Mortgage servicing rights and interest rate volatility

While there is consensus that an increase in interest rate volatility reduces the fair value of mortgages and mortgage-backed securities, there is less agreement on the question of how volatility affects the value of mortgage servicing rights (MSRs). A volatility dependent prepayment model is needed to better reflect the true value of MSRs, say **Andrew Kalotay** and **Qi Fu**

Mortgage servicing rights (MSRs) exist simply because every mortgage loan must be serviced. Servicing of a mortgage loan involves administrative tasks such as collecting monthly payments and forwarding the proceeds to the owners of the loan (Fabozzi & Modigliani, 1992). Servicing rights on mortgage loans are important to financial institutions because they can produce significant revenue over the life of the loan, while also allowing the institution to maintain a relationship with the customer for the life of the loan (Clark, 1995).

There is a secondary market for servicing rights (that is, for the sale and transfer of the right to service a mortgage loan). The sale of servicing rights must be approved by the investor in the loans, or in the case of a mortgage loan that has been securitised, by the conduit that has securitised it, for example, Fannie Mae or Freddie Mac. There are brokers and listing services specialising in the trading of servicing rights and the industry includes major investment banking firms such as Merrill Lynch and Bear Stearns (Fabozzi & Modigliani, 1992).

The mortgage banking industry has experienced tremendous growth in the area of MSRs since the 1980s. As MSRs' significance to the industry has increased, their proper valuation in compliance with Financial Accounting Standard Board requirements have also become more important. Mortgage banking institutions generally ascribe fair value to their individual MSR assets using valuation models. Fair values of MSRs are significantly affected by changes in the interest rate environment due to the effect of those changes on the estimated prepayment speed. In addition, mortgage banking institutions typically employ derivative instruments to mitigate the risks inherent in MSRs, and the understanding of proper hedging has become more important to ensure the steady flow of income (Donoghue, 2006).

Considerable effort has been spent on the valuation of mortgage-related products such as mortgage-backed securities (MBSs), and practitioners' perceptions of the effect of changes in interest rate volatility on their value have largely converged. However, opinions on the effect of interest rate volatility on the value of MSRs are another matter. A key reason for this lack of consensus is that MSRs are typically valued using prepayment models that, crucially, fail to incorporate interest rate volatility. Such models implicitly assume that mortgagors do not take account of interest rate volatility in their refinancing decisions. We believe that this is an instance of ascribing to reality the limitations of the model. The results in this paper use an option-based, volatility-dependent prepayment model to value MSRs, which we propose as an alternative to current approaches used by practitioners.

It is generally agreed that an increase in interest rate volatility reduces the value of MBSs (or whole loans/pools of mortgages). The reasoning for this argument runs as follows: the higher the volatility, the more opportunities the borrower will have to refinance at a lower rate, to the detriment of the investors. The result is an increase in the value of the refinancing option that commensurately reduces the value of the mortgage pool or MBS.

But the question to bear in mind is, what is the effect on the value of MSRs when volatility increases? Does it decrease or increase?

Prior research on this question has failed to achieve a consensus. A particular example is Lin's research. In Lin (2003) and Lin & Ho (2005), regarding the effects of volatility, Lin states that, as interest rate volatility increases, so does the level of prepayments, therefore decreasing the value of the MSRs. Lin & Buttimer (2005) then state that, contrary to intuition, when volatility increases, MSRs values may actually increase, because:

