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A Model for Pricing Federal Housing Finance Obligations

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Abstract

This paper presents a risk-neutral approach used by the Congressional Budget Office to inform its estimates of the fair-value cost of mortgage obligations. The fair-value cost is the amount that a private entity would charge in a competitive market for taking the risks associated with a government activity. CBO's approach adjusts the probability distribution of macroeconomic variables to obtain a risk-neutral distribution of default, recovery, and prepayment rates. The macroeconomic variables are calibrated by determining the adjustment that leads the estimates of the fair-value of credit-risk–transfer securities to match their observed prices and fit the pricing of private mortgage insurance. CBO then uses that risk-neutral distribution to develop projections of cash flows that incorporate market risk and can be discounted to the present with Treasury rates to obtain estimates of the fair-value cost of government mortgage obligations. To demonstrate the approach, this paper applies it to estimate the cost of backstopping pools of mortgages against catastrophic losses.

Keywords: credit-risk transfer, fair value, market risk, private mortgage insurance, risk premiums

JEL Classification: G12, G18, G21, H81

Contents

The Congressional Budget Office estimates the cost of many government activities that support mortgage markets by maintaining a stable flow of funds to finance home purchases and help members of targeted groups become homeowners. CBO estimates the cost of the mortgage obligations of federal agencies, such as the Federal Housing Administration (FHA) and the Department of Veterans Affairs (VA), according to the requirements of the Federal Credit Reform Act (FCRA), but CBO often supplements those FCRA estimates with estimates of the fair-value cost of those obligations. CBO uses fair value as the main measure of the cost of the mortgage obligations of Fannie Mae and Freddie Mac, which are private entities with a government charter.

Fair-value cost is the amount that a private entity would charge in a competitive market for taking the risks associated with a government activity. CBO views the fair-value approach as a more comprehensive measure of the costs of loans and loan guarantees than the measures required under FCRA because the fair-value approach incorporates market risk.[1] Market risk in loans and loan guarantees arises from uncertainty in the rates of default, prepayment, and other outcomes that depend on the future state of the economy. For example, when the economy is performing poorly, borrowers suffer financial strains, and the likelihood of default for all borrowers rises. Pooling the loans of many borrowers diversifies some risks but cannot eliminate market risk.

The federal government supports housing finance by guaranteeing home mortgages and by backing government-sponsored enterprises (GSEs), such as Fannie Mae and Freddie Mac, that take on the risk of mortgage default. The government directly guarantees mortgages with low down payments through FHA's mutual mortgage insurance program, which serves low-income participants; VA's mortgage guarantee program, which is available to veterans; and the Department of Agriculture's (USDA's) rural housing insurance fund, which serves rural communities.

The federal government also indirectly supports mortgage markets through its sponsorships of the GSEs: Fannie Mae, Freddie Mac, and the Federal Home Loan Bank system.[2] Although they are private companies, CBO has treated Fannie Mae and Freddie Mac as government entities in the budget since the entities were placed in conservatorship by their regulator in 2008. The government effectively controls and owns Fannie Mae and Freddie Mac through those conservatorships and the entities' financial agreements with the Treasury.

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[1] See Congressional Budget Office, *Measuring the Cost of Government Activities that Involve Financial Risk* (March 2021), www.cbo.gov/publication/56778.

[2] We did not analyze the Federal Home Loan Bank system because its support is in the form of an implicit guarantee, and the budget does not currently incorporate a cost for its activities.

An Overview of the Fair-Value and FCRA Models

The net cost to the government of a mortgage obligation depends on the terms of the obligation, such as the guarantee fee, and on the mortgage's estimated default and prepayment rates.[3] Those default and prepayment rates in turn depend on the characteristics of the borrower and the economic environment in which the borrower repays the loan. Accordingly, forecasts of default and prepayment rates depend on an economic projection.

In this paper, we present our modeling approach to estimate the fair value of federal mortgage obligations. We create a risk-neutral distribution of future macroeconomic variables that are used to estimate default and prepayment rates.[4] A risk-neutral distribution is an adjusted-probability distribution that can be used in valuing assets and liabilities. In creating a risk-neutral distribution, the actual distribution of default and prepayment rates is shifted toward more adverse outcomes. The adjusted distribution of default and prepayment rates, in combination with the terms of the guarantee and of the mortgage itself, generates a projection of cash flows that incorporates market risk.

We calibrate the probability distribution using the pricing of both credit-risk–transfer securities (CRTs) and the premiums charged by private mortgage insurers (PMIs). CRTs are bonds that pay principal and interest to investors on the basis of the performance of an underlying pool of mortgages guaranteed by Fannie Mae and Freddie Mac. Private mortgage insurance covers Fannie Mae and Freddie Mac against the risk of losses from individual mortgages up to the limit specified in the policies. Our estimation process uses the two sources of market pricing data—CRT prices and the premiums charged by PMIs—in combination.

We can estimate an implied risk premium under this approach. The projections of cash flows already incorporate market risk through the adjustment to the probability distribution of the error terms and therefore can be discounted using a Treasury rate to obtain a fair-value estimate. The fair value obtained from the adjusted-probability distribution can be used in combination with the unadjusted cash flow projection to solve for an implied risk premium. The implied risk premium is the rate that produces the estimated fair-value cost when added to the discount rates for the unadjusted projection of cash flows.

This approach views a portfolio of mortgage guarantees as a derivative of housing wealth and applies concepts developed in options-pricing theory. The use of risk-neutral probabilities was developed by Cox and Ross as an alternative to the approach to pricing options outlined by Black

[3] Guarantee fees are charged by an agency or enterprise in exchange for the guarantee of a mortgage obligation. Those fees may be charged upfront or annually.

[4] See Michael Falkenheim, *Fair-Value Cost Estimation and Government Cash Flows*, Working Paper 2021-05 (Congressional Budget Office, April 2021), www.cbo.gov/publication/57062.

and Scholes, whose model requires the specification of dynamic hedging strategies.[5] Cox and Ross showed that the same answer could be obtained by adjusting probabilities to make the expected return of an underlying asset equal to the risk-free rate. The adjusted probabilities are termed risk neutral because they generate cash flows that can be discounted at the risk-free rate, as if the investor were risk-neutral. Risk-neutral probabilities have been used to estimate the cost of a variety of governmental obligations.[6] They have also been used to estimate the value of private mortgage obligations.[7] Our approach is closely related to work by Davidson, Levin, and Qin (2016), who use prices on CRTs to estimate the risk-neutral distribution of default rates for mortgages guaranteed by the GSEs, and use the resulting distribution to estimate the guarantee fee implied by those prices.[8]

The key assumption of the model is that the market risk of mortgage obligations derives from a stochastic term affecting house prices and other macroeconomic variables. This approach differs from the approach to options pricing under the capital asset pricing model (CAPM), which treats economic variables as derivatives of the Standard and Poor's (S&P) 500 index, a proxy for the market portfolio. The approach of this paper follows the philosophy of multifactor models, such as arbitrage pricing theory, rather than CAPM. Under multifactor models, the S&P 500 index is not a sufficient statistic of market risk. The market prices risk that arises from multiple factors rather than merely from covariance with a single market portfolio.

We estimate the risk-neutral distribution by first estimating a vector autoregression (VAR) model of macroeconomic variables that generates stochastic simulations around its central forecast (see Figure 1). That model supplies projections of house price appreciation, unemployment rates, and interest rates for use in the projection of default and prepayment rates. We estimate a multinomial logit model of default and prepayment rates that includes covariates that derive from those three macroeconomic variables while also relating mortgage outcomes to borrowers' and

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[5]See John C. Cox and Stephen A. Ross, "The Valuation of Options for Alternative Stochastic Processes," *Journal of Financial Economics*, vol. 3, no. 1–2 (January–March 1976), pp. 145–166, https://doi.org/10.1016/0304-405X(76)90023-4; and Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *The Journal of Political Economy*, vol. 81, no. 3 (May–June 1973), pp. 637–654, http://www.jstor.org/stable/1831029?origin=JSTOR-pdf.

[6] See, for example, Wendy Kiska, Jason Levine, and Damien Moore, *Modeling the Costs of the Pension Benefit Guaranty Corporation's Multiemployer Program,* Working Paper 2017-04 (Congressional Budget Office, June 2017), www.cbo.gov/publication/52749; and Michael Falkenheim and George Pennacchi, "The Cost of Deposit Insurance for Privately Held Banks: A Market Comparable Approach," *Journal of Financial Services Research*, vol. 24 (October 2003), pp. 121–148, https://doi.org/10.1023/B:FINA.0000003320.95646.5f.

