Volume I, Issue 2
March 2002

FannieMae
PAPERS

Implications of the New Fannie Mae and Freddie Mac Risk-based Capital Standard

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This study was commissioned by Fannie Mae as an independent analysis of the risks posed to the government by Fannie Mae and Freddie Mac given the Office of Federal Housing Enterprises' risk-based capital standard. The views and opinions expressed in this study are solely those of the authors and do not necessarily reflect the views and opinions of Fannie Mae or any of the institutions with which the authors are associated. They should not be attributed to the staff, officers, or trustees of Columbia University, the University of Southern California, or the Brookings Institution, or any of the other organizations with which the authors are or have previously been associated.

Introduction

Fannie Mae and Freddie Mac are government-sponsored enterprises that operate in the secondary market for home mortgages. Although Fannie Mae and Freddie Mac do not originate home mortgages, they play two roles in the mortgage market: They provide credit guarantees on conforming mortgages, which are bundled together in mortgage-backed securities that are held by other investors. They also hold mortgages and mortgage-backed securities in their own portfolios.

The Government-Sponsored Enterprises (GSEs) receive through their Congressional charters a variety of government-conferred benefits, including that their earnings are exempt from state and local corporate income tax; their securities are exempt from registration requirements under the Securities Act of 1933, and are treated as government securities for the purposes of the Securities Exchange Act of 1934; their securities are eligible for Federal Reserve open-market purchases, and are eligible collateral for Federal Reserve Bank discount loans and Treasury tax and loan accounts; their securities are eligible for unlimited investment by federally insured thrifts, national banks, and state bank members of the Federal Reserve system; and the Secretary of the Treasury is authorized to purchase up to $2.25 billion of each GSE's securities. In addition, extant capital standards for banks assign lower credit-risk weights to mortgage-backed securities (MBS) issued by Fannie Mae and Freddie Mac than for the mortgages themselves, which raises demand for MBS relative to the underlying mortgages. MBS issued by Fannie Mae or Freddie Mac are assigned a 20 percent risk weight, relative to a 50 percent risk weight on whole mortgages.[1]

In exchange for these benefits, the GSEs also face several constraints. First, their activities are limited to the

Foreword

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Since their introduction in 1988, the Basel Accords have gained currency as a framework for prudent risk management for financial institutions. Central to these standards is the idea that capital should protect financial institution solvency against unforeseen, even unlikely, losses. One way to evaluate capital adequacy is to subject the institution to the economic equivalent of an engineering stress test — apply severe and sustained pressure to see whether the entity can withstand the strain.

Even the reformed Basel standards do not contemplate stress testing for any of the three common sources of financial institution failure: interest-rate, credit and operations risk — and, indeed, do not include interest rate risk at all.

In contrast, Fannie Mae's and Freddie Mac's risk-based capital requirement subjects the company to a decade-long "nuclear-winter" scenario along the interest-rate and credit risk vectors and adds a 30 percent safety cushion for operations risk. If the company can withstand the rigors of such punishing and rare strain, the likelihood is that its capital is more than adequate to its risk. And the rarer the probability of the scenario, the more likely is the adequacy of the company's capital.

So how rare is the scenario in the test? In 1997, former Federal Reserve Chairman Paul Volcker wrote that the possibility of default if Fannie Mae met the test was "remote." To update that analysis, we commissioned Joseph Stiglitz (2001 Nobel Prize winner in economics), Jonathan Orszag, and Peter Orszag to examine the likelihood of the risk-based capital scenario. Their econometric analysis found that the probability of the stress test scenario is conservatively one in 500,000 and may be smaller than one in three million. As a result, they find that the risk of a default by these companies, if they hold sufficient capital to meet the stress test, is "effectively zero."

We are pleased to publish this second issue of Fannie Mae Papers. It adds new analysis of the risk based capital rule and contributes to the evolving public dialogue on financial institution capital standards.

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[1] Asset-backed securities (including MBS) that carry the highest or second highest credit rating (e.g., AAA or AA) are also assigned a 20 percent risk weight.

secondary mortgage market; they are not permitted to originate mortgages or to enter other lines of business. Second, their mortgage purchases and MBS guarantees are limited to mortgages below the conforming loan limit ($300,700 in 2002). Third, they are required to meet affordable housing goals set by the Department of Housing and Urban Development. Fourth, the Department of the Treasury has the authority to approve new GSE debt issues, to ensure that GSE debt issuance does not interfere unduly with Treasury debt activities. Finally, shareholders of the GSEs are not free to elect all the members of their Board of Directors; rather, the President has the right to appoint five Directors to each Board.[2]

Their various special attributes, taken together, have led many observers to believe that the debt of Fannie Mae and Freddie Mac carries an implicit guarantee from the Federal government, despite the fact that the law requires these securities to state explicitly that they are not backed by the full faith and credit of the U.S. government. In other words, the belief in an implicit guarantee arises because of market expectations that, given their GSE status, the Federal government would not allow Fannie Mae or Freddie Mac to default on their obligations.

A series of analyses by the Congressional Budget Office (CBO), the Department of the Treasury, and others have suggested that the GSEs receive a significant subsidy from the government. The most recent study was published by CBO in May 2001 and found that Fannie Mae and Freddie Mac received a gross subsidy of $10.6 billion from the GSE status.[3] Some observers have interpreted the CBO figures as showing that the government faces substantial expected costs from potential GSE defaults.