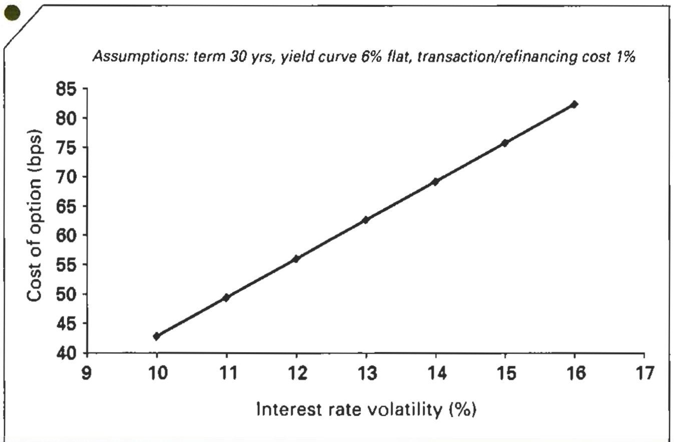

Figure 1. The cost of the refinancing option depends on volatility

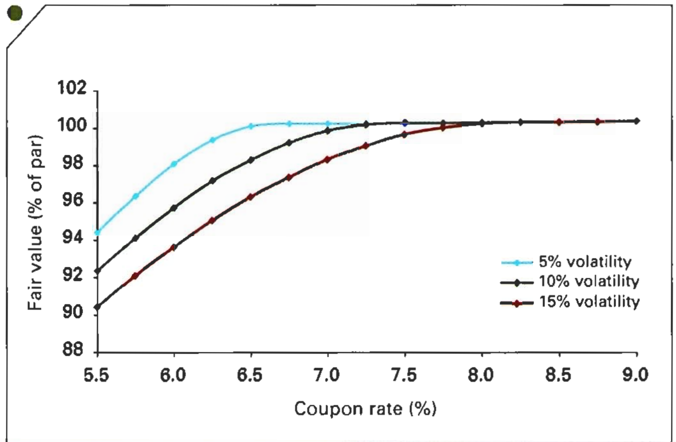

Figure 2. 30-yr callable amortising bond fair value at various volatilities

- mortgagors may wait longer to refinance for a more optimal opportunity, and
- even though mortgagors may be more in-the-money by the time they refinance, this only affects the MBS investor, not the MSR holder.

But Lin & Chu (2006) simply state that the value of MSRs decreases when volatility increases, ignoring Lin's own previous argument in Buttimer & Lin. Although Lin's intuition is partially valid, it fails to be consistent.

Because MSRs are very similar to the interest-only (IO) strips of MBSs, studies on MSRs tend to be based on IO analysis. The results suggest that when volatility increases, the value of the MSR decreases – yet intuition indicates otherwise. We will demonstrate that the primary cause of this incongruity is the nature of the prepayment model used. A prepayment model is defined by a rule that specifies the rate of prepayments in any given "environment", components of which include the prevailing term structure of interest rates, the term structure of interest rate volatility, etc. Conventional prepayment models – the widely used S-shaped curves, for example – are not volatility-dependent.

The prepayment rate is usually a function of the term structure, say a linear combination of the two-year, five-year and 10-year Treasury rates, but not of volatility. Given that conventional prepayment models are based on statistical analysis of historical prepayments, the exclusion of volatility is not surprising, but it raises questions regarding the adequacy of such models to determine the effect of volatility on asset value.

Conventional prepayment models implicitly assume that mortgagors are either ignorant of or indifferent to interest rate volatility. But what if we were to use a prepayment model that incorporates interest volatility and assumes that most mortgagors exercise their refinancing option close to optimally?

Because the fair value of an MSR directly depends on the expected life on the underlying mortgage pool, we will explore how volatility affects the effective duration/expected life of that pool, which can be used as a proxy for the fair value of MSRs. But first, we look at the effect of volatility on mortgage rates.

Interest rates vs mortgage rates

Let's consider what happens to mortgage rates when interest rate volatility increases and all other variables are held constant. In practice, quoted mortgage rates refer to those mortgages that can be prepaid by the borrower at any time without a penalty. This option allows borrowers to refinance their mortgage when interest rates fall. Lenders/investors charge the borrowers for granting such options, in the form of higher mortgage rates; this rate premium depends, among other things, on the structure of the mortgage and on the assumed interest rate volatility. Since higher volatility increases the likelihood of interest rates falling below the borrower's mortgage rate, thus facilitating economic refinancing, the value of the refinancing option is more valuable and therefore carries a larger rate premium.

