issuance in 2007 was that PMI firms knew that the 2006 book of policies would perform especially poorly, and that they would need to bring in additional revenue to cover losses. Despite being aware of house price declines and heightened risk, they may have attempted to write more policies to stay solvent longer, and high-LTV loans with large loan amounts bring in the largest premiums. Such behavior would be consistent with a "risk-shifting" model (Jensen and Meckling 1976, Fama 1980), where the PMI firms are essentially gambling for resurrection by writing new policies and hoping to prop up the housing market by providing additional liquidity in high-cost and high-risk areas. To be clear, a gambling for resurrection motive is a type of moral hazard, but takes a slightly different form and is triggered by an expectation of insolvency in the absence of the gamble.

However, in Panel A of Figure 16, we show that PMI issuance accelerated sharply six months before insurers' stock prices plummeted.[54] This pattern is contrary to the strict "gambling for resurrection" narrative where only firms in severe distress take on additional risk. The red line represents a composite stock price for the publicly traded firms with available data, while the blue line presents the year-over-year growth in issuance over time, both from January 2006 to December 2007.

[52] Appendix Figure A-5 shows the share of issuance accounted for by the top four lenders separately for each PMI firm. With the exception of Radian, where the top four accounted for nearly 40 percent of issuance, the top four lenders account for less than 30 percent of issuance at every PMI firm.

[53] Results available in Appendix Table A-3.

[54] The figure shows a market cap-weighted index based on four publicly-traded firms, whose individual share prices (indexed to January 2007) are shown in Appendix Figure A-6.

Our interpretation of the timing of expanded issuance and subsequent share price declines is related to PMI stock holders having risk-seeking incentives compared with subprime mortgage bond investors. As MBS investors fled private-label securitizations, PMI companies, alongside the GSEs, ramped up business in their wake as they faced no constraints on writing additional policies.

After this ramp-up in issuance in late 2006 and early 2007, investors reached a relatively quick realization of the implications of this heightened risk-taking. Panel B of Figure 16 shows that the PMI stock price index lost about 50 percent by the third quarter of 2007, dropping well before many other corporations severely affected by the financial crisis, mostly notably the GSEs, represented here by Freddie Mac's stock price.

Nonetheless, Panel A of Figure 16 shows that even as the stock price of PMI firms continued to fall, issuance continued to grow at a rapid pace. This phase of mid- to late-2007 may indeed reflect "gambling for resurrection" motives on the part of PMI firms. These firms had few binding regulatory constraints from either state regulators or the GSEs to prevent them from continuing to issue new policies even as their capital base eroded. If the GSEs were worried about counterparty risk and the financial strength of the PMI industry, they likely would have sharply curtailed PMI-backed risky lending when PMI stock prices fell. The continued expansion of new PMI policies is consistent with the broader moral hazard concerns with insurers' ability to write risky policies without adequate capital.

VI Conclusion

The U.S. residential mortgage market is one of the largest financial markets in the world. Default risk in this market is currently largely borne by government entities, but many proposals recommend shifting this burden to the private market. The exposure of private capital in a first-loss position is traditionally viewed as an effective means of providing risk discipline. Using unprecedented data on private mortgage insurance companies' decision-making during the housing boom, we show that rather than acting as a check on risky behavior, insurers were willing to take on additional risk with no change in premiums at the same time the rest of the private market was tightening standards or actively fleeing the U.S. housing market.

The behavior of PMI firms may be best be understood in the context of the moral hazard of insurance providers, as well as the institutional frictions in the mortgage market. The relationships between lenders, insurers, and the GSEs led to an environment in which the party in the first-loss position did the least amount of underwriting and had incentives to underprice risk. PMI firms had relatively little capital on hand to withstand a large downturn.[55] The PMI firms delegated or ceded underwriting, abdicating their perceived role in limiting excessive risk-taking. In the absence of ex-ante screening, the PMI firms instead relied on ex-post denial of coverage, or rescissions, to try and stay solvent.

Of the eight active firms during the boom, three were unable to make their payments in full and went out of business. Several others both aggressively rescinded policies and needed regulatory forbearance to stay in business. Ten years since the events of 2007, the basic relationships between the parties in the mortgage market are unchanged relative to how they interacted during the boom, and while market participants have self-imposed additional capital requirements and underwriting standards, there is nothing structural to prevent a similar "race to the bottom" dynamic in mortgage insurance in the future.[56] As Jaffee and Russell (1997) point out, there are few private markets capable of supporting catastrophe-style insurance, and the recent housing crisis has made it clear that PMI is, at its core, insurance against a national housing downturn, a form of systemic risk.[57]

An alternative approach to involving private capital in the GSE market is the credit risk transfer (CRT) approach, where the GSEs sell derivatives contracts that protect pools from losses.[58] This approach deals directly with investors, and thus avoids the organizational and regulatory issues related to insurance companies, especially their limited liability. It is not clear whether investors will be willing to bear this risk during a downturn, which could reduce the potential countercyclical

[55]Based on data from the Mortgage Insurance Companies of America, the industry's risk-to-capital ratio was roughly 10:1, or roughly half of what capital would have been prudent to withstand a large surge in defaults (Zandi, Parrott and deRitis 2014). That said, if tighter capital standards were in place, it would have likely forced PMI companies to raise premiums significantly, thereby discouraging the issuance of many of their riskiest policies.

[56]In contrast to the constant pricing of risk during the boom, a number of PMI firms have recently increased premiums in response to weaker underwriting standards (increases in the debt-to-income (DTI) ratio) imposed by the GSEs. See Ramirez (2018).

[57]In MGIC's 2007 10k disclosure to the SEC, they write "The private mortgage insurance industry is exposed to the risk of catastrophic loss," and describe the pattern from a prior recession: "To maximize market share, until the mid-1980s, private mortgage insurers employed liberal underwriting practices, and charged premiums rates which, in retrospect, generally did not adequately reflect the risk assumed..." (p. 16).

[58]See the discussion of CRT in Finkelstein, Strzodka and Vickery (2018). Investors in credit risk transfers are not exposed to PMI counterparty risk.

liquidity benefits of the GSEs. However, the PMI companies also proved to be an impediment to the ability of the GSEs to provide countercyclical liquidity. Their willingness and ability to write insurance collapsed by 2009, sharply limiting the GSEs' ability to fund higher-LTV loans often associated with first-time home buying (Avery et al. 2010). Considering our new evidence on the behavior of mortgage insurers during the boom, a careful examination of the tradeoffs between the PMI and CRT approaches to dealing with the GSEs' exposure to systemic risk is an area worthy of further investigation.

References

Acharya, Viral V, John Biggs, Matthew Richardson, and Stephen Ryan, "On the Financial Regulation of Insurance Companies," *Stern School of Business, Working paper*, 2009.

___ **, Matthew Richardson, Stijn Van Nieuwerburgh, and Lawrence J White**, *Guaranteed to Fail: Fannie Mae, Freddie Mac, and the Debacle of Mortgage Finance*, Princeton University Press, 2011.

Adelino, Manuel, W Scott Frame, and Kristopher Gerardi, "The effect of large investors on asset quality: Evidence from subprime mortgage securities," *Journal of Monetary Economics*, 2017, *87*, 34–51.

Agarwal, Sumit, Brent W Ambrose, and Vincent W Yao, "Lender Steering in Residential Mortgage Markets," *Real Estate Economics*, 2016.

An, Xudong and Cordell, Larry , "Regime Shift and the Post-Crisis World of Mortgage Loss Severities," Technical Report, Federal Reserve Bank of Philadelphia 2017. Working Paper No. 17-08.

Association, Mortgage Bankers, "GSE Reform: Creating a Sustainable, More Vibrant Secondary Mortgage Market," Technical Report 04 2017.

Avery, Robert B., Neil Bhutta, Glenn B. Canner, and Christa N. Gibbs, "The 2008 HMDA Data: The Mortgage Market during a Turbulent Year," *Federal Reserve Bulletin*, 2010, *96*, A39–A77.

Bhutta, Neil, "The Community Reinvestment Act and Mortgage Lending to Lower Income Borrowers and Neighborhoods," *The Journal of Law and Economics*, 2011, *54* (4), 953–983.

___ **, Jane Dokko, and Hui Shan**, "Consumer Ruthlessness and Mortgage Default during the 2007 to 2009 Housing Bust," *The Journal of Finance*, 2017, *72* (6), 2433–2466.

___ **, Steven Laufer, and Daniel R. Ringo**, "Residential Mortgage Lending in 2016: Evidence from the Home Mortgage Disclosure Act Data," *Federal Reserve Bulletin*, 2017, *103* (6).

Blanchard, Olivier Jean, Florencio Lopez de Silanes, and Andrei Shleifer, "What Do Firms Do with Cash Windfalls?," *Journal of Financial Economics*, 1994, *36* (3), 337–360.

Bohn, James G and Brian Hall, "The Moral Hazard of Insuring the Insurers," in "The Financing of Catastrophe Risk," University of Chicago Press, 1999, pp. 363–390.

Borch, Karl, "Equilibrium in a Reinsurance Market," *Econometrica*, 1962, pp. 424–444.

Calhoun, Charles A, "The Hidden Risks of Piggyback Lending," *June memo*, 2005.

Canner, Glenn B and Wayne Passmore, "Private Mortgage Insurance," *Federal Reserve Bulletin*, 1994, *80*, 883.

Congressional Budget Office, "Federal Subsidies and the Housing GSEs," Technical Report May 2001.

___ , "Fannie Mae, Freddie Mac, and the Federal Role in the Secondary Mortgage Market," Technical Report December 2010.

Deng, Yongheng, John M. Quigley, and Robert Van Order, "Mortgage Terminations, Heterogeneity and the Exercise of Mortgage Options," *Econometrica*, 2000, *68* (2), 275–307.

Doherty, Neil and Kent Smetters, "Moral hazard in reinsurance markets," *Journal of Risk and Insurance*, 2005, *72* (3), 375–391.

Downey, Kirstin, "Insurers Urge Action on Risky Mortgages; Firms Want More Loan Restrictions," *Washington Post*, August 19 2006.

England, Robert Stowe, "A Rebound at United Guaranty," *Mortgage Banking Magazine*, December 2012.

Fama, Eugene F, "Agency Problems and the Theory of the Firm," *Journal of Political Economy*, 1980, *88* (2), 288–307.

Finkelstein, David, Andreas Strzodka, and James Vickery, "Credit Risk Transfer and De Facto GSE Reform," Staff Report 838, Federal Reserve Bank of New York February 2018.

Froot, Kenneth, *The Financing of Catastrophe Risk* National Bureau of Economic Research Project Report, Chicago: University of Chicago Press, 1999.

Gerardi, Kristopher, Kyle F. Herkenhoff, Lee E. Ohanian, and Paul S. Willen, "Can't Pay or Won't Pay? Unemployment, Negative Equity, and Strategic Default," *The Review of Financial Studies*, 2017, *31* (3), 1098–1131.

Ghent, Andra C., Ruben Hernandez-Murillo, and Michael T. Owyang, "Did Affordable Housing Legislation Contribute to the Subprime Securities Boom?," *Real Estate Economics*, 2015, *43*, 820–854.

Goodman, Laurie S. and Jun Zhu, "Loss Severity on Residential Mortgages: Evidence from Freddie Mac's Newest Data," *The Journal of Fixed Income*, 2015, *25* (2), 48–57.

Gorton, Gary B, Andrew Metrick, and Lei Xie, "An Econometric Chronology of the Financial Crisis of 2007–2008," Technical Report 2015.

Henderson, M Todd, "Credit Derivatives Are Not Insurance," *Connecticut Insurance Law Journal*, 2009, *16* (1), 1–60.

Hurst, Erik, Benjamin J Keys, Amit Seru, and Joseph Vavra, "Regional Redistribution through the US Mortgage Market," *The American Economic Review*, 2016, *106* (10), 2982–3028.

Jaffee, Dwight, "Monoline Restrictions, with Applications to Mortgage Insurance and Title Insurance," *Review of Industrial Organization*, 2006, *28* (2), 83–108.

Jaffee, Dwight M and Thomas Russell, "Catastrophe insurance, capital markets, and uninsurable risks," *Journal of Risk and Insurance*, 1997, pp. 205–230.

Jensen, Michael C., "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers," *The American Economic Review*, 1986, *76* (2), 323–329.

___ **and William H. Meckling**, "Theory of the firm: Managerial behavior, agency costs and ownership structure," *Journal of Financial Economics*, 1976, *3* (4), 305–360.

Kahn, James A. and Benjamin S. Kay, "Mortgage Market Distortions from Mispricing During the Boom: Evidence from Insurance Premiums," Working Paper, Yeshiva University 07 2017.

Keys, Benjamin J, Tanmoy Mukherjee, Amit Seru, and Vikrant Vig, "Did Securitization Lead to Lax Screening? Evidence From Subprime Loans," *The Quarterly Journal of Economics*, 2010, *125* (1), 307–362.

Kilgore, Austin, "Growing Trend of Mortgage Insurance Claim Denials are Costing Servicers," *Housing Wire*, February 26 2010.

LaCour-Little, Michael, Charles A Calhoun, and Wei Yu, "What Role Did Piggyback Lending Play in the Housing Bubble and Mortgage Collapse?," *Journal of Housing Economics*, 2011, *20* (2), 81–100.

Liu, Haoyang, "Does Skin-In-The-Game Discipline Risk Management? Evidence from Mortgage Insurance," Working Paper, Florida State University 09 2017.

Mason, Joseph R. and Joshua Rosner, "How Resilient are Mortgage Backed Securities to Collateralized Debt Obligation Market Disruptions," *Drexel University Working Paper*, 2007.

Mayer, Christopher, Karen Pence, and Shane M Sherlund, "The Rise in Mortgage Defaults," *Journal of Economic perspectives*, 2009, *23* (1), 27–50.

MICA, "Fact Book and Member Directory 2008–2009," Technical Report, Mortgage Insurance Companies of America 2009.

Michel-Kerjan, Erwann O, "Catastrophe economics: the national flood insurance program," *The Journal of Economic Perspectives*, 2010, *24* (4), 165–186.

Milner, Mark F., "Slow and Steady Wins the Race," Technical Report, PMI Mortgage Insurance Co. summer 2006.

___ , "Understanding a Changing Market," Technical Report, PMI Mortgage Insurance Co. fall 2006.

Orin, Rhonda D. and Pamela D. Hans, "Another View: Rewriting History in the Mortgage Crisis," *New York Times*, July 29 2009.

Park, Kevin A, "Mortgage Insurance in the Great Recession." Ph.D. dissertation, University of North Carolina - Chapel Hill 2015.

___ , "FHA Loan Performance and Adverse Selection in Mortgage Insurance," *Journal of Housing Economics*, 2016, *34*, 82–97.

Parrott, Jim, Lewis Ranieri, Gene Sperling, Mark Zandi, and Barry Zigas, "A More Promising Road to GSE Reform: Why It Leads to a Government Corporation," Technical Report, Urban Institute 2016.