This paper does not examine the validity of CBO's overall estimate of the cost to the government from the GSEs;[4] other papers have undertaken such an analysis and have reached different conclusions than CBO.[5] Rather, the purpose of this paper is to provide further insight into the magnitude of the expected direct costs from the implicit government guarantee on GSE securities. In analyzing these expected default costs, it is important to recognize that the government's risk exposure may be significantly reduced by a risk-based capital standard recently promulgated by the GSEs' regulator.[6]

The Federal Housing Enterprises Financial Safety and Soundness Act of 1992 mandated the adoption of two capital tests for Fannie Mae and Freddie Mac. The first, a minimum capital regulation, requires each GSE to hold capital equal to 2.5 percent of their on-balance sheet assets and 0.45 percent of their off-balance sheet obligations and assets. The second is the risk-based capital standard, which is the focus of this analysis. The risk-based capital standard subjects the GSEs to a severe national economic shock that is assumed to last for ten years, and requires the GSEs to maintain sufficient capital to withstand the shock, and requires additional capital for management and operations risk. It also requires the GSEs to hold more capital if they enter into riskier activities, and reflects a comprehensive view of the risks the GSEs could undertake.

Given the risk-based capital standard, one method of estimating the expected GSE default costs to the government is to make three simple assumptions: First, assume that the implicit government guarantee on GSE debt is equivalent to an explicit guarantee; second, assume that the risk-based capital standard is enforced effectively by Office of Federal Housing Enterprise Oversight (OFHEO), which regulates the GSEs; and third, assume that Fannie Mae and Freddie Mac hold enough capital to withstand the stress test imposed under the capital standard. Then the probability that the GSEs become insolvent must be less than the probability that a shock occurs as severe (or more severe) as the one embodied in the stress test. Note that to the extent an implicit government guarantee is not fully equivalent to an explicit guarantee, the expected risks faced by the government would be exaggerated under this approach because an implicit guarantee provides the government with more flexibility than an explicit one; on the other hand, to the extent that the risk-based capital standard is not enforced effectively, the approach would underestimate the expected risk to the government.

The paper concludes that the probability of default by the GSEs is extremely small. Given this, the expected monetary costs of exposure to GSE insolvency are relatively small — even given very large levels of outstanding GSE debt and even assuming that the government would bear the cost of all GSE debt in the case of insolvency. For example, if the probability of the stress test conditions occurring is less than one in 500,000, and if the GSEs hold sufficient capital to withstand the stress test, the implication is that the expected cost to the government of providing an explicit government guarantee on $1 trillion in GSE debt is less than $2 million. To be sure, it is difficult to analyze extremely low-probability events, such as the one embodied in the stress test. Even if the analysis is off by an order of magnitude, however, the expected cost to the government is still very modest.

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2 In particular, the President is allowed to appoint 5 of the 18 members of each board; the other 13 members are elected by shareholders.

3 See, for example, Congressional Budget Office, *Federal Subsidies and the Housing GSEs*, May 2001.

4 The CBO methodology does not directly estimate the expected costs to the government from such potential defaults. Rather, CBO's estimated cost to the government from the GSEs reflects two components that are not separately estimated: the expected direct costs to the government (e.g., from the risk of default by the GSEs) and the opportunity costs of not auctioning the rights to GSE status. CBO's methodology does not distinguish between these two components. See Letter from CBO Director Daniel Crippen to the Honorable Richard H. Baker, July 11, 2001. Our analysis suggests that the opportunity cost component represents the vast majority of CBO's total estimated costs.

5 See, for example, Miller and Pearce (2001), Toevs (2001), and Cochran and England (2001).

6 It is important to recognize that most previous estimates of the risk exposure to the government from the GSEs did not take into account the recent capital standards.

Background

The Federal Housing Enterprises Financial Safety and Soundness Act of 1992 specified several of the details regarding the risk-based capital standard, and directed OFHEO to adopt a final regulation implementing the standard by December 1, 1994. In February 1995, OFHEO published an Advance Notice of Proposed Rulemaking, soliciting public comments on issues relating to the standard. In June 1996, OFHEO issued a Notice of Proposed Rulemaking (NPR1), which identified a proposed historical credit loss experience to be used as part of the risk-based capital standard.[7] In April 1999, OFHEO published another Notice of Proposed Rulemaking (NPR2), delineating the rest of its proposed approach to implementing the risk-based capital standard. The final regulations were issued on September 13, 2001, and OFHEO posted final changes to the rule on its website on February 20, 2002.[8]

The GSEs are exposed to both interest rate risk and default risk. A decline in interest rates represents a risk to the GSEs because of prepayments (i.e., refinancings); as interest rates fall, more homeowners refinance their mortgages – affecting the GSEs' cash flows and posing a re-investment risk for the GSEs since the new mortgages carry lower interest rates. An increase in interest rates also represents a risk to the GSEs, albeit of a different nature, because it induces a decline in the price of mortgages and an increase in defaults. (The GSEs attempt to manage these risks through a variety of mechanisms, including by issuing callable debt.) Mortgage defaults also expose the GSEs to risk. The stress test therefore embodies shocks on both interest rates and default rates at the same time.