While observable mortgage rates include such premiums, it is nevertheless conceptually essential to recognise the existence of (unobservable) optionless mortgage rates and note that these hypothetical optionless mortgage rates do not depend on volatility. We also see this by considering the effect of volatility on new adjustable-rate mortgage (ARM) rates: increasing the volatility should increase ARM rates (decrease ARM fair values) by only a very small amount, reflecting the modest appreciation in the value of the period cap and lifetime cap. On the other hand, as we will see, the effect of volatility is considerably more pronounced in the case of fixed-rate mortgages (FRMs).

The refinancing option

The cost of the refinancing option, that is, the premium that the market charges in excess of the optionless rate, depends on the term of the loan; it is highest for 30-year FRMs. Figure 1 shows how this premium depends on interest rate volatility in the case of 30-year FRMs. The underlying optionless mortgage yield curve is assumed to be 6% flat. These estimates were obtained using the approach described in Kalotay,

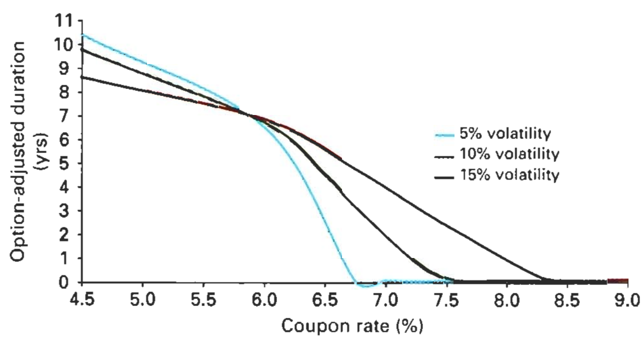

Figure 3. 30-yr callable bond option-adjusted duration at various volatilities

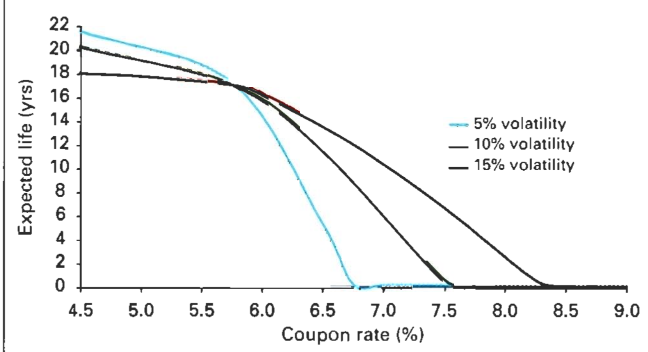

Figure 4. 30-yr callable bond expected life at various volatilities

Yang & Fabozzi (2004, 2007, & 2008). As shown in Figure 1, the value of the refinancing option is about 82 basis points (bps) at 16% volatility, and 42bps at 10% volatility. Thus we estimate that if the perceived interest rate volatility increases from 10% to 16%, the rate of a new 30-year FRM will increase by about 40bps. We note that if the assumed optionless curve were upward sloping, then a change in volatility would have a smaller effect on the value of the refinancing option.

The instantaneous effect of volatility

A common line of reasoning regarding the effect of interest rate volatility on the speed of refinancing is as follows:

- When volatility increases, the prevailing mortgage rates also increase.
- Higher mortgage rates reduce refinancing incentive in the short run, and encourage mortgagors to wait longer.
- Therefore a volatility increase slows down the instantaneous rate of refinancing.

Although the conclusion of the above argument is correct, its reasoning is flawed. It takes into consideration the rates of *new* mortgages, but ignores the embedded option of the *outstanding* mortgages. A more accurate line of reasoning would be:

- An increase in volatility increases the value of the refinancing option of outstanding mortgages.
- Higher *option values* reduce refinancing incentive in the short run, and encourage mortgagors to wait longer.
- Therefore a volatility increase slows down the instantaneous rate of refinancing.