Piazzesi, Monika and Martin Schneider, "Momentum traders in the housing market: survey evidence and a search model," *American Economic Review*, 2009, *99* (2), 406–11.

Plantin, Guillaume, "Does Reinsurance need Reinsurers?," *Journal of Risk and Insurance*, 2006, *73* (1), 153–168.

___ **and Jean-Charles Rochet**, *When insurers go bust: an economic analysis of the role and design of prudential regulation*, Princeton University Press, 2009.

Qi, Min and Xiaolong Yang, "Loss Given Default of High Loan-to-Value Residential Mortgages," *Journal of Banking & Finance*, 2009, *33* (5), 788–799.

Ramirez, Kelsey, "Mortgage Insurance Companies Push Back Against 50% DTI," *Housing Wire*, March 2 2018.

Shiller, Robert J, "Understanding Recent Trends in House Prices and Homeownership," Technical Report, Proceedings – Economic Policy Symposium – Jackson Hole, Federal Reserve Bank of Kansas City 2007.

Stein, Jeremy C, "Takeover Threats and Managerial Myopia," *Journal of Political Economy*, 1988, *96* (1), 61–80.

Thomas, Jason and Robert Van Order, "A Closer Look at Fannie Mae and Freddie Mac: What We Know, What We Think We Know and What We Don't Know," 2011. George Washington University, Department of Finance.

Thompson, James R, "Counterparty Risk in Financial Contracts: Should the Insured Worry About the Insurer?," *The Quarterly Journal of Economics*, 2010, *125* (3), 1195–1252.

United States Departments of Treasury and Housing and Urban Development, "Reforming America's Housing Finance Market: A Report to Congress," Technical Report, Washington, D.C. feb 2011.

United States Federal Housing Finance Agency, "State of the Private Mortgage Insurance Industry: Implications for U.S. Mortgage Markets and the Enterprises," Technical Report, Mortgage Market Note 09-4 August 2009.

Weiss, David, Matthew Rosso, and Whitney Clymer, "What About Insurers? A Case for Holding Mortgage Insurers Accountable for the Mortgage Crisis," Technical Report, LexisNexis Emerging Issues Analysis May 2012.

Zandi, Mark, Jim Parrott, and Cristian deRitis, "Putting Mortgage Insurers on Solid Ground," Technical Report, Moody's Analytics August 2014.

Table I: PMI Issuance Growth and Other Correlates

	y = Δ (number of PMI policies) 2006-07		y = Δ ln(PMI policies), 2006-07											
			All policies						Policies with LTV ≥ 95% & FICO < 680					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Change in number of piggyback loans in tract *i*, 2006-2007	-0.2778 (0.0700)													
Change in number of 80-20 piggyback loans in tract *i*, 2006-2007		-0.3882 (0.0941)												
Share of 80/20 piggyback loans in tract or county in 2006			1.21 (0.10)						1.6424 (0.1980)					
Change in ln(county HPI), 2006-2007[a]				-0.0732 (0.0254)						-0.0900 (0.0380)				
Counties with declining house prices					0.0967 (0.0289)						0.2097 (0.0802)			
Acceleration in ln(county HPI), 2004-05 vs 2005-06[a]						-0.0445 (0.0290)						-0.0562 (0.0396)		
Counties with slowing house prices							0.0337 (0.0246)						0.0060 (0.0301)	
PMI Co. MSA Housing Risk Score[a]								0.1415 (0.0551)						0.1994 (0.0566)
Change in ln(county avg wage), 2006-2007[a]				0.0052 (0.0276)	0.0037 (0.0251)	0.0036 (0.0258)	-0.0016 (0.0280)		-0.0144 (0.0117)	0.0154 (0.0412)	0.0211 (0.0334)	0.0146 (0.0405)	0.0063 (0.0408)	
Change in ln(county employment), 2006-07[a]				0.0372 (0.0240)	0.0311 (0.0232)	0.0229 (0.0249)	0.0176 (0.0269)		-0.0401 (0.0222)	-0.0010 (0.0313)	0.0047 (0.0264)	-0.0211 (0.0357)	-0.0271 (0.0388)	
County level regression				x	x	x	x	x	x	x	x	x	x	x
Tract level regression	x	x	x											
State fixed effects				yes	yes	yes	yes		yes	yes	yes	yes	yes	
County fixed effects	yes	yes	yes											
Adjusted R^2	0.34	0.36	0.25	0.78	0.78	0.77	0.77	0.19	0.59	0.65	0.67	0.64	0.64	0.25
N	63961	63961	55496	989	989	970	970	255	2538	961	961	944	944	245

Standard errors in parentheses, clustered at state level in all columns except in columns 8 and 14 where clustering is at the MSA level. PMI data for regressions in columns 1-8 are from the FFIEC PMIC data. Regressions in columns 3-14 weighted by total population in 2000. PMI data for regressions in columns 9-14 use the complete McDash data on first-lien home purchase loans with PMI. Data on piggyback lending from HMDA data (see text for details on identifying piggyback loans in HMDA). House price data are from Zillow. Wage and employment data are from the BLS; counties with wage growth or employment growth below the 1st percentile or above the 99th percentile are trimmed. County growth rates in PMI issuance also trimmed at 1st and 99th percentiles.

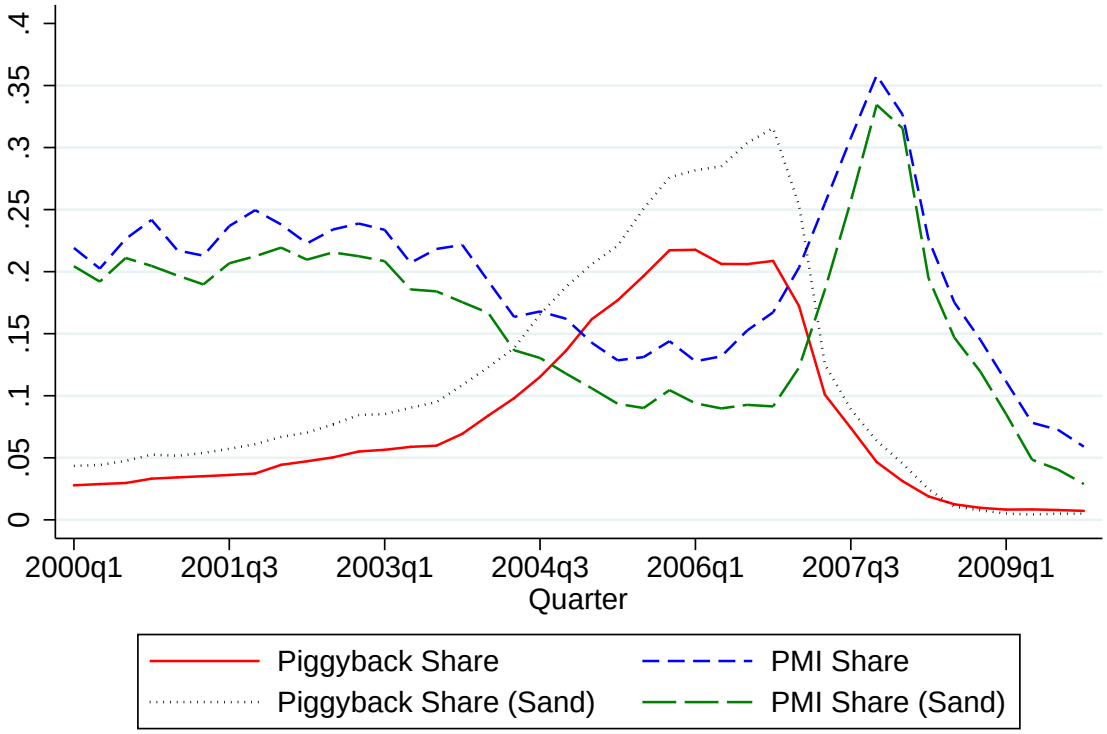
[a] Variable normalized by its sample standard deviation.

Table II: Risk Scores

	Year	
MSA	2005	2006
Boston-Quincy, MA	535	588
Nassau-Suffolk,NY	511	589
Oakland-Fremont-Hayward, CA	488	582
San Jose-Sunnyvale-Santa Clara, CA	481	559
San Diego-Carlsbad-San Marcos, CA	467	599
Cambridge-Newton-Framingham, MA (MSAD)	446	537
Santa Ana-Anaheim-Irvine, CA	431	588
Los Angeles-Long Beach-Glendale, CA	404	575
Sacramento-Arden-Arcade-Roseville, CA	403	585
San Francisco-San Mateo-Redwood City, CA	396	560
Providence-New Bedford-Fall River, RI-MA	389	568
Detroit-Livonia-Dearborn,MI	379	337
Riverside-San Bernardino-Ontario, CA	339	583
New York-Wayne-White Plains, NY-NJ	334	498
Edison,NJ	315	536
Minneapolis-St. Paul-Bloomington, MN-WI	251	355
Fort Lauderdale-Pompano Beach-Deerfield Beach, FL	236	441
Denver-Aurora,CO	211	149
Newark-Union,NJ-PA	206	459
Washington-Arlington-Alexandria,DC-MD-VA-WV	189	431
Miami-Miami Beach-Kendall, FL	181	359
Warren-Farmington Hills-Troy, MI	161	184
Tampa-St. Petersburg-Clearwater, FL	143	294
Baltimore-Towson, MD	115	307
Las Vegas-Paradise, NV	108	481

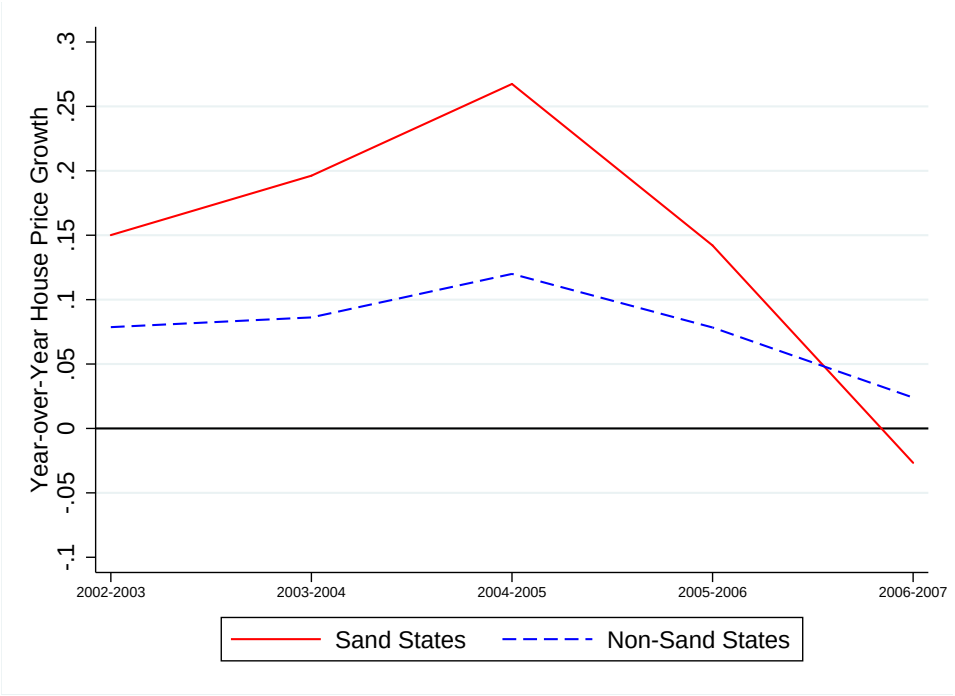
Source: PMI Company's "Economic and Real Estate Trends" reports. Notes: This table shows risk scores for housing markets as evaluated by the PMI industry for the 25 riskiest markets as of 2005 for the years 2005–2006. The risk scores represent the likelihood of a decline in house prices in a given market over the next two years. A score of 500 translates to a 50% chance of a decline in house prices in a given market.

Figure 1: Share of Loans with "Piggyback" Second Lien and with PMI, 2000–2009



Source: PMIC and HMDA data. Notes: This figure plots the share of loans with "piggyback" financing (inferred as a fraction of first liens from HMDA), and the share of loans with PMI by quarter of origination from 2000 to 2009, separately for the U.S. as a whole and for the sand states.

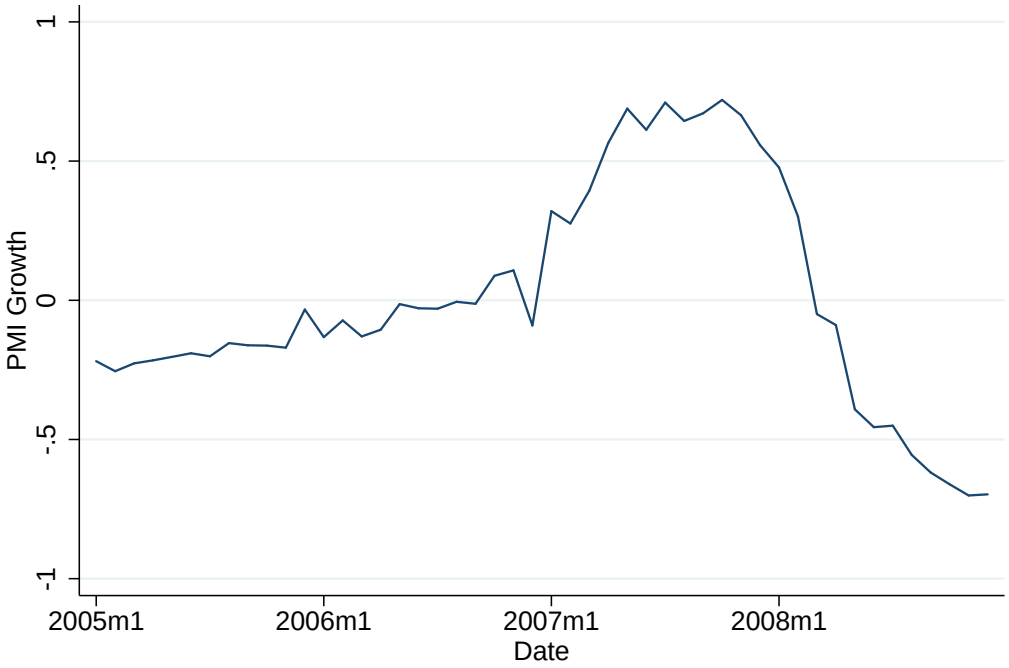
Figure 2: Year-over-Year Changes in House Prices, by Sand/Non-Sand States, 2002-2007



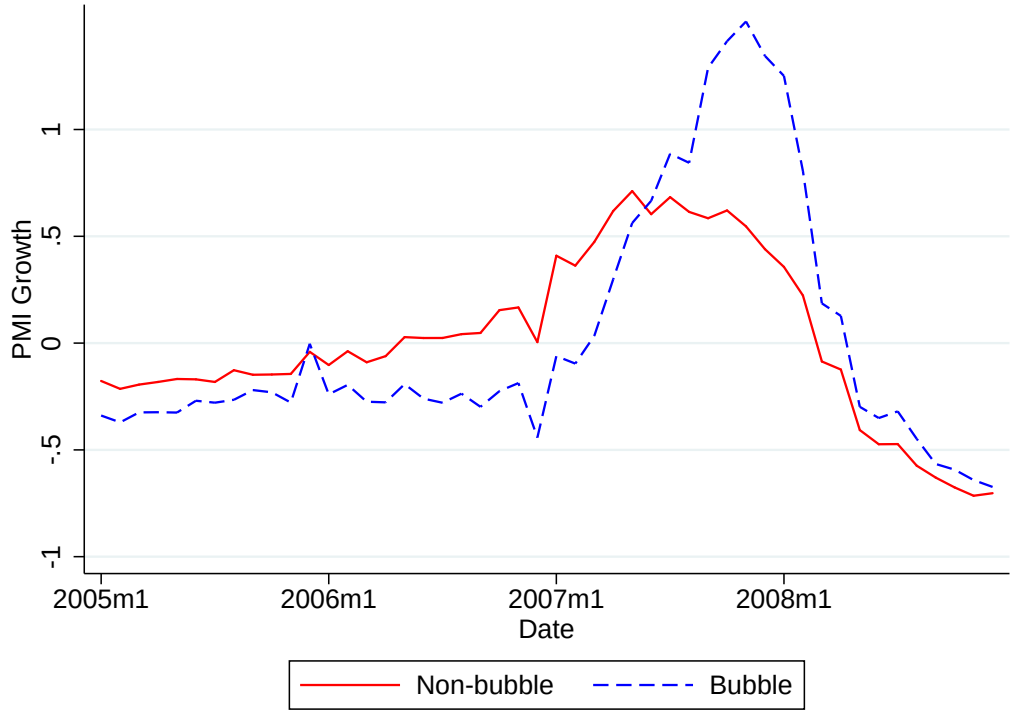
Source: Zillow and U.S. Census Bureau. Notes: This figure shows year-over-year house price growth, as measured using Zillow MSA-level data, for sand states (AZ/CA/FL/NV) and non-sand states (weighted by population). Each year's growth rate is measured January to January.

