© *The Journal of Risk and Insurance*, 1993 Vol. 60, No. 2, 288-299

SHORTER ARTICLES

An Option-Based Pricing Model of Private Mortgage Insurance

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ABSTRACT

This study uses option-pricing techniques to determine the impact of changes in the mortgage contract or in the economic environment on mortgage insurance values. We found that actual variations in insurance prices for changes in the loan-to-value ratio are substantially less than those called for in theory. This article demonstrates that option-based pricing models can play a useful role in providing firms with estimated insurance prices that reflect the economic environment and the terms of the mortgage contract.

Introduction

The market for private mortgage insurance (PMI) has grown substantially in size and importance in recent years. Part of the explanation for PMI growth is the rising number of mortgages originated with loan-to-value ratios above 80 percent, combined with the requirements of the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae) that conventional mortgages used as collateral in their mortgage-backed security pools be insured whenever the original downpayment is less than 20 percent of the property value.

In the 1980s, delinquency rates on mortgages soared, resulting in foreclosures that produced substantial losses for private mortgage insurers. The Equity Programs Investment Corporation, or EPIC,[1] defaulted on more than $1 billion of mortgage instruments, seriously threatening the viability of private mortgage-insurers. The collapse of EPIC left private mortgage insurance firms with combined losses (exposures) of some $400 million, about 18 percent of the industry's total capital. Serious losses were suffered by such major firms as

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[1] EPIC was a private firm that sold homebuilders' model units to syndicated investors and issued mortgaged-backed securities to provide the long-term funding for the homes.

Ticor Mortgage Insurance of Los Angeles (with an exposure of $166 million), Republic Mortgage Insurance (with an exposure of $66 million), and Mortgage Guaranty Insurance Corporation (with an exposure of $15 million), thereby calling into question the viability of the mortgage insurance industry (see Knight, 1985; Kiley, 1988).

This article concentrates on one particular explanation for excessive losses in the mortgage insurance industry: insurers' failure to appropriately adjust mortgage insurance prices with regard to the economic environment or the particular terms of the mortgage contract. For example, in the 1980s, originators wrote a growing number of mortgages with high loan-to-value ratios; this in turn led to a surge in business for insurers. In this period, the number of new mortgages with loan-to-value ratios above 90 percent grew to about 20 percent, from about 10 percent in the 1970s (see Kiley, 1988, p. 44). This history produced a desire to relate performance to price and resulted in the development of Performance Incentive Programs (PIPs) in 1986. These programs provided discounts of mortgage insurance premiums based on the performance of the lender's PMI loans (see Dickey, 1987, p. 42).

This article uses option-pricing techniques as an alternative to PIPs or other performance-price models to determine the required impact on mortgage insurance of changes in the mortgage contract or in the economic environment. The desire here is not so much to predict the level of insurance prices as to see how sensitive these insurance prices should be to economic and contractual changes. The results indicate that considerable variability in insurance prices is required in order to respond to changes in loan-to-value ratios and house prices. The insurance prices resulting from the model are then compared with current market prices of a mortgage insurance firm. This comparison reveals that actual variations in insurance prices for changes in the loan-to-value ratio are substantially less than those called for in theory. The comparison suggests that option-pricing models can play a useful role in determining the adjustments in mortgage insurance prices made necessary by economic and contractual changes.

The Insurance Valuation Model

Economic Environment

Insurance values are obtained by evaluating the insured asset, the mortgage. Below we briefly discuss the procedure used to value the mortgage, where the goal of the process is to extract insurance prices.

We employ contingent claims analysis in the setting of perfect capital markets. The term structure of the mortgage contract and the value of the house are assumed to be the underlying sources of uncertainty. Standard option-pricing techniques are then used to obtain the value of the mortgage numerically as the solution of a two-dimensional partial differential equation (PDE) in backward time, whose terminal and boundary conditions embody the terms of the contract.