As specified by statute, the risk-based capital standard involves a 10-year stress period, during which severe interest rate and credit loss shocks occur simultaneously. In particular, the statute specifies two interest rate shocks (one in which interest rates increase by up to 600 basis points, and the other in which interest rates decline by up to 600 basis points, and then remain at their new level for the remainder of the ten-year period). In addition, GSE performance is affected by the shape of the yield curve (i.e., the level of long-term interest rates relative to short-term interest rates); the risk-based capital standard also specifies particular yield curves for the two interest rate shocks. The interest rate shock and associated yield curve assumption that produce the higher level of required capital are then the determinative ones for capital purposes.

The test assumes that a substantial deterioration in credit quality occurs at the same time as the interest rate shocks; the *national* credit experience is based upon the highest *regional* rate of credit loss over two years in any contiguous area comprising at least five percent of the U.S. population.[9] This assumption of the stress test is severe for two crucial reasons. First, in a large economy such as the United States, different regions experience different economic conditions. The stress test nonetheless applies the worst regional credit loss rate to the nation as a whole. The implied credit loss rate is more than five times as large as the national credit loss rate in any year since 1980. Second, the stress test assumes that this credit loss rate persists for ten years. Even the worst regional experience did not persist for such a long period.

The required level of capital is then determined as the level that allows the GSE to remain solvent in each and every quarter throughout the 10-year stress period, *plus* an additional 30 percent to account for management and operations risk.

Impact of Risk-Based Capital Standard

The risk-based capital standard requires the GSEs to hold sufficient capital to withstand a severe and extended economic shock without defaulting on their obligations, and the level of required capital depends on the risks that the GSEs are taking. The required capital cushion provides a significant layer of protection in the event of severe financial distress.

Probability of stress test environment and the costs of the implicit guarantee

To estimate the probability of a shock as severe (or more severe) than the one embodied in the proposed risk-based capital standard, this paper investigates statistically the likelihood of several events involving interest rates and mortgage credit loss rates.[10] Specifically, historical data were used to create millions of potential future scenarios. The outcomes of those scenarios were then examined, to see whether they were as severe as the assumed events. The events were chosen to proxy the stress test imposed by the risk-based capital standard. The percentage of scenarios that were as severe as the specified events then provides an estimate for the probability of the events occurring. The details of the estimation procedure are contained in the Appendix. As explained in the Appendix, the available data on credit loss rates were much more limited than the interest rate data. Much of the analysis therefore focuses only on changes in interest rates, which overestimates the probability of the stress-test scenario – and thus the expected costs to the government – because it ignores the relatively unlikely credit loss assumptions required by the risk-based capital standard.

The estimation was undertaken both conditional on relatively recent observations of interest rates and credit loss rates, and also unconditionally (i.e., across all

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[7] NPR1 also addressed the housing price index used in the risk-based capital standard.

[8] See http://www.ofheo.gov/docs/regs/rbcamendfinal.pdf

[9] For a description of this "benchmark loss experience," see NPR1. The benchmark loss experience is based upon 30-year fixed-rate single-family mortgages originated in 1983 and 1984 in Arkansas, Louisiana, Mississippi, and Oklahoma. The resultant 10-year loss rate is 9.4 percent.

[10] Risk Control Limited of London implemented the econometric analysis for the authors. The authors particularly thank Professor William Perraudin of Risk Control Limited and the University of London for his assistance on the econometric analysis.

possible starting points). Table 1 shows the probabilities based on recent data. Out of three million simulations, only 65 contained an interest rate shock as large as the reduction in the down-rate scenario, and none contained an interest rate shock as large as the increase in the up-rate scenario. Even without incorporating the yield curve assumptions and credit loss assumptions, it is therefore clear that the interest rate shocks embodied in the risk-based capital standard are extremely unlikely based on historical experience and current conditions. Combined with the other components of the stress test environment, the probability falls even further – and becomes so small that it is difficult to detect even in as large a simulation as the one conducted here.

Probability of stress test conditions given recent economic situation[11]

	Number of cases	
	per 3,000,000 simulations	per 1,000,000 simulations
Down-rate		
Initial interest rate change: The ten-year Constant Maturity Treasury (CMT) yield falls by 600 basis points below the average yield during the previous nine months, or by 60 percent of the average yield during the previous three years, whichever represents a smaller decline. In addition, the decline cannot be more than 50 percent of the average yield during the previous nine months.	65	22
Interest rate level maintained: After change above, ten-year CMT yield remains at or below the lower level obtaining after the first twelve months for nine additional years.	18	6
Interest rate movement sustained plus yield curve assumption: In addition to the yield changes described above, the Treasury yield curve assumes a specific shape for the final nine years of the stress period.[12]	0	0
Interest rate movement and benchmark credit loss: In addition to the yield curve assumptions above, the annual credit loss rate reaches or exceeds 0.9823 percent and remains at or above that level for ten years.[13]	0	0
Up-rate		
Initial interest rate change: The ten-year Constant Maturity Treasury (CMT) yield increases by 600 basis points above the average yield during the previous nine months, or by 160 percent of the average yield during the previous three years, whichever represents a larger increase. In addition, the increase cannot be more than 75 percent of the average yield during the previous nine months.	0	0
Interest rate level maintained: After change above, ten-year CMT yield remains at or above the higher level obtaining after the first twelve months for nine additional years.	0	0
Interest rate movement sustained plus yield curve assumption: In addition to the yield changes described above, the Treasury yield curve assumes a specific shape for the final nine years of the stress period.[14]	0	0
Interest rate movement and benchmark credit loss: In addition to the yield curve assumptions above, the annual credit loss rate reaches or exceeds 0.9823 percent and remains at or above that level for ten years.	0	0