Figure 3: Time Series of PMI Issuance Growth

Panel A. PMI Issuance Growth in the U.S., 2005–2009



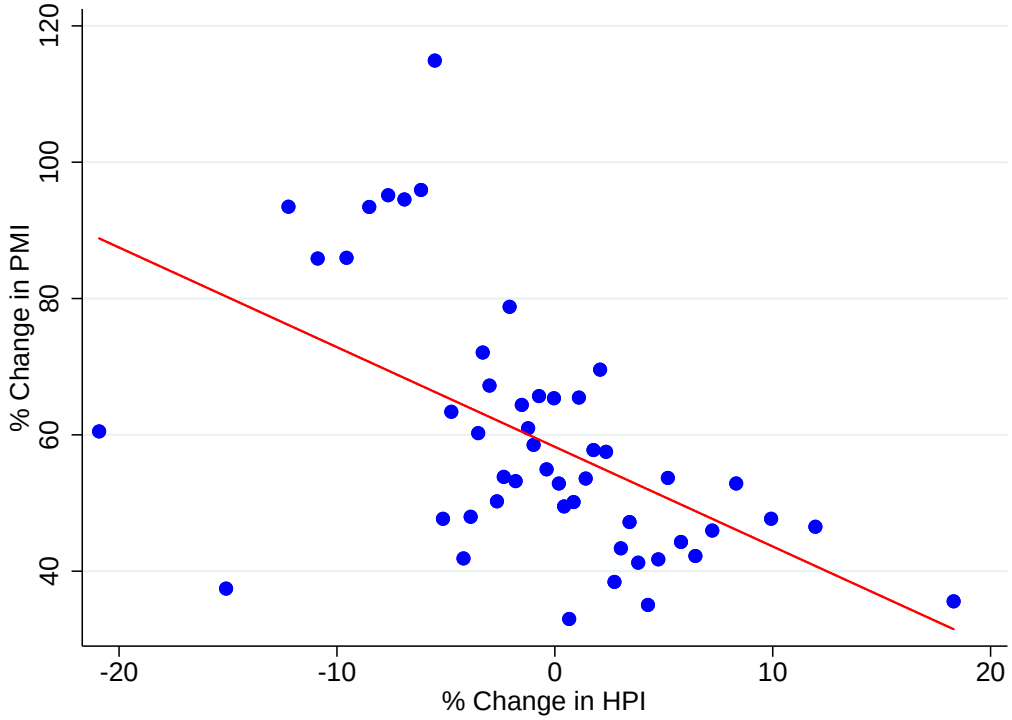
Panel B. PMI Issuance Growth in Sand and Non-Sand States, 2005–2009



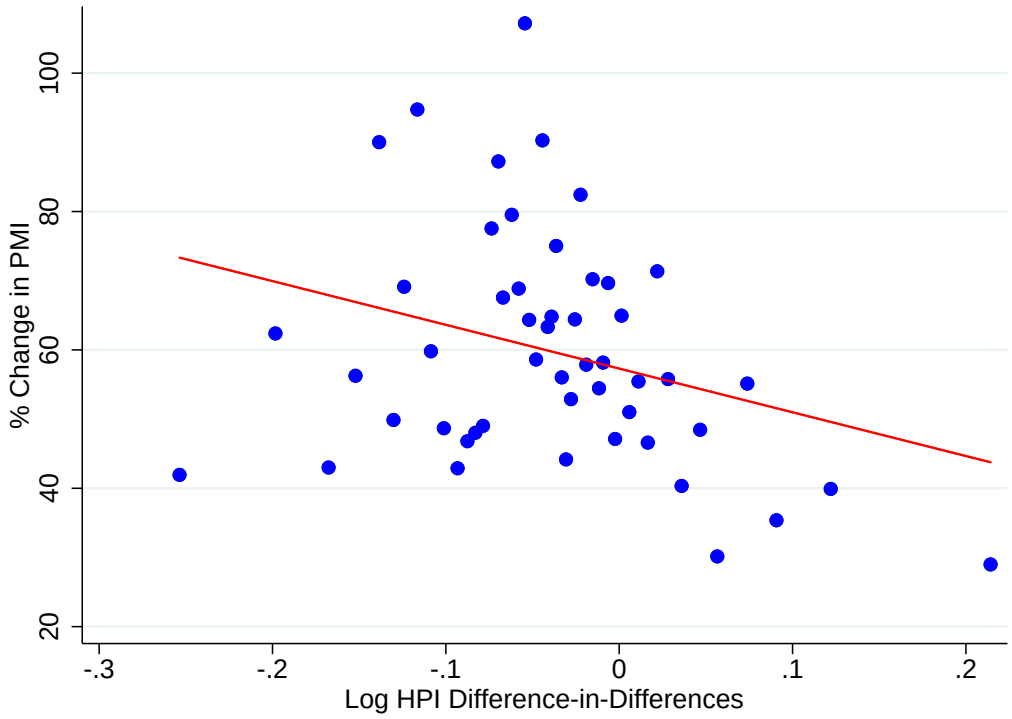
Source: PMIC data. Notes: The first panel of this figure plots the annual growth rate of PMI issuance in the United States from 2005 to 2009. The second panel plots the growth of PMI issuance in the "sand states" of California, Arizona, Florida, and Nevada (in red), and the growth of PMI issuance in all other states (in blue).

Figure 4: Local Relationship between PMI growth and House Prices

Panel A. PMI Growth and House Price Growth, 2006–2007

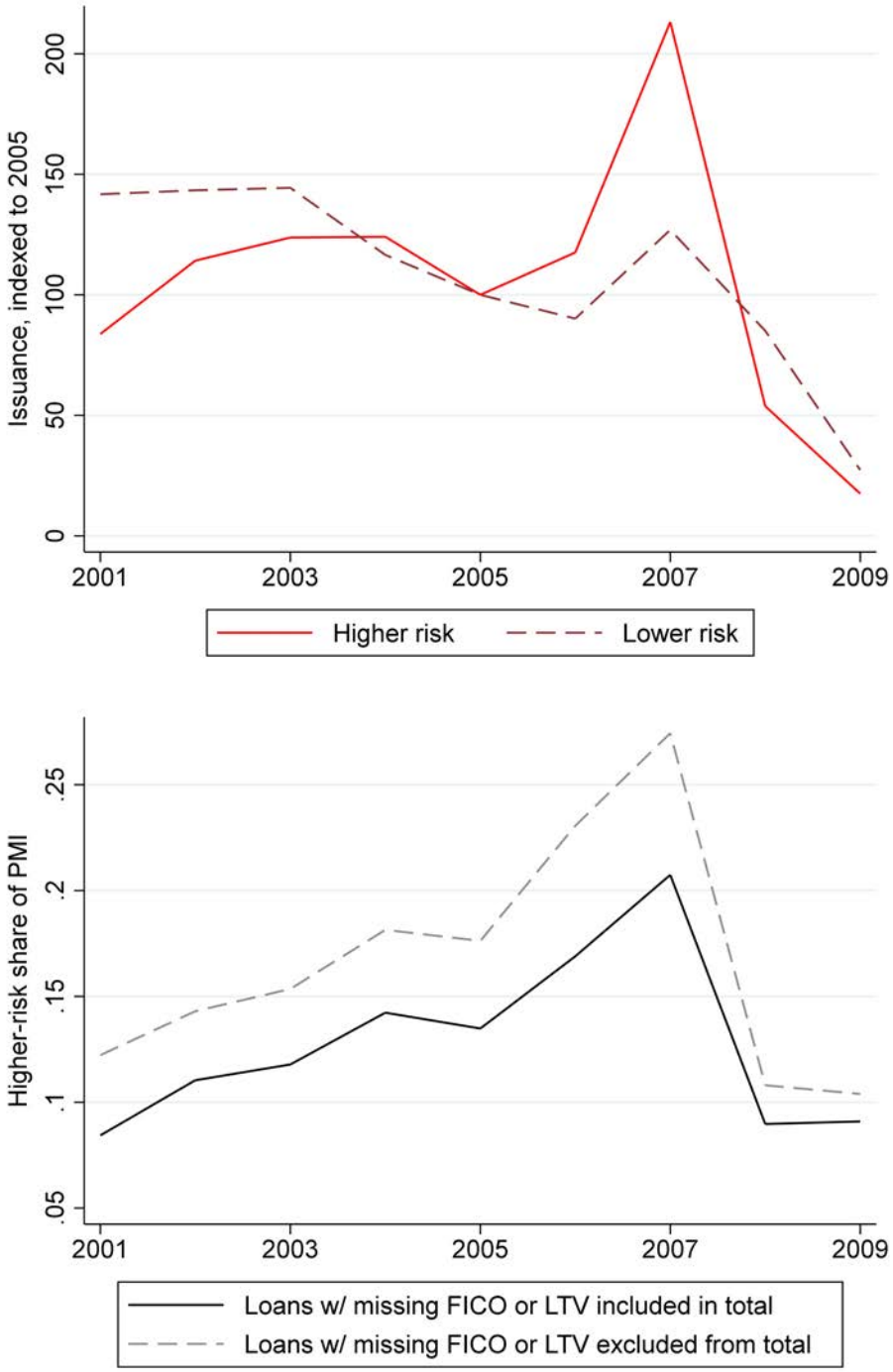


Panel B. PMI growth and House Price Slowdown, 2006–2007



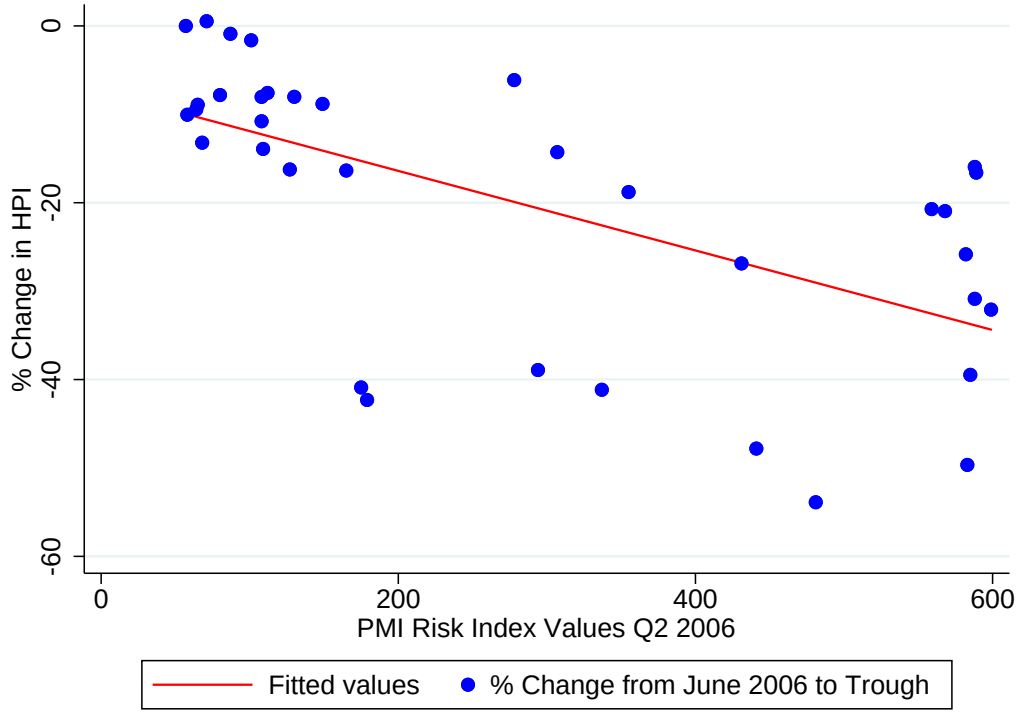
Source: PMIC data and Zillow. Notes: The first panel of the figure shows the relationship between the change in PMI issuance and the change in house prices at the county level from 2006 to 2007. The second panel shows the relationship between the change in PMI issuance between 2006 and 2007 and the change in house price growth (the difference-in-differences) at the county level from 2005 to 2006.

Figure 5: PMI Issuance, by Risk Level



Source: McDash. Notes: The top panel of the figure shows the issuance from 2001 to 2009 across higher risk and lower risk mortgages, where high risk is defined as FICO scores below 680 and LTV ratios above 95 percent. The lower panel shows the high risk share by year, using a definition that includes missing FICO/LTV values (solid) and excludes missing values (dashed), for 2001 to 2009.