The value of the house, H, is assumed to follow a standard lognormal process, with μ and σ_H^2 representing the instantaneous total expected return and proportionate volatility, respectively. The return to using the house is the service flow, s; we assume the service flow to be proportional to the value of the house. In the absence of taxes, this would be the rent the house should earn. Since the remaining part of the total expected return μ must take the form of asset appreciation, the stochastic process for the house's value is

$$\frac{dH}{H} = (\mu - s)dt + \sigma_H dz_H, \tag{1}$$

where dz_H represents a standard Wiener process. Since at least the work of Merton (1973), the lognormal process of equation (1) has been the standard for modeling a dividend yielding asset.

The interest rate process assumed in this study is

$$dr = \gamma(\theta - r)dt + \sigma_r\sqrt{r}\, dz_r. \tag{2}$$

This is a mean-reverting square root process, with θ representing the steady-state value for the spot interest rate r, while γ is the speed of adjustment, and σ_r is the volatility parameter. For a detailed examination of this process, see Cox, Ingersoll, and Ross (1985), who derive this form within a general equilibrium model. This is a standard approach for describing the term structure by a single stochastic variable.

With the stochastic processes specified by equations (1) and (2), the PDE for valuation of assets, which is solely a function of the house price and the interest rate, takes the form

$$\begin{aligned} &\frac{1}{2}H^2\sigma_H^2\frac{\partial^2 X}{\partial H^2} + \rho H\sqrt{r}\,\sigma_H\sigma_r\frac{\partial^2 X}{\partial H \partial r} + \frac{1}{2}r\sigma_r^2\frac{\partial^2 X}{\partial r^2} + \gamma(\theta - r)\frac{\partial X}{\partial r} \\ &\quad + (r - s)H\frac{\partial X}{\partial H} + \frac{\partial X}{\partial t} - rX = 0, \end{aligned} \tag{3}$$

where any correlation between volatility in house prices and the term structure is represented as

$$dz_r(t)dz_H(t) = \rho dt,$$

and where X denotes the value of the relevant asset. The derivation of equation (3) follows from standard arguments in finance (e.g., Cox, Ingersoll, and Ross, 1985, or Merton, 1973).

Perhaps the best way to see the role of the PDE is to note, as may be verified by substitution, that the solution X(r,H,T) to equation (3) is given by the expected present value calculation

$$E\left[e^{-\int_t^T r(s)ds}\,\bar{X}(r,H,T)\right], \tag{4}$$

where $\bar{X}(r,H,T)$ is the value of the mortgage at termination time T. For expression (4) to be generally correct, though, one has to risk adjust the stochastic processes for r and H and so introduce risk premia reflecting individuals' attitudes about interest-rate risk and house-price risk. The seminal contribution of Black and Scholes (1973), however, was to show that no risk premium is needed if the source of risk is a continuously tradeable asset, as we assume houses are. The interest rate r, on the other hand, is not a traded asset as such, and in neglecting to explicitly introduce a risk premium for it, we must either invoke the local expectations hypothesis (an assumption about intertemporal risk attitudes), or, as is commonly done, we must assume that any risk premium has been absorbed into the chosen values of the other interest rate parameters, γ and θ.

Of course, expression (4) assumes that the mortgage contract is inactive until maturity. To capture the fact that payments must be made each month and that the borrower has the opportunity to default at those times, we must solve a compound set of these problems backward in time. For instance, the solution X(r,H,n-1;n) to expression (4) represents the value of the last month (n) of the mortgage one month before maturity (time n-1) when the next to last payment has just been made. This value is used to determine whether the next to last payment will in fact be made at that time, which then yields the terminal conditions for calculating mortgage values via expression (4) over the next to last month. This process is continued until the beginning of the contract, where the initial interest rate r(0) and house price H(0) are known.

In addition to the option to default, which must be checked for at each month's end, we must also check for prepayment, which can, in principle, occur at any time. The computational procedure solves the PDE (3) by an explicit finite difference method, with a free boundary at low interest rates and high house prices, where prepayment is endogenously determined. A detailed description of the valuation procedure is provided in Kau et al. (1990, 1993, 1992).