TABLE 1

[11] This analysis is based on data through September 2000. Between September 2000 and February 2002, the constant maturity yield for the ten-year Treasury security has trended downwards. The reduction in interest rates since September 2000, given the positive correlation between the variance of interest rates and their initial level, would tend to make the stress test environment even less likely now than in September 2000.

[12] In particular, the yield curve assumes the following shape: the yields for the 3-month Treasury bill, 6-month Treasury bill, one-year Treasury note, three-year Treasury bond, five-year Treasury bond, and twenty-year Treasury bond are based on the average yield for the respective Treasury security during the period May 1986 to April 1995, divided by the average yield for the ten-year CMT during that period, multiplied by the assumed ten-year CMT yield. The yields on the bills are expressed on a bond-equivalent basis. The statistical modeling was less stringent than the actual test: All the points on the yield curve were allowed to vary by plus or minus 10 percent relative to their stipulated values.

[13] The benchmark loss experience is based upon credit losses for fixed-rate 30-year single-family mortgages. The credit loss rate over a 10-year period under that benchmark loss experience is 9.4 percent. An annual credit loss rate of 0.9823 percent (on the stock of outstanding mortgages in any given year) cumulates over a 10-year period to a loss rate of 9.4 percent (on the initial stock of mortgages). The analysis here relies on aggregate credit loss rate data from OFHEO's annual report to Congress, rather than the credit loss rate on fixed-rate 30-year single-family mortgages. Aggregate credit losses tend to be smoother over time than loan-level losses, so the use of aggregate credit loss rates may be misleading. To test the sensitivity of the results to potential biases in the credit loss rate data, and to be conservative by reducing the threshold loss rate that would need to be reached, the analysis was also undertaken for a credit loss rate of 0.5 percent per year (roughly half the benchmark loss rate). The results are not significantly different, suggesting that any biases created by the definition of the credit loss rate are unlikely to be critical. For additional evidence on the likelihood of the credit event, see Fratantoni (2002).

[14] In particular, the yield curve is assumed to flatten and remain horizontal for ten years. Yields for the 3-month Treasury bill, 6-month Treasury bill, one-year Treasury note, three-year Treasury bond, five-year Treasury bond, and twenty-year Treasury bond are assumed to converge to the ten-year CMT yield over the first twelve months of the stress test, and then remain equal to the ten-year CMT yield over the subsequent nine years. (The yields on the bills are expressed on a bond-equivalent basis.) In other words, the yield curve becomes flat for the final nine years. The statistical modeling was less stringent than the actual test: All the points on the yield curve were allowed to vary by plus or minus 10 percent relative to their stipulated values.

The probability of an event as severe as the stress test environment is thus extremely unlikely given recent economic conditions. But under other possible economic conditions, movements of the magnitude assumed under the stress test may be more likely: The volatility of interest rates, for example, tends to be higher when the level of interest rates is higher. Since interest rates are currently at a relatively low level, the probability of severe interest rate shocks may be lower now than at other times. Therefore, the analysis was also undertaken unconditionally – that is, across all possible starting points. The unconditional events are somewhat more likely, but still have extremely low probabilities associated with them. As Table 2 below shows, the probability of a severe interest rate shift, sustained over ten years, combined with high credit loss rates, is effectively zero.

Analyses were also undertaken to investigate the likelihood of the initial interest rate shock (of 600 basis points) combined simply with the credit loss rate assumption (in other words, excluding the assumptions regarding whether the interest rate change was sustained over nine additional years and the assumptions regarding the yield curve shape). Those analyses suggested no simulations that were as severe as the stress test either conditional on recent conditions or unconditionally.

Potential Shortcomings in the Risk-Based Capital Standard

These results regarding the risk-based capital standard are striking: They suggest that on the basis of historical experience, the risk to the government from a potential default on GSE debt is effectively zero. Given this striking result, it may be worthwhile exploring three potential shortcomings in the standard. None of the potential shortcomings appears to be significant enough to alter the basic conclusion that the risk-based capital standard provides substantial protection against insolvency.