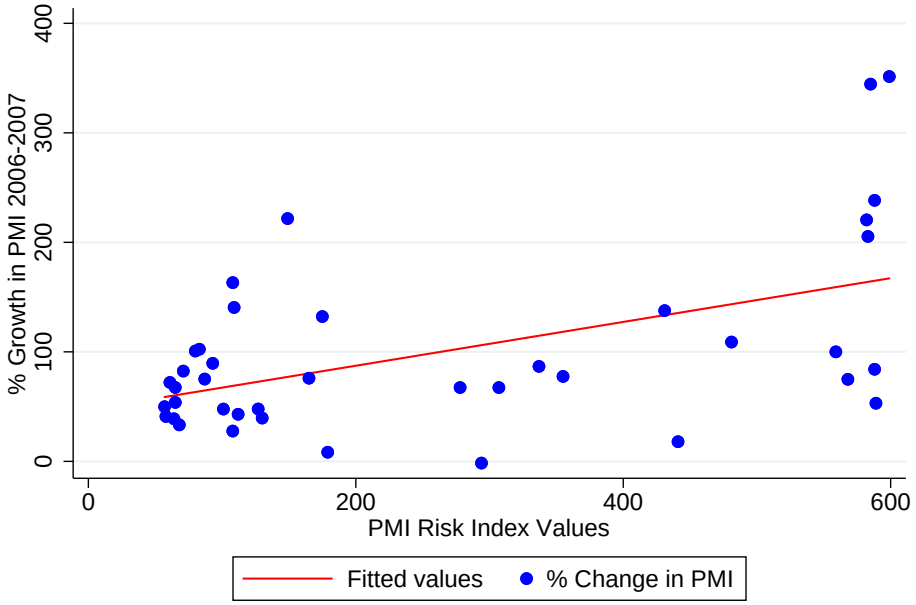
Figure 6: Relationship between Forecasted Risk and Subsequent House Price Declines



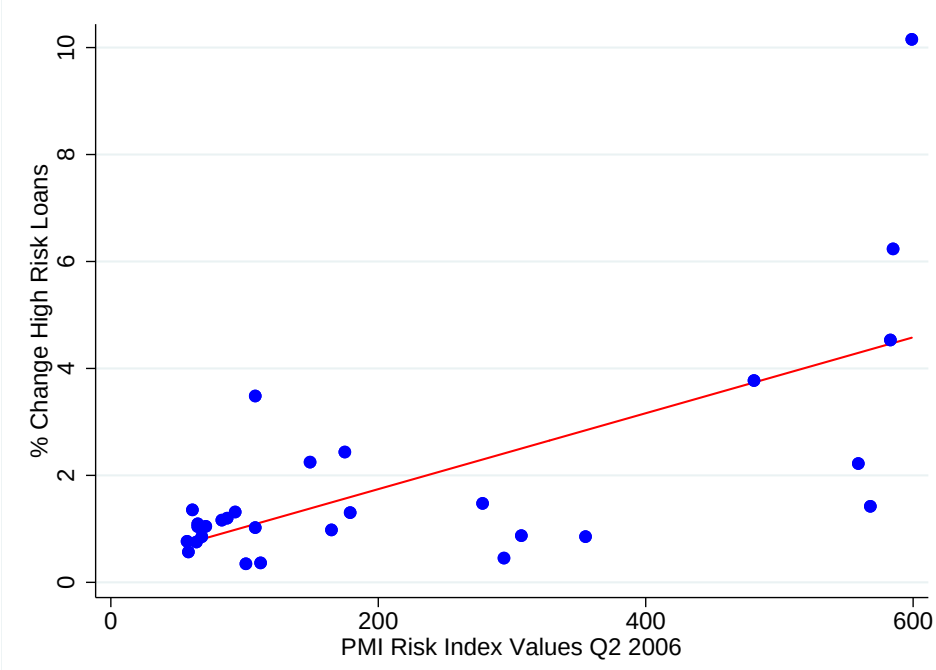
Source: PMI Company reports and Zillow. Notes: This chart plots PMI industry risk scores on the x-axis against HPI changes on the y-axis. The HPI change is measured as the change from September 2006 to the lowest house price measured after that date in a given metro.

Figure 7: Relationship between Industry Ex-Ante Forecasted Risk and Growth in PMI Issuance

Panel A. Relationship between Risk Index and Growth in PMI Issuance

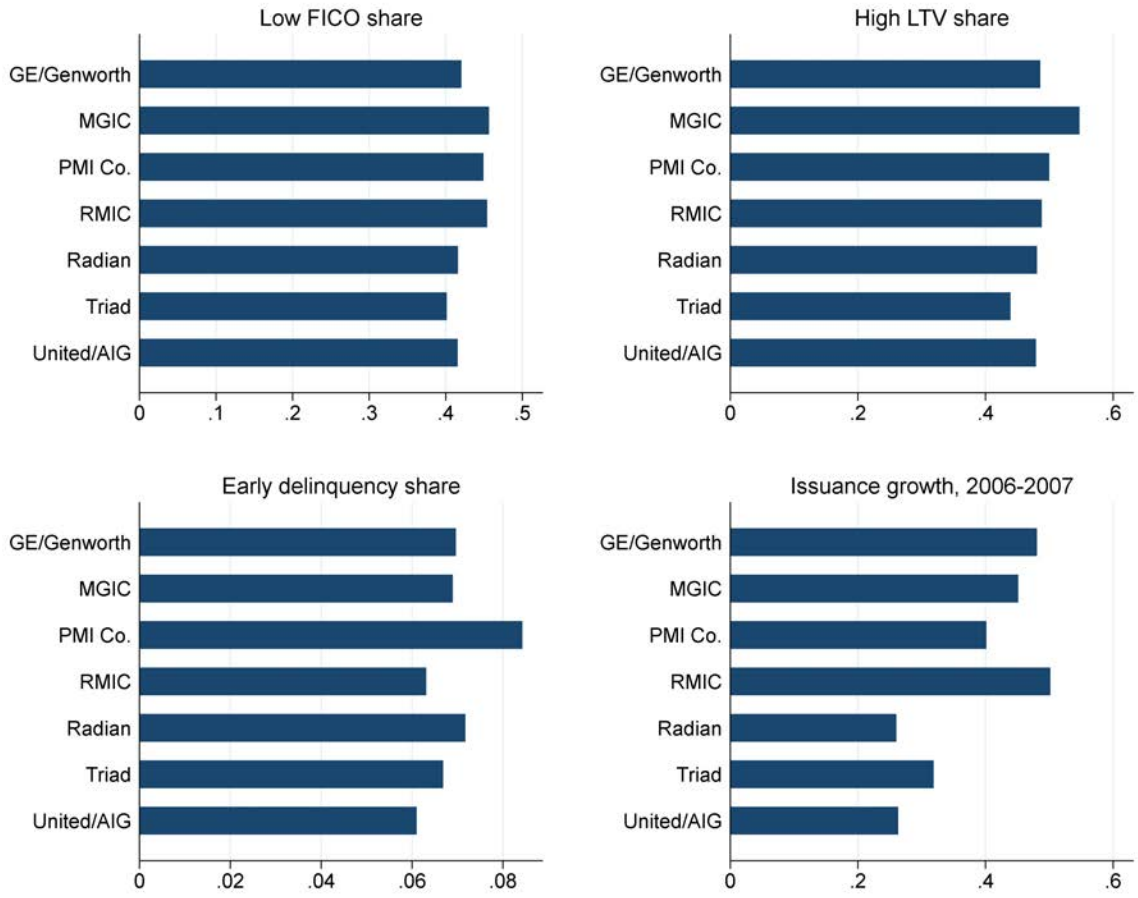


Panel B. Relationship between Risk Index and Growth in High-Risk PMI Issuance



Source: PMI Company reports, PMIC data, and McDash. Notes: The first panel of this chart plots PMI industry risk scores on the x-axis against changes in PMI issuance from September 2006 to September 2007. The panel shows that some of the riskiest locations according to the PMI industry report were saw the fastest growth in PMI issuance in the run up to the housing crisis. The second panel plots PMI industry risk scores on the x-axis against changes in PMI issuance from September 2006 to September 2007 on low-FICO, high-LTV (97%) loans. The panel shows that some of the riskiest locations according to the PMI industry report saw the fastest growth in high-risk PMI issuance in the run up to the housing crisis.

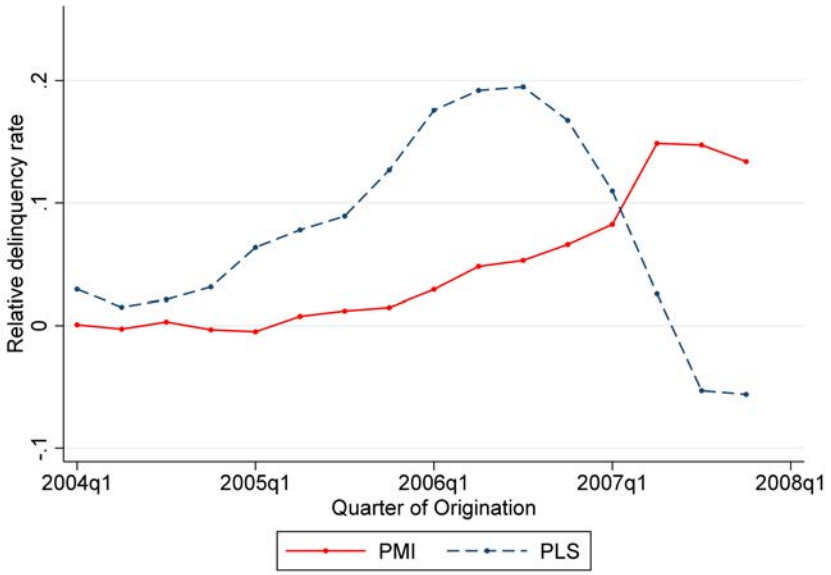
Figure 8: Limited Variation across PMI Firms



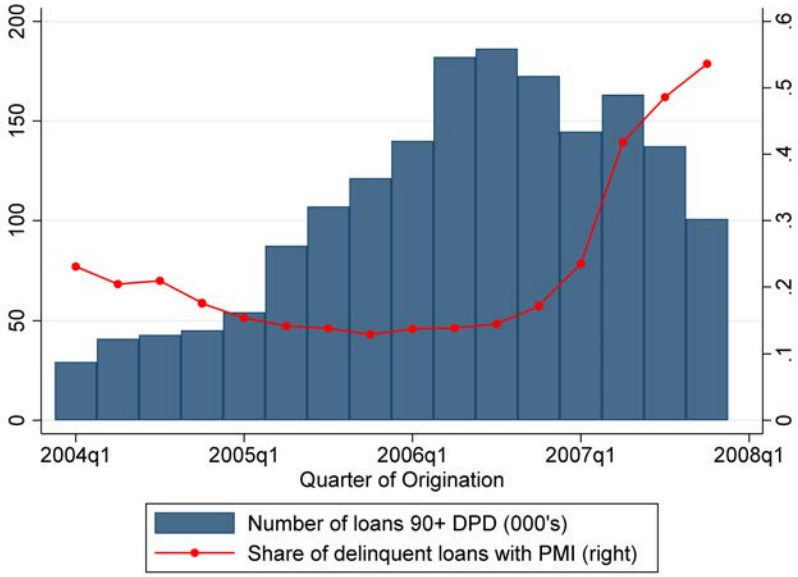
Source: PMIC data and McDash. Notes: This figure shows the share of PMI issuance in 2007 with low FICO scores (below 680) in panel a, high LTV ratios (above 95 percent) in panel b, early delinquency rates in panel c, and issuance growth from 2006 to 2007 in panel d.

Figure 9: Performance of Loans with PMI, by Quarter of Origination

Panel A. Delinquency Rate (60+ DPD) of PMI and PLS loans

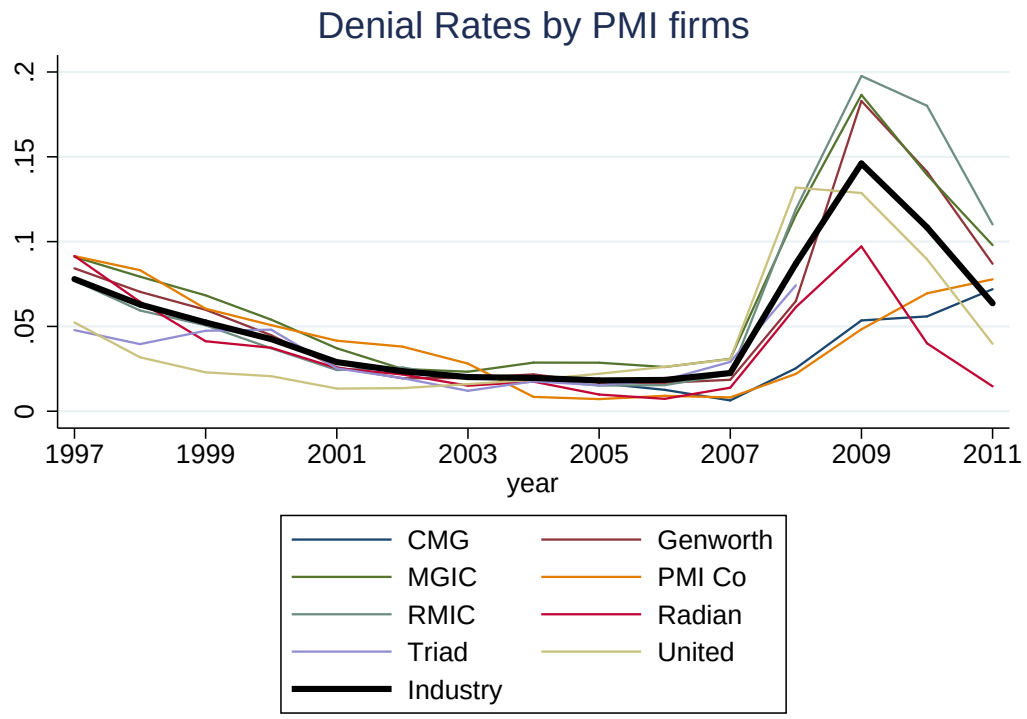


Panel B. Number of Loans with PMI Delinquent (60+ DPD) within 36 Months of Origination