Note that the above line of reasoning ignores the structure of the replacement mortgage. Of course, the refinancing decision in general should also take into account the value of the refinancing option in the replacement mortgage, as discussed in Kalotay, Yang & Fabozzi (2004). However, as they demonstrate, when the replacement is an FRM, its option value would be insufficient to offset its higher mortgage rate due to higher volatility – hence the so-called refinancing efficiency would decline. In summary, we can safely conclude that an increase in volatility will reduce the instantaneous prepayment rate, regardless of the structure of the replacement mortgage.

The long-run effect of volatility

Let's first consider low-coupon mortgages. When the volatility is low, mortgage rates are unlikely ever to drop low enough for low-coupon mortgages to be economically refinanced; they will behave like optionless amortising bonds and hence their duration will be relatively long. While low volatility reduces the probability of economical refinancing, higher volatility increases it – the higher the volatility, the greater the chance that rates will eventually decline to a level where economic refinancing is possible. Therefore the increase of volatility will actually decrease the expected life of low-coupon mortgages. We note that this effect is primarily due to the interest rate process and has little to do with the prepayment model.

The case of higher coupon mortgages is considerable more complex. As we discussed above, when volatility increases, the duration of above-market coupon mortgages that were on the verge of being refinanced will increase. But what happens to the duration of current-coupon mortgages? What is the point of inflection, that is, at what rate is the duration of the mortgage independent of volatility? We now turn to the investigation of these questions.

Insights from callable amortising bonds

As mentioned before, the fair value of the MSR essentially depends on the effective duration of MBSs or pool of mortgages that fund it. To help illustrate this, consider callable amortising bonds that are structurally identical to mortgages. The critical difference between them is refunding. Bonds, which are issued by institutions, are refunded optimally or nearly so; the refinancing of mortgages by individuals is often suboptimal.

The institutional borrower's optimum refunding strategy for callable bonds is well established: the issuer should call and refund the bond when the resulting present value interest savings equal the value of the forfeited option (Boyce & Kalotay, 1979, and Kalotay, Yang & Fabozzi, 2007 and 2008). Note that both the interest savings and option value depend on the associated (refunding) transaction cost, which in this analysis is assumed to be 1% of the outstanding principal.

In the examples below, we consider new bonds structurally

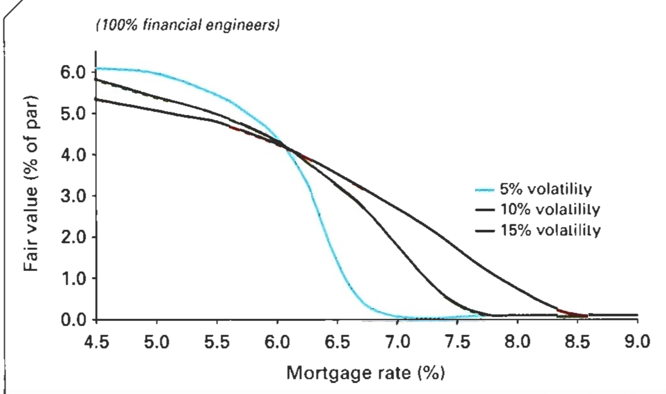

Figure 5. 1% interest-only (IO) strip fair value at various volatilities

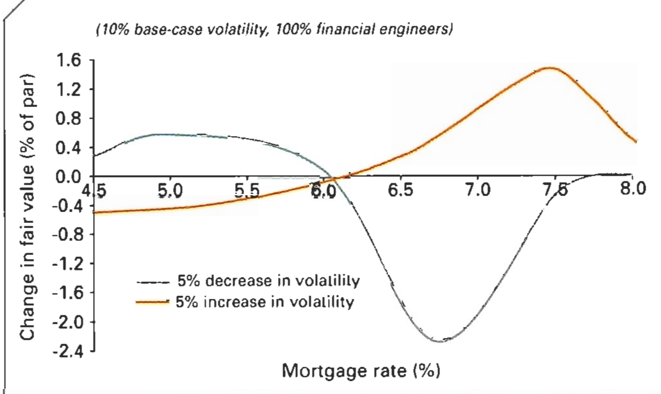

Figure 6. The effect of change in volatility on the fair value of 1% IO strip

identical to 30-year FRMs: 30-year term, level monthly payments, mortgage-like amortisation and callable at any time at par. We will focus on the effect of change in interest rate volatility, assuming a Black-Karasinski stochastic interest rate model with 0% mean reversion, and a flat 6% yield curve.