[7] See Alexander Levin and Andrew Davidson, "The Concept of Credit OAS in the Valuation of MBS," *The Journal of Portfolio Management*, vol. 34, no. 3 (Spring 2008), pp. 41–55, https://doi.org/10.3905/jpm.2008.706242.

[8] See Andrew Davidson, Alex Levin, and Harry Lijia Qin, "Risk Neutralization of Agency Credit Model, Relative Value, and Implied G-Fee," *Quantitative Perspectives* (October 2016), www.ad-co.com/quantitative-perspectives.

loans' characteristics. We estimate an ordinary least squares regression to model loss given default.

To generate FCRA estimates, we simulate 1,000 paths of the macroeconomic variables using the estimated parameters of the VAR and center those projections on CBO's central forecast, also referred to as macroeconomic baseline projections.[9] We then use the estimated parameters of the multinomial logit and the loss-given-default model to project defaults, prepayments, and recoveries under each of those 1,000 paths. We use those rates to estimate the cash flows of the obligations and discount them at Treasury rates to calculate their net present value (NPV) under each of the 1,000 simulations. Our FCRA estimate of the cost of those obligations is equal to the mean NPV under the simulations.

For fair-value estimates, we follow the same process but make an adjustment to the stochastic simulation of the macroeconomic variables. We shift the distribution of the stochastic component of house prices toward a lower mean, such that the macroeconomic projections become centered on an adverse scenario. The parameters of the VAR model propagate those lower stochastic components of house prices through interest rates and unemployment rates as well as the future values of house prices. The adjusted simulation is centered on lower house prices, higher unemployment, and lower interest rates. We use the default, prepayment, and recovery rates that are conditional on that set of simulations to estimate fair values. The implied risk premium is the constant adjustment to the risk-free discount rate that sets the NPV under the simulation of the macroeconomic baseline equal to the risk-neutral NPV.

The Macroeconomic Vector Autoregression

We project a vector of macroeconomic variables z_t, observed on a quarterly basis.

$$z_t = c + A_1 z_{t-1} + \varepsilon_t \qquad (1)$$

The vector z_t includes quarterly appreciation in the Federal Housing Finance Agency's purchase-only house price index, the 10-year Treasury rate, and the unemployment rate. It is a linear function of a vector of constant terms c, the vector of its lagged values z_{t-1}, and a vector of stochastic terms ε_t.[10] The matrix A_1 determines the effect of the lagged terms on the current values and the impulse responses to the stochastic term. We estimate the coefficients of that model using data from 1990 to 2017 to capture a period of relatively stable inflation that includes the 2007–2009 recession but ends before the coronavirus pandemic.

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[9] CBO's spring 2018 macroeconomic baseline budget projections were used for this analysis. See Congressional Budget Office, *The Budget and Economic Outlook: 2018 to 2028* (April 2018), www.cbo.gov/publication/53651.

[10] We chose one lag for the VAR to generate smooth projections in the risk-neutral forecast.

The estimated coefficients show that shocks to house price growth tend to persist; high house price growth tends to be followed by high house price growth and low growth by low growth (see Table 1). Unemployment is negatively related to recent house price growth. That is, high unemployment tends to follow low house price appreciation, consistent with the possibility that both conditions arise from a weak economy. Low house price appreciation leads to lower interest rates, reflecting the tendency for interest rates to fall during recessions.

The Model of Default and Prepayment

We model default and prepayment as terminal states, conditional on the mortgage being active in the previous period. Default is defined as the last time a mortgage becomes 90 days delinquent prior to mortgage termination. The default d_t^i and prepayment p_t^i rates are predicted by a multinomial logit, specified as follows:

$$d_t^i = \frac{e^{\beta_1 y_{\mathrm{t}}^i}}{1+e^{\beta_1 y_{\mathrm{t}}^i}+e^{\beta_2 y_{\mathrm{t}}^i}} \tag{2}$$

$$p_t^i = \frac{e^{\beta_2 y_{\mathrm{t}}^i}}{1+e^{\beta_1 y_{\mathrm{t}}^i}+e^{\beta_2 y_{\mathrm{t}}^i}} \tag{3}$$

Under that specification, y_{t}^i is a set of covariates for loan *i* at time *t* that includes elements from the vector of macroeconomic variables z_t, characteristics of the loan and borrower x_0^i, and functions of those two things in combination, as well as dummy variables to capture the cohort's fixed effects. For example, the loan-to-value ratio (LTV) of a loan in time t is a function of its LTV at origination (an element of x_0^i) and house price appreciation between origination and time t, which depends on the sequence of z_1 to z_t. The set of variables y_{t}^i also includes fixed effects for each year in which loans originated. Those cohort effects capture everything that might influence the default and prepayment behavior of loans originated in one year that is not captured by macroeconomic variables and observable loan characteristics. We use the average of the cohort effects in the projection of default and prepayment.

We estimate a separate loss given default for CRTs and for PMIs. The rate of loss l_t^i is defined as the loss amount, net of recovery, divided by the unpaid balance at the time the mortgage is assumed by Fannie Mae or Freddie Mac. To estimate l_t^i, we specify a linear model using the same covariates y_t^i and others measuring the terms of the private mortgage insurance coverage m_0^i:

$$l_t^i = \beta_3 y_{\mathrm{t}}^i + \beta_4 m_0^i. \tag{4}$$

That estimated loss is used to reduce the principal of the junior tranche of the CRT. Loss given default for the PMI is estimated as the product of the unpaid balance at default, the coverage ratio, and a haircut representing the PMI's rejection of some claims.[11]

Mortgage Performance Data for Default and Prepayment Estimation

We use the Federal Housing Finance Agency's National Mortgage Database (NMDB) to estimate the models of mortgage performance in equations (2) and (3). The NMDB is a nationally representative sample of 5 percent of residential mortgages in the United States, and it is maintained by the Federal Housing Finance Agency and the Consumer Financial Protection Bureau. The data set contains information on mortgages and borrowers' attributes (see Table 2 for variable definitions). Mortgage data include product type, loan amount, property value, interest rate, and property location (at the level of metropolitan statistical area). Borrowers' attributes include credit score, income, debt-to-income ratio, and first-time–home-buyer status. Mortgage performance, as reported by the servicer, is available at a monthly level from mortgage origination to termination. The data are restricted to 30-year, fixed-rate mortgages. The coefficients of the multinomial logit model were estimated on a 12 percent sample of the mortgages in the NMDB that were acquired by Fannie Mae and Freddie Mac between 2000 and 2015. A panel of quarterly mortgage performance was constructed using data from the date of mortgage origination through 2017 (see Table 3 for summary statistics). Because the NMDB does not contain data on credit losses, the model of loss given default in equation (4) is estimated using Fannie Mae's single-family loan performance data.

The choice of variables to include in y_t^i is based on the theory that mortgage default is driven by a "double trigger" of falling home values and a borrower's economic hardship.[12] Under that theory, falling home values give borrowers some incentive to default but are not usually sufficient to trigger default on their own. Borrowers whose homes are "underwater"—worth less than the mortgage on the homes—generally refrain from defaulting as long as they have sufficient income to make payments. The model captures that theory by including the unemployment rate in addition to the amount of home equity that borrowers are likely to have. It also includes other characteristics of borrowers and loans that have been shown to affect default rates.

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[11] PMIs are not required to pay claims on loans for reasons that have been established in the insurance contracts, for example, because a loan's documentation did not follow established requirements.

[12] See Neil Bhutta, Hui Shan, and Jane Dokko, "The Depth of Negative Equity and Mortgage Default Decisions," Working Paper No. 2010-35 (Board of Governors of the Federal Reserve System, May 2010), http://dx.doi.org/10.2139/ssrn.1895493; and Kristopher Gerardi, Kyle Herkenhoff, Lee Ohanian, and Paul S. Willen, "Can't Pay or Won't Pay? Unemployment, Negative Equity, and Strategic Default," *The Review of Financial Studies*, vol. 31, no. 3 (March 2018), pp. 1098–1131, https://doi.org/10.1093/rfs/hhx115.

The model controls for mortgage and borrower characteristics at origination and variables that depend on macroeconomic variables after origination. The age of the mortgage serves as the base hazard rate. Attributes of the mortgage at origination include the original LTV, the size of the loan relative to the state average, the spread at origination, the type of refinance, and the vintage. Borrowers' attributes at origination are credit score, debt-to-income ratio (DTI), and first-time home buyer status. Risk attributes that vary with macroeconomic series include the current LTV ratio, which depends on house prices; the mortgage premium (MP), also known as the refinance incentive, which depends on interest rates; and the unemployment rate, a proxy for the risk of an income disruption for the borrower. Separate regressions were estimated for purchase and refinance mortgages.

