Crashes in Bond Markets and the Hedging of Mortgage-Backed Securities

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Trading in bond markets is usually regarded as significantly less exciting than trading in stock markets. The fixed maturities and coupons of bonds limit the possibility for speculation and the volatility of prices. Large and fast movements of prices are not commonly observed, and the few times they have occurred in the past could in most cases be easily explained by actual or anticipated changes in monetary policy, inflation, and economic conditions, or events in other markets like the stock market.

Against this background, the developments in the U.S. bond market during Summer 2003 can only be described as extraordinary. On November 6, 2002, the Federal Reserve reduced the federal funds rate by 50 basis points to 1.25% in a well-anticipated move. The yield on ten-year Treasury bonds had fluctuated since October 2002 at around 4%. In early May 2003, this yield quickly began to fall substantially, reaching a low of 3.1% on June 13, 2003. Another widely anticipated cut in the federal funds rate by 25 basis points to 1.0% on June 25, 2003, was accompanied by a sharp increase in the yield of ten-year Treasury bonds, reaching 4.5% on August 14, 2003.

Exhibit 1 illustrates these developments. Although indications were for improving economic conditions in the long run, these changes did in no way justify such a great increase in the yield, just as the extent of the previous reduction in the yield could not be attributed to a more negative economic outlook.

These developments, while not noteworthy if they had been observed in the stock market, were significant enough to receive attention in the general financial press ("On the Foundations of Troy" [2003] and "The Message of the Markets" [2003]). Commentators agreed the likely cause of this movement could be found in the hedging of mortgage-backed securities by investors. The idea behind this claim is that such hedging activity amplifies any movements of interest rates.

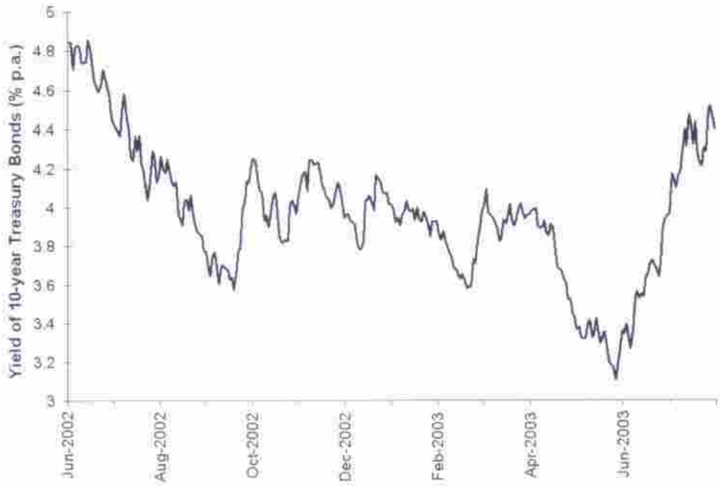
Clearly such an explanation, although in essence correct, is overly simple. We therefore analyze the effect of the hedging of mortgage-backed securities on bond prices in a simple equilibrium model. The model is very similar to that of Genotte and Leland [1990], developed to explain the stock market crash of 1987 with portfolio insurance activities, but offers some additional insights.

I. HEDGING MBS

The first mortgage-backed security (MBS) was issued in 1970. With constant modification to their specification, the market for MBS has grown to about $4 trillion in the U.S. alone. MBS are bonds issued by mortgage providers and collaterized by a pool of mortgages granted to homeowners. The interest payments and capital repayments of the mortgage holders are used to generate the cash flow required to pay the interest and redemption of the MBS.

Although mortgages in the U.S. are usu-

EXHIBIT 1
Development of Yield of 10-Year U.S. Treasury Bonds



Source: Thomson Datastream.

ally granted for 30 years at a fixed interest rate, homeowners have the right to repay mortgages in part or in full at any time with no financial penalties (prepayment). As these prepayments are passed on to MBS investors, their securities also will be partly repaid before maturity. Hence an MBS maturity is not fixed as with ordinary bonds, but rather depends on homeowners' exercise of their prepayment option. MBS valuation therefore depends significantly on the modeling of homeowner prepayment behavior.

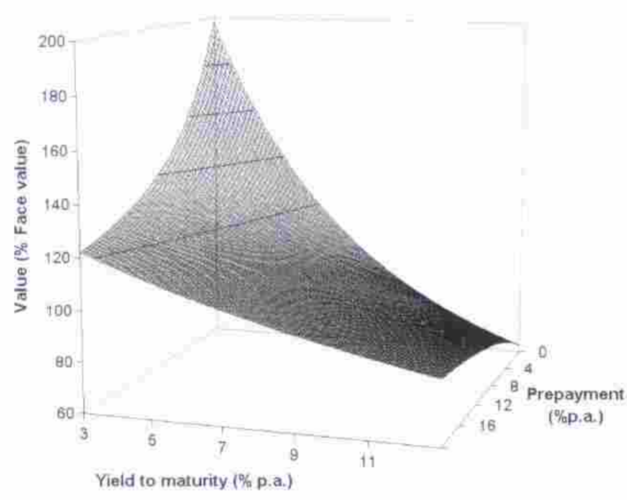
We use a simple valuation method for MBS by assuming that every year a fixed fraction p of the outstanding amount of a 30-year MBS is repaid. The MBS has a fixed annual coupon of C. Thus the value of this MBS is given by:

$$V = \sum_{\tau=1}^{30} C\frac{(1-p)^{\tau-1}}{(1+i)^{\tau}} + B\frac{(1-p)^{29}}{(1+i)^{30}} \tag{1}$$

where i is the current yield to maturity of this MBS, and B denotes the face value of the MBS when issued. Exhibit 2 illustrates how the value of an MBS is affected by its yield to maturity and the prepayment of homeowners.

Quite sophisticated models of MBS valuation have been developed over the past decades that take the prepayments of homeowners into account in very accurate way; see Fabozzi [2001] for an overview. Despite these

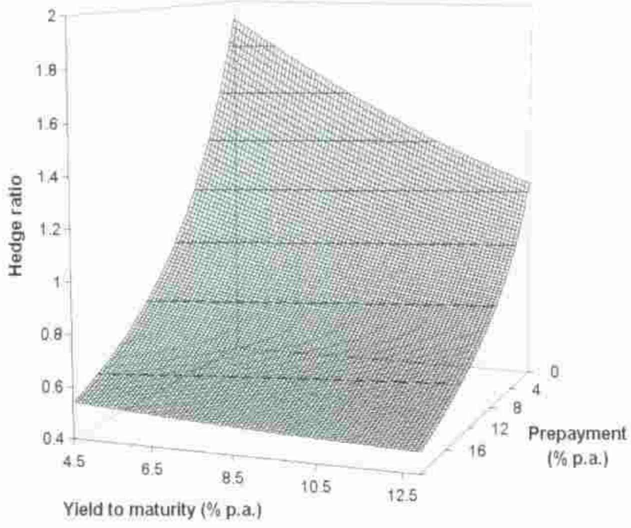
EXHIBIT 2
Value of Mortgage-Backed Securities



advances our simple model of valuing MBS is good enough for our purposes, and more sophisticated methods would not change our results significantly.

It is reasonable to assume that homeowner prepayment will depend on the yield of the MBS, which is closely linked to the interest rate charged on mortgages. With a falling yield, homeowners are ever more likely to take advantage of falling interest rates by remortgaging, i.e., repaying their current mortgage with the proceeds

EXHIBIT 3
Hedge Ratio for a 30-Year MBS with a 10-Year T-Bond



from a new mortgage. Similarly, with rising interest rates, remortgaging becomes less likely.

As interest rates rise, homeowners find it more attractive to invest any surplus funds into high-yield accounts rather than repay mortgages that may have a lower interest rate. The opposite is likely to happen with falling interest rates. Hence we see that the prepayment rate will rise with falling yields and decline with rising yields.

Once we have found a suitable model of the prepayment rate that depends on the yield to maturity, we see from Equation (1) that the risk to the value of an MBS originates only from a change in the yield to maturity. Given the wide-ranging protection of MBS against default, interest rate risk is the only risk an investor should reasonably be concerned about when investing in MBS. The exposure to interest rate risk is very different from investing in ordinary bonds because of the prepayment possibility, which has to be taken into account in any hedging strategy.

To enable MBS investors to hedge their exposure to interest rate risk, the Chicago Board of Trade introduced futures contracts on MBS in 1975. A lack of demand caused these derivatives to be withdrawn in 1987, and a second attempt to establish such derivatives in 1989 was abandoned in 1992. Thus there is currently no standardized derivative available that directly hedges the interest rate risk of MBS, and investors must seek alternative methods of hedging.

The sensitivity of bond prices to changes in the yield to maturity is usually measured by the duration of the bond. The greater the duration, the more sensitive bond prices are to a change in the yield, and thus the greater the interest rate risk. A duration of zero corresponds to the absence of interest rate risk and would be the aim of a perfect hedge.

Given the duration of MBS, investors can hedge their exposure to interest rate risk by an appropriate short position in a highly correlated ordinary bond. Apart from the prepayment options, Treasury bonds have a similar exposure to interest rate risks as MBS, and their default risk is usually regarded to be as negligible as that of MBS. An analysis of the typical duration of MBS and T-bonds shows that ten-year T-bonds have a duration roughly similar to 30-year MBS. And there is a liquid futures market in ten-year T-bonds, making the required short position available at low cost. For this reason it is common to hedge MBS with short positions in ten-year T-bonds.

We can obtain the appropriate hedge ratio, h, by solving the equation:

$$0 = D^{MBS} - hD^{TB} \tag{2}$$

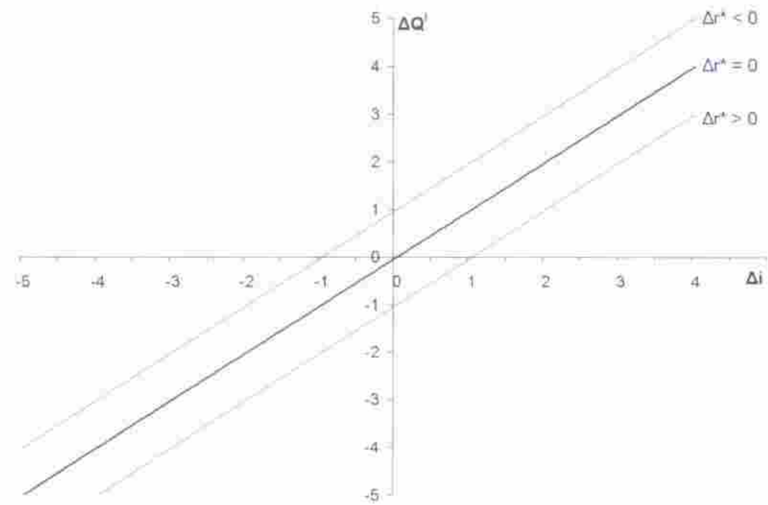
where D^{MBS} and D^{TB} denote the duration of MBS and T-bonds, respectively. As this hedging strategy matches the duration of MBS and T-bonds, it is also called a *duration hedge*.

Data show that over the last couple of months the yield of MBS exceeded that of T-bonds by about 150 basis points. This difference in the yields can be explained by the prepayment option MBS investors grant homeowners. For our purposes, we therefore use a ten-year T-bond with a coupon and yield to maturity 150 basis points below that of the MBS it hedges. We can now easily derive the hedge ratio as a function of the yield to maturity and the prepayment.

This relationship is illustrated in Exhibit 3. Using MBS or T-bonds that do not have a coupon equaling the differences in their yields, or have another difference in their yields, would provide us with a very similar result.

As Fernald, Keane, and Mosser [1994] point out, such a duration hedge is commonly used by a wide range of investors. Although more sophisticated dynamic hedging strategies have been developed more recently (see Koutmos and Pericli [1999] among others), they are so far not widely used. As they are also not fundamentally different from the simple static duration hedge described above, using them would not change our results significantly.

EXHIBIT 4
Investor Demand



II. EQUILIBRIUM IN THE MARKET FOR TREASURY BONDS

We consider only the market for ten-year Treasury bonds, and assume that all traders have perfect knowledge of the fundamental interest rate r^*, which is exogenously determined by economic conditions and monetary policy. The model uses the current position of all traders as a benchmark, implying that we are investigating changes to only the fundamental interest rate Δr^*; the equilibrium interest rate Δr; the observed interest rate Δi; and the demand ΔQ. We also assume the MBS and the T-bond are issued with par coupons.

We assume furthermore that the market consists of two types of otherwise homogeneous traders, called investors and hedgers. Investors are concerned only about the return they can achieve from holding T-bonds, and do not know about hedgers. Hedgers, on the other hand, are not concerned about the returns the T-bonds generate but seek only to hedge their exposure to interest rate risk arising from their investment in MBS, which is given exogenously. We finally consider only equilibrium interest rates rather than the dynamics of adjusting to equilibriums from the current observed interest rate.

Suppose the actual interest rate increases more than the fundamental interest rate; i.e., $\Delta i > \Delta r^*$. In this case investors infer that T-bonds are undervalued and increase their demand with an expectation of making additional profits once prices adjust to their fundamental value. The opposite effect can be expected when the actual interest rate increases less than the fundamental interest rate, $\Delta i < \Delta r^*$. Risk aversion and uncertainty about the future fundamental interest rate limit the amount by which investors increase their demand.

Let us propose a linear relationship between the changes in interest rates and the demand of investors:

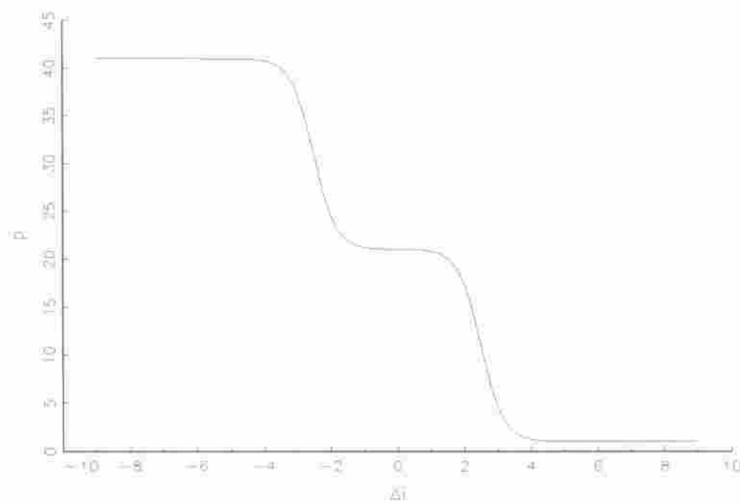
$$\Delta Q^I = \phi(\Delta i - \Delta r^*) \tag{3}$$

where the parameter ϕ includes the sensitivity of this demand to changes in the interest rates, ϕ', as well as the number of investors, α', by setting $\phi = \phi'\alpha'$. Exhibit 4 illustrates this demand for various changes in fundamental interest rates.

In order to obtain the demand from hedgers, we must explicitly model the prepayments of homeowners. Our assumption that the yields of MBS and T-bonds differ by a fixed spread of 150 basis points allows us to overlook that the yields of MBS and T-bonds differ as we consider only changes to the yield.

We here assume that the prepayments by homeowners form a double S-shaped curve as shown in Exhibit 5. The reasoning behind this shape is that homeowners will not alter their prepayments significantly if faced with only small changes in mortgage rates, because their transaction costs like information acquisition and negotiating the new mortgage would outweigh the benefits.

EXHIBIT 5
Prepayment Function



Evidence suggests that once a critical value for the change of mortgage rates is exceeded, homeowners change their prepayment behavior significantly. As most homeowners will have made their adjustments, an even greater change in mortgage rates will have only limited additional impact on the prepayments. These considerations give rise to an S-shape for an increase as well as a decline in mortgage rates. For simplicity, we assume the effects on prepayments are symmetric for increases and declines in mortgage rate.

Note that the shape of the prepayment function is not critical to the essential outcomes of our model. It would easily be possible to use other empirical or theoretical prepayment functions, like the more common single S-shaped curve, without significantly changing the main results.

Equipped with such a prepayment function, we can now easily determine the duration of the MBS for all possible yields to maturity, which then in turn determines the hedge ratio. The hedge ratio immediately determines the demand for a short position in T-bonds by each individual hedger. Hence the change in demand of α hedgers is given by:

$$\Delta Q^H = -\alpha \Delta h \tag{4}$$

which implicitly assumes that hedgers immediately adjust their holdings of T-bonds to a change in the hedge ratio.

The change in hedging demand, ΔQ^H, as a function of the change in the yield, Δi, is shown in Exhibit 6. We see that the double S-shape is preserved, although the symmetry vanishes. The reason for the emerging asymmetry is that the duration of MBS increases more upon a drop in yield than it declines upon a rise of the same size as we can see in Exhibit 3.

The relative importance of hedging demand to investors' demand can be evaluated by using the ratio of the number of hedgers and investors, $\lambda = \alpha/\alpha'$. The total demand thus changes by

$$\Delta Q = \Delta Q^I + \Delta Q^H \tag{5}$$

The shape of this function is shown in Exhibit 7 for various changes of the fundamental interest rate. We immediately see that the slope of this demand function is no longer monotonic, which would imply multiple equilibriums. With the amount of T-bonds outstanding assumed to be fixed in the short run, we have the obvious equilibrium condition that:

$$\Delta Q = 0 \tag{6}$$

We plot in Exhibit 8 the equilibrium Δr as a function of changes of the fundamental interest rate, Δr^*, for an increasing relative importance of hedgers, $\lambda_1 > \lambda_2$, $\lambda_3 > \lambda 4$. We observe that the number of hedgers can change the shape of these equilibriums substantially, so we can

EXHIBIT 6
Hedging Demand

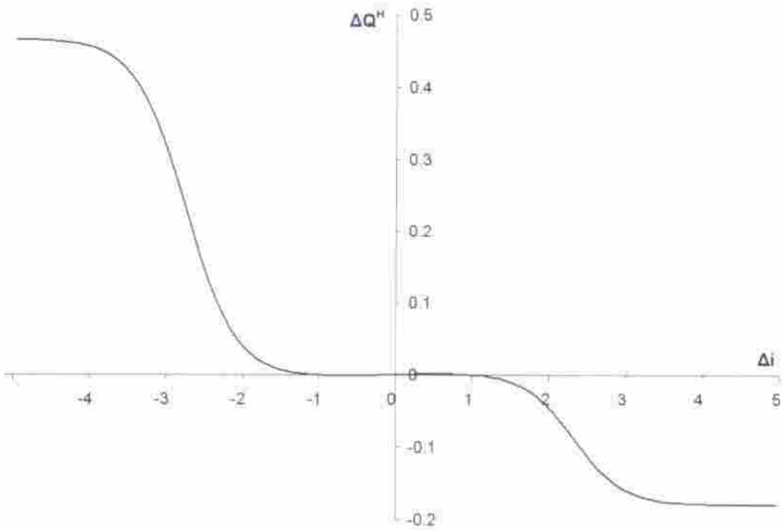
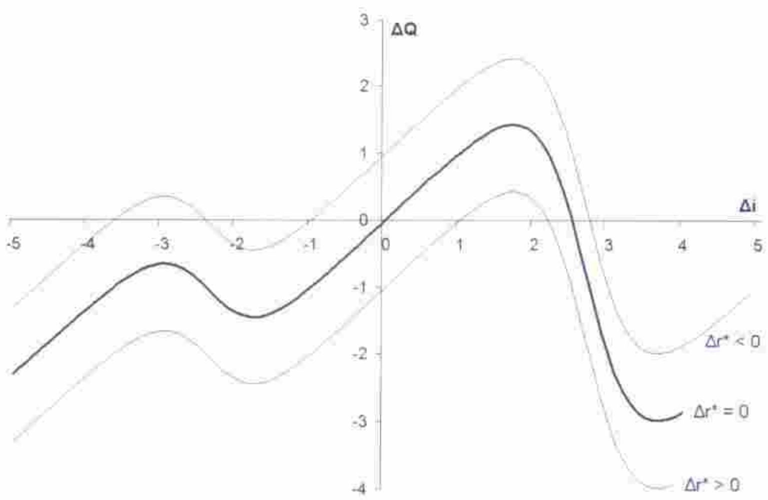


EXHIBIT 7
Total Demand



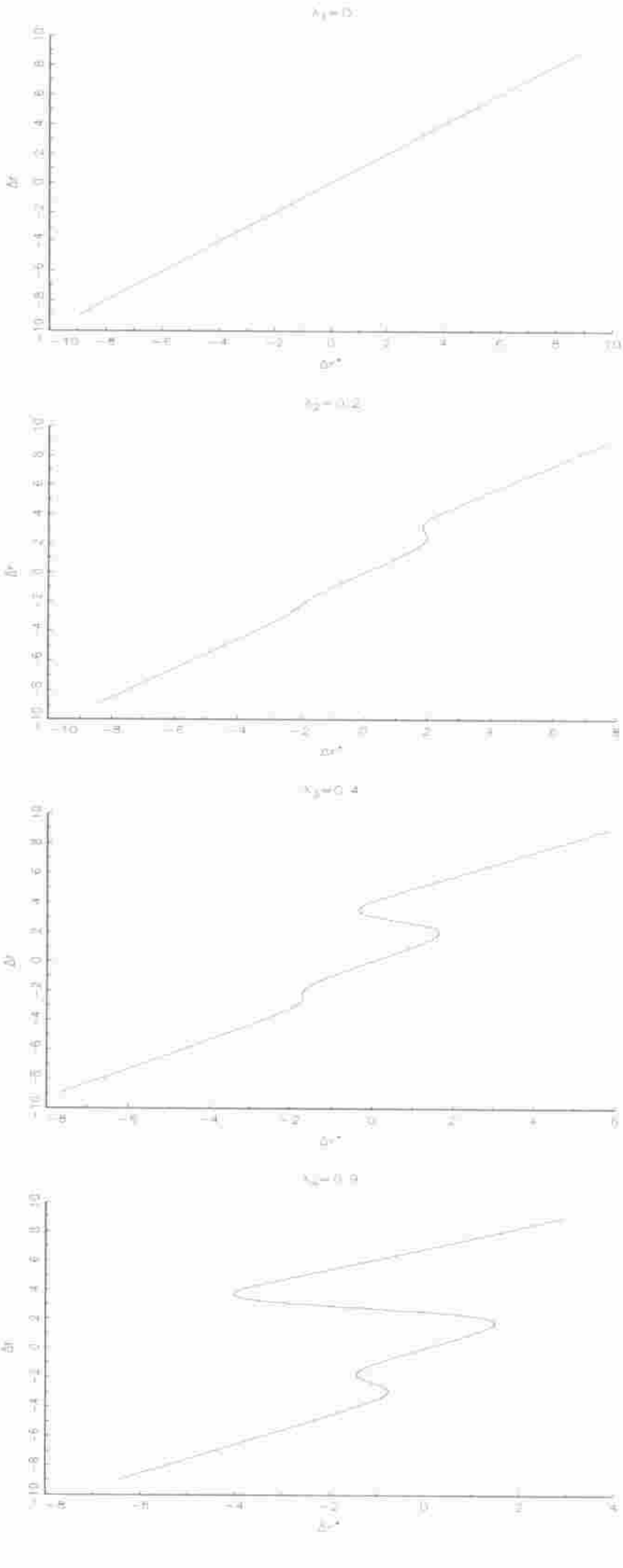
therefore expect to observe significantly different properties of bond prices arising from these situations.

Our focus is exclusively the equilibrium interest rates and how they are affected by a change in the fundamental interest rate and the importance of hedging. Exhibit 8 shows that while the equilibrium is unique when hedging is relatively minor, there may be as many as five equilibriums when hedging is very important. We further observe that the equilibrium change in interest rates can differ substantially from the fundamental change.

We can use Exhibit 9 to explore how equilibrium interest rates change with the fundamental interest rate. Suppose we are currently at point *A*, the origin representing our benchmark. When the fundamental interest rate increases slowly to point *B*, the equilibrium interest rate also steadily increases, although at a slightly higher rate. At point *B*, however, this equilibrium ceases to exist, and any further rise in the fundamental interest rate causes the equilibrium interest rate to jump to point *C*.

We thus observe a discontinuity in the equilibrium

EXHIBIT 8
Equilibriums for Selected Importance of Hedging Demand



interest rate; an *upward crash* has been induced by a small increase in the fundamental interest rate. Any further increase in the fundamental interest rate to point D and beyond would be accompanied by a steady increase of the equilibrium interest rate at a slightly lower rate.

A subsequent drop in the fundamental interest rate to point E would be accompanied by a steady reduction in the equilibrium interest rate at a marginally higher rate, although compared to the benchmark the total equilibrium change is too high. At point E, a further reduction causes another crash to point F as this upper equilibrium vanishes. A drop in the fundamental interest rate to point G or beyond at an equilibrium below the fundamental change would then again be steady as would an increase toward point H. Any increase beyond point H would induce another, although smaller, upward crash, and a movement from point A below point J would also cause a crash.

These considerations show that at four points very small changes in the fundamental interest rate can cause large changes in the equilibrium interest rates. We will distinguish these four discontinuities by calling those at points H and J the *small discontinuity* and those at points B and E the *large discontinuity*.

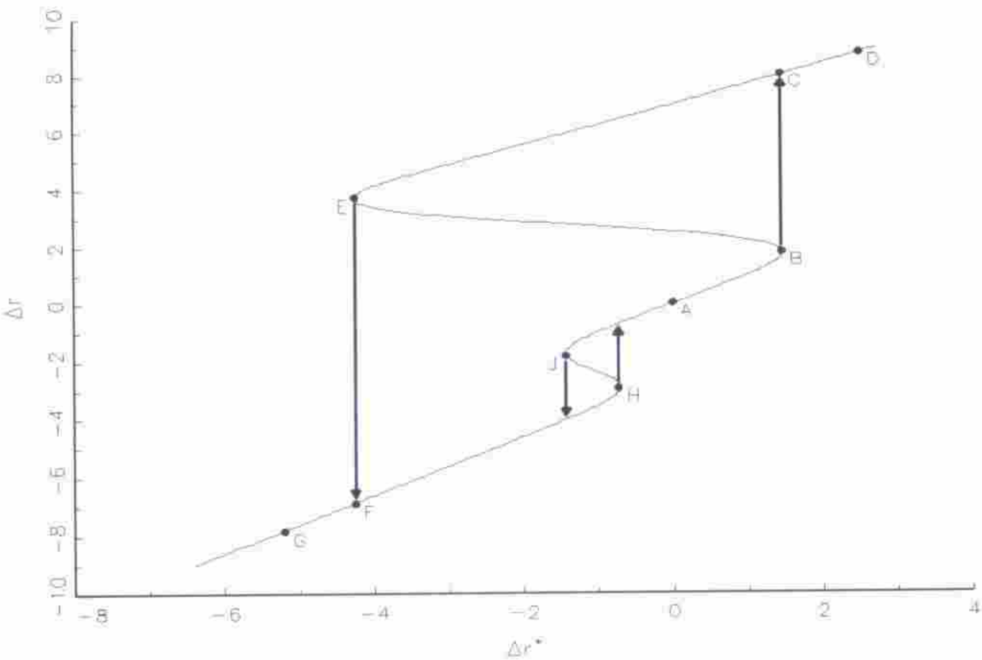
From this description, you can see that the equilibriums between points B and E as well as H and J cannot be reached. As we can furthermore show easily that all other equilibriums are locally stable, we cannot expect any sudden switches between equilibriums, ruling out that these equilibriums are ever reached.

We have thus established that the hedging of MBS can introduce discontinuities into the equilibrium interest rate of T-bonds that manifest themselves in upward crashes and the more common downward crashes upon only a very small change in the fundamental interest rate. We can use Exhibit 10 to briefly evaluate the effect of hedging on the properties of these equilibriums and the presence of discontinuities. We generally observe that discontinuities grow with the importance of hedging, but that the two discontinuities are not of the same size. The origin of the difference in their size lies in the asymmetry of the hedging demand we saw in Exhibit 6.

Another observation is that, when hedging is not very important, there are no discontinuities, and the equilibrium is unique. As the importance of hedging grows, we first see the emergence of a large discontinuity, only for an even higher importance of hedging also the small discontinuity emerges. Finally, the downward crash of the large discontinuity is significantly greater than the upward crash, and the small discontinuity is symmetric. The reason

EXHIBIT 9

Equilibriums with a Fixed Hedging Demand



for the asymmetry of the large discontinuity is that its downward crash also embeds the small discontinuity.

It is worth noting that we analyze only situations where the hedging demand does not dominate total demand too much, as this seems to us to be the more realistic case. If hedging demand dominates, we would see a single discontinuity in the equilibrium interest rates, but the changes in the equilibrium interest rates would in most cases have a sign opposite from the change in the fundamental interest rate.

We can now also analyze the sensitivity of the equilibrium interest rate to a change in the fundamental interest rate. Assuming that in the case of multiple equilibriums all equilibriums are attained with equal probability, we can run a simple regression for each possible degree of the importance of hedging, λ:

$$\Delta r = \gamma_0 + \gamma_1 \Delta r^* \tag{7}$$

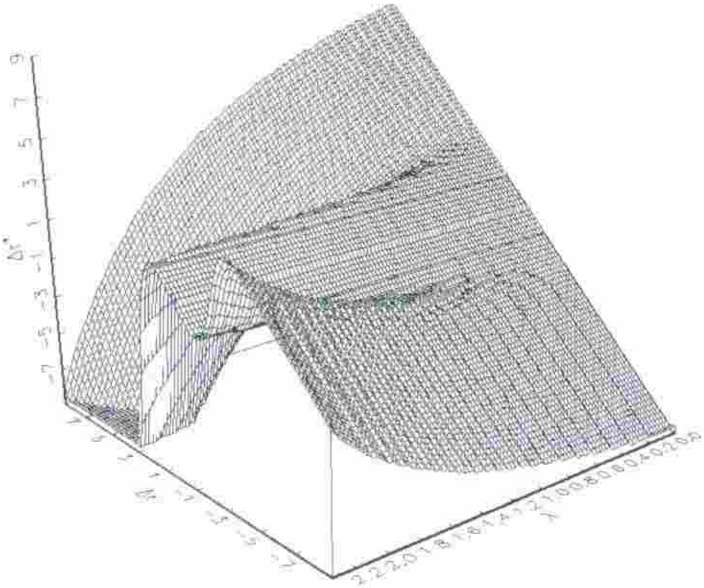
Exhibit 11 shows the results of this regression using the prepayment function with which we illustrated our model before. Note that the equilibrium interest rate becomes more sensitive with the importance of hedging (γ_1). When hedging starts to dominate, the increasing discontinuities reduce this sensitivity until the fundamental and equilibrium interest rate move in opposite directions.

The R^2 of this regression declines constantly before recovering again when hedging starts to dominate. Although the exact shape of these relationships depends on the model specification, in particular the prepayment function, the general properties are quite robust to a wide range of functions. We have not been able to find a prepayment function with these general properties that produces fundamentally different results.

We thus have established some properties connecting the equilibrium and fundamental interest rates that can be empirically tested in order to evaluate the model. Besides the yield of a ten-year T-bond, representing the equilibrium interest rate, we also need the fundamental interest rate for such an investigation. The fundamental interest rate should be determined by monetary policy, which should aggregate all available information on economic conditions. We can thus use the federal funds rate as our fundamental interest rate.

Although the fundamental interest rate for a ten-year T-bond will be different from the federal funds rate, our interest in changes to these rates suggests that the level of interest rates is not relevant. Given properly anticipated monetary policy, we should expect mostly parallel shifts

EXHIBIT 10
Equilibrium Interest Rates



of the yield curve, validating our use of changes to the federal funds rate.

As information on the motivations of traders in financial markets is notoriously difficult to obtain, the importance of hedging, λ, can only be estimated from other sources. We might assume that among holders of MBS a fixed fraction is involved in hedging their exposure, and similarly that a fixed fraction of traders in Treasury securities behave like our investors, and the remainder are treated as noise traders, which we ignore in our model. We can in this case determine the relative importance of the hedging demand as the ratio of the outstanding amounts of MBS and T-bonds.

III. EXPLAINING MOVEMENTS IN THE U.S. BOND MARKET

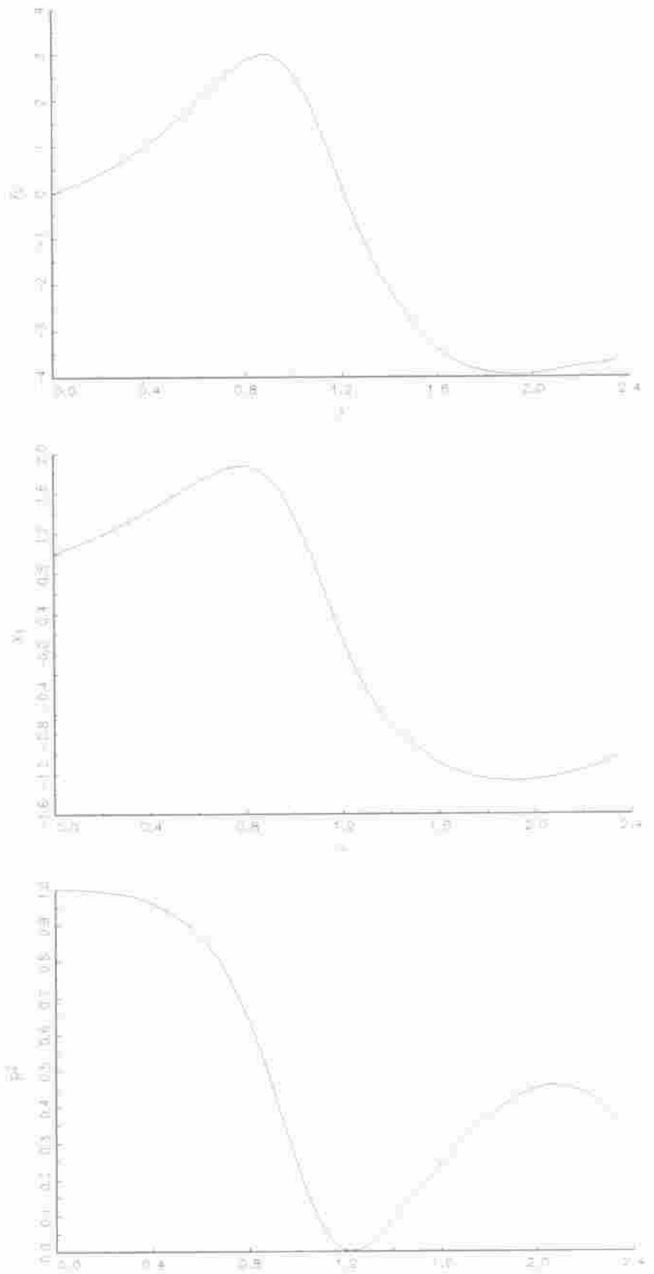
Recent years have seen MBS continue to grow in importance compared to Treasury securities. As Exhibit 12 shows, the outstanding amount of MBS has exceeded that of Treasury securities since 2000, and in early 2003 the trading volume of these securities reached similar levels. We would expect only a small fraction of MBS investors to actually hedge their exposure to prepayment risk; hence, the actual hedging demand for T-bonds will be only a small fraction of this outstanding amount.

Yet a large fraction of Treasury securities are also not available to investors. Substantial amounts are in the hands of monetary authorities, foreign investors (including foreign central banks), and long-term investors such as banks and insurance companies (*see Exhibit 13*). Of the remaining holders of Treasury securities, holding about a third of the outstanding amount, many will not trade actively but hold them as a fixed part of their investment portfolio, e.g., pension funds and many mutual funds. Thus only a small fraction of the total outstanding amount will actually be held by what we call investors. It is therefore reasonable to assume that hedging activities account for a significant fraction of the total demand for Treasury securities.

Although our model suggests that the hedging of MBS is conducted only with ten-year Treasury bonds, and potentially those of shorter maturity in the case of MBS with maturities of under 30 years, we can justify using the entire amount of Treasury securities, as arbitrage along the yield curve is very effective. This arbitrage easily transmits any disturbances in demand and supply of a specific T-bond to all other maturities. Hence, the relevant market can be determined as that of all Treasury securities.

We can now apply our model to the developments in the U.S. bond market. Since Autumn 2002, the T-bond yield has been fluctuating around 4%, with the MBS yield at about 5.5%, for a spread of 150 basis points. The yield remained relatively stable until late April 2003. This period of time makes it reasonable to propose it as the

EXHIBIT 11
Sensitivity of Equilibrium to Fundamental Interest Rate



benchmark from which we will evaluate changes.

The cut in the federal funds rate by 25 basis points in late June 2003 was a well-anticipated move, given the economic indicators. As there had long before been speculation about an even greater cut in the federal funds rate of 50 basis points, it is reasonable to propose that as early as May 2003 the fundamental interest rate had dropped by 25 to 50 basis points.

Exhibit 14 illustrates the effect this change had on the equilibrium interest rate, i.e., the yield of the ten-year T-bond. We propose that the reduction in the federal funds rate was enough to cross the small discontinuity, causing the yield of the T-bond to fall by about twice the reduction in the federal funds rate. Hence, the observed reduction in the yield of ten-year T-bonds by around 90 basis points is consistent with the predictions of the model.

Subsequent to these developments, the economic conditions in the U.S. were generally regarded as slowly improving, suggesting a future rise in the federal funds rate. The ten-year T-bond yield increased by 140 basis points until August 2003, suggesting a new equilibrium located just below the large discontinuity as indicated in Exhibit 14. This equilibrium would correspond to an expectation that the federal funds rate would increase to 1.75% to 2.00%.

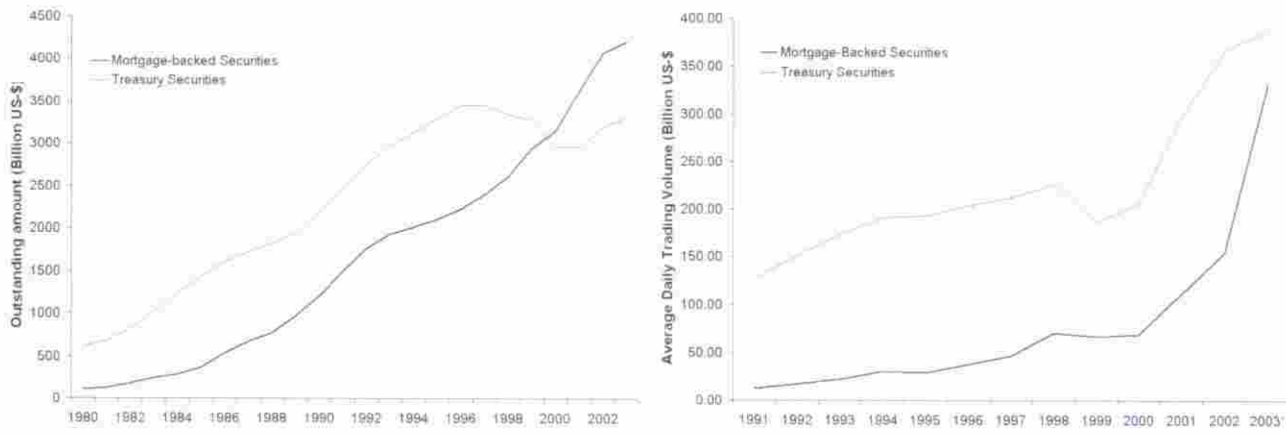
According to many market commentators, this would be a realistic level, given that the economy improved as widely anticipated. A further increase in the expected federal funds rate would in our model be crossing the large discontinuity and be accompanied by an increase in the yield of the ten-year T-bond to around 6%, a level last seen in mid-2000 and not to be regarded as completely unreasonable.

An attempt to find an appropriate prepayment function and parameterization of our model would enable us to provide more precise predictions, but this is beyond the scope of our research here.

A main difference between our model and the real developments is that the model suggests sudden changes in yields, once the discontinuity is crossed. The data, however, do not show such sudden movements. Although they are rapid, they lack the distinctive feature of a crash like the stock market crash in 1987 with large movements in a single day. An explanation for this difference is that our model is static and does not consider how the market changes from one equilibrium to another. These dynamic developments may well be the reason we see only rapid movements but no real crash.

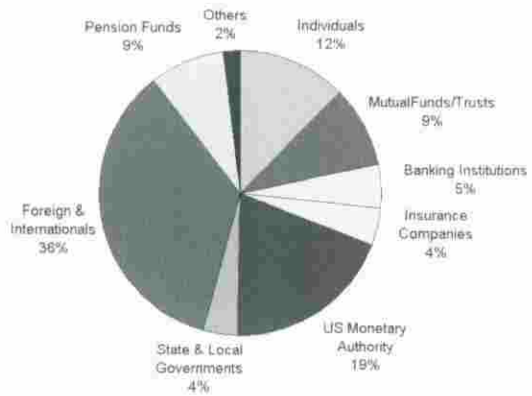
Although the model seems to be able to explain why T-bond yields changed significantly more than the federal funds rate, supporting evidence for the relevance of hedging MBS in this process would strengthen our arguments. Fernald, Keane, and Mosser [1994] argue that the slope of the yield curve changes as a result of hedging MBS. A reduction in the fundamental interest rate should result in a flatter yield curve and an increase in a steeper yield curve. The reason for this change is, according to

EXHIBIT 12
Outstanding Amounts and Trading Volume of MBS and Treasury Securities



Source: The Bond Market Association.

EXHIBIT 13
Ownership of Treasury Securities in 2003



their arguments, that hedging activity affects the yield of the ten-year T-bond by reinforcing the trend with a multiplier effect.

With this multiplier effect, an increase in the yield results in more short sales due to hedging, thus increasing the yield further, which again causes short sales to increase and so forth, until the new equilibrium has been reached. Arbitrage along the yield curve then changes the yields at other maturities accordingly, resulting in the described changes of the slope.

An inspection of the yield curves in Exhibit 15 supports this view. From March through June 2003, the yield curve flattened slightly, while it became significantly steeper until August 2003. We can use this observation as further evidence of the importance of hedging MBS and its influence on equilibrium interest rates of T-bonds.

Fernald, Keane, and Mosser [1994] also point out that, with the same arguments as used for the change in the yield curve, the hedging of MBS increases the sensitivity of the yield of the ten-year T-bond to changes in the federal funds rate. As our model suggests a similar result, we can easily investigate this sensitivity empirically to find further evidence for the relevance of hedging MBS in the bond market.

Following Cohen and Wenninger [1994], we conduct rolling five-year regressions of the monthly changes of the federal funds rate on changes in the yield of the ten-year T-bond as in Equation (7). Then we take the average of our estimates for every year, as well as an average R^2, and plot them against the importance of the hedging demand (the ratio of the outstanding amounts of MBS and Treasury securities). The results are shown in Exhibit 16.

Comparing these results with the theoretical predictions from Exhibit 11, we see a broad consistency for the sensitivity γ_1 and the R^2. As the estimates for, γ_0 are in many cases not statistically significant, the absence of the predicted pattern for this parameter has no further implications for the validity of our results. It is furthermore encouraging that the patterns for γ_1 and R^2 are also consistent with each other, in that they both show low values at the same hedging demand of around 1.0-1.2, the same values as in Exhibit 11.

Exhibit 14
Explaining Movements During Summer 2003

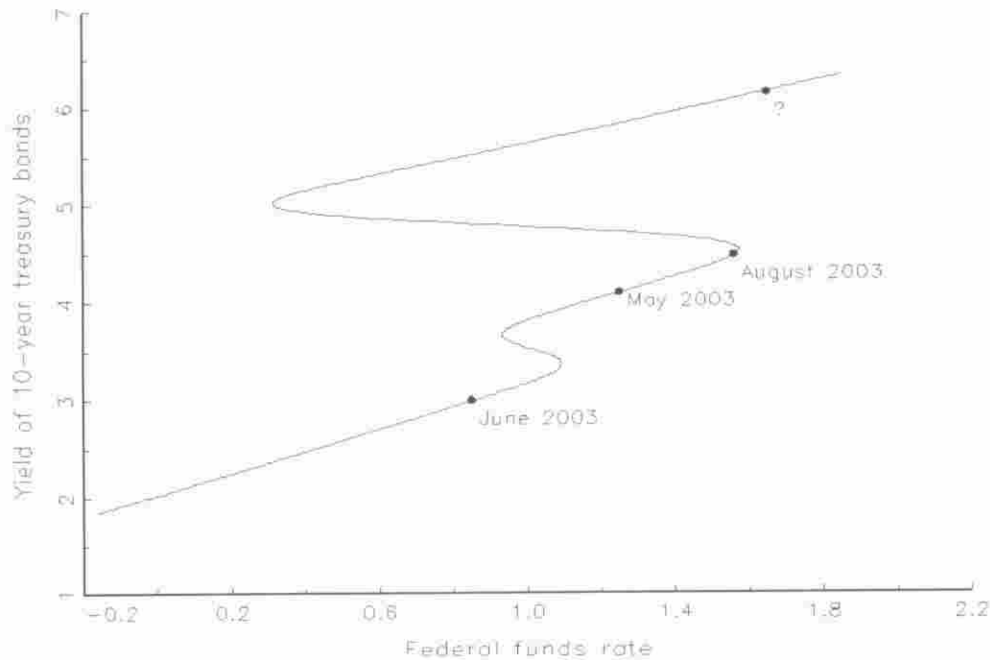
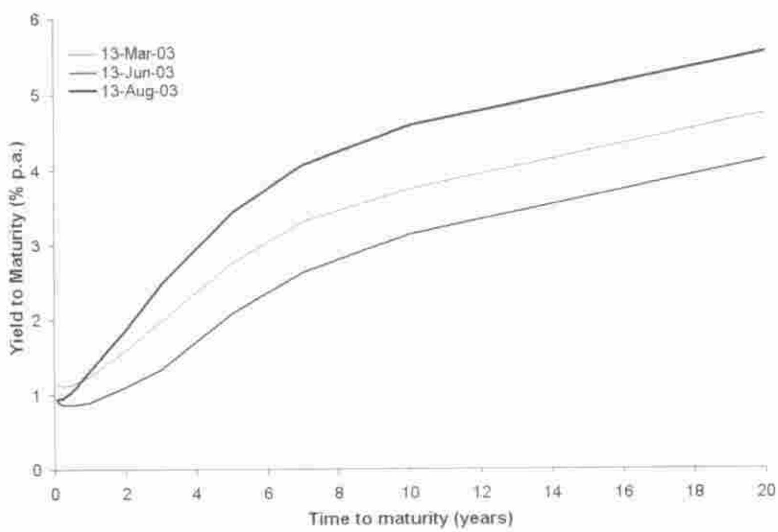
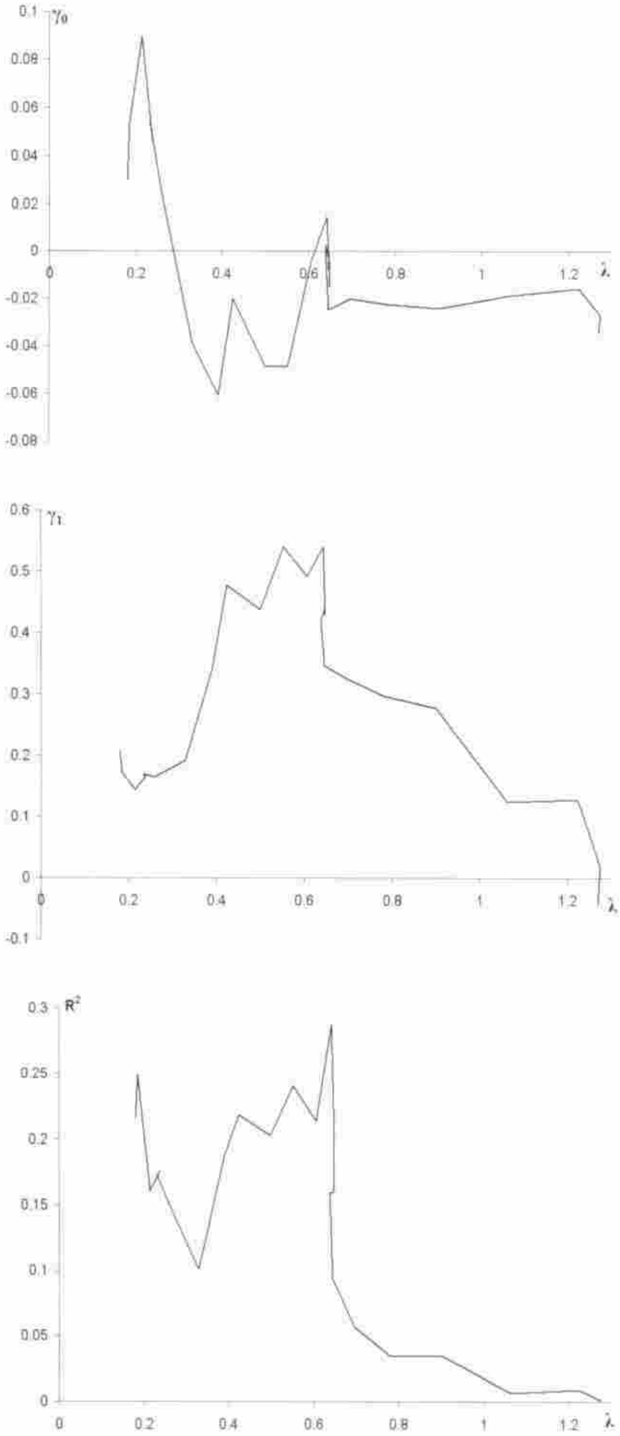


Exhibit 15
Yield Curves for U.S. Bonds



Source: U.S. Treasury.

EXHIBIT 16
Sensitivity of Treasury Bond Yields to Hedging Demand



With five-year rolling regressions and data on the outstanding amounts of MBS available only from 1980, before the amount was very insignificant, the data set is reduced significantly. This relatively small sample size effectively prevents us from applying conclusive statistical tests on the validity of the model. Nevertheless, we find further indications for the influence of hedging MBS on the yield of T-bonds, consistent with the model predictions.

Despite this mounting evidence in favor of hedging MBS as the cause for the recent extreme movements of the U.S. bond market, it remains to be answered why such movements have not been observed earlier and not in other countries. As has been pointed out earlier, we observe discontinuities of a significant size only once the hedging demand has achieved considerable importance. We can argue that the rapid growth of MBS in recent years has now generated discontinuities great enough to be clearly observed despite all the other factors affecting the yields of bonds. In the past, hedging was not important enough to let its effects be detected.

European countries do not have a significant amount of U.S.-style MBS. Mortgages are either refinanced within the banking sector as in Great Britain or cannot be repaid early as in Germany. There is thus not the prepayment risk that investors are hedging and that has been found responsible for creating the discontinuities. For this reason, these countries cannot be subject to similar hedging demands as in the U.S. bond markets, and they consequently do not face such extreme movements.

IV. COMPARISON WITH PORTFOLIO INSURANCE AND THE CRASH OF 1987

Our model has a striking resemblance with that developed by Genotte and Leland [1990] to explain the stock market crash of 1987. Their model also uses hedging strategies to explain the discontinuities that can cause crashes. Despite these similarities, the two models have certain distinctive features that are worth noting here.

The hedging strategies followed in the stock market prior to the crash of 1987, called portfolio insurance, sought to protect investors from loss in the event of a stock market downturn, while they enabled them to gain from further increases in the market. We can thus say that the hedging activity was directed against adverse movements in the very markets invested in. Hedging of MBS is conducted in a different market, the market for Treasury securities.

Furthermore, the primary risk investors hedge against is not interest rate risk, the risk dominating the

Treasury securities market, but prepayment risk. Although these two risks are strongly correlated via the prepayment function, hedging is directed against a risk that is not present in the market used to conduct the hedge.

We can conclude that in our model we observe a difference in the risks hedged and the instruments used, while the two were identical in the case of portfolio insurance. The model is therefore a good example of how activities originating in one market, MBS, can have substantial effects in another market, Treasury bonds. This is further evidence of the increasing interdependence of markets through the creation of new securities.

Another difference between our model and the one for the stock market crash in 1987 is that we generate two discontinuities rather than a single discontinuity. The origin of the single discontinuity in portfolio insurance was the replication of put options as a hedging tool. Hence we observe hedging demand only in the form of short sales, which increase with a market downturn and fade away in an upturn. Our model uses a duration hedge, which not only hedges against a downturn in prices, but also prevents hedgers from making gains in an upmove; hedging demand does not fade away in the case of a market rise, with the consequent two discontinuities.

Although the two models of the stock market crash of 1987 and the bond market are based on a very similar idea—the hedging of investors causing discontinuities that can give rise to crashes—there are some significant differences in the details and the implications.

V. CONCLUSIONS

We have shown how the hedging activity of investors in mortgage-backed securities can induce crashes in the market for ten-year Treasury bonds that are subsequently transmitted to all Treasury securities by arbitrage along the yield curve. A feature of the model is that it introduces two discontinuities, generally of different sizes, which cause the yields of Treasury bonds to fluctuate more than fundamental changes would imply.

We apply the model to explain the recent movements of U.S. bond prices that were generally deemed to be in excess of the changes implied by economic conditions. The sensitivity of bond yields to changes in the federal funds rate are broadly consistent with our model.

There are many interesting questions for future research. We should try to calibrate the model to more precisely fit the data. It would also be important to include the influences of hedging activities in the modeling of interest rates. This then in turn would affect the valuation of bonds, interest rate derivatives, and even mortgage-backed securities, and might even have implications for the conduct of monetary policy. Another strand of research would be a search for other developing influences from various markets on the bond market, such as other securitization markets or the fast-growing market for credit derivatives.

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