Figure 2 displays the fair value of bonds over a range of coupons from 5.5% to 9%, at interest rate volatilities of 5%, 10%, and 15%. A price of 100 indicates that the bond is on the verge of being called (to be precise, due to the assumed 1% transaction cost the theoretical fair value can actually exceed 100; however, these considerations go beyond the scope of this analysis). We observe from this figure that at 5% volatility, bonds with coupons exceeding 6.75% will be called, while at 15% volatility the threshold increases to 8.25%.

Figure 3 shows the duration of these bonds at various levels of volatility. If a high-coupon bond is on the verge of being called, its duration is essentially zero. But if volatility increases, the durations of high-coupon bonds will also increase, because the issuers are more likely to wait for an opportunity for larger savings.

As stated earlier, if the volatility increases, the duration of low-coupon bonds will decline. According to Figure 3, the effect of a change in volatility on low-coupon bonds is relatively insignificant compared to the effect on high-coupon bonds, because even if volatility increases the probability of low-coupon bonds being called remains relatively low.

Of particular interest is the point of inflection, ie, where the duration is independent of volatility. This occurs when the coupon is slightly below the prevailing optionless rate, in this case 6%. At this point, the effects of change in volatility on low-coupon and high-coupon bonds simply cancel out one another. We note that because of the presence of the embedded call option, the fair value of callable bonds in this range would actually be at a discount.

Figure 4 shows the expected lives of the bonds corresponding to different volatilities; the pattern on this graph is identical to Figure 3 for duration. As volatility increases, the expected life of low-coupon bonds decreases, while the expected life of high-coupon bonds increases, but by a much greater margin. For example, as volatility increases from 10% to 15%, the expected life of a 5% bond declines from 19.2 to 17.9 years. But a 7% bond increases from zero to about five years, a much more dramatic change. Again, the inflection point is slightly less than the prevailing optionless rate at 6%.

To summarise our findings for callable bonds: assuming optimal refunding as defined in Kalotay, Yang & Fabozzi (2007 and 2008), the borrower will refund only if the call efficiency reaches 100%. Optimal refunding is obviously volatility-dependent, because the decision depends on the value of the forfeited call option. We have shown that as volatility increases, the expected life of low-coupon bonds decreases and the expected life of high-coupon bonds increases. The point of inflection occurs roughly where the coupon equals the prevailing optionless rate.

These results provide considerable insights into the valuation of IOs in general and MSRs in particular. The value of an MSR is directly dependent on the duration/expected life of the MBS or pool of mortgages that funds it. Since the only significant difference between mortgages and callable amortising bonds is the degree of optimality of option exercise, we can expect MSR fair value to respond in a pattern similar to that of the duration of callable bonds when volatility changes.

Valuation of MSRs with an option-based prepayment model

The residential mortgage market is extremely competitive, both in terms of product range and lending rates, and this information is widely disseminated. In addition, sophisticated option-based tools are available to assist the general public with financing and refinancing decisions, which enable a homeowner to play the mortgage game like a professional. (For example, one can find option-based financing and refinancing calculators at www.kalotay.com/calculators.)