Piecewise-linear splines, in which the slope of a linear relationship shifts at specified points, were used for most variables: the coefficients for each segment are the slopes between the spline knots. The age spline assumes a slope of zero for ages greater than 12 quarters, and the MP spline assumes a slope of zero for $MP < -1$, to ensure that the likelihood of prepayment increases monotonically with MP. The default equation is constrained to set the coefficients on MP and burnout to zero. Variables that are correlated with the interest rate can have a spurious correlation with default rates due to the low interest rates and high default rates that prevailed following the 2007–2009 recession.[13]

The estimated coefficients generally take the expected signs: a higher MP increases the probability of prepayment, a higher LTV increases the probability of default, a higher credit score decreases the probability of default, and a higher unemployment rate increases the probability of default (see Table 4 for model estimates).

The model of the rate of loss after default is estimated by the ordinary least squares regression. Most of the variables from the default and prepayment model are included in the regression, along with data on the mortgage insurance policy held by the borrower (see Table 5 for model estimates).

Generating Scenarios

To simulate mortgage performance and the cash flows of mortgage obligations, we simulate cash flows under 1,000 paths and take their average. We randomly draw 1,000 sequences of the stochastic components in the vector of macroeconomic variables $\varepsilon_1, \dots, \varepsilon_T$. Those stochastic components are drawn from the joint normal distribution of errors from equation (1). Equation (1) is used to generate the path of each variable in period t, using the values of the variables from

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[13] For discussion of many of the variables in the default and prepayment model, see Robert M. Dunsky and others, "FHFA Mortgage Analytics Platform, Version 2.0," FHFA Policy, Programs & Research White Papers (Federal Housing Finance Agency, May 2020), https://go.usa.gov/xtGnj.

the previous period and the stochastic component ε_t. Those paths of macroeconomic variables are used as inputs in equations (2), (3), and (4) to simulate sequences of the default, prepayment, and loss rates $d_1^i, \ldots, d_T^i$, $p_1^i, \ldots, p_T^i$, and $l_1^i, \ldots, l_T^i$. We calculate the cash flows of a mortgage obligation under each of those sequences of default and prepayment rates, and discount them to the date of origination at Treasury rates to get the NPV of projected average cash flows—the measure that is used under FCRA.

To streamline the simulation of mortgage performance, we simulate the performance of bins of mortgages as opposed to individual loans. The bins are defined by mortgage type and ranges of LTV and credit score, matching the pricing buckets of the mortgage insurers. We assign each bin a weight on the basis of how much business the GSEs did in each bin of mortgages in 2018.

The probability distribution is modified by shifting the mean of the stochastic component of house prices, which is the first element in the vector ε_t, and the unemployment rate and interest rate based on their conditional expectation under the shifted mean of the first error term.[14] Under the actual probability distribution, all three error terms are centered on zero. Under the risk-neutral distribution, the center of the first error term—applied to house prices—is shifted downward to the point at which its mean is equal to $\alpha_1 + \alpha_2$ in quarter 1 and α_2 in all subsequent quarters, where in general $\alpha_1, \alpha_2 < 0$. The value α_1 can be interpreted as a shock to house prices immediately after origination that propagates over several quarters, and α_2 can be interpreted as a shift in the long-run growth rate of house prices.

Calibration of the Pricing of Private Mortgage Insurance and Credit-Risk–Transfer Securities

We use a combination of CRT pricing and private mortgage insurance premiums to estimate the values of α_1 and α_2, which measure the shift in the distribution of the stochastic term ε_t under the risk-neutral distribution. Both the premiums charged by PMIs and the prices of CRTs are easy to compare with the risks taken by government programs.[15] The loans guaranteed by PMIs

[14] We use a Cholesky factorization of the matrix to determine the relative size of the shift in each error term's mean. For every 1 percent shift in the stochastic term of house prices, we shift the unemployment rate by approximately 0.05 percent and interest rates by about 0.14 percent.

[15] The interest rate charged on mortgages that are too large to qualify for purchase by Fannie Mae and Freddie Mac (called jumbo loans) can also be used to assess federal credit risk in otherwise similar loans that qualify for purchase (known as conforming loans). The difference between the interest rates on jumbo and conforming loans is called the jumbo-conforming spread. Between 2000 and 2013, the spread averaged 46 basis points. For more information, see Lynn M. Fisher and others, *Jumbo Rates Below Conforming Rates: When Did This Happen and Why?* AEI Economic Policy Working Paper Series (American Enterprise Institute, August 2020), https://tinyurl.com/3r9y3eku. The positive jumbo-conforming spread in that period suggests that Fannie Mae and Freddie Mac were charging lower guarantee fees than fully private entities would require, although that spread could also have originated from differences in the liquidity of private mortgages and differences in default and prepayment behavior of borrowers

are almost all also guaranteed by the GSEs. Thus, the risk taken by the GSEs is comparable to the risk taken by PMIs. The main difference is that the risk on any given loan for a PMI is capped in its contract, and Fannie Mae and Freddie Mac are responsible for the rest.[16] The payments on CRTs depend on the performance of the same loans that are guaranteed by Fannie Mae and Freddie Mac.

The prices of CRTs and private mortgage insurance play complementary roles in our calibration process, reflecting the advantages of each as a data source. The main advantages of CRTs as a source of pricing information are that they are sold competitively to any investors who might wish to buy them, and that the prices of different tranches can be used to gauge the risk of different depths of portfolio loss. But CRT prices do not vary by loan characteristic because they apply to an entire reference portfolio. The prices of private mortgage insurance, in contrast, are available for different combinations of LTV and FICO score but do not vary by the depth of portfolio loss. Prices for private mortgage insurance are potentially affected by regulatory requirements and by barriers to entering the industry. They are also somewhat opaque because their published prices differ from the prices borrowers pay after discounts. In addition, the pricing of private mortgage insurance is subject to other complications, such as the potential for moral hazard and the potential for rejection of claims.[17]

We find sets of the two parameters in which the estimated value of CRTs is equal to the market price of those CRTs.[18] Applying that condition does not fully identify α_1 and α_2 because it subjects the two parameters to a single equation, leaving a degree of freedom. We use that degree of freedom to fit the model to the pricing of private mortgage insurance. That is, among the sets of α_1 and α_2 that equate estimated CRT values to their observed prices, we choose the set that

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with large balances. Between 2014 and 2019, however, the spread averaged negative 28 basis points, suggesting that the GSEs priced their guarantees at a rate that was equal to or higher than the rate that private lenders would see as fair compensation for risk. That rate was consistent with their regulator's intent and was also consistent with CBO's estimates, which showed that the fair-value cost of their guarantees was small. Although a negative spread suggests a subsidy that is negative for mortgages with balances near the conforming loan limit, it is less relevant for mortgages with balances that are lower than the limit. Last year, CBO estimated that the subsidy for mortgages guaranteed by the GSEs was only $71 billion over 10 years on a loan volume of $12.9 trillion, an average subsidy rate of 0.55 percent. See Congressional Budget Office, *The Budget and Economic Outlook: 2021 to 2031* (February 2021), www.cbo.gov/publication/56970.

[16] The risk taken by PMIs is even more similar to the risk taken by VA in its mortgage guarantees. VA insures between 25 and 50 percent of a loan's unpaid principal balance, which is paid to the mortgage lender after a claim is filed. Similar to PMIs, VA is in the first-loss position. For more information about VA's mortgage insurance, see Congressional Budget Office, *The Role of the Department of Veterans Affairs in the Single-Family Mortgage Market* (September 2021) www.cbo.gov/publication/57462.

[17] Moral hazard occurs when an entity has an incentive to increase its exposure to risk because it does not bear the full costs of that risk.

[18] We use M securities, also known as mezzanine securities, because they cover relatively deep losses and thus bear risks comparable to those taken by government.

best fits the observed schedule of private mortgage insurance for different classes of mortgages. That process of fitting uses additional parameters to take into consideration such factors as administrative costs, claim rejection, discounts, and other factors that might systematically affect the revenues or costs of mortgage insurance.

Model for Credit-Risk–Transfer Securities

We estimate the fair market value of CRTs as the discounted value of their projected payments under the risk-neutral distribution. The CRTs are divided into different bonds, called tranches, that have different levels of seniority and different coupon rates. The most junior tranches absorb the first losses through reductions in their principal. They have the highest coupon rate to compensate for that level of risk. The senior tranches are paid first when borrowers in the reference pool pay off their principal balance. For the GSEs' recent issuances of credit-risk notes, average spreads have ranged from approximately 1 percentage point for the most senior tranche to 10 percentage points for the most junior tranche.[19]

We capture that structure of CRT in a cash flow model that translates projected default and prepayment rates into projected payments on each of the tranches of the CRTs. For each quarter and each tranche, we project the cash flows to the investor as the principal and interest of CRTs that are paid on the original schedule, in addition to the amount that is prepaid. Then we update the balance at the start of the next quarter on the basis of scheduled principal payments, projected prepayments, and projected reductions in principal that occur to cover default costs.