The first potential shortcoming is that the risk-based capital standard, while based on a hypothetical economic shock significantly more severe than anything that the economy has actually experienced over the past forty years, may fail to reflect the probability of another Great Depression-like scenario. Fundamentally, the extremely rare events located in the tail of a distribution are often quite difficult to analyze accurately. Interestingly, however, the Office of Management and Budget tested Fannie Mae's and Freddie Mac's capital adequacy in the early 1990s by subjecting their business activities to a ten-year stress test that simulated the financial and economic conditions of the Great Depression. The test showed that if a Depression lasted ten years, given 1990 levels of capital, both Fannie Mae and Freddie Mac had sufficient capital to survive. This result led OMB to conclude that in the event of a severe nationwide economic downturn, the probability of either Fannie Mae or Freddie Mac defaulting would be

TABLE 2

Probability of stress test conditions across all possible starting points

	Number of cases per 3,000,000 simulations	Number of cases per 1,000,000 simulations
Down-rate		
Initial interest rate change: The ten-year Constant Maturity Treasury (CMT) yield falls by 600 basis points below the average yield during the previous nine months, or by 60 percent of the average yield during the previous three years, whichever represents a smaller decline. In addition, the decline cannot be more than 50 percent of the average yield during the previous nine months.	49,777	16,592
Interest rate level maintained: After change above, ten-year CMT yield remains at or below the lower level obtaining after the first twelve months for nine additional years.	29,709	9,903
Interest rate movement sustained plus yield curve assumption: In addition to the yield changes described above, the Treasury yield curve assumes a specific shape for the final nine years of the stress period.	0	0
Interest rate movement and benchmark credit loss: In addition to the yield curve assumptions above, the annual credit loss rate reaches or exceeds 0.9823 percent and remains at or above that level for ten years.	0	0
Up-rate		
Initial interest rate change: The ten-year Constant Maturity Treasury (CMT) yield increases by 600 basis points above the average yield during the previous nine months, or by 160 percent of the average yield during the previous three years, whichever represents a larger increase. In addition, the increase cannot be more than 75 percent of the average yield during the previous nine months.	22,746	7,582
Interest rate level maintained: After change above, ten-year CMT yield remains at or above the higher level obtaining after the first twelve months for nine additional years.	256	85
Interest rate movement sustained plus yield curve assumption: In addition to the yield changes described above, the Treasury yield curve assumes a specific shape for the final nine years of the stress period.	0	0
Interest rate movement and benchmark credit loss: In addition to the yield curve assumptions above, the annual credit loss rate reaches or exceeds 0.9823 percent and remains at or above that level for ten years.	0	0

"close to zero."[15] This implies that if Fannie Mae and Freddie Mac hold sufficient capital to withstand the risk-based capital scenario, they would likely fare well under any conceivable economic environment.

A second concern is that while it is extremely unlikely that the risk-based capital scenario would occur, if the risk-based capital regulation is not implemented properly the results of the test may not be robust. Model risk, the likelihood that the model omits or mischaracterizes important elements of the real economy, is always a potential problem. The model depends on a large number of data inputs and parameters, each of which is subject to error. To a large extent, the mitigation of this risk requires that OFHEO accurately model the true risks that the companies face in the event of a catastrophic scenario. In addition, the regulatory oversight process for the GSEs needs to be sufficiently strong to catch problems early. Wallison and Ely (2000) argue, "Given the experience of the 1980s – not only with the S&Ls but with banks themselves – we should be skeptical about the effectiveness of regulators in controlling the risks of the companies they regulate."[16] CBO (1996) adds that, "even though OFHEO has the legal authority and the institutional capacity to closely monitor and evaluate the financial position of Fannie Mae and Freddie Mac, it cannot possibly have access to all of the information the agencies possess." However, OFHEO does have the statutory authority to regulate the GSEs effectively, and also has a continuous on-site presence at both companies. As OFHEO stated in its 2001 Report to Congress, "[t]rained examiners with years of regulatory and industry experience verify the quality and integrity of risk management tools, risk measurements, financial and management reports, operational controls, documentation standards, and a host of other qualitative and quantitative judgments. In short, there is no substitute for the value provided from examining the Enterprises on-site."[17] The requirement that the GSEs maintain an additional capital cushion that is equal to 30 percent of the capital required to survive the risk-based capital scenarios provides additional protection against model, regulatory, and other risks.

In addition, in October 2000, the GSEs voluntarily committed to a series of steps intended to make their financial position more transparent through additional disclosures and to raise additional capital. These include the issuance of subordinated debt, increased disclosures of the company's exposure to interest rate and credit risk, disclosure of a liquidity measure, interim results from the risk-based capital test, and disclosure of an annual credit rating.[18] Moody's described these disclosures as "a new standard… for the global financial market."[19] This increased transparency should improve market confidence and market discipline with regard to the GSEs.

Conclusion

This analysis shows that, based on historical data, the probability of a shock as severe as embodied in the risk-based capital standard is substantially less than one in 500,000 – and may be smaller than one in three million.[20] Given the low probability of the stress test shock occurring, and assuming that Fannie Mae and Freddie Mac hold sufficient capital to withstand that shock, the exposure of the government to the risk that the GSEs will become insolvent appears quite low.

Given the extremely small probability of default by the GSEs, the expected monetary costs of exposure to GSE insolvency are relatively small — even given very large levels of outstanding GSE debt and assuming that the government would bear the costs of all GSE debt in the case of insolvency. For example, if the probability of the stress test conditions occurring is less than one in 500,000, and if the GSEs hold sufficient capital to withstand the stress test, the implication is that the expected cost to the government of providing an explicit government guarantee on $1 trillion in GSE debt is just $2 million.