The Mortgage Contract

This article examines mortgage insurance for both fixed and adjustable rate mortgages. For a thorough review of the pricing of default insurance, determinants of foreclosure, and comments on the use of option models, see Clauretie and Jameson (1990), Jackson and Kaserman (1980), and Swan (1982).[2] Here we concentrate on the default and insurance characteristics of a mortgage. Note, however, that a complete description of mortgage pricing is indeed necessary before insurance prices can be obtained. The present value of

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[2] Most articles on mortgage insurance have concentrated on mortgage rate insurance (see Capozza and Gau, 1984, and Sharp, 1989).

amortizing mortgage payments (A) and the ability of the borrower to release himself from these payments through either prepayment (C) or default (D) must be considered. The prepayment decision is obviously influenced by interest rates, whereas the house price clearly influences the decision to default. For this reason the house price and the term structure of interest rates were chosen as the underlying sources of uncertainty in our model. It is, of course, default that triggers insurance payouts. Although we are not directly interested in prepayment, it is an alternative to default, and, as such, its determinants have an effect on insurance values.[3]

Mortgage valuation could never be handled by forward-pricing approaches, such as the Monte Carlo technique, because valuing the choices made available in the present by the prepayment or default option first requires valuing similar possible choices in the future. On the other hand, for fixed rate mortgages (FRMs), this problem can be straightforwardly treated by solving the fundamental valuation equation (3) backward in time, until the correct value in the present is obtained. Adjustable rate mortgages (ARMs) with caps, however, pose major problems for this standard valuation technique. The terms of these mortgages are such that the contract rate at any given time is a function of the past path of interest rates. This rules out the usual sort of backward pricing methods, because such past values are not yet available when working backward in time. To deal with this apparent dilemma, the ARM valuation model used in this study introduces an additional state variable carrying the required information concerning past contract rates (see Kau et al, 1990, 1993). By augmenting the state space in this way, the backward pricing approach again becomes feasible. Use of this technique allows a direct comparison of adjustable and fixed rate mortgages. This permits us to examine, in the presence of both prepayment and default, differences in insurance values due to differences in mortgage design.

Default and Insurance

Default rationally occurs only at the end of a payment period when payment is due, because the service flow of the house is enjoyed until then. If default does not occur at the end of period i, then the value of the default option D(i,i), just becomes the current value of the option to default in the next period or thereafter, D(i;i+1). On the other hand, if one defaults, the immediate value of doing so is A(i) - H, because the house H is surrendered in turn for abandoning

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[3] Not all prepayment is for financial reasons. Situations particular to the individual, such as divorce or change in employment, could result in the mortgage being prepaid when one would not otherwise wish to do so. These prepayments for nonfinancial reasons are introduced into the model in terms of a Poisson process that describes their occurrence. This behavior is parametrized by the mortgage industry's standard Public Securities Association (PSA) schedule, reflecting actual termination behavior collected on a monthly basis (see Sullivan and Lowell, 1988, p. 94).

the present value of the promised payments A.[4] The current value of default before a payment in period i is therefore

$$D(i;i) = \begin{cases} D(i;i+1) \quad \text{if} \quad A(i) - C(i) - D(i;i+1) < H \qquad \text{(no default)} \\ A(i) - H \text{ otherwise} \quad \text{(default)}. \end{cases} \tag{5}$$

Note that if prepayment occurs the value of default immediately goes to zero.

Default occurs when the value of the mortgage to the lender (A - C - D), which is the cost of the mortgage to the borrower, exceeds the house value H. Default does not occur as soon as the value of promised payments A exceeds the value of the house H, because this would ignore the value of being able to terminate the contract in the future. This future value of termination can be quite substantial; indeed it must be so if the value of default, as part of the value of termination, is to be of significant magnitude.