In light of these developments, it is safe to say that the percentage of mortgagors who make close to optimal refinancing decisions will be steadily increasing. Following the terminology of Kalotay, Yang & Fabozzi (2004), we refer to mortgagors who refinance optimally as 'financial engineers', and those who do not as 'laggards'. Even the

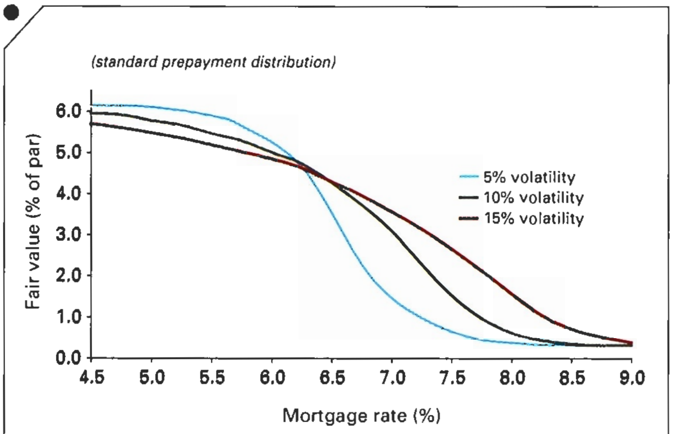

Figure 7. 1% IO strip fair value at various volatilities

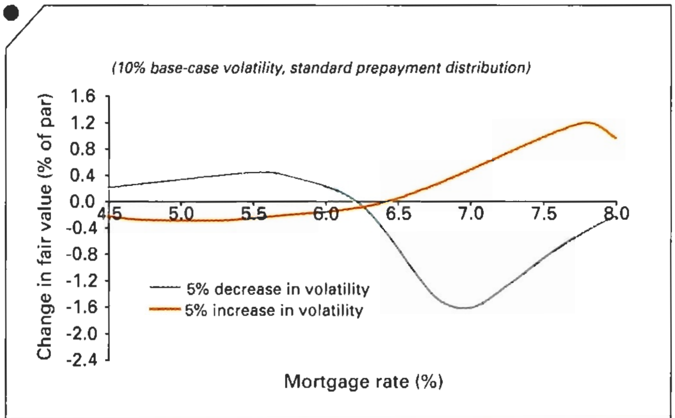

Figure 8. The effect of change in volatility on the fair value of 1% IO strip

refinancing decisions made by the laggards can be characterised as option-based except that they are suboptimal and therefore delayed. Also as in Kalotay, Yang & Fabozzi, there is a wide range of laggard behaviour, and the distribution of financial engineers and laggards defines the prepayment distribution.

We will first consider the case where every mortgagor in the prepayment distribution is assumed to be a financial engineer, implying that all the refinancing will be optimal. This is identical to the case of callable amortising bonds except that mortgages prepay for reasons other than refinancing. We will assume this latter type of prepayment, known as turnover, occurs at a rate of 8%.

In Figure 5, we present results using the prepayment model discussed in Kalotay, Yang & Fabozzi of how changes in interest rate volatility affects the fair value of IO strips/MSRs assuming 100% of the mortgagors refinance optimally.

As Figure 6 shows, the effect of volatility on the fair value of MSRs is nearly identical to the effect of volatility on the durations of callable amortising bonds. When volatility increases, the values of high-mortgage rate MSRs increase and those of low-mortgage rate MSRs decrease, with the inflection point occurring at the prevailing optionless rate, and the effect being much more pronounced for higher-mortgage rate MSRs than for lower ones.

We note that Levin (2004) observed a similar effect of how change in volatility affects the value of MSRs. However, his focus was on the choice of interest rate models, and his conclusions were based more on computer-generated technical results than on intuitive reasoning. In our study, we employed an internally consistent model based on accepted financial theory that fully accounts for the effect of volatility on the valuation of MSRs and in a manner that accords with intuition.

Now we consider a more realistic case, where mortgagors exhibit a level of suboptimal refinancing behaviour. An example of such a prepayment distribution can be found in Kalotay, Yang & Fabozzi, 2004 and is used here. As we show in Figure 7, the pattern remains the same: as volatility increases, the fair values of high-rate MSRs increase and those of low-rate MSRs decrease. In the case of the former, the rise in fair values is accentuated by suboptimal refinancing, a dampener of prepayment speed. When rates are high enough (see extreme right of graph), mortgagors are likely to prepay regardless of volatility.