Two other points are worth noting. First, analysis of the risks posed by Fannie Mae and Freddie Mac must carefully consider the alternatives. In the absence of Fannie Mae and Freddie Mac, mortgage risk would likely be held by large banks and other types of financial institutions, which themselves benefit from the perception that they are "too big to fail." Fannie Mae and Freddie Mac are among the largest financial institutions in the country. Even in the absence of a GSE charter it is likely that they would continue to benefit from their size, since the government has intervened on behalf of other large institutions in the past.[21]

Secondly, and more broadly, Fannie Mae and Freddie Mac would likely require government assistance only in a severe housing market downturn. Such a severe housing downturn would, in turn, likely occur only in the presence of a substantial economic shock. Regardless of the structure of the mortgage market, the government would almost surely be forced to intervene in a variety of markets — including the mortgage market — in such a scenario. Fundamentally, given the public's aspirations to homeownership and the myriad ways in which government subsidies are channeled to homeownership, the government is indirectly exposed to risks from the mortgage market regardless of the existence of the GSEs.

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[15] OMB (1991) and CBO (1991).

[16] Wallison and Ely (2000), pages 30-31.

[17] Office of Federal Housing Oversight, 2001 Report to Congress, June 15, 2001, pages 1-2.

[18] "Freddie Mac and Fannie Mae Enhancements to Capital Strength, Disclosure, and Market Discipline," released by Freddie Mac and Fannie Mae (available on both companies' websites), October 19, 2000.

[19] Moody's Investors Service, *New Freddie Mac and Fannie Mae "Open Book" Policy: A Positive Credit Development*, October 2000.

[20] The simulations above suggest that the probability of a shock as severe as the one embodied in the risk-based capital standard is infinitesimal. Given the difficulties in estimating low-probability events, the figure cited in the text is intended merely to provide an upper bound for, rather than the best prediction of, the actual probability.

[21] Previous examples of government intervention in support of private firms include Continental Illinois, Lockheed, Chrysler, Long Term Capital Management (although this intervention did not include direct government funds), and the recent cash assistance and loan guarantee program for the airline industry.

Appendix: Estimation Details

The econometric estimation described in this paper relies on both yield curve data and default loss data.

Yield curve data for the United States are available over a long period (since December 1958). The length of the data series allows an important econometric advantage: It facilitates use of the so-called bootstrap approach to the Monte Carlo simulations. The bootstrap approach is important because the distribution of interest rate innovations is "fat-tailed"; assuming a normal distribution is therefore inappropriate. Instead of making such an assumption, the bootstrap uses the actual error terms from the estimated vector autoregressive moving average (VARMA) models of ten-year interest rates and interest rate spreads to generate interest rate movements in the Monte Carlo simulation.[22]

The other input into the Monte Carlo simulations involved credit losses. Credit loss rate data for Fannie Mae and Freddie Mac were obtained from OFHEO publications, but are only publicly available on an annual basis from 1983. Given the short time series, an estimation approximation was necessary. Our approach was to assume that changes in log credit loss rates depend linearly on their first lag, a constant, and lagged log interest rates. This relationship was then used as part of the Monte Carlo simulations. In particular, to estimate the probability of the events involving credit loss rates, the analysis simulated interest rates using the bootstrap method and, conditional on these, simulated the log credit loss rate assuming independent and normally distributed innovations. This approach, although imperfect, has the advantages of parsimony and incorporation of correlations between interest rate and credit loss rate events.

Yield curve modelling

Seven time series were used in the yield curve structure modelling: the constant-maturity yield for the three-month, six-month, one-year, three-year, five-year, ten-year and twenty-year Treasury securities.[23] The yields on Treasury securities at constant fixed maturity are derived from composite quotes reported by U.S. government securities dealers to the Federal Reserve Bank of New York. To obtain the constant maturity yields, the Treasury Department constructs a yield curve each business day and yield values are then read from the curve at fixed maturities.

The frequency of the yield data used in the estimation is monthly; the data extend from December 1958 to September 2000.[24] Tables A.1 and A.2 provide descriptive statistics and the unit root tests for the levels of interest rates. The augmented version of the Dickey-Fuller test (ADF) was used to explore the presence of unit roots.[25] Twelve lags were used, which seemed appropriate given the frequency of the data. The null hypothesis of non-stationarity cannot be rejected, suggesting the presence of a unit root. The series were therefore first-differenced, and the first differences appeared to be stationary (see Tables A.3 and A.4). However, Table A.3 suggests that the hypothesis of normality is rejected. In particular, there is clear evidence of leptokurtosis, highlighting the benefits of the bootstrap technique.

Three different approaches were attempted to estimate the relationships among the variables: (1) Johansen, (2) Engle-Granger, and (3) a vector autoregression (VAR) method in which *a priori* long-run relationships were imposed. Of these, the first two proved unsatisfactory for different reasons (see below), so the third approach was adopted.

1. *The Johansen approach*: Johansen techniques on the yields were applied, but problems emerged in that the distribution of the residuals was non-normal and it was hard to eliminate autocorrelation in the residuals. The distribution of residuals is quite important: to make accurate inferences and forecasts from the cointegration analysis in multivariate systems, it is essential to determine correctly the number of cointegrating vectors. Testing for reduced rank depends heavily on the distributional assumptions of the noise.