Insurance against default obviously depends on the borrower's ability or inclination to make payments.[5] If the borrower makes the mortgage payment, the value of insurance becomes merely its value against future default. On the other hand, if default occurs, the insurer must pay the difference between the house's value and the face value of the loan up to some fraction ϕ of the face value, typically 20 percent, to be referred to as the coverage fraction. In other words, coverage, ϕ, is the percent of the loan's face value that is insured against default.

Numerical Analysis

In order to investigate the properties of our model further, we have completed a set of numerical solutions that examine changes in insurance values required by differing economic environments and mortgage contracts. In particular, comparison is made between adjustable and fixed rate mortgages. Unless otherwise noted, we express the value of all assets to par, that is as a percent of the loan's remaining face value.

In all of the numerical solutions, we use a set of baseline values for the underlying economic parameters. The parameters of the economic environments are shown in Table 1 (see Titman and Torous, 1989).

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[4] We ignore the defaulter's liability for any shortfall. For residential mortgages, borrowers are rarely made to account for this liability.

[5] Insurance charges are offered in two ways. One is an annual premium with a first-year fee, usually ranging from 0.45 to 0.65 percent of the original loan, with annual renewals at approximately 0.34 percent, until the loan amortizes to 80 percent of the original sale price. The other is a one-time premium, with coverage until the loan amortizes to 80 percent of the sale price. The market data used for comparison in this study are one-time premia, consistent with the procedure used in the model.

Table 1
Base Values for Fixed Rate Mortgages and Adjustable Rate Mortgages

Economic Environment	*Contract*
σ_r = 10% interest rate volatility	n = 360, mortgage term in months
r(0) = 8% initial spot interest rate	δ =1½ points on the loan
θ = 10% steady-state spot rate	y = 2% yearly cap on an ARM[a]
γ = 25% reversion coefficient	l = 5% lifetime cap on an ARM
s = 5% house service flow	α = 3% teaser for an ARM[b]
ρ = 0% correlation coefficient	90% loan-to-value ratio
0% PSA nonfinancial prepayment rate	

[a] For an ARM, a new contract rate is calculated on each adjustment date.The caps require that the new contract rate never exceed the original rate by more than the life-of-loan cap and that the new contract rate never deviate from the previous contract rate by more than the yearly cap.

[b] Teasers usually lower the initial contract rate for one year, at a cost of a higher rate over the course of the loan. In practice, the teaser is defined as the amount the initial contract rate is lowered from the contract rate that would be charged if there were no teaser.

Conspicuously absent from the baseline values are σ_H and ϕ, the house price volatility parameter and the coverage fraction, respectively. These two parameters are sufficiently important for insurance that we do not establish baseline values for them; instead, we consider a range of values for these parameters.

The effects of coverage and house price variance on FRM insurance values are shown in Figure 1. The most startling feature of these results is that for all house price volatilities there is virtually no increase in insurance value above a coverage level of 20-25 percent. Most mortgage defaults occur before house values can fall sufficiently to make coverage beyond these levels of any value.

Numerically derived insurance values for a wide range of house-price volatility parameters σ_H, and coverage rates ϕ, with four different loan-to-value ratios of 80, 85, 90, and 95 percent, are shown in Table 2.[6] All results are for the baseline parameter values, with the contract rate fixed at 10.36 percent, the rate at which a 90 percent loan-to-value ratio balances the lender's position on a newly originated loan. With σ_H = 20 percent and ϕ = 25 percent, as the loan-to-value ratio increases in increments of 5 percentage points from 80 to 95 percent, insurance prices rise from 0.5 percent, to 1.12 percent, 2.23, percent and 3.81 percent of the loan value, respectively. For any given coverage value, the impact of increasing σ_H is significant. For example, at a 90 percent loan-to-value ratio and a coverage of 25 percent, insurance prices rise from 0.016 percent when σ_H equals 5 percent to 2.92 percent when σ_H equals 25 percent.

[6] A complete set of insurance values was also determined for an FRM with 100 percent PSA. There was little difference (.01 percent) in results as compared to the 0 percent PSA results presented in Table 2. This is to be expected, given the minor role that prepayment for nonfinancial reasons should play in determining insurance values.