Figure 8 should be compared to Figure 6 to observe the dampening effect of suboptimal refinancing on the response of MSR fair value to changes in volatility.

We examine the effect of suboptimal refinancing on the fair values of MSRs more closely in Figure 9. At 5% volatility, suboptimal refinancing makes virtually no difference for lower coupon MSRs: if volatility is minimal, low-coupon mortgages are unlikely to be refinanced at all.

As discussed earlier, when volatility is low, the expected life of high-coupon mortgages (that is, above 8%) is basically zero. Because there is little incentive to wait for higher savings, laggards will not wait much longer than financial engineers to refinance; therefore suboptimal refinancing makes little difference in the value of high-coupon MSRs when volatility is low. But if volatility were to increase, the laggards' behaviour will vary more significantly than that of the financial engineers, as we will see.

At 15% volatility, because there is now a realistic probability that mortgages rates will fall sufficiently for a 4.5% mortgage to be economically refinanced, suboptimal refinancing will result in a more significant change in the overall level of prepayment. Thus when volatility is high, there is a more discernible difference in the value of low-rate MSRs if the mortgagors refinance optimally. For example, as Figure 9 shows, at 5% volatility, the value of a 4.5% MSR is virtually independent of prepayment behaviour. However, as Figure 10 shows, at 15% volatility, suboptimal refinancing will increase the fair value of a 4.5% MSR by about 0.4% of par.

For high-rate MSRs, while all mortgagors will wait longer to refinance in a higher volatility regime, the laggards will wait somewhat longer than the financial engineers. Therefore suboptimal refinancing makes a more discernible difference to the fair value. For example, at 5% volatility, the fair value of 8.5% MSR is very close to zero, regardless of prepayment distribution, but at 15% volatility, its

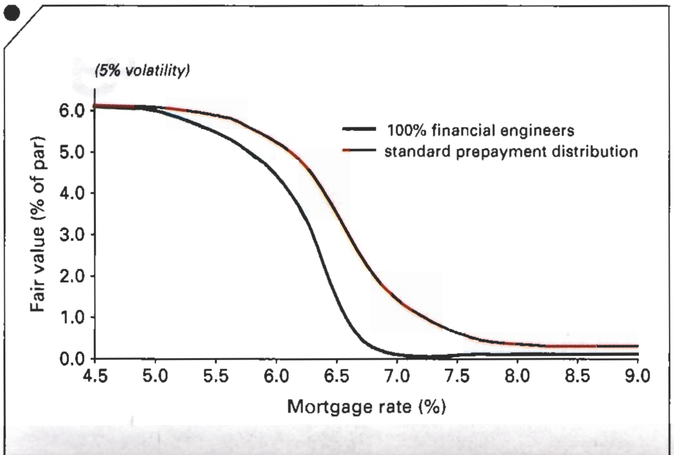

Figure 9. 1% IO strip fair value

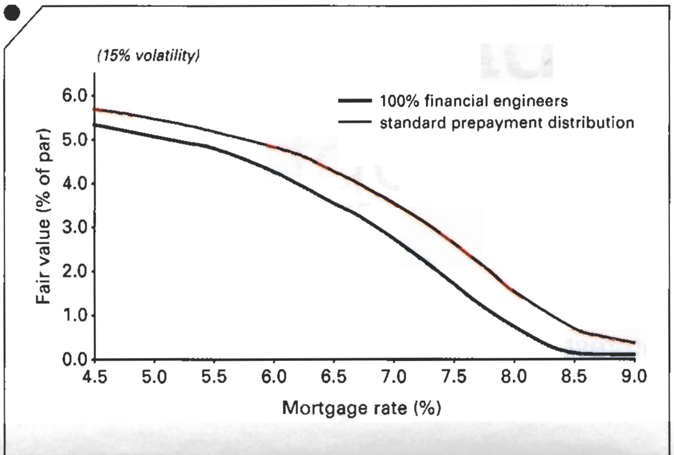

Figure 10. 1% IO strip fair value

value – still very close to zero under optimal refinancing – rises to about 0.7% of par in a suboptimal refinancing regime.