2. *The Engle and Granger approach*: The no-arbitrage principle suggests that in the long run, points along the yield curve should be cointegrated and, in particular, there should be only one cointegrating vector. If this is the case, the Engle and Granger approach seems to be a viable technique to study the long-run dynamics of the yield curve. When this approach was implemented, the hypothesis of no cointegration was decisively rejected regardless of the rate selected as dependent variable in the cointegrating equations. This finding suggests two important issues: (1) which long-run relationship is to be used in the vector error correction model (VECM) form of the model, and (2) the dynamic specification of the VECM. It was not possible to eliminate the autocorrelation by introducing a reasonable number of lags in the dynamic specification of the VECM. Furthermore, the application of the Johansen approach suggests the presence of one or more cointegrating relationships, even if these results must be read with due care. This approach thus did not appear auspicious.

[22] For a description of vector autoregressive moving average models, along with the bootstrap technique, see Hamilton (1994).

[23] The data were obtained from the Federal Reserve Board of Governors.

[24] Missing observations were imputed in the following manner. First, the three- and six-month constant maturity yields for the period December 1958 to December 1981 were imputed using the time series for the three- and the six-month Treasury bill rates, respectively. Second, the 20-year constant maturity yield estimated by the Department of the Treasury was interrupted between January 1987 and September 1993. For this period of time, missing data were interpolated by averaging the ten- and thirty-year constant maturity yields.

[25] For a discussion of unit roots and the augmented Dickey-Fuller test, see Hamilton (1994).

3. *The VAR approach*: Given the previous results, the analysis explored a dynamic specification capable of dealing with the non-stationary nature of the data and the long-run relationships between the yields. It focused on the dynamic of the first difference of the ten-year bond and the adjacent spreads, i.e., the spread between the six and the three months, the spread between the one year and the six month yield, and so on. Economic intuition suggests that these spreads should be stationary over time. Tests for the stationarity of these series were conducted and could not reject the hypothesis. Extensive data analysis suggested a VARMA (4,1): $\Delta X_t = c + a_1 \Delta X_{t-1} + a_2 \Delta X_{t-2} + a_3 \Delta X_{t-3} + a_4 \Delta X_{t-4} + b\varepsilon_t$, where the X_t is a (7x1) vector containing the spreads and the first difference of the ten-year yield and ε is assumed to be independently distributed. (The analysis still discovered instances of statistical evidence for autocorrelation, but the size of the phenomenon was negligible.) The estimation of the VARMA was carried out in two stages. In the first stage, a VAR (4) was estimated and then, in the second stage, a VAR (1) on the residuals of the first stage was estimated. The main attraction of this approach was that it avoided the necessity of imposing any distributional assumption on the error terms.

Credit loss rate modeling

The other important modelling issue involved the credit loss risk. Two complications arose: First, the credit loss rate must always be non-negative and may depend upon the interest rate. Second, the available data series was short. The first point motivated modelling the log of the credit loss rate as depending on its lagged value and on the lagged value of the log of the ten-year yield: $d_t = \alpha + \beta d_{t-1} + \gamma r_{t-1} + \sigma \varepsilon_t$ where d_t and r_t are the log of the credit loss rate and the ten-year yield, respectively. The error term was assumed to be normally and individually independently distributed with a mean of zero and a variance of one. This formulation has two advantages. First, it models the relationship between the credit loss rate and the long-run end of the yield curve in a simple fashion. Second, it facilitates simulations of the credit loss rate distribution conditional on a path for the yield on the ten-year bond.

The time series estimation was undertaken using PC Give, whereas the bootstrap and Monte Carlo calculations used the Gauss matrix programming language. The Gauss code is available upon request to the authors.

Descriptive Statistics for Interest Rate Data

	Tcm3m	Tcm6m	Tcm1y	Tcm3y	Tcm5y	Tcm10y	Tcm20y
Mean	6.117888	6.404880	6.551036	6.940398	7.104402	7.257470	7.353068
Std.Devn.	2.731341	2.734135	2.757250	2.617918	2.573670	2.542617	2.532456
Skewness	1.334990	1.251990	1.231084	1.106526	1.035051	0.904033	0.783402
Excess Kurtosis	2.133412	1.716426	1.588047	1.148074	0.904462	0.521703	0.299275
Minimum	2.320000	2.590000	2.810000	3.230000	3.470000	3.710000	3.740000
Maximum	16.880000	16.380000	16.720000	16.220000	15.930000	15.320000	15.130000
Normality χ^2	209.33 [0.000]**	195.32 [0.000]**	194.93 [0.000]**	161.2 [0.000]**	144.52 [0.000]**	114.27 [0.000]**	83.209 [0.000]**

TABLE A.1

The time series used are: the three (Tcm3m) and the six (Tcm6m) months, the one (Tcm1y), three (Tcm3y), five (Tcm5y), ten year (Tcm10y) and twenty year (Tcm20y) constant maturity yield. The data are from December 1958 to September 2000. The frequency is monthly. This table reports the descriptive statistics for these series and the result for the normality test, which is rejected for all the time series. Skewness and excess kurtosis are equal to zero for a standard normal random variable. The ** indicates significance at 1% level. P-values for the normality tests are in square brackets.