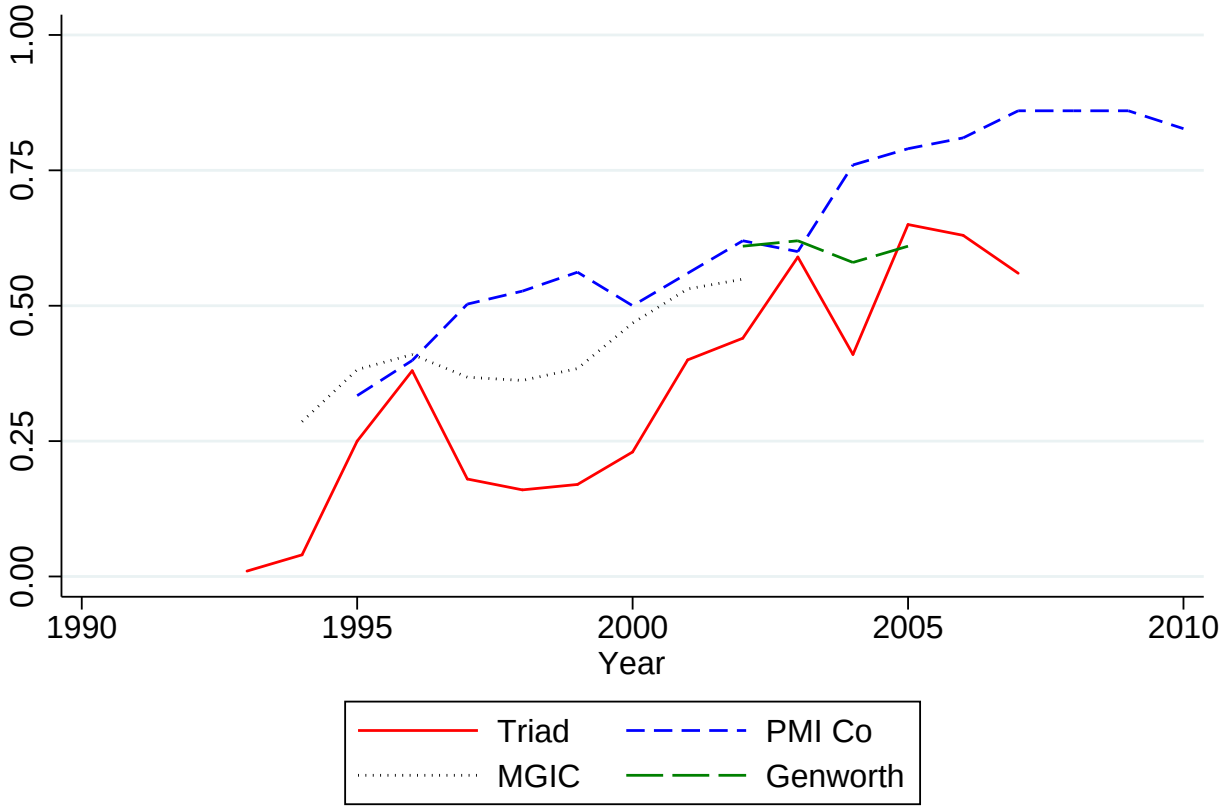
Source: McDash. Notes: The first panel figure shows the delinquency rate (60 days or more past due) within 36 months of origination, by quarter of origination, from 2004 to 2007, for loans with PMI (blue) and private-label securitization loans (red), shown relative to the performance of non-PMI, non-PLS loans from the same vintage and same county. The second panel shows the number of loans with PMI 60 days or more past due within 36 months of origination, by quarter of origination, from 2004 to 2007, in thousands (left-axis). The red line (right-axis) presents the share of delinquent loans covered by PMI over the same time period.

Figure 10: PMI Denial Rate, 1997–2011, by Firm



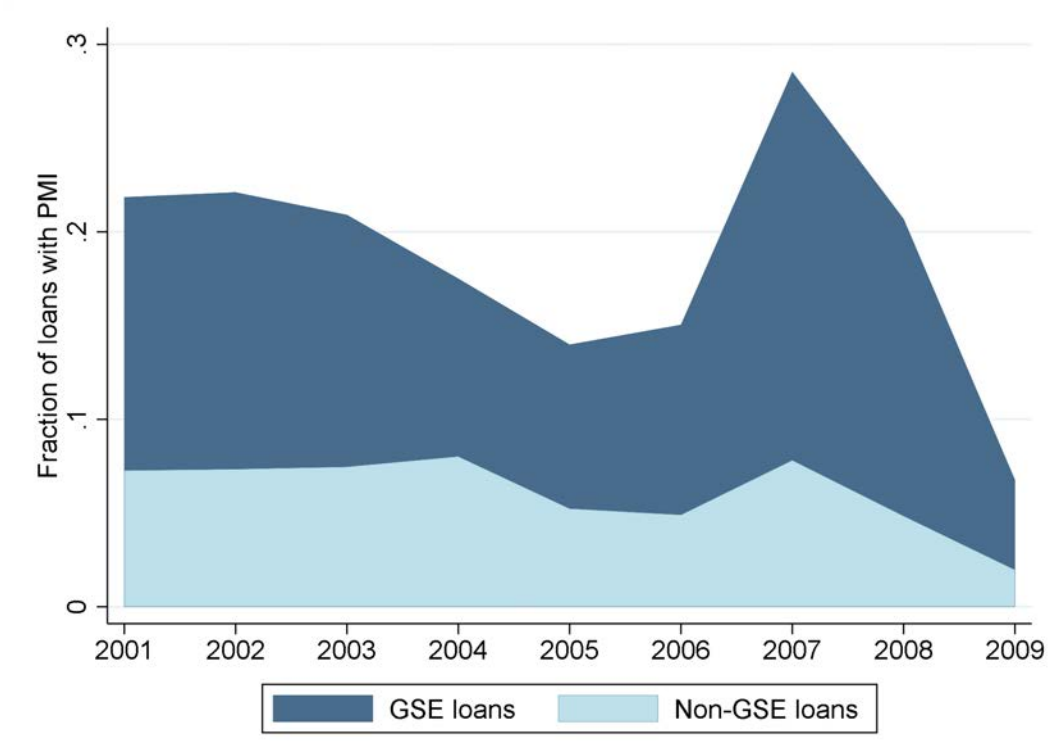
Source: PMIC data. Notes: This figure plots the denial rate of PMI applications by PMI firm from 1997 to 2011.

Figure 11: Prevalence of Delegated Underwriting, 1993–2010



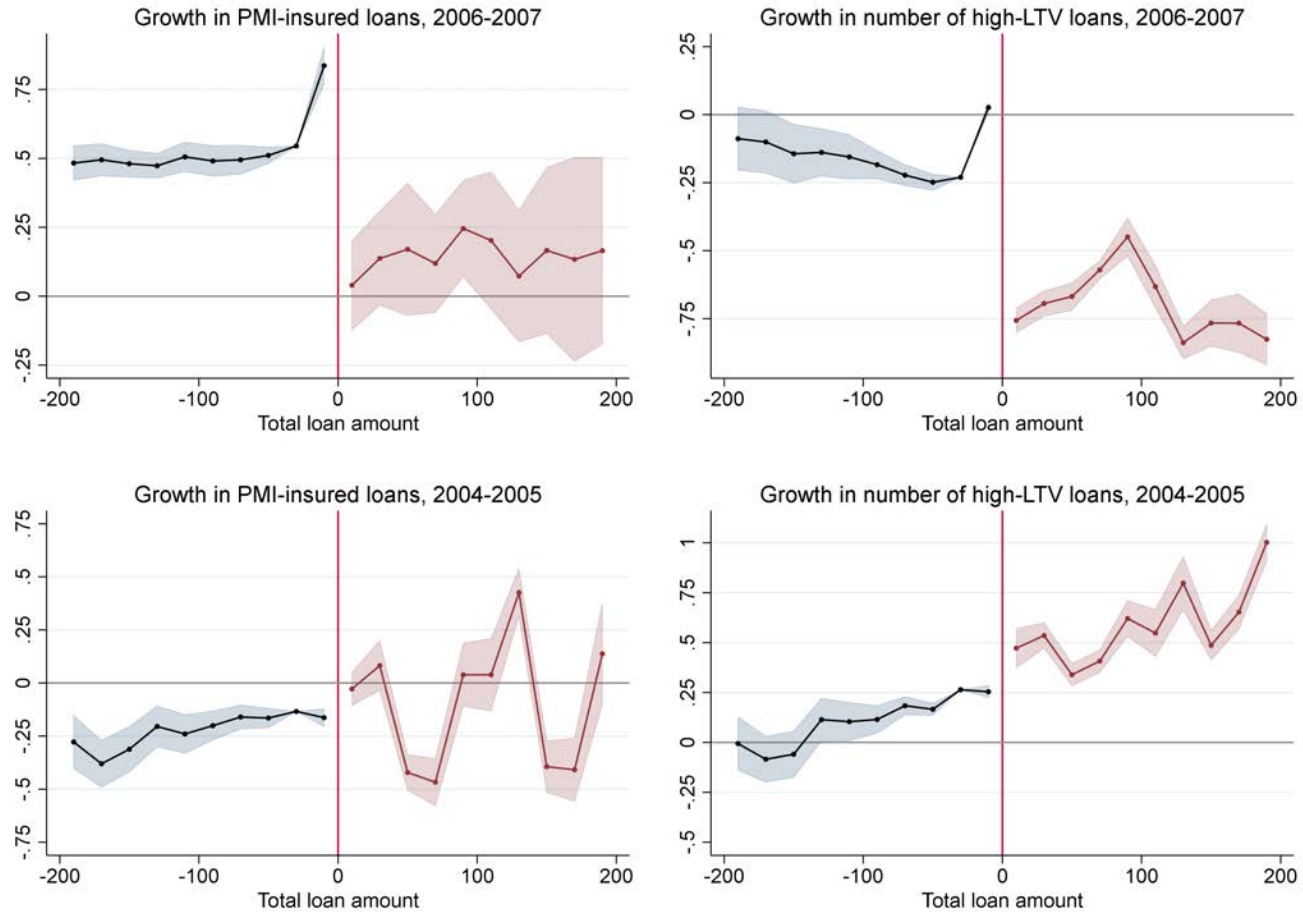
Source: PMI firms' 10-K disclosures. Notes: The figure shows the percentage of new insurance written that was based on delegated underwriting agreements. Only select years have 10-K reports available, and the percentage through delegated underwriting is not reported by all firms in all years.

Figure 12: PMI Market Share, 2001–2009, by GSE and non-GSE Share



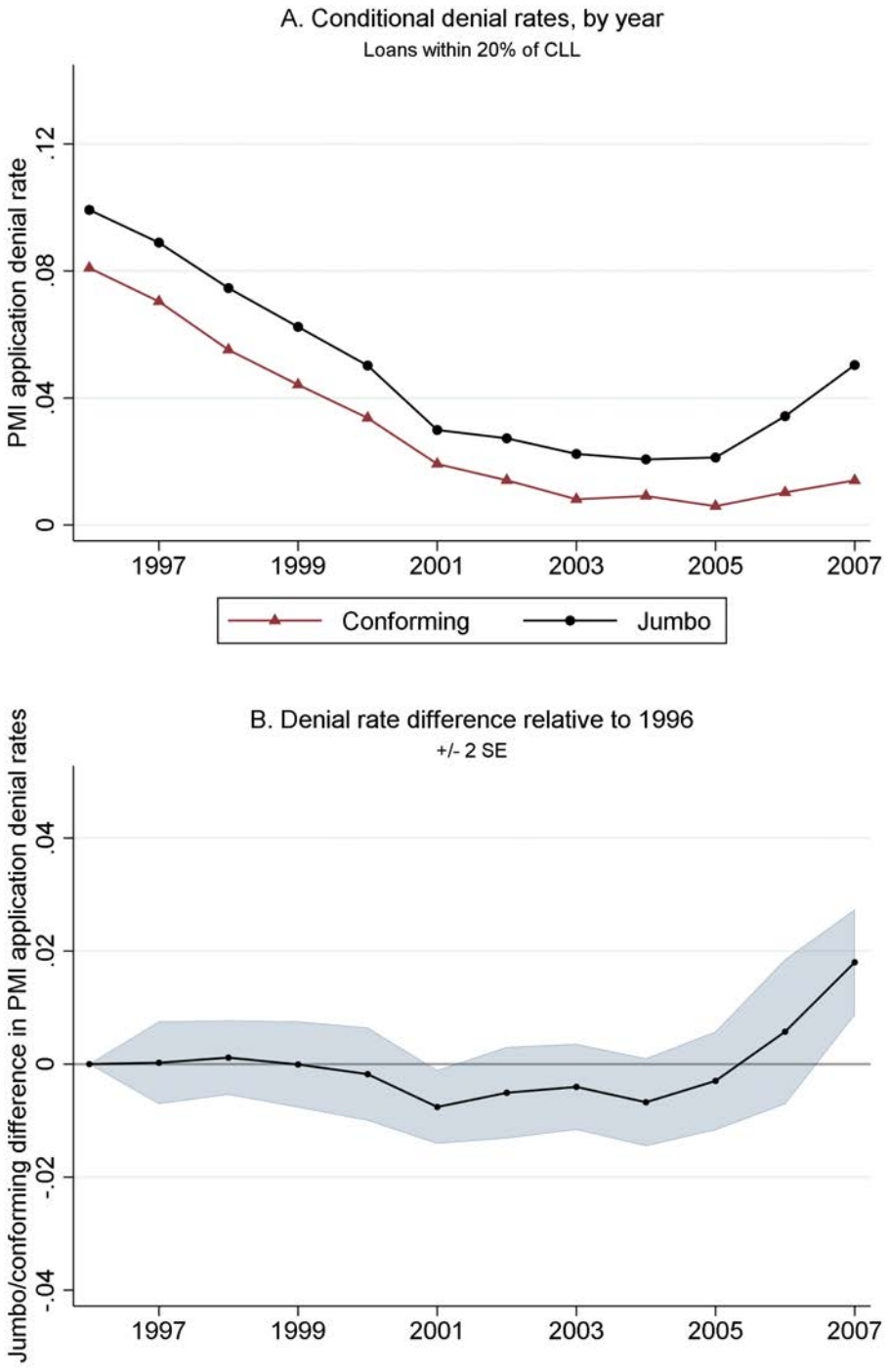
Source: McDash. Notes: This figure shows the composition of PMI-backed purchase mortgages across the GSE and non-GSE markets from 2001 to 2009. Distinction between GSE and non-GSE is identified based on the reported investor when the loan is six months old; If the loan is not observed at six months, then status is determined based on whether the GSEs were ever the reported investor.