Conclusion

Given the exposure of financial institutions to MSRs, the valuation and understanding of MSRs is of considerable practical importance.

While there is consensus that an increase in interest rate volatility reduces the value of the underlying pool of mortgages, opinions about its effect on the value of MSRs vary. This ambiguity can be attributed to the prepayment models used in valuation. Conventional prepayment models are not volatility-dependent; they implicitly assume that mortgagors are indifferent to the volatility of interest rates when deciding if and when to refinance. We believe that this oversimplification leads to misleading conclusions regarding the valuation of MSRs.

We used an option-based, volatility-dependent prepayment model to analyse the effect of interest rate volatility on the fair value of MSRs. We first considered the effect of volatility on the rate of a 30-year FRM and showed that the market charges between 40 and 80 bps for the refinancing option.

Next, in order to gain some intuition about the effect of option-based refinancing behaviour, we determined the expected life of callable amortising bonds. We found that when volatility increases, the expected life of a low-coupon bond decreases marginally due to higher likelihood of refunding, while the expected life of a high-coupon increases, but considerably more dramatically. The expected life of bonds whose coupon is near to the prevailing optionless rate are is essentially independent of volatility. Last, we applied an option-based prepayment model that allows for sub-optimal refinancing behaviour, and we showed that the expected life of an MSR responds to changes in volatility in a manner like that of a similar callable bond, but sub-optimal refinancing dampens the effect. ■

Andrew J. Kalotay is the president and Qi Fu is a quantitative analyst at Andrew Kalotay Associates in New York. Email: andy@kalotay.com and qifu@kalotay.com

References

Boyce W M & A Kalotay, 1979
Optimum bond calling and refunding
Interfaces, November

Buttimer R J & C Lin, 2005
Valuing US and Canadian Mortgage Servicing Rights with Default and Prepayment
Journal of Housing Economics, 14(3), pages 194-211

Clark S J, 1995
Accounting for mortgage servicing rights under the FASB's proposed standard
The Journal of Bank Cost & Management Accounting

Donoghue P, 2006
FASB: Servicing Rights. Financial Accounting Standards Board
from http://72.3.243.42/project/servicing_rights.shtml, February

Fabozzi F & F Modigliani, 1992
Mortgage & Mortgage-Back Securities Markets
Harvard Business School Press

Kalotay A, D Yang & F Fabozzi, 2004
An option-theoretic prepayment model for mortgages and mortgage-backed securities
International Journal of Theoretical and Applied Finance, December

Kalotay A, D Yang & F Fabozzi, 2008
Optimum refinancing: bringing professional discipline to household finance
Forthcoming in Applied Financial Economics Letters, 4, 141-149

Kalotay A, D Yang & F Fabozzi, 2007
Refunding efficiency: a generalized approach
Applied Financial Economics Letters, 3, 141-146

Levin A, 2004
Interest rate model selection: a conscientious choice for mortgage investors
The Journal of Portfolio Management, winter

Lin C, 2003
Valuing Individual Mortgage Servicing Contracts: An Option-Adjusted Spread Approach
Journal of Housing Studies, 12 (1), pages 31-42

Lin C & T Chu, 2006
Valuation of Mortgage Servicing Rights with Foreclosure Delay and Forbearance Allowed
Review of Quantitative Finance and Accounting, 26(1), pages 41-54

Lin C & L Ho, 2005
Valuing Individual Mortgage Servicing Contracts: A Comparison between Fixed-Rate Mortgages and Adjustable-Rate Mortgages
Review of Pacific Basin Financial Markets and Policies, 8 (1), pages 131-146