That process results in cash flows to investors in each tranche that are functions of the default and prepayments in the current and all prior quarters. Expressing the projected cash flow to investors in tranche j in period t as $f_t^j(\theta, \alpha_1, \alpha_2)$, the estimated value of a tranche at origination, $V^j(\theta, \alpha_1, \alpha_2)$ is:

$$V^j(\theta, \alpha_1, \alpha_2) = \sum_{t=1}^{T} \frac{f_t^j(\theta, \alpha_1, \alpha_2)}{(1 + r_t)^t}$$

That value is the sum of discounted projected cash flows and is a function of the vector of parameters governing default prepayment and credit losses, θ, as well as the calibration parameters α_1 and α_2.

Model of Private Mortgage Insurance

Our estimates of what PMIs charge are based on tables published by the Mortgage Guaranty Insurance Corporation (MGIC). We use the nonrefundable, borrower-paid monthly premiums

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[19] For more information on CRTs, see Congressional Budget Office, *Transferring Credit Risk on Mortgages Guaranteed by Fannie Mae or Freddie Mac* (December 2017) www.cbo.gov/publication/53380.

that went into effect on July 9, 2018. All mortgages are assumed to take the GSE-mandated coverage level for their LTV bucket.[20]

We expect that PMIs charge premiums that maximize their economic profits considering the fair-value cost of insurance and competition between them, by pricing them so that marginal revenue equals marginal cost. Several factors that determine which premiums will maximize profits are difficult to observe, including the following:

- The actual price charged by PMIs, which is usually at a discount from published prices based on deals that the insurers have with mortgage lenders who channel business to them;[21]
- PMIs' administrative costs for overhead, underwriting, and claims resolution;
- The potential for rejection of claims by PMIs for causes such as inadequate documentation;[22] and
- The nature of competition between PMIs.
- The potential for moral hazard, given limited capital.[23]

Given that we cannot directly observe the effects of those factors on pricing, we estimate the marginal costs and marginal revenues of PMIs in two steps. First, we estimate gross unadjusted revenues and costs by projecting cash flows under the published premium schedules, assuming that all mortgage claims are paid, there are no administrative costs, and there are no discounts. Then we estimate adjustments to those costs and revenues that best fit the observed premiums, meaning that they produce net marginal revenue that is as close as possible to zero.

The estimated cash flows of a private mortgage insurance contract under our process are a function of the annual premium rate, coverage limits m^i, borrower characteristics x_0^i, other

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[20] For current rate cards for mortgage insurance from MGIC, see MGIC Investment Corporation, "Mortgage insurance rate cards" (accessed February 8, 2022), www.mgic.com/rates/rate-cards.

[21] According to conversations with mortgage insurers, those discounts are approximately 10 percent.

[22] Rejections of claims reached as high as 25 percent in the aftermath of the 2007–2009 recession. See David Weiss, Matthew Rosso, and Whitney Clymer, "What About Mortgage Insurers? A Case for Holding Mortgage Insurers Accountable for the Mortgage Crisis," *LexisNexis Emerging Issues Analysis 6333* (May 2012).

[23] See Neil Bhutta and Benjamin Keys, "Moral Hazard During the Housing Boom: Evidence from Private Mortgage Insurance" (Board of Governors of the Federal Reserve, March 2021), http://dx.doi.org/10.2139/ssrn.3811996; James A. Kahn and Benjamin S. Kay, "The Impact of Credit Risk Mispricing on Mortgage Lending During the Subprime Boom," BIS Working Paper no. 875 (Bank for International Settlements, August 2020), https://www.bis.org/publ/work875.pdf; Kevin Alan Park, "Choice, Capital and Competition: Private Mortgage Application and Availability," *Housing Policy Debate*, vol. 30, no. 2 (October 2019), https://doi.org/10.1080/10511482.2019.1645036; and Kevin Alan Park, "Mortgage Insurance in the Great Recession" (Ph.D. dissertation, University of North Carolina, 2015) https://cdr.lib.unc.edu/concern/dissertations/x059c8253.

parameters of the contracts, and parameters in the models for macroeconomic variables, default, and prepayment. Ideally, our model would estimate a marginal net revenue of zero for all borrowers, under the assumption that PMIs are maximizing profits. With one degree of freedom and many prices, we minimize a weighted sum of square deviations from that ideal level, with weights w_i equal to the share of mortgages that each individual *i* is meant to represent. We used data from the NMDB on mortgages acquired in 2018 to estimate the weights that should be applied to each category of mortgages (see Table 6 for summary statistics for those variables).

We project the unadjusted premiums $\pi_t^i(\theta, \alpha_1, \alpha_2)$ and unadjusted insurance costs $c_t^i(\theta, \alpha_1, \alpha_2)$ of each category of mortgages in each period t as a function of the default prepayment and loss parameters θ as well as the calibration parameters α_1 and α_2. The present value of those unadjusted premiums and costs are:

$$\pi^i(\theta, \alpha_1, \alpha_2) = \sum_{t=1}^{T} \frac{\pi_t^i(\theta, \alpha_1, \alpha_2)}{(1 + r_t)^t}, \text{ and } c^i(\theta, \alpha_1, \alpha_2) = \sum_{t=1}^{T} \frac{c_t^i(\theta, \alpha_1, \alpha_2)}{(1 + r_t)^t}.$$

Estimation

The parameters are estimated under the following equation:

$$\hat{\alpha}_1, \hat{\alpha}_2, \hat{\gamma}_1\, \hat{\gamma}_2 = \underset{\alpha_1, \alpha_2, \gamma_1, \alpha\gamma_2}{\text{argmin}} \; \textstyle\sum_{\forall i} w_i \left(\pi^i(\theta, \alpha_1, \alpha_2) - \gamma_1 - \gamma_2 c^i(\theta, \alpha_1, \alpha_2)\right)^2$$

$$s.t. \;\; \textstyle\sum_{\forall i} w_j\, V^j(\theta, \alpha_1, \alpha_2) = \sum_{\forall i} w_j\, P^j. \qquad (5)$$

Under that equation, the parameters γ_1 and γ_2 are adjustments for the factors affecting the profits of PMIs, such as administrative costs, discounts, claim rejections and market structure, as identified earlier. Equation (5) optimizes the fit of the model under those adjustments to PMI pricing under the constraint that the total value of CRTs, $\sum_{\forall i} w_j\, V^j(\theta, \alpha_1, \alpha_2)$, is equal to the sum of their prices, $\sum_{\forall i} w_j\, P^j$.

Results

We solve equation (5) using a grid search. Our estimated values $\hat{\alpha}_1$ and $\hat{\alpha}_2$ from that minimization process are zero and -0.00325, meaning that the adjustment that results in the best fit with the pricing of private mortgage insurance is a large shift in the distribution of all shocks to house prices. Those adjustments effectively center the path for the macroeconomic series on a more adverse scenario than under CBO's baseline projections (see Figure 2). Those central paths show a growth rate of -5 percent in house prices, an elevated unemployment rate, and an interest rate that falls to near zero by 2027.

The shift in macroeconomic projections leads to higher default rates, which raises the NPV cost of PMI's coverage, shifting the distribution rightward (see Figure 3). Discounting cash flows using the rates on Treasury securities, the NPV gain for investors in the M tranches of CRTs is centered on 0.0688 under the actual probability distribution, meaning that investors expect to earn a return of 6.8 percent. By design, the calibration process shifts that center to exactly zero under the risk-neutral probability distribution.

Application: Covering Losses Over a Limit on a Mortgage Portfolio

We apply the risk-neutral approach to estimate the fair-value cost to the government of an illustrative policy where the government backstops private guarantors against catastrophic losses on a pool of mortgages drawn from those the GSEs currently guarantee. That policy is similar to some of the policies lawmakers have considered in the past.[24] We find that the cost of the backstop is large at a low trigger and declines gradually as the coverage is pushed toward a catastrophic level.

Specifically, we consider a case in which the government covers any NPV losses over a share of the initial principal, limiting the losses of the private guarantor to that amount. For example, under a limit of 1 percent of initial principal on a pool of mortgages of $200 billion, the government takes any losses above $2 billion, with losses defined as the amount of NPV in excess of defaults over guarantee fees. If those net losses equal $5 billion, then the government will pay $3 billion to the private guarantor to cover the difference between those losses and 1 percent of the $200 billion.