Figure 13: Growth in PMI-insured and High-LTV Loans around the Conforming Loan Limit



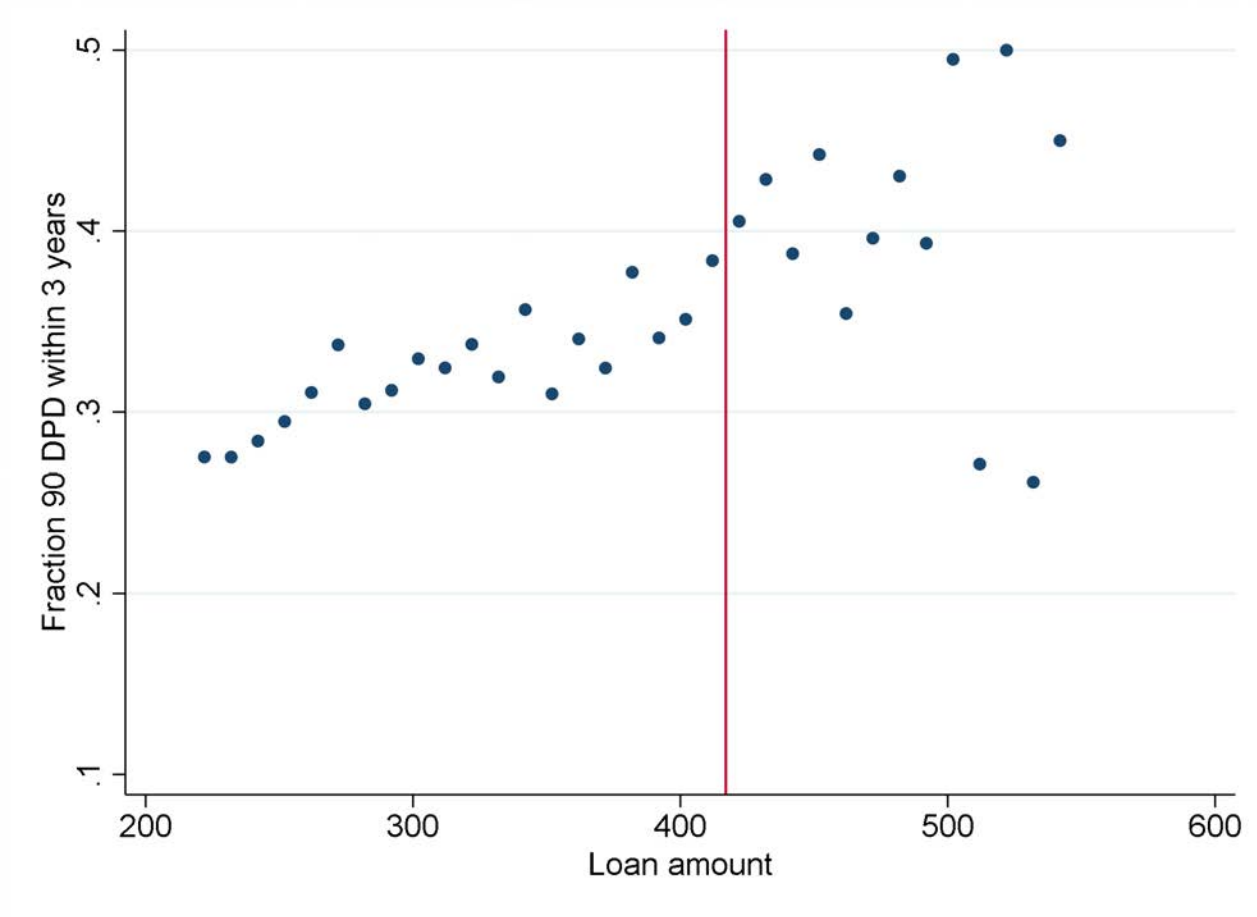
Source: PMIC and HMDA data. Notes: The top-left panel of the figure presents the growth in the number of PMI-insured loans between 2006 and 2007, by total loan amount. The vertical line indicates the conforming loan limit. Loans made to the left of the limit are conforming and eligible based on loan size to be sold to the GSEs, whereas loans above this limit are ineligible and can be sold to the non-agency secondary market. The top-right panel presents the growth in the number of high-LTV loans between 2006 and 2007, by total loan amount. The bottom left and bottom right panels are the equivalent figures for 2004–2005, when the non-agency market was active.

Figure 14: Denial Rate on PMI Applications, Jumbo and Conforming Loans, 1996–2007



Source: PMIC data. Notes: Panel A of this figure shows the denial rate of PMI applications, by year, for conforming and jumbo loans within 20% of the conforming loan limit (CLL) from 1996–2007. Panel B shows the jumbo-conforming difference in denial rates, over time, along with 95% error bands. The series is benchmarked to the 1996 difference.

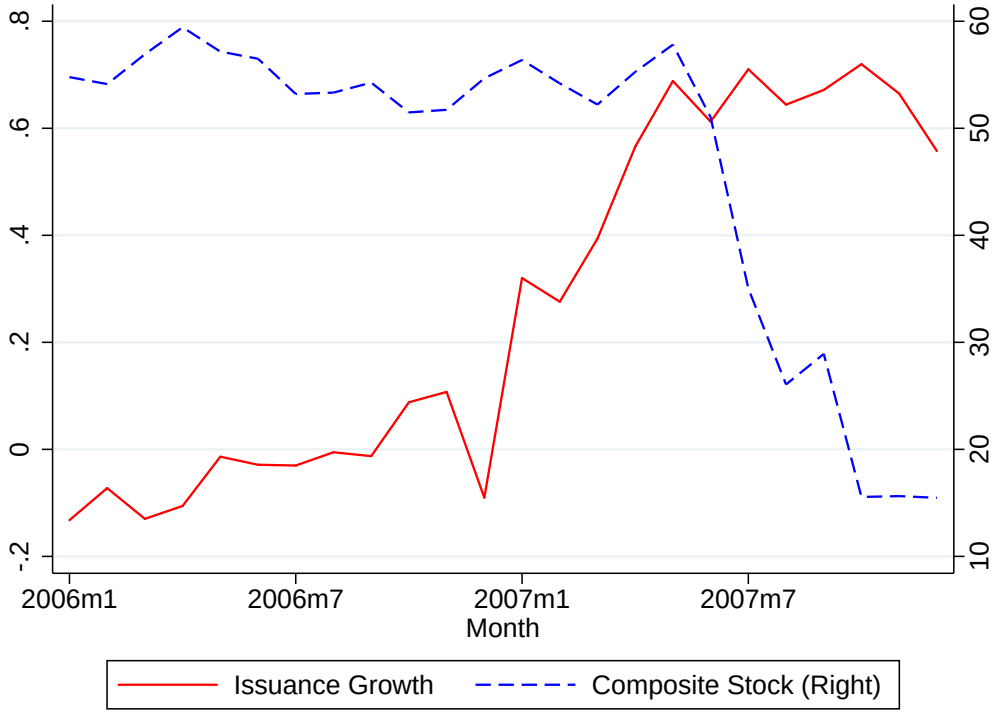
Figure 15: Delinquency Rate of PMI-Insured Loans in 2007, around the Conforming Loan Limit



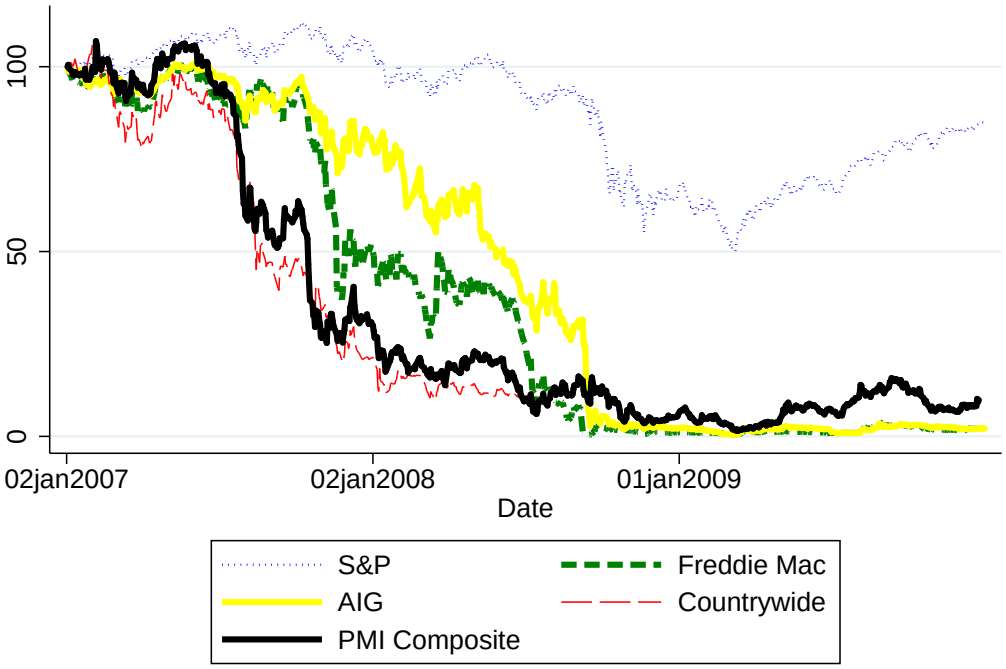
Source: McDash. Notes: This figure presents delinquency rate (as measured by the fraction of loans that reach 90 days or more past due within three years after origination) among PMI-Insured loans originated in 2007, by total loan amount. The vertical line indicates the conforming loan limit of $417,000. Loans made to the left of the limit are conforming and eligible based on loan size to be sold to the GSEs, whereas loans above this limit are ineligible and can be sold to the non-agency secondary market.

Figure 16: PMI Stock Prices and Issuance

Panel A. PMI Composite Stock Prices and Policy Issuance



Panel B. PMI Stock Price Relative to Other Notable Firms, Indexed to 2007



Source: PMIC data and CRSP. Notes: The top panel of the figure shows the time series of PMI stock prices (left-axis, based on a market-cap-weighted composite of Radian, Triad, PMI Co., and MGIC) and the volume of issuance (right-axis) from January 2006 to December 2007. The bottom panel shows the time series of PMI stock prices relative to other notable firms, indexed to 100 in January 2007.

Table A-1: Home Purchase Loans and PMI Issuance, 2001–2009 (in thousands)

Values in thousands unless otherwise indicated	2001	2002	2003	2004	2005	2006	2007	2008	2009
A. HMDA Data									
(1) First lien purchase loans	4,772	4,888	5,276	5,646	6,016	5,309	4,061	3,041	2,747
(2) First lien conventional jumbo purchase loans	303	335	393	595	711	462	317	74	40
(3) Junior lien purchase loans	na	na	na	791	1,374	1,431	603	98	46
(4) Junior lien purchase loans (inferred)[a]	171	241	323	618	1,137	1,111	402	55	22
(5) Junior liens for 80/20 combos (inferred)[a]	34	73	136	376	754	705	154	4	1
Junior lien share [(3)/(1)]	na	na	na	0.140	0.228	0.270	0.148	0.032	0.017
Inferred junior liens as share of all junior liens [(4)/(3)]	na	na	na	0.781	0.827	0.776	0.667	0.556	0.476
Inferred junior lien share [(4)/(1)]	0.04	0.05	0.06	0.11	0.19	0.21	0.10	0.02	0.01
80/20 share [(5)/(4)]	0.20	0.30	0.42	0.61	0.66	0.63	0.38	0.07	0.03
B. PMIC Data									
(6) PMI on first lien purchase loans	1,093	1,138	1,156	960	816	766	1,131	660	212
(7) PMI on first lien purchase jumbo loans	34	32	30	33	26	12	18	4	1
PMI share [(6)/(1)]	0.23	0.23	0.22	0.17	0.14	0.14	0.28	0.22	0.08
PMI jumbo share [(7)/(2)]	0.11	0.10	0.08	0.06	0.04	0.03	0.06	0.06	0.01
C. McDash Data									
(8) First lien purchase loans	2,312	2,545	3,674	3,860	4,531	4,187	3,408	2,310	2,362
(9) PMI on first lien purchase loans	506	565	771	680	646	685	1,000	480	160
(10) PMI on first lien GSE purchase loans	337	376	494	366	396	424	706	366	113
(11) PMI on first lien non-GSE purchase loans	169	189	278	314	250	261	294	114	47
(12) PMI on first lien purchase loans, high risk[b]	43	62	91	97	87	116	208	43	15
(13) PMI on first lien GSE purchase loans, high risk[b]	28	46	69	59	59	88	168	22	0
(14) PMI on first lien non-GSE purchase loans, high risk[b]	14	16	22	38	28	28	39	22	14
(15) PMI on first lien purchase loans, missing FICO or LTV	157	129	179	147	152	183	244	81	20
McDash share of first liens [(8)/(1)]	0.48	0.52	0.70	0.68	0.75	0.79	0.84	0.76	0.86
McDash share of PMI [(9)/(6)]	0.46	0.50	0.67	0.71	0.79	0.89	0.88	0.73	0.75
GSE share of PMI [(10)/(9)]	0.67	0.67	0.64	0.54	0.61	0.62	0.71	0.76	0.71
High risk share of PMI [(12)/(9)]	0.08	0.11	0.12	0.14	0.13	0.17	0.21	0.09	0.09
High risk share of PMI, ex obs w/ missing data [(12)/((9)-(15))]	0.12	0.14	0.15	0.18	0.18	0.23	0.27	0.11	0.10

a. Junior lien purchase loans (also referred to as piggyback loans), inferred by identifying pairs of loans reported in HMDA originated by the same lender, on the same day, secured by property in the same census tract and to a borrower with the same income. The smaller loan among such a pair is assumed to be the junior lien.

b. 'High risk' defined as FICO < 680 and LTV ≥ 95%.

Table A-2: PMI Issuance Growth and High-LTV Lending around the Conforming Loan Limit

Outcome:	Δ ln(high-LTV loans) 2006-07	Δ ln(PMI) 2006-07	Δ ln(high-LTV loans) 2004-05	Δ ln(PMI) 2004-05
Total loan amount relative to CLL ($, 000's)				
-199 to -180	0.142*	-0.062	-0.270**	-0.144*
	(0.05815)	(0.03147)	(0.06679)	(0.06248)
-179 to -160	0.130*	-0.050	-0.349**	-0.247**
	(0.05727)	(0.02908)	(0.05744)	(0.05512)
-159 to -140	0.087	-0.064*	-0.323**	-0.178**
	(0.05399)	(0.02436)	(0.05821)	(0.05373)
-139 to -120	0.092*	-0.072**	-0.150**	-0.071
	(0.04370)	(0.02230)	(0.05361)	(0.04815)
-119 to -100	0.075	-0.039	-0.160**	-0.106*
	(0.04077)	(0.02680)	(0.04804)	(0.04555)
-99 to -80	0.047	-0.054	-0.149**	-0.067
	(0.02597)	(0.02782)	(0.03459)	(0.03450)
-79 to -60	0.008	-0.050	-0.080**	-0.026
	(0.01935)	(0.02619)	(0.02308)	(0.02818)
-59 to -40	-0.018	-0.034*	-0.098**	-0.031
	(0.01471)	(0.01478)	(0.01505)	(0.02276)
-19 to 0	0.257**	0.291**	-0.010	-0.029
	(0.00893)	(0.03459)	(0.01548)	(0.02106)
1 to 20	-0.526**	-0.505**	0.208**	0.106**
	(0.02289)	(0.08140)	(0.04900)	(0.03909)
21 to 40	-0.464**	-0.408**	0.271**	0.216**
	(0.02319)	(0.08539)	(0.03258)	(0.05884)
41 to 60	-0.438**	-0.375**	0.075*	-0.288**
	(0.02542)	(0.11994)	(0.02828)	(0.04212)
61 to 80	-0.340**	-0.426**	0.143**	-0.333**
	(0.01677)	(0.08918)	(0.02815)	(0.05577)
81 to 100	-0.219**	-0.299**	0.357**	0.173*
	(0.03497)	(0.08753)	(0.04511)	(0.07464)
101 to 120	-0.402**	-0.343**	0.284**	0.173*
	(0.03941)	(0.12464)	(0.05902)	(0.08525)
121 to 140	-0.608**	-0.472**	0.534**	0.560**
	(0.03036)	(0.11964)	(0.06706)	(0.05746)
141 to 160	-0.536**	-0.379*	0.222**	-0.260**
	(0.04262)	(0.15071)	(0.03725)	(0.06090)
161 to 180	-0.536**	-0.411*	0.389**	-0.275**
	(0.05379)	(0.18512)	(0.04243)	(0.07472)
181 to 200	-0.595**	-0.380*	0.738**	0.271*
	(0.04754)	(0.16913)	(0.04667)	(0.11958)
Adjusted R^2	0.909	0.858	0.777	0.724
N	944	883	943	912

* p<0.05, ** p<0.01. Standard errors, clustered at the state level, in parentheses. This table shows regression coefficients and standard errors underlying Figure 13. Observations at the state-by-loan amount level, and all regressions include state fixed effects. Reference total loan amount category is -39 to -20. Total loan amount refers to the first lien plus junior lien, if applicable. High LTV loans refers to the sum of PMI-backed loans plus piggyback loans identified in HMDA that have an implied cumulative LTV ratio of 95 percent to 100 percent. The CLL was $417,000 in 2006 and 2007, $359,650 in 2005 and $333,700 in 2004. Source: PMIC and HMDA data.

