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Hedging individual mortgage risk

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Abstract

This paper investigates the feasibility of an individual hedging the interest rate risk involved in planning to take out a mortgage at a future point in time. Simulation using market data indicates that a simple futures hedge reduces the variation in mortgage capacity by about one half. Expected mortgage capacity is very close to 100% of the original capacity at a very low cost. Hedging the individual mortgage with a put futures option is less effective in reducing downside risk and has a higher expected cost. © 1999 Elsevier Science Inc. All rights reserved.

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1. Introduction

One of an individual's more frustrating financial events is watching an increase in mortgage interest rates make one's dream house unaffordable. The housing search often begins with determining the maximum loan for which a borrower can qualify at the current level of interest rates. A 1% increase in rates can easily lead to a shortfall of 10% toward the purchase price of the house.

Although mortgage lenders offer a lock-in, or guarantee, in rates, these are generally good for a limited time and often require that a specific property has been identified. The housing search may easily take longer than the typical 30–60 day lock-in period. The delay is often compounded when the present home must be sold before purchasing a new home.

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Homeowners often begin a serious search for a new home after selling their present home; yet, the decision to sell may well have been predicated upon expecting to be able to move up to a particular price that may be vulnerable to changes in interest rates. This paper examines the feasibility of individuals protecting themselves against unforeseen changes in interest rates that may lead to the disappointment of being unable to make the planned purchase of a home.

1.1. An illustration of the problem

The Smiths have saved $25,000 for a down payment on their dream home. This will serve as the 20% down payment on a $125,000 home, thus avoiding the extra costs of private mortgage insurance (PMI). At an annual percentage rate (APR) of 8%, the Smith's monthly mortgage payment on a 30-year mortgage for principal and interest will be $733.76. Based on the Smith's income, their lender will qualify them for this monthly payment, but no more.

Alas, before the Smiths locate a suitable home, interest rates rise to 9%. Now, the monthly payments of $733.76 will only support a $91,193.63 mortgage, leaving the Smiths $8,806.37 short. Because of the Smiths' current incomes, they will not qualify for the $804.62 payments now needed for the $100,000 mortgage.

For many home buyers the problem is even worse. For example, the normal practice for financing newly constructed homes is to obtain a short-term construction loan with the permanent mortgage rate not being determined until the house receives a certificate of occupancy, that can be many months after the start of construction. Unlike the Smiths, who were deeply disappointed in being unable to buy their dream home, the Jones, who had a custom-built home constructed, are committed to paying the new rate.

1.2. A solution

Both the Smiths and the Jones could reduce a great deal of the uncertainty about their financing by *hedging* their interest rate risk. The organized futures markets have developed over the years precisely to enable risk to be transferred from those unwilling to shoulder it to those willing to bear it. Common textbook examples of those benefiting from hedging are the farmer who is unsure of the price of wheat he will receive at harvest and the baker who is unsure of the price she will pay for wheat in the future. The organized futures exchanges enable the farmer and baker to match these offsetting risks without having to be concerned with locating a person to take the other side of the deal. Furthermore, the exchange's clearinghouse effectively eliminates the credit risk one normally faces when dealing with individuals or corporations. Both the farmer and baker need only be concerned with determining how much to buy or sell and the price they will receive or pay.

2. Literature review

Hedging of mortgage-backed securities has become so commonplace that Fernald, Keane and Mosser (1994) argue that hedging activity related to mortgage securities has affected the level of Treasury interest rates. As would be expected, a voluminous literature has developed to analyze this hedging by financial institutions.

Previous studies on hedging interest rate risk in mortgages have focused on the investor in mortgages rather than the individual home owner. For example, mortgages are typically pooled for resale in a secondary market. Investors purchase securities that share in the cash flow from these mortgage pools. These mortgage-backed securities are subject to not only the pure interest-rate risk of treasury bonds, but also the risk of greatly-accelerated prepayment when rates decline.

The original GNMA futures contract failed in 1985 and the cash settled GNMA futures contract failed in 1986 due to low trading volume. Johnston and McConnell (1989) present evidence that the demise of the GNMA futures contracts was due to the poor design of the futures contracts. The variety of delivery options resulted in poor hedging quality relative to using Treasury bonds in the difficult interest rate environment of the early 1980s. Patel (1994) reports that a futures contract on mortgage interest rates also failed in the London market, apparently because of the inability to actually buy the index underlying the contract.

Follain and Park (1989) show that the optimal hedge ratio for a lender using futures contracts varies with the level of interest rates. They use a regression approach to estimating the best hedge ratio. Goodman and Ho (1997) also find that the regression approach gives better hedge ratios than does using option-adjusted duration. Breeden (1994) finds that hedging using either short-term Eurodollar futures or long-term Treasury bond futures reduced the volatility of investing in FNMA mortgage pools by about 40% during the 1992–1994 period. Breeden (1994) notes that the 7-year Treasury note has the highest correlation with mortgage-backed securities. Breeden (1991) shows that from a lender's perspective, a mortgage is equivalent to issuing a bond and buying a call option, or equivalently, buying a put option. The exercise price of these options is the par value of the bond. Breeden (1991) also finds that increased volatility in interest rates leads to a greater spread between Treasury bond rates and mortgage rates because the imbedded prepayment option becomes more valuable. Murphy and Gordon (1990) suggest that put options on treasury futures may result in better hedges than hedging with the futures contracts themselves if downside risk is considered most important to the owner of a portfolio of mortgages.

In contrast to the literature discussed above concerning hedging of existing mortgages is a smaller literature on hedging commitments to future loans. Berkovitch and Greenbaum (1991) note that banks use loan commitments to act as hedging instruments. The commitment fee paid by the potential borrower may be viewed as the cost of option to obtain a loan at a fixed rate; however, although option pricing models assume all-or-nothing behavior, bank's loan commitments are usually exercised in part. Maris and White (1989) use the Black-Scholes option pricing model to value this loan commitment for residential mortgages. They find that the embedded put option for a 45 day commitment is worth about 1% of the mortgage value, that is also a typical commitment fee. Kutner and Seifert (1991) use a similar methodology to estimate the value of a commitment for residential mortgages over a range of interest rate levels and volatilities. They find that 1–3% of the mortgage value is the fair price for a 30–45 day rate commitment using parameters from the 1985–1987 time period.

Hochstein (1998) quotes practitioners who note that lenders view hedging the mortgage pipeline (the time during which the rate commitment is made) as prohibitively expensive compared with the expected benefit due to the short hedge times and generally low volatility. Cross (1998) suggests that lenders can effectively manage pipeline risk by cutting the time between rate lock and closing the loan.

In contrast to the extensive literature on institutional hedging of mortgage risks, almost nothing has been written about the interest rate risk facing an individual wanting to take out a mortgage at a future date. The most relevant paper is by Sharp (1989) who uses an option pricing model to value the insurance premium (put option) charged in Canada to partially protect homeowners against mortgage rate increases on their variable rate mortgages. He notes that the price of the option is so high that the insurance is rarely purchased.

One other way an individual can deal with interest rate risk is to use an adjustable rate mortgage (ARM). Templeton, Main and Orris (1996) and Chiang, Gosnell and Heuson (1997) both use simulations to assess the risks faced by individuals taking out ARMs. Using an ARM substitutes uncertainty about interest rates in the distant future for uncertainty about interest rates in the near future for the borrower expecting to get a fixed rate mortgage. This paper does not explore the use of ARMs.

3. Methodology and data

3.1. Hedging with futures contracts

A *futures* contract is often viewed as a standardized *forward* contract. A forward contract is a contract to deliver something at a later date where the delivery price is fixed as of the date of the contract. Thus, a loan commitment can be viewed as a forward contract. In practice, the borrower under the loan commitment is not obligated to take the funds, whereas the lender also often has some freedom to not deliver funds. Viewing the commitment, however, as a forward contract aids in visualizing how futures contracts and options contracts may be used in the mortgage origination process. The good to be delivered is the loan and the price is the guaranteed interest rate. Both the lender and borrower face the uncertainty of changing interest rates. The lender's risk is that rates will fall and less income will be generated by the loan than expected, whereas the borrower must deal with the risk of rising rates and the prospect of paying more interest than anticipated. Both parties can minimize the effects of changing interest rates via the futures market. The lender can establish a long position that will rise in value as rates decline by purchasing interest rate futures contracts. Conversely, the borrower can create a short position by selling interest rate futures contracts that will increase in value as rates rise.

Futures contracts have several advantages over forward contracts because of the existence of the clearinghouse. The two parties to the contract do not have to know each other because the clearinghouse will match up their respective futures positions. Neither party needs to be concerned with the others' credit worthiness because of the *margin* requirement imposed by the clearinghouse. Each party posts a good faith deposit of funds with the clearinghouse in a margin account. The clearinghouse requires that funds be deposited in a margin account when a futures position is established. This amount is knows as the initial margin. If losses are incurred by the futures position, then the clearinghouse permits the margin account to fall to a minimum level known as the maintenance level. If the account falls below the maintenance level then the clearinghouse requires that enough funds be deposited to restore the account to the initial level. If gains accrue to the account then any funds that exceed the initial balance can be withdrawn. The clearinghouse adjusts the margin account each day to reflect gains or losses that accrue to the open futures position. This daily adjustment is known as *marking to market* and ensures that the necessary funds will be available to satisfy the contract.

Margin differs from the earnest money usually posted by the home buyer in that both parties to the futures contract make the same initial deposit and then are required to maintain a minimum balance in the margin account. Furthermore, adjusting the margin account balance daily to reflect changes in interest rates ensures that both parties still have a strong interest in fulfilling each end of the bargain. Either party can pass on their obligation to another at any time by entering into an offsetting contract at the then current price via the futures exchange and clearinghouse. Thus, there is an effective exit possibility.

Of course, the one-size-fits-all nature of a standardized futures contract has some disadvantages. Two of the drawbacks that are especially relevant to the case of hedging individual home mortgages are the limited number of discrete sizes of contracts (generally multiples of $100,000) and the less than perfect substitute contract for a mortgage. This relatively poor match between mortgages and futures contracts arises because of the mortgage prepayment option. Because mortgages can be prepaid and retired before maturity, it makes the effective *duration* of a mortgage less than that of a Treasury bond of the same maturity. If one wants to hedge a mortgage based on maturity, then a 30-year Treasury bond contract is available; however, according to Breeden (1994), the closest available substitute for a 30-year mortgage in terms of interest rate sensitivity is the 10-year Treasury note contract.

A third potential drawback to hedging individual mortgage rate risk with futures contracts is that hedging means that the individual is committed (at least financially) to taking out a mortgage at a future point in time. If the individual decides to not take out a mortgage, he must accept whatever losses or gains the futures contract has made without the benefit of the offsetting gain or loss in the size of the mortgage. Therefore, hedging with futures contracts is a serious commitment. This commitment is quite appropriate when a contract for constructing a house has been signed, but may not be appropriate when a family is merely touring Sunday open-houses.

If one is serious about purchasing a house but is uneasy about the obligation imposed by a Treasury bond futures position, then options on Treasury bond futures are a viable alternative. The simplest and most effective strategy is to execute the purchase of a put option on a Treasury bond futures contract. This strategy will protect against rising interest rates, yet will provide the flexibility to benefit from falling rates. When compared to a short futures position, the long put option position usually will require more of a cash outlay when the position is established, however.

3.2. Institutional details

Treasury bond futures and Treasury note futures contracts are traded on the Chicago Board of Trade. Both have a $100,000 face value and an assumed coupon of 8% (beginning in January 2000, the assumed coupon will be 6% for the 10-year note and the 30-year bond). The initial margin for the 30-year T-Bond contract is $2,700, whereas the maintenance margin is $2,000. Initial and maintenance margins for the 10-year T-Note contract are $1,620 and $1,200 respectively. A smaller contract would make hedging an individual mortgage potentially more attractive by reducing the error in the hedge ratio. Such contracts, known as Mini T-Bond contracts, are traded on the Mid America Commodities Exchange. Both a 10-year Treasury note and a 30-year Treasury bond contract are available in $50,000 face value denominations. Several authorities have noted that a 10-year note provides better tracking of mortgage rates than the 20- or 30-year bond. The initial margin required on the 10-year note contract is $810 with a maintenance margin of $600. The corresponding margins on the 30-year bond contract are $1,350 and $1,000. The margins on the mini or half-sized contracts are half the margin on the full-sized contracts traded on the CBOT. The Smiths would need two of the Mid American contracts to approximate the hedging effectiveness of one of the CBOT contracts. In both cases, the margin they would be required to post is only a small fraction of the down payment they have already saved. Thus, the hedge seems financially feasible.

The Treasury bond and note futures contracts are traded on the March-June-September-December cycle. In general, the near-term contracts are considered most liquid; however, because the individual mortgage hedger is not concerned with large positions, adequate liquidity would exist with any of the four maturities. Because the futures contract needs to be closed out before the contract month to avoid the possibility of having to deliver the underlying securities, the Smiths are well advised to select a contract month beyond the time they expect to close on their mortgage.

Most individuals do not have a futures trading account; however, the financial capacity that is necessary to support a futures trading account is well within the reach of many small investors. The Lind-Waldock brokerage