Table 2
Par Value of Insurance for Fixed Rate Mortgages

Level of Coverage ϕ	*Loan-to-Value Ratio = 80% House Price Volatility,* σ_H 5%	10%	15%	20%	25%	*Loan-to-Value Ratio = 85% House Price Volatility,* σ_H 5%	10%	15%	20%	25%
5%	0	.025	.122	.252	.371	.001	.092	.329	.563	.746
10%	0	.034	.191	.422	.644	.002	.124	.510	.948	1.31
15%	0	.036	.211	.485	.760	.002	.130	.560	1.09	1.55
20%	0	.036	.215	.502	.797	.002	.130	.568	1.12	1.61
25%	0	.036	.216	.505	.806	.002	.131	.570	1.12	1.63
30%	0	.036	.216	.506	.808	.002	.131	.570	1.12	1.63
100%	0	.036	.216	.506	.809	.002	.131	.570	1.12	1.63

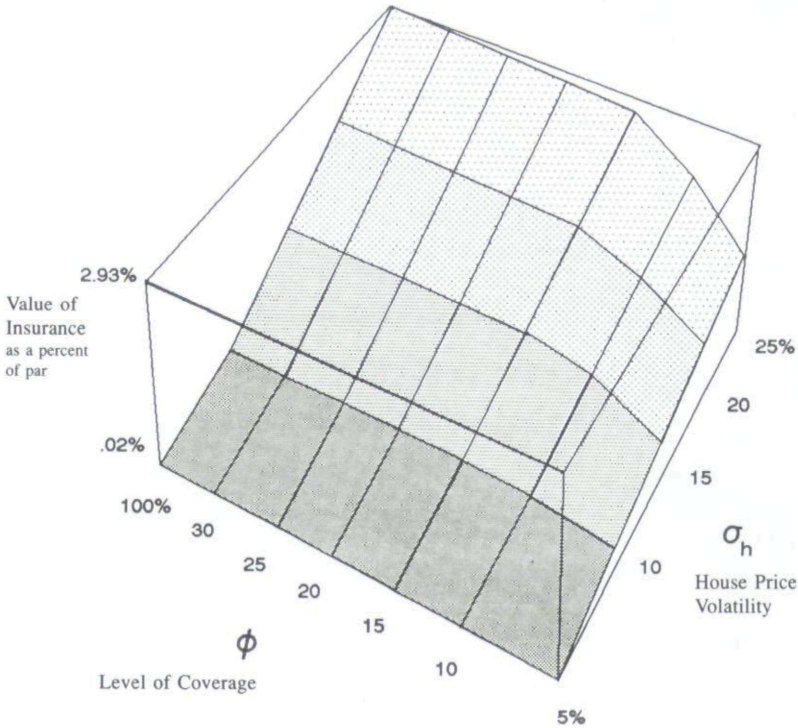
Level of Coverage ϕ	*Loan-to-Value Ratio = 90% House Price Volatility,* σ_H 5%	10%	15%	20%	25%	*Loan-to-Value Ratio = 95% House Price Volatility,* σ_H 5%	10%	15%	20%	25%
5%	.015	.311	.745	1.06	1.25	.146	.857	1.35	1.63	1.78
10%	.016	.424	1.20	1.87	2.31	.158	1.21	2.34	3.06	3.46
15%	.016	.440	1.32	2.15	2.77	.159	1.26	2.62	3.67	4.35
20%	.016	.442	1.34	2.20	2.90	.159	1.26	2.66	3.79	4.59
25%	.016	.442	1.34	2.23	2.92	.159	1.26	2.66	3.81	4.63
30%	.016	.442	1.34	2.23	2.93	.159	1.26	2.66	3.81	4.64
100%	.016	.442	1.34	2.23	2.93	.159	1.26	2.66	3.81	4.64

Note: The baseline values for the economic parameters are a rising term structure (8 percent spot interest rate r(0), 10 percent steady state rate θ), 10 percent interest rate volatility σ_r, 5 percent service flow s, 0 correlation coefficient ρ, 25 percent mean reversion γ, 1½ percentage points on the loan δ, and 30-year term to maturity. All results are expressed to par, that is, as a percent of the original loan. The level of coverage ϕ is the percentage of the loan's face value insured against default.