Table A-3: PMI Issuance Growth and Lender Concentration

	y = Δ ln(PMI policies), 2006-07							
	All policies				Policies with LTV ≥ 95% & FICO < 680			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PMI Co. MSA Housing Risk Score			0.1437	0.1209			0.1851	0.1744
			(0.0540)	(0.0477)			(0.0570)	(0.0514)
Top 4 county market share	0.0298		-0.0208		-0.0034		0.1916	
	(0.0198)		(0.0966)		(0.0283)		(0.1111)	
Top 2 county market share		0.0259		0.3574		-0.0039		0.4399
		(0.0214)		(0.1421)		(0.0248)		(0.2053)
Change in ln(county avg wage), 2006-2007	0.0034	0.0042			-0.0074	-0.0075		
	(0.0102)	(0.0104)			(0.0149)	(0.0152)		
Change in ln(county employment), 2006-07	0.0268	0.0284			-0.0152	-0.0152		
	(0.0184)	(0.0198)			(0.0220)	(0.0231)		
State fixed effects	yes	yes			yes	yes		
Adjusted R^2	0.71	0.71	0.18	0.28	0.56	0.56	0.26	0.34
N	2788	2788	253	253	2538	2538	245	245

Standard errors in parentheses, clustered at state level in columns 1, 2, 5 and 6, and at the MSA level in other columns. PMI data for regressions in columns 1-4 are from the FFIEC PMIC data. PMI data for regressions in columns 5-8 use the complete McDash data on first-lien home purchase loans with PMI. Regressions weighted by total population in 2000. Wage and employment data are from the BLS; counties with wage growth or employment growth below the 1st percentile or above the 99th percentile are trimmed. County growth rates in PMI issuance also trimmed at 1st and 99th percentiles. All right hand side variables normalized by their sample standard deviation.

Figure A-1: MGIC Insurance Premiums Rate Sheet, March 2006

MONTHLY PREMIUMS & ZOMP!

Premium adjustments noted under rate chart

MONTHLY PREMIUMS & ZOMP!			FIXED LEVEL PAYMENTS FOR THE FIRST FIVE YEARS		TEMPORARY BUYDOWNS & ARMs WITH ANNUAL CAPS OF 1% OR LESS AND GPMs		ARMs WITH ANNUAL CAPS GREATER THAN 1%	
			30-Year	25-Year & Under	30-Year	25-Year & Under	30-Year	25-Year & Under
Base LTV (%)	MGIC Coverage (%)	Reduces Exposure To (%)	1st Year & Renewals No Refund	1st Year & Renewals No Refund	1st Year & Renewals No Refund	1st Year & Renewals No Refund	1st Year & Renewals No Refund	1st Year & Renewals No Refund
95.01 & Greater	40	62	1.09%	.98%	1.30%	1.19%	1.34%	1.23%
	35	67	.96	.85	1.17	1.06	1.21	1.10
	33	70	.91	.80	1.12	1.01	1.16	1.05
	30	73	.84	.73	1.05	.94	1.09	.98
	28	75	.79	.68	1.00	.89	1.04	.93
	25	78	.71	.60	.92	.81	.96	.85
	20	83	.59	.48	.80	.69	.84	.73
	18	85	.55	.44	.76	.65	.80	.69
95 -90.01	35	62	.90	.79	1.05	.94	1.09	.98
	30	67	**.78**	**.67**	.88	.77	.92	.81
	27	70	.71	.60	.77	.66	.81	.70
	25	72	.67	**.56**	.73	.62	.77	.66
	22	75	.63	.52	.69	.58	.73	.62
	16	80	.54	.37	.59	.39	.61	.43
90 -85.01	35	59	.67	.56	.82	.71	.86	.75
	30	63	.60	.49	.73	.62	.77	.66
	25	68	**.52**	**.41**	**.61**	**.50**	**.65**	**.54**
	22	71	.47	.36	.55	.44	.59	.48
	20	72	.42	.31	.48	.37	.52	.41
	17	75	.39	.28	.44	.33	.48	.37
	12	80	.34	**.23**	.35	.24	.39	.28
85 & Under	35	56	.60	.49	.71	.60	.77	.66
	30	60	.52	.41	.61	.50	.65	.54
	25	64	.43	.32	.49	.38	.53	.42
	22	67	.41	.30	.47	.36	.51	.40
	20	68	.39	.28	.44	.33	.48	.37
	17	71	.37	.26	.38	.27	.42	.31
	12	75	**.32**	**.21**	**.33**	**.22**	**.37**	**.26**
	6	80	.27	**.19**	.29	.20	.32	.22

Premium Adjustments for Monthly Premiums & ZOMP!

Rate-and-Term Refinances	– .05%
Cash-Out Refinances	+ .10%
Second Homes	+ .14%
Investment Properties	+ .38%
Manufactured Homes	+ .20%
Negative Amortization	+ .05%
Super Jumbo (> $650,000)	+ .10%
Relocation Loans	
• loans with LTVs of 85% or less	– .07%
• loans with LTVs greater than 85%	– .10%
Refundable	+ .01%

Note: Rates cannot be reduced below .15%.

Fannie Mae/Freddie Mac Standard Coverage Requirements:

- **Grey** 30-year fixed- and all nonfixed-rate mortgages.
- **Yellow** 25-year fixed-rate mortgages.
- **Purple** 15- and 20-year fixed-rate mortgages.

Notes:

• **Nonrefundable Monthly Premiums:** Nonrefundable plan coverage cancelled or terminated under the Homeowners Protection Act of 1998 will receive a pro rata refund.

Notes for 95.01 & Greater LTVs for Monthly, Level Annual and Single premiums:

95.01 & Greater

Max. LTV and Borrower's Own Funds are based on FICO Credit Score, as shown below:

Agency AU Decision/FICO Score	Max. LTV	Borrower's Own Funds
700+	103%	0%
660-699	100%	3%
	97%	0%
Less than 660	97%	3%
DU – Approve/Eligible	100%	Per DU Requirements
LP – Accept/Eligible	100%	Per LP Requirements

- No Cash-Out Refinances, Second Homes or Investment Properties.
- LTVs greater than 100% are limited to fixed-rate mortgages and ARMs with initial terms of 3 years or more and principal in excess of 100% must only be used to finance loan closing costs. ARMs with initial terms less than 5 years and LTVs greater than 100% are not eligible in IL.
- No negative amortization or balloons.

FLEX 97/LOWEST COST/CUSTOM MI

CHECK YOUR DU FINDING FOR COVERAGE ELIGIBILITY

MONTHLY PREMIUMS & ZOMP!			FIXED LEVEL PAYMENTS FOR THE FIRST FIVE YEARS	
			30-Year	25-Year & Under
Base LTV (%)	MGIC Coverage (%)	Reduces Exposure To (%)	1st Year & Renewals No Refund	1st Year & Renewals No Refund
97 -95.01	18	80	.50%	.44%
95 -90.01	18	78	.48	.41
90 -85.01	18	74	.38	.28
85 -80.01	18	70	.38	.27

Flex 97/Lowest Cost/Custom MI

Rates shown are available for Fannie Mae Flex 97 or other MGIC-approved programs reflecting similar credit and eligibility requirements. Use of Flex 97/Lowest Cost/Custom MI coverages may require payment of a "loan-level delivery fee" to Fannie Mae. Special 18% coverage rates shown are not eligible for Rate-and-Term Refinance or Relocation Loan discounts.

Let us do the work for you!

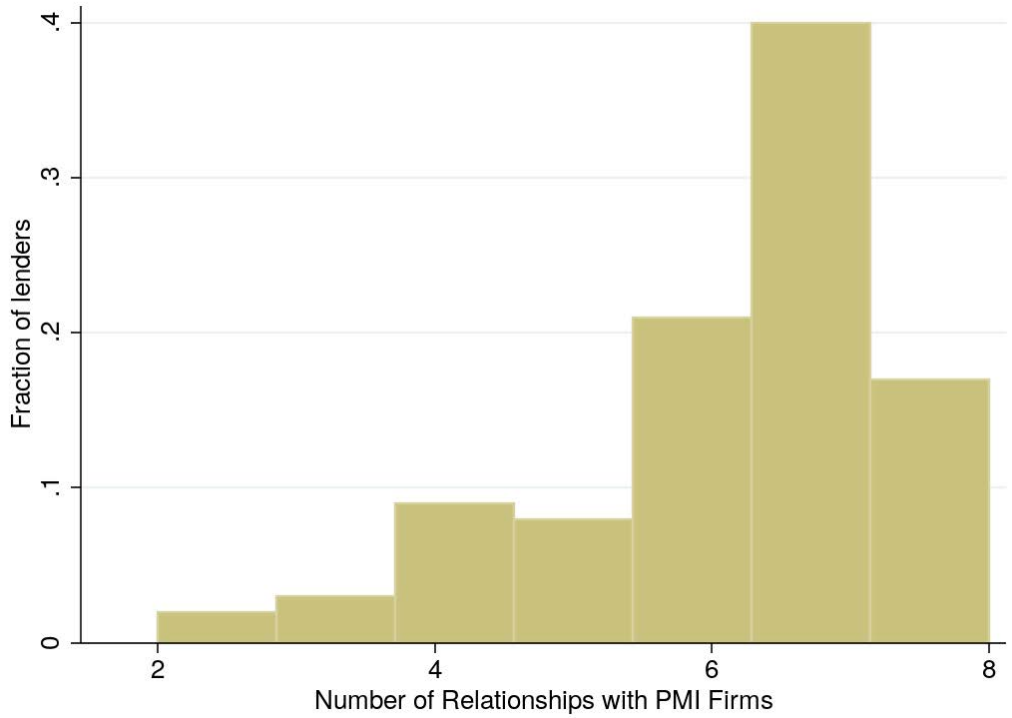
MGIC's **Rate Finder** will calculate your initial and renewal premium rates.
Visit our rate finder at ***www.mgic.com.***

See MGIC's website, www.mgic.com, for additional information on rate filings and our complete Underwriting Guide.

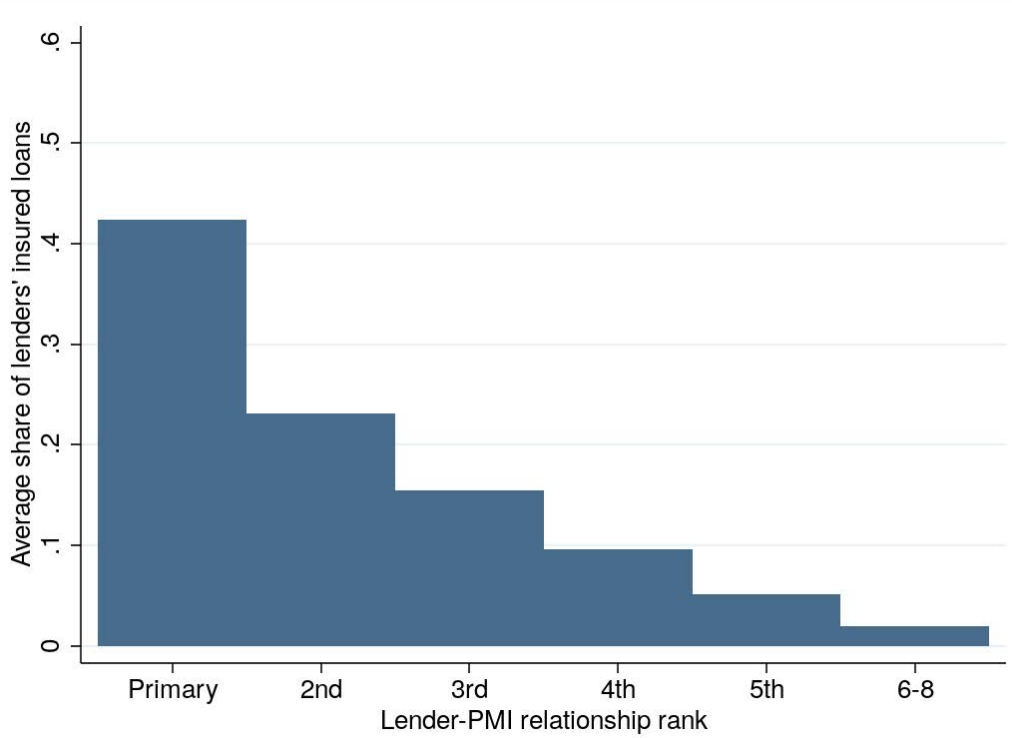
Notes: This figure shows the PMI firm MGIC's premium rate sheet for "national" pricing in March 2006. Accessed through the Internet Wayback Machine at `http://web.archive.org/web/20060603192958/http://www.mgic.com:80/pdfs/71-6704.pdf`. The premiums shown here are based on MGIC's national pricing, and a footnote on a cover page notes that rates and underwriting requirements may vary from state to state.