TABLE A.2

Stationarity Tests for Interest Rates

Lag	Tcm3m	Tcm6m	Tcm1y	Tcm3y	Tcm5y	Tcm10y	Tcm20y
	Unit-root tests Critical values: 5%=-2.868 1%=-3.446; Constant included						
12	-2.0155	-2.0946	-2.044	-2.0084	-1.9565	-1.8406	-1.8545
11	-2.3474	-2.3521	-2.3336	-2.1759	-2.0737	-1.993	-1.9645
10	-2.2087	-2.1198	-2.0351	-1.9799	-1.9285	-1.8554	-1.8159
9	-2.3387	-2.1548	-2.0133	-1.8982	-1.8194	-1.7612	-1.7756
8	-2.1219	-2.1125	-2.0638	-1.9319	-1.8428	-1.7659	-1.773
7	-1.8766	-1.8177	-1.8351	-1.7483	-1.7264	-1.6682	-1.7095
6	-1.8885	-1.8629	-1.8224	-1.7796	-1.7217	-1.6676	-1.6998
5	-2.4642	-2.4078	-2.3772	-2.1082	-1.9964	-1.841	-1.8066
4	-2.3641	-2.2616	-2.1214	-1.9062	-1.79	-1.6553	-1.6426
3	-2.3976	-2.298	-2.2114	-1.9801	-1.8683	-1.689	-1.6478
2	-2.3872	-2.3196	-2.2013	-1.9111	-1.7569	-1.5825	-1.5797
1	-2.9899*	-2.9166*	-2.854	-2.4601	-2.2736	-1.9344	-1.8723

This table summarizes the results of the ADF tests for the different constant maturity yield series. We have included a constant and lags up to 12. The * indicates significance at 5%.

TABLE A.3

Descriptive Statistics for Changes in Interest Rate Data

	Dtcm3m	Dtcm6m	Dtcm1y	Dtcm3y	Dtcm5y	Dtcm10y	Dtcm20y
Mean	0.006607	0.006128	0.005669	0.004591	0.004212	0.003872	0.004451
Std.Devn.	0.516181	0.498752	0.485054	0.399854	0.355038	0.299875	0.272218
Skewness	-1.659818	-1.601070	-1.398706	-0.832156	-0.483362	-0.468065	-0.303841
Excess Kurtosis	21.387857	17.156188	13.791760	8.296885	6.256910	6.007524	6.035365
Minimum	-4.790000	-4.460000	-3.910000	-2.580000	-2.030000	-1.760000	-1.570000
Maximum	2.710000	2.290000	1.900000	1.960000	1.860000	1.610000	1.560000
Normality χ^2	652.34 [0.000]**	456.89 [0.000]**	382.44 [0.000]**	296.67 [0.000]**	257.79 [0.000]**	245.46 [0.000]**	269.54[0.000]**

The time series used in this table are the first difference of Tcm3m, Tcm6m, Tcm1y, Tcm3y, Tcm5y, Tcm10y and Tcm20y, denoted by, respectively, Dtcm3m, Dtcm6m, Dtcm1y, Dtcm3y, Dtcm5y, Dtcm10y and Dtcm20y. This table reports the descriptive statistics for these series and the result for the normality test, which is rejected for all the time series. Skewness and excess kurtosis are equal to zero for a standard normal random variable. The ** indicates significance at 1% level. P-values for the normality tests are in square brackets.

Stationarity Tests for Changes in Interest Rates

Unit-root tests Critical values: 5%=-1.94 1%=-2.57							
Lag	**D3m**	**D6m**	**D1y**	**D3y**	**D5y**	**D10y**	**D20y**
12	-5.9412**	-5.9298**	-5.8794**	-5.8013**	-5.6966**	-5.6611**	-5.7183**
11	-7.2350**	-6.7065**	-6.6439**	-6.1629**	-5.9677**	-5.8554**	-5.6708**
10	-6.3691**	-6.1394**	-5.9655**	-5.8334**	-5.7758**	-5.4883**	-5.4177**
9	-7.1309**	-7.1989**	-7.2536**	-6.7549**	-6.5250**	-6.1976**	-6.2481**
8	-7.0202**	-7.4534**	-7.7739**	-7.4696**	-7.3514**	-6.9221**	-6.7399**
7	-8.3184**	-8.0884**	-8.0422**	-7.7558**	-7.6649**	-7.2644**	-7.1003**
6	-10.529**	-10.545**	-10.039**	-9.4586**	-8.9466**	-8.3742**	-7.9625**
5	-11.887**	-11.590**	-11.376**	-10.225**	-9.8334**	-9.0663**	-8.6265**
4	-9.7545**	-9.6093**	-9.2960**	-9.1942**	-8.9697**	-8.6261**	-8.5170**
3	-11.433**	-11.514**	-11.824**	-11.529**	-11.345**	-10.885**	-10.755**
2	-13.078**	-13.190**	-13.183**	-12.801**	-12.424**	-12.132**	-12.266**
1	-16.274**	-16.133**	-16.491**	-16.617**	-16.625**	-16.294**	-16.138**

TABLE A.4

This table summarizes the results of the ADF tests for the first difference of the various constant maturity yield series. We have included a constant and lags up to 12. The * indicates significance at 5% and the ** indicates significance at 1%.

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