Insurance values for an adjustable rate mortgage display the same pattern as a fixed rate mortgage in response to changes in the cross house price volatility and coverage percentage (see Table 3). For the standard coverage level of 25 percent, insurance values are also approximately the same between contracts; at lower coverage rates, insurance prices are smaller for ARMs than for FRMs, especially at the higher house price volatilities.

The above numerical solutions provide insight into the changes in insurance prices that might be expected for various economic conditions and contract provisions. We compared our findings with the actual insurance prices charged by a private firm, GE Capital Mortgage Insurance (1989) (see Table 4). Comparisons with the model's results, though, can serve only as a guide, because the term structure and other parameters required by the model are not specified for the given time period, and the GE data are aggregated over a range of loan-to-value ratios. Nevertheless, GE prices follow the same pattern as the model for differing coverage and loan-to-value ratios. For FRMs, the GE insurance prices for 86-90 percent loan-to-value ratios and 20-25 percent coverage levels are only 5 and 18 basis points greater, respectively, than the prices predicted by our FRM model using a 25 percent house price volatility and a 90 percent loan-to-value ratio. For ARMs, the GE insurance prices for 86-90 percent loan-to-value ratios and 20-25 percent coverage levels are

Figure 1
Value of Insurance for a Range of Coverage and House Price Volatilities (Loan-to-Value Ratio = 90 percent)



For a 30-year fixed-rate mortgage with 1.5 points. The term structure is rising with a current interest rate of 8 percent the a long-term mean spot rate of 10 percent. The interest rate volatility is 10 percent.

111 and 97 basis points greater, respectively, than those of our ARM model using a 25 percent house price volatility and a 90 percent loan-to-value ratio.

The insurance prices generated by the model are approximately the same between an ARM and an FRM at the representative 25 percent coverage level and 90 percent loan-to-value ratio. In contrast, the insurance price for a GE Capital ARM is 80 basis points higher than an FRM at an 86-90 percent loan-to-value ratio and a 25 percent coverage level. Indeed, the GE price for an ARM is at least 70 basis points greater than the GE price for an FRM, in all variations presented. The reason for this discrepancy may be that the model's ARM estimates of insurance prices do not account for payment shock. Federal regulators use only first-year payments to determine whether a borrower qualifies for a loan. With teasers, an ARM's lower first-year payment qualifies borrowers that are more likely to default after the one-year teaser's effect on the mortgage payment ceases. To the extent that it represents liquidity problems due to a lack of perfect capital markets, this sort of phenomenon is not captured in any current options models, including this one.

Table 3
Par Value of Insurance for an Adjustable Rate Mortgage
(Loan-to-Value Ratio = 90%)

Level of Coverage ϕ	*House Price Volatility,* σ_H				
	5%	*10%*	*15%*	*20%*	*25%*
5%	.014	.266	.537	.634	.676
10%	.014	.430	1.05	1.28	1.35
15%	.014	.444	1.32	1.87	2.03
20%	.014	.449	1.37	2.21	2.64
25%	.014	.449	1.37	2.28	2.93
30%	.014	.449	1.38	2.29	3.00
100%	.014	.449	1.38	2.29	3.01

Note: The baseline values for the economic parameters are a rising term structure (8 percent spot interest rate r(0), 10 percent steady state rate θ), 5 percent service flow s, 0 correlation coefficient ρ, 30-year term to maturity, 10 percent interest rate volatility σ_r, a 3 percent teaser α, a 2 percent yearly cap, and a 5 percent lifetime cap. All results are expressed to par, that is, as a percent of the original loan. The level of coverage ϕ is the percentage of the loan's face value insured against default.