Figure A-2: Lenders' Relationships with PMI Firms

Panel A. Number of Relationships with PMI Firms, Top 100 Lenders



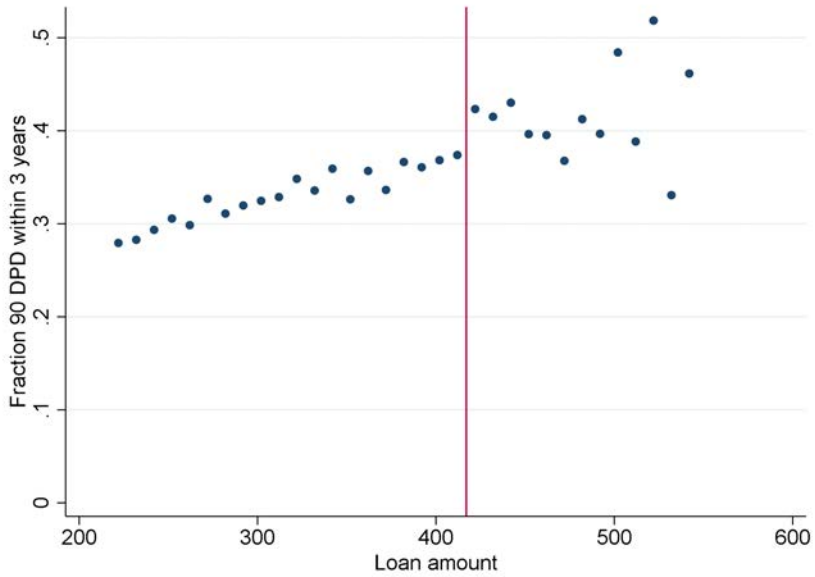
Panel B. Concentration of PMI Issuance, Top 100 Lenders



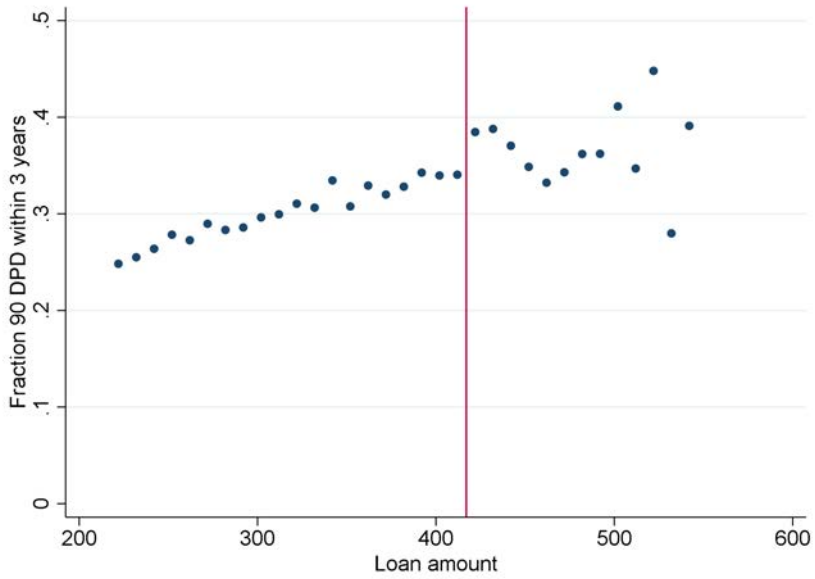
Source: PMIC and HMDA data. Notes: The top panel of this figure shows the distribution of the number of relationships with PMI firms for the 100 largest lenders in 2007. The bottom panel shows the concentration of PMI issuance for the 100 largest lenders in 2007. On average, the largest lender-PMI relationship is roughly 40% of overall issuance. Source: FFIEC HMDA and PMI data. We are able to match roughly 66 percent of the PMI policies on year, location (census tract), loan amount, loan purpose, loan type, and borrower income to a loan in the HMDA dataset for matched policy-loan analysis.

Figure A-3: Delinquency Rate of PMI-Insured Loans around the Conforming Loan Limit

Panel A. Delinquency Rate of PMI-Insured Loans, Purchase+Refi, 2007

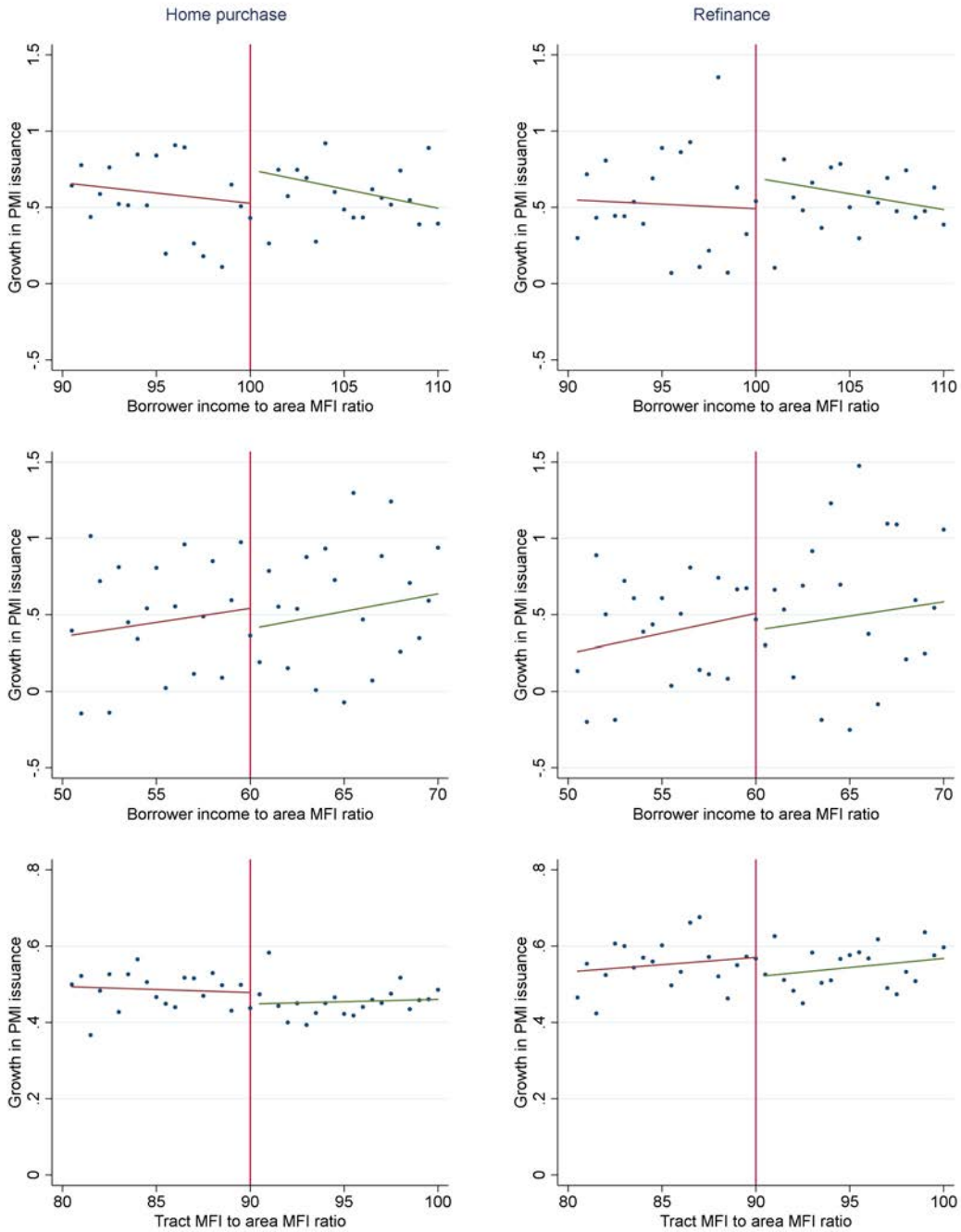


Panel B. Delinquency Rate of PMI-Insured Loans, Purchase+Refi, 2006–2007



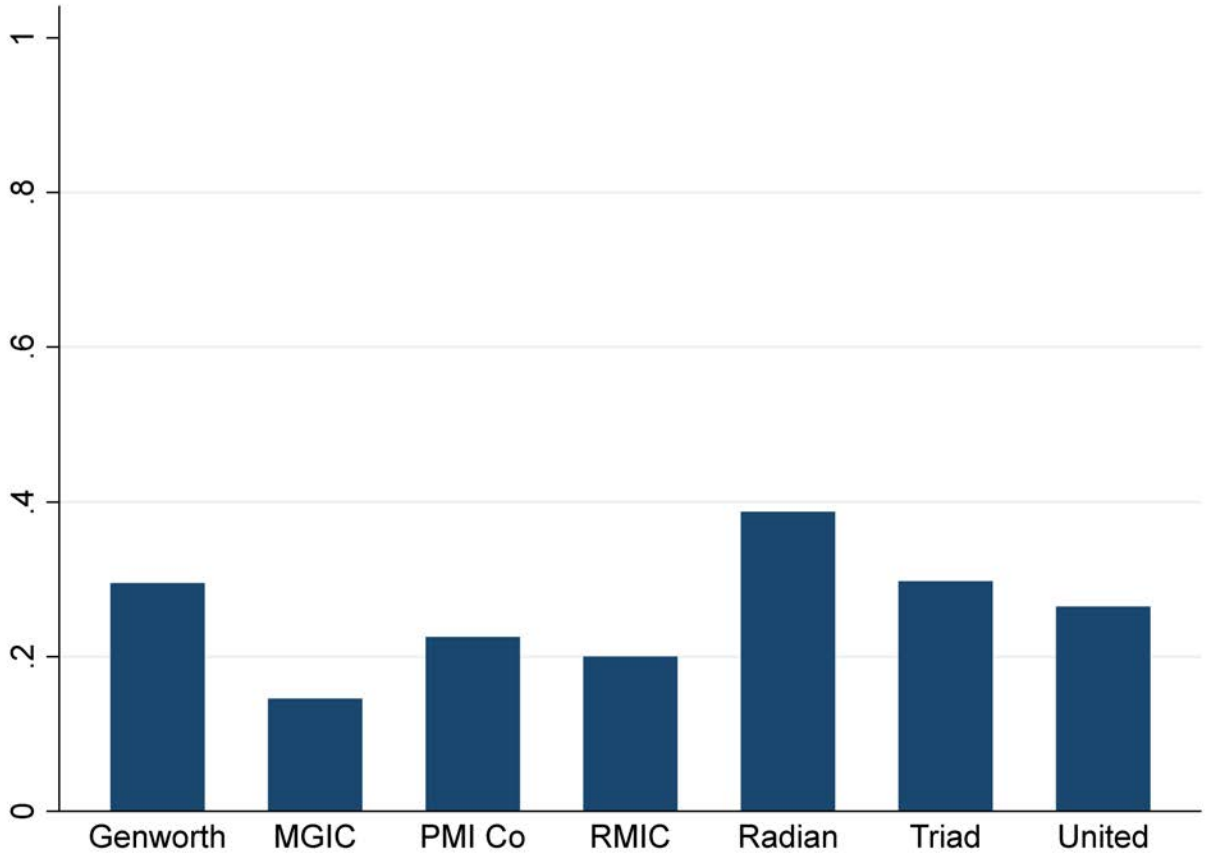
Source: McDash. Notes: The first panel of the figure presents the delinquency rate (as measured by the fraction of loans that reach 90 days or more past due within three years after origination) among PMI-Insured loans originated in 2007, by total loan amount, combining both loans for purchase and for refinancing. The vertical line indicates the conforming loan limit of $417,000. Loans made to the left of the limit are conforming and eligible based on loan size to be sold to the GSEs, whereas loans above this limit are ineligible and can be sold to the non-agency secondary market. The second panel pools loans for purchase and refinancing, as well as loans originated in 2006 and 2007.

Figure A-4: Growth in PMI Issuance, 2006–2007, around HUD Affordability Goals



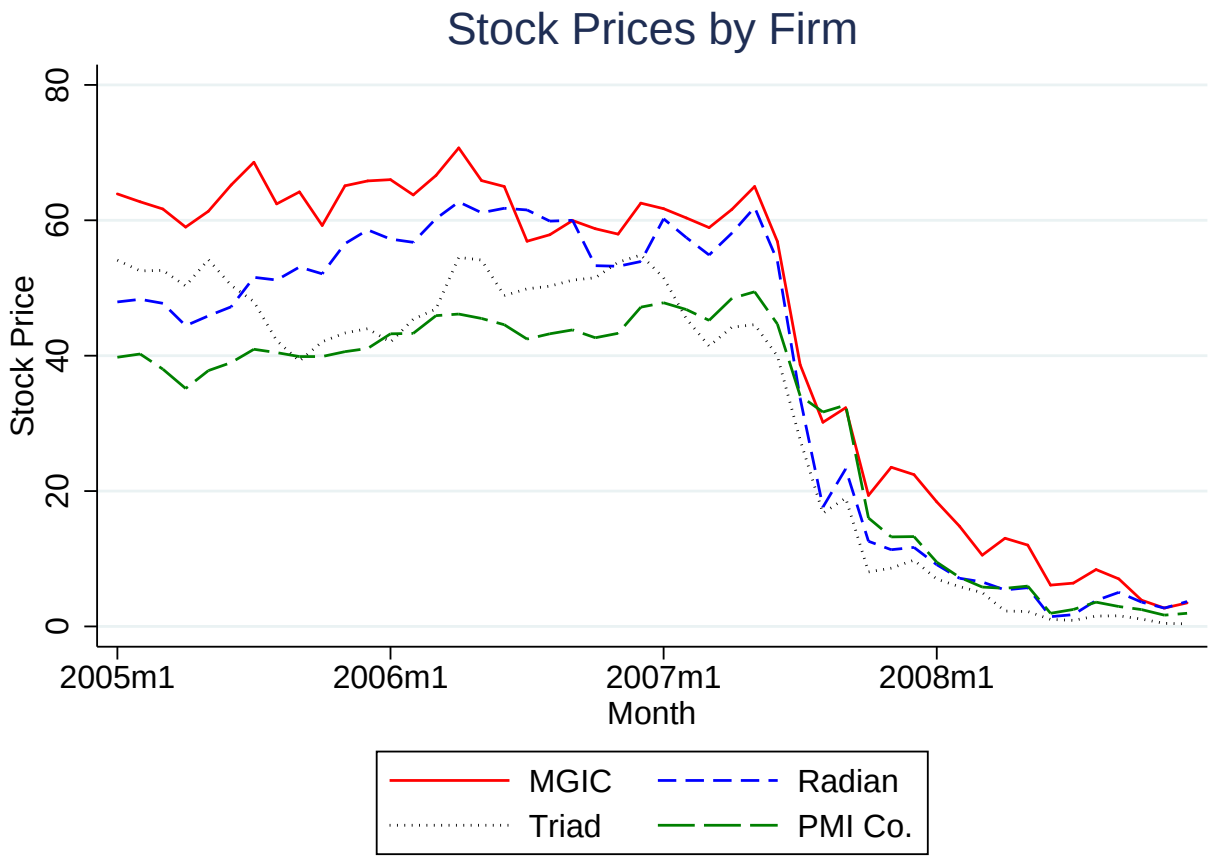
Source: PMIC and FFIEC Census 2000 data. Notes: This figure shows the growth in PMI issuance around the three HUD affordability goal thresholds (Borrower to area MFI ratios of 60 and 100, and tract MFI to area MFI ratio of 90), for home purchase and refinance mortgages, from 2006 to 2007.

Figure A-5: Lender Concentration, by PMI firm



Source: PMIC and HMDA data. Notes: This figure shows the share of PMI issuance on loans originated by the top 4 lenders (Wells Fargo, Bank of America, Countrywide, and J.P. Morgan Chase) for each of the major private mortgage insurers in 2006 and 2007. We are able to match roughly 66 percent of the PMI policies on year, location (census tract), loan amount, loan purpose, loan type, and borrower income to a loan in the HMDA dataset for matched policy-loan analysis.

Figure A-6: Stock Prices by Firm, 2005–2008



Source: CRSP. Notes: This figure shows the time series of share prices of Radian, Triad, PMI Co., and MGIC from January 2005 to December 2008.