This illustrative proposal captures the essence of a few actual proposals. It mimics the structure of a government backstop to GSEs, in which private shareholders would absorb losses up to their level of capital before the government needed to step in. It also resembles some proposals for housing finance reform, which would replace Fannie Mae and Freddie Mac with catastrophic coverage and structured obligations such as CRTs.[25]

The estimates are based on the risk-neutral distribution of NPVs that the model generates for the cohort of mortgages disbursed in 2018 and guaranteed by the GSEs (see Figure 4). The model shows that this catastrophic coverage would decline gradually with the level of losses retained by

[24] For example, the Housing Finance Reform and Taxpayer Protection Act of 2014 (S. 1217) would have established a government agency that would have guaranteed pools of mortgages against losses greater than 10 percent. See Congressional Budget Office, cost estimate for S. 1217, Housing Finance Reform and Taxpayer Protection Act of 2014 (September 5, 2014), www.cbo.gov/publication/45687.

[25] See Congressional Budget Office, *Transitioning to Alternative Structures for Housing Finance: An Update* (August 2018), www.cbo.gov/publication/54218, *Transferring Credit Risk on Mortgages Guaranteed by Fannie Mae or Freddie Mac* (December 2017), www.cbo.gov/publication/53380, *The Effects of Increasing Fannie Mae's and Freddie Mac's Capital* (October 2016) www.cbo.gov/publication/52089, and *Transitioning to Alternative Structures for Housing Finance* (December 2014), www.cbo.gov/publication/49765.

the private guarantor (see Table 7). At a limit of 1 percent of the balance of loans when they are made, the cost of covering excess losses would be 15 basis points. At a limit of 4 percent, the cost would be 2 basis points.

Appendix: The Adjusted-Discount-Rate Method for Measuring the Cost of Housing-Related Obligations

The Congressional Budget Office's standard method to estimate the fair value of housing and real estate loans and loan guarantees is to add a risk premium to the discount rates used to calculate the present value of cash flows.[26] Although that approach is easy to understand and transparent, it requires judgment in the many cases in which risk is divided between the government and its private partners in complicated ways. In those cases, it is not clear what fraction of market risk is taken by each party in the transaction, making it unclear how the premium should be divided and how CBO's rules of thumb should be calibrated.

CBO bases the risk premium for each federal mortgage guarantee program on the characteristics of the mortgages and the nature of the guarantee, using a mix of market and loan performance data. CBO estimates the premiums that would be charged on loans made by the Federal Housing Administration (FHA) and the Department of Veterans Affairs (VA) using the rates that private mortgage insurers would charge to borrowers with similar characteristics and levels of down payment (subtracting expected losses and administrative costs), and then adjusting for the amount of loss that FHA and VA are likely to experience. For the two government-sponsored enterprises (GSEs), Fannie Mae and Freddie Mac, CBO considers a variety of sources of information in determining the appropriate adjustment to discount rates. Those include the pricing of private mortgage insurance, the pricing of credit-risk transfers, the difference between the rates on loans that are too large to be eligible for purchase by the GSEs (jumbo loans) and those that they can purchase (conforming loans), bunching of lending at the conforming loan limit, and the lack of significant fully private lending in the conforming market. (The conforming loan limit is the maximum mortgage amount that Fannie Mae and Freddie Mac will purchase or guarantee.)

The adjusted-discount-rate method works well for situations in which the government takes on straightforward risk but not in situations where the government takes a complex slice of risk. The government takes a relatively complex share of risk when it covers excess loss on a pool of mortgages—for example, when it is backstopping a government-sponsored enterprise.
The market risk of a credit guarantee depends on the overall state of the economy. When the government and private partners share the cost of a guarantee in fixed proportions, then the losses of both parties will rise and fall with the overall state of the economy in the same way. In that situation, it is valid to infer the market value of the government's stake on the basis of the private partner's pricing under the multiple-of-loss approach, where the market value of an obligation is a fixed multiple of average losses.

However, when the government serves as a backstop to the private partner, the two stakeholders have fundamentally different relationships to the state of the economy, and it is not possible to

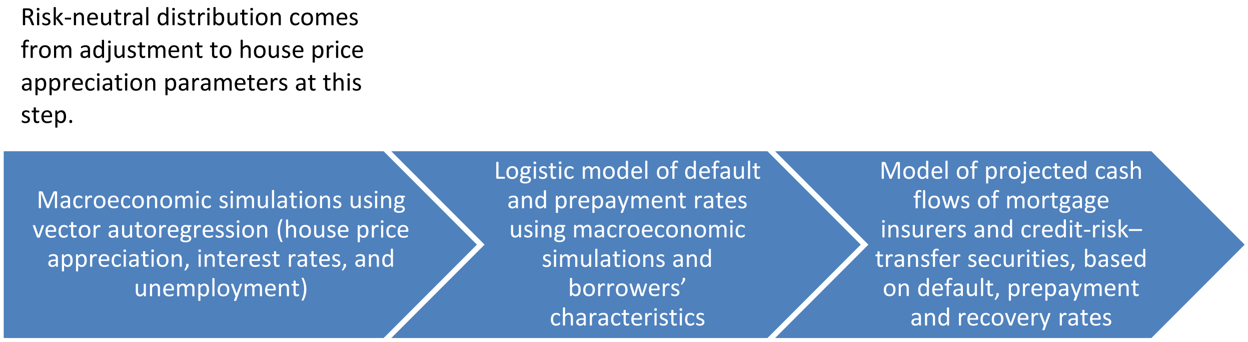
[26] See Michael Falkenheim and Wendy Kiska, *How CBO Estimates the Market Risk of Federal Credit Programs*, Working Paper 2021-14 (Congressional Budget Office, November 2021), www.cbo.gov/publication/57581.

infer the value of the government obligation using the multiple-of-loss approach. If the government covers losses over some high limit, then its obligation will result in costs only under very bad states of the economy. The government's losses will be much more sensitive to the state of the economy than private exposures, which take some losses in almost all scenarios and thus are more subject to market risk.

Figures

Figure 1. [Return to Text]

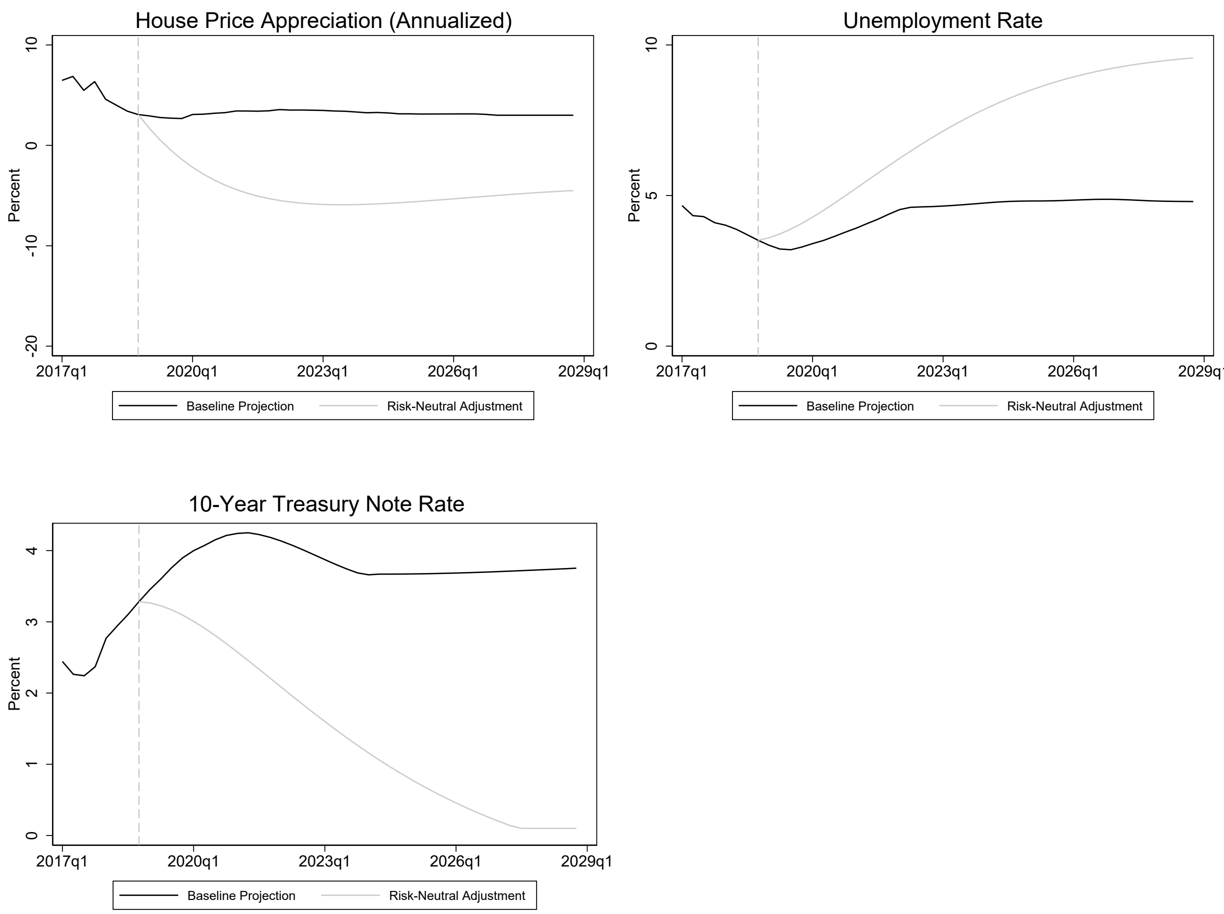
The Risk-Neutral Valuation Model of Mortgage Obligations



The cash flows of mortgages, mortgage guarantees, and other mortgage-related assets and liabilities are functions of default, prepayment, and recovery rates. Those rates depend on macroeconomic variables such as house prices, unemployment rates, and interest rates.

Figure 2. [Return to Text]

Projections of Macroeconomic Variables With and Without Risk-Neutral Adjustment



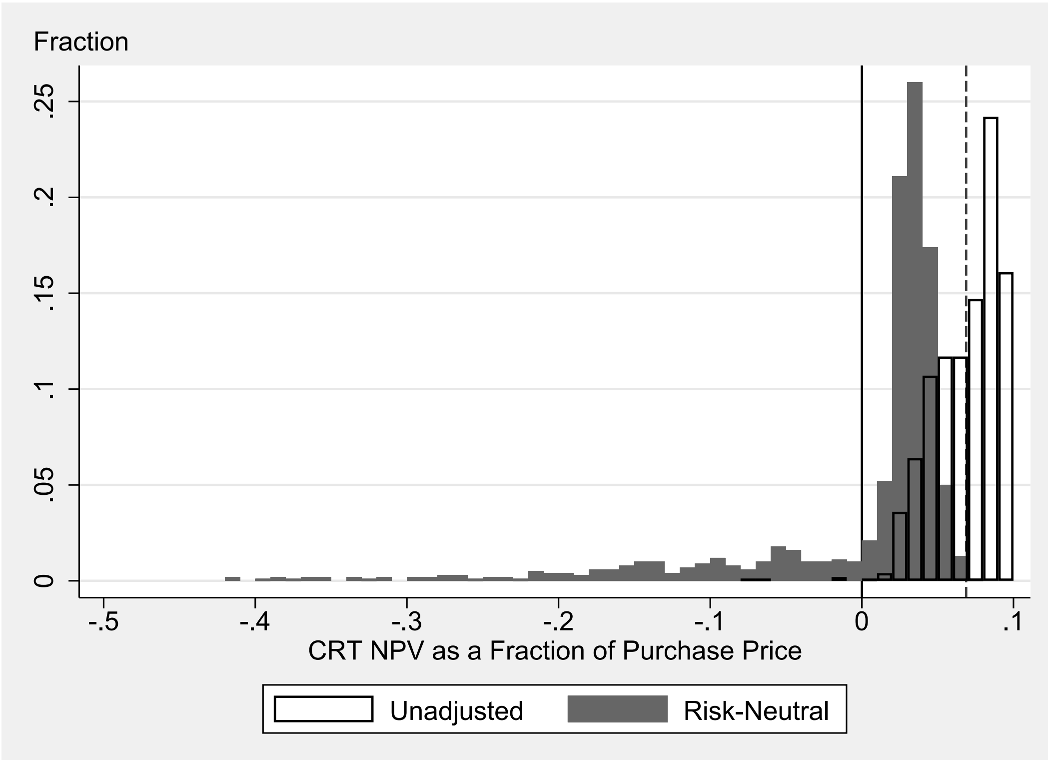
Data sources: Congressional Budget Office, using data from the Federal Housing Finance Agency, Bureau of Labor Stastistics, and Federal Reserve.

The baseline projections are from CBO's Spring 2018 macroeconomic baseline. See *The Budget and Economic Outlook: 2018 to 2028* (April 2018), www.cbo.gov/publication/53651.

The risk-neutral adjustment is generated with shock parameters $\alpha_1 = 0$ and $\alpha_2 = -0.0032495$.

Figure 3. [Return to Text]

The Distribution of Unadjusted and Risk-Neutral NPVs of CRTs



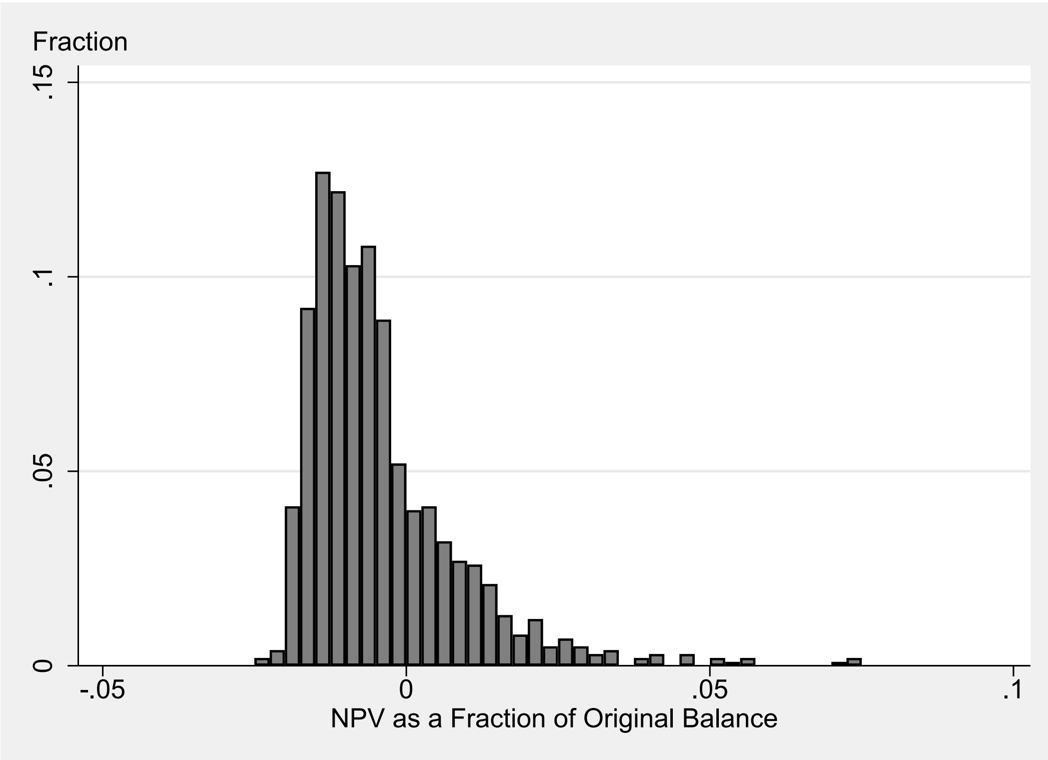
Data source: Congressional Budget Office.

Vertical lines show the means of distribution. The unadjusted mean is .0688 and the risk-neutral mean is zero. Positive values indicate gains to investors as a fraction of the CRT purchase price of the M, or mezzanine, tranches. The distribution is from 1,000 simulated paths around the unadjusted and risk-neutralized vector autoregression of house prices, interest rates, and the unemployment rate.

CRT = credit-risk transfer; NPV = net present value.

Figure 4. [Return to Text]

Risk-Neutral Distribution of GSE Losses



Data source: Congressional Budget Office.

The mean of the distribution is -.0041. Positive values indicate losses as a fraction of the original loan amounts. The distribution is from 1,000 simulated paths around the risk-neutralized vector autoregression of house prices, interest rates, and the unemployment rate.

GSE = government-sponsored enterprise.

Tables

Table 1. [Return to Text]

Vector Autoregression of House Price Appreciation, Unemployment, and Interest Rates

	House Price Appreciation	Unemployment	10-year Treasury Rate
Lag of House Price Appreciation	0.889***	-0.135***	0.0676*
	(18.46)	(-6.31)	(2.17)
Lag of Unemployment	0.0145	0.956***	0.00275
	(0.40)	(58.93)	(0.12)
Lag of 10-year Treasury Rate	-0.0149	0.0138	0.974***
	(-0.55)	(1.15)	(55.59)
Constant	0.000751	0.00300*	0.0000642
	(0.25)	(2.26)	(0.03)
Memorandum:			
Number of Observations	116		

Data source: Congressional Budget Office, using data from the Federal Housing Finance Agency, Bureau of Labor Stastistics, and Federal Reserve.

A vector autoregression was performed on quarterly data between 1990 and 2017.

T statistics are in parentheses: * p<0.05, *** p<0.001.

Table 2. [Return to Text]

Glossary of Mortgage Performance Variables

Variable	Description
Age	Number of quarters since mortgage origination.
Original Loan-to-Value Ratio (OLTV)	The loan-to-value ratio at the time of mortgage origination, calculated as 100 times the loan amount divided by the property value.
Loan-to-Value Ratio (LTV)	The current loan-to-value ratio, updated on the basis of the mortgage amortization schedule and a quarterly house price index. Historical data uses the FHFA house price index at the MSA level, and projected data uses the index at a national level.
Credit Score	The VantageScore 3.0 credit score of the primary borrower.
Mortgage Premium (MP)	The difference between the mortgage note rate and the current market rate, a measure of the refinance incentive.
Burnout	A measure of missed opportunities to refinance. Calculated as the greater of zero and the four-quarter lag of the mortgage premium.
Loan Size Ratio	Measured as 100 times the mortgage amount divided by the average mortgage amount by state and origination year.
Debt-to-Income Ratio (DTI)	Measured as 100 times the monthly payments on all debts divided by monthly income.
Spread at Origination (SATO)	The difference between the mortgage note rate and the average mortgage interest rate at origination.
First-Time Home Buyer	1 – Indicates that the home purchase is the buyer’s first; 0 – Indicates that home is not the buyer’s first purchase.
Owner-Occupied	1 – Indicates that the property is the owner's primary residence; 0 – Indicates that property is not the primary residence.
Manufactured Home	1 – Indicates that the mortgage is for a manufactured home; 0 – Indicates that the home is not manufactured.
Refinance	1 – Indicates that the mortgage is a refinance of a previous mortgage; 0 – Indicates that the mortgage is not a refinance.
Cash-out Refinance	1 – Indicates that the refinance is for a higher balance than the previous mortgage; 0 – Indicates that the refinance is for an equal or lower balance than the previous mortgage.

Data source: Congressional Budget Office.

FHFA = Federal Housing Finance Agency; MSA = metropolitan statistical area.

Table 3. [Return to Text]

Summary Statistics for a Sample of GSE-Backed Mortgages

	Purchase		Refinance	
	Mean	SD	Mean	SD
Credit Score	744.889	60.020	745.489	60.439
Original Loan-to-Value Ratio (Percent)	80.612	13.094	70.254	17.463
Loan Amount (Dollars)	183,273	100,226	203,302	107,246
Relative Loan Size (Percent)	100.34	45.34	101.22	44.68
Income (Dollars)	88,584	75,249	93,169	74,425
Debt-to-Income Ratio (Percent)	36.37	12.17	34.82	14.65
Interest Rate (Percent)	6.000	1.211	5.518	1.102
Spread at Origination (Percent)	0.187	0.389	0.173	0.365
First-Time Homebuyer	0.379	0.485	0.003	0.057
Owner-Occupied	0.878	0.327	0.910	0.287
Manufactured Home	0.003	0.056	0.002	0.041
Cash-out Refinance	n.a.	n.a.	0.086	0.280
Memorandum:				
Number of Observations	106,142		125,249	

Data source: Congressional Budget Office, using data from the Federal Housing Finance Agency's National Mortgage Database, https://go.usa.gov/x7eeB.

GSE = governnment-sponsored enterprise; SD = standard deviation; n.a. = not applicable.

Multinomial Logit Regressions of the Performance of GSE-Backed Mortgages, by Product Type

	Purchase		Refinance	
	Default	Prepay	Default	Prepay
Age Spline (quarters)				
1–4	1.082***	0.796***	1.000***	0.793***
	(14.03)	(59.41)	(12.26)	(66.54)
5–8	0.163***	0.137***	0.210***	0.0691***
	(8.25)	(31.74)	(10.03)	(16.98)
9–12	-0.0118	-0.0953***	0.0204	-0.0841***
	(-1.01)	(-30.17)	(1.72)	(-28.51)
MP Spline				
-1 < MP ≤ 0	0	0.524***	0	0.478***
	n.a.	(14.27)	n.a.	(16.13)
0 < MP ≤ 1	0	1.410***	0	1.442***
	n.a.	(76.98)	n.a.	(91.18)
1 < MP ≤ 2	0	0.575***	0	0.487***
	n.a.	(36.17)	n.a.	(31.49)
2 < MP	0	0.115***	0	0.148***
	n.a.	(7.59)	n.a.	(8.60)
OLTV Indicators				
60 < OLTV ≤ 80	-0.225*	-0.239***	0.00748	-0.0954***
	(-2.15)	(-15.99)	(0.13)	(-8.87)
80 < OLTV ≤ 85	-0.268*	-0.290***	-0.0640	-0.147***
	(-2.00)	(-11.03)	(-0.79)	(-7.04)
85 < OLTV ≤ 90	-0.454***	-0.273***	-0.0962	-0.0996***
	(-4.00)	(-13.96)	(-1.36)	(-5.19)
90 < OLTV ≤ 95	-0.423***	-0.218***	-0.147	-0.0688**
	(-3.79)	(-11.22)	(-1.73)	(-2.94)
95 < OLTV	-0.522***	-0.309***	0.121	-0.174***
	(-4.71)	(-13.79)	(1.25)	(-6.22)
LTV Spline				
LTV ≤ 60	0.0352***	0.00617***	0.0500***	0.00323***
	(5.89)	(10.52)	(12.12)	(7.14)
60 < LTV ≤ 80	0.0514***	-0.00183*	0.0476***	-0.0112***
	(12.96)	(-2.55)	(14.87)	(-16.23)
80 < LTV ≤ 90	0.0363***	-0.0212***	0.0336***	-0.0320***
	(5.84)	(-12.15)	(5.52)	(-14.11)
90 < LTV ≤ 100	0.0479***	-0.0257***	0.0310***	-0.0242***
	(6.94)	(-8.72)	(4.11)	(-6.00)

100 < LTV ≤ 110	0.0275***	-0.00658	0.000223	-0.0245***
	(3.54)	(-1.41)	(0.02)	(-3.81)
110 < LTV ≤ 120	0.0228**	-0.0117*	0.0265**	0.000547
	(3.08)	(-2.04)	(2.88)	(0.07)
120 < LTV	0.0134***	-0.00902***	0.00687**	-0.00674*
	(9.51)	(-4.66)	(2.97)	(-2.12)
Credit Score Spline				
Credit Score ≤ 650	-0.00545***	0.00352***	-0.00380***	0.00208***
	(-9.20)	(10.32)	(-5.27)	(6.13)
650 < Credit Score ≤ 700	-0.00706***	0.00236***	-0.00461***	0.00226***
	(-7.04)	(6.43)	(-4.66)	(6.60)
700 < Credit Score ≤ 750	-0.00558***	0.00257***	-0.00781***	0.00198***
	(-4.70)	(8.16)	(-6.45)	(6.54)
750 < Credit Score ≤ 800	-0.0143***	0.000861**	-0.0111***	0.00134***
	(-8.82)	(3.00)	(-6.68)	(4.88)
800 < Credit Score	-0.0161**	-0.000518	-0.0209***	-0.00173**
	(-2.90)	(-0.77)	(-3.50)	(-2.70)
Relative Loan Size Spline				
Loan Size ≤ 80	0.00102	0.00992***	-0.00754***	0.0116***
	(0.75)	(24.56)	(-5.12)	(27.51)
80 < Loan Size ≤ 100	0.00192	0.00637***	0.000321	0.00737***
	(0.69)	(7.92)	(0.11)	(9.55)
100 < Loan Size ≤ 120	-0.00345	0.00896***	-0.00302	0.0103***
	(-1.25)	(12.21)	(-1.06)	(14.90)
120 < Loan Size	0.00112	0.00177***	0.000602	0.00200***
	(1.64)	(12.93)	(0.90)	(15.64)
DTI Spline				
DTI < 15	-0.0156	0.00415	-0.0431*	0.0104**
	(-0.73)	(0.87)	(-2.33)	(3.10)
15 < DTI ≤ 30	0.00831	0.000901	0.0221***	0.000819
	(1.42)	(0.78)	(4.16)	(0.85)
30 < DTI ≤ 45	0.0145***	-0.00209*	0.0187***	-0.00503***
	(4.63)	(-2.56)	(6.03)	(-6.38)
45 < DTI	-0.000304	-0.000968	0.00642*	-0.00394***
	(-0.11)	(-1.00)	(2.34)	(-4.35)
SATO	0.653***	-0.152***	0.510***	-0.0667***
	(18.69)	(-12.51)	(13.69)	(-5.61)
Unemployment Rate	0.104***	-0.103***	0.151***	-0.107***
	(11.82)	(-38.06)	(17.02)	(-43.23)
Burnout	0	-0.229***	0	-0.260***
	n.a.	(-25.82)	n.a.	(-30.03)

First-Time Home Buyer	-0.160***	-0.0959***	-0.00121	-0.165**
	(-5.53)	(-12.00)	(-0.01)	(-2.87)
Owner-Occupied	0.0507	0.150***	-0.122**	0.212***
	(1.07)	(12.62)	(-2.67)	(16.34)
Manufactured Home	0.0572	-0.358***	-0.116	-0.314***
	(0.33)	(-5.06)	(-0.51)	(-3.58)
Cash-Out Refinance	0	0	-0.0329	0.125***
	n.a.	n.a.	(-0.53)	(10.10)
Quarter Indictor				
Quarter = 2	0.0222	0.119***	-0.00365	0.112***
	(0.59)	(11.81)	(-0.10)	(11.65)
Quarter = 3	0.0424	0.122***	0.0356	0.169***
	(1.13)	(11.98)	(0.94)	(17.65)
Quarter = 4	0.0921*	0.0676***	0.0158	0.102***
	(2.48)	(6.65)	(0.42)	(10.59)
Cohort Fixed Effects				
2000	1.414***	1.009***	1.942***	0.710***
	(5.82)	(32.68)	(5.42)	(18.09)
2001	1.393***	0.873***	1.677***	0.721***
	(5.89)	(29.30)	(5.15)	(23.82)
2002	1.541***	0.815***	1.885***	0.570***
	(6.60)	(27.36)	(5.84)	(18.86)
2003	1.513***	0.596***	1.666***	0.380***
	(6.55)	(19.68)	(5.19)	(12.58)
2004	1.568***	0.544***	1.815***	0.346***
	(6.80)	(17.62)	(5.62)	(10.63)
2005	1.623***	0.484***	1.794***	0.299***
	(7.09)	(15.63)	(5.59)	(9.26)
2006	1.717***	0.511***	1.906***	0.303***
	(7.51)	(16.64)	(5.94)	(9.25)
2007	1.602***	0.561***	1.930***	0.334***
	(7.01)	(18.06)	(6.03)	(10.24)
2008	1.166***	0.755***	1.687***	0.562***
	(5.02)	(23.46)	(5.24)	(16.99)
2009	0.0755	0.502***	0.913**	0.334***
	(0.28)	(15.38)	(2.81)	(10.88)
2010	-0.349	0.352***	0.795*	0.0583
	(-1.14)	(10.63)	(2.44)	(1.88)
2011	-0.378	0.380***	0.793*	-0.00126
	(-1.12)	(11.31)	(2.39)	(-0.04)
2012	-0.709*	0.369***	0.416	0.0629*
	(-1.99)	(10.46)	(1.26)	(1.96)

2013	-0.121	0.231***	0.691*	-0.0249
	(-0.40)	(6.92)	(2.08)	(-0.74)
2014	-0.160	0.117***	0.852*	0.0458
	(-0.50)	(3.48)	(2.35)	(1.21)
Constant	-11.71***	-11.47***	-13.17***	-10.27***
	(-17.24)	(-48.37)	(-18.34)	(-44.80)
Memorandum:				
Number of Observations	2,127,123		2,555,221	

Data source: Congressional Budget Office, using data from the Federal Housing Finance Agency's National Mortgage Database, https://go.usa.gov/x7eeB.

T statistics are in parentheses: * p < 0.05, ** p < 0.01, *** p < 0.001.

DTI = debt-to-income ratio; GSE = government-sponsored enterprise; LTV = loan-to-value ratio; MP = mortgage premium; OLTV = origination loan-to-value ratio; SATO = spread at origination; n.a. = not applicable.

Table 5. [Return to Text]

Ordinary Least Squares Regression of Loss Given Default

Variables	Coefficients	Variables (cont.)	Coefficients
Age 1 to 4	-0.00694 (-1.56)	DTI ≤ 15	-0.00964*** (-13.77)
Age 5 to 8	0.00898*** (10.78)	15 < DTI ≤ 30	-0.00146*** (-8.66)
Age 9 to 12	0.0259*** (55.49)	30 < DTI ≤ 45	-0.000915*** (-9.67)
Age 13 to 120	0.00321*** (70.14)	45 < DTI	-0.000215* (-2.10)
Credit Score ≤ 650	-0.000108*** (-3.92)	DTI Missing	-0.190*** (-19.08)
650 < Credit Score ≤ 700	-0.000531*** (-17.98)	Purchase	0 n.a.
700 < Credit Score ≤ 750	-0.000166*** (-5.02)	Refinance	0.0513*** (58.13)
750 < Credit Score ≤ 800	-0.000357*** (-7.36)	Unemployment Rate	0.00128*** (3.75)
800 < Credit Score	0.000936** (2.90)	HPA	-0.578*** (-79.89)
Credit Score Missing	-0.0883*** (-4.98)	OLTV < 80	0.00743 (0.86)
LTV ≤ 60	0.00122*** (18.37)	No MI Coverage	-0.0484*** (-5.42)
60 < LTV ≤ 80	-0.00162*** (-19.68)	MI Coverage Percent	-0.538*** (-53.74)
80 < LTV ≤ 90	-0.00517*** (-23.55)	MI Coverage Indicator	-0.00969*** (-5.46)
90 < LTV ≤ 100	-0.00281***	Constant	0.418***

	(-10.96)	(15.78)
100 < LTV ≤ 110	-0.00122**	
	(-3.18)	
110 < LTV ≤ 120	-0.00141**	
	(-2.59)	
120 < LTV	0.000421*	
	(2.08)	
Memorandum:		
Number of Observations	583,106	

Data source: Congressional Budget Office, using data from the Fannie Mae Single-Family Loan Performance Data.

T statistics are in parentheses: * p < 0.05, ** p < 0.01, *** p < .001.

DTI = debt-to-income ratio; LTV = loan-to-value ratio; MI = Mortgage Insurance; OLTV = original loan-to-value ratio; SATO = spread at origination; n.a. = not applicable.

Table 6. [Return to Text]

Summary Statistics of PMI Mortgages in 2018

	Purchase		Refinance	
	Mean	SD	Mean	SD
Credit Score	747.119	50.014	744.515	47.396
OLTV (Percent)	92.542	3.867	87.273	4.231
Loan Amount (Dollars)	245,760	114,273	266,026	119,642
Relative Loan Size (Percent)	104.633	42.908	111.071	45.066
Income (Dollars)	93,448	57,656	104,012	55,268
DTI (Percent)	37.782	8.259	37.581	10.338
Interest Rate (Percent)	4.844	0.418	4.760	0.425
SATO (Percent)	30.8	36.4	31.1	33.1
FTHB	0.529	0.499	0.007	0.084
Owner-Occupied	0.966	0.180	0.960	0.196
Manufactured	0.010	0.102	0.011	0.103
Cash-out Refinance	n.a.	n.a.	0.035	0.183
Multiple Borrowers	0.406	0.491	0.500	0.500
Three or More Units	0.001	0.028	0.002	0.049
DTI > 45	0.188	0.391	0.186	0.390
Memorandum:				
Number of Observations	45,400		1,679	

Data source: Congressional Budget Office, using data from the Federal Housing Finance Agency's National Mortgage Database, https://go.usa.gov/x7eeB.

DTI = debt-to-income ratio; FHTB = first-time home buyer; LTV = loan-to-value ratio; OLTV = loan-to-value ratio at origination; PMI = private mortgage insurer; SATO = spread at origination; SD = standard deviation; n.a. = not applicable.

Table 7. [Return to Text]

The Fair-Value Cost of Limiting Losses on the GSEs' Portfolio of Guarantees

Loss Limit (Percent of original balance)	**Fair-Value Cost** (Basis points)
0.5	22
1.0	15
1.5	10
2.0	7
2.5	5
3.0	4
3.5	3
4.0	2

Data source: Congressional Budget Office.

GSE = government-sponsored enterprise.