Table 4
GE Capital Mortgage Insurance Prices
for a Loan with a 30-Year Term

Level of Coverage	*Fixed Rate Mortgage Loan-to-Value Ratio*		*Adjustable Rate Mortgage Loan-to-Value Ratio*	
	81-85%	*86-90%*	*81-85%*	*86-90%*
20%	2.35	2.95	3.05	3.75
25%	2.45	3.10	3.15	3.90

Note: Data express financial one-time premiums for September 1989 for coverage until the loan amortizes to 80 percent of the loan value (see GE Capital, 1989). All results are expressed as a percent of the original loan.

The model produces a wider range of insurance values than GE Capital as a function of loan-to-value ratios. For GE Capital, insurance prices increase approximately 25 percent for an FRM going from an 81-85 percent to an 86-90 percent loan-to-value ratio, for either 20 or 25 percent coverage. For the model, assuming a 25 percent house price volatility, the change in insurance prices, going from an 85 to a 90 percent loan-to-value ratio, is approximately 80 percent. This lower variation for GE Capital may be due, in part, to aggregation among categories.

For 20-25 percent coverage, when the aggregate loan-to-value ratio is 81-85 percent, GE Capital figures show that for an FRM insurance values vary from 2.35 to 2.45, respectively, a 4 percent change. For the 86-90 percent loan-to-value ratio, the change is 5 percent. Using the same parameters for an ARM, the changes are 3 and 4 percent, respectively (see Table 4). For 20 and 25 percent coverage levels in the FRM model, the changes are 0 and 1 percent at an 85 percent loan-to-value ratio and 1 percent (for both) at a 90 percent loan-to-value ratio. For the ARM model, the change in the insurance values for a 90 percent loan-to-value ratio, assuming a 25 percent house price volatility, is 11 percent; for a 20 percent house price volatility there is a 3 percent change in insurance value. For coverage of ARMs, the comparisons of the model versus GE Capital produce fewer differences and ones in most cases that are of smaller magnitude than those resulting from changes in the loan-to-value ratios. Overall for level of coverage, the results obtained in our analysis are very similar to the insurance prices charged by GE Capital.

Summary and Conclusions

The most striking results of this article's model are the marked variations in insurance prices with respect to loan-to-value ratios and the absence of any such variation with respect to coverage levels beyond 20 percent. The model's results are similar in the direction of change to actual pricing of private mortgage insurance firms, as represented by the prices of GE Capital. In terms of total percent change over the range of parameters, though, the model produces a wider range of insurance values for changes in the loan-to-value ratios. As for level of coverage, a change from 20 to 25 percent in most cases produces small changes in insurance values, both in the model and in the GE data. Also, for any given loan-to-value ratio and coverage level, the impact of increasing the house price volatility is significant.

The absolute differences found here between the model's results and actual practice are clearly dependent on the set of parameters used in the model.[7] Option models can be an effective guide to the impact of changes in the economic and contractual parameters included in the model. Future researchers examining rate practice over time may be able to use the option pricing techniques presented here to help insurance firms respond to changing conditions in the economy. Option-based pricing models should have a useful role to play in providing firms with prices that accurately reflect the economic environment and the terms of the mortgage contract.[8]

[7] For example, a complete set of insurance values was determined for an FRM with a downward sloping term structure, resulting from a 12 percent spot rate and a 10 percent steady-state rate. In the base case, where the term structure is upward sloping, with σ_H equal to 20 percent, a coverage level equal to 25 percent and a loan-to-value ratio of 90 percent, the insurance value is 2.23 percent. With the downward sloping term structure, however, insurance is valued at 1.52 percent. The downward sloping term structure results in more prepayment, reducing the occurrence of default and, correspondingly, the value of insurance.

[8] The option model programming code used for the numerical analysis in this study is available upon request. All copyright restrictions apply to the use of this code. Any commercial use of this code is strictly prohibited except by written permission from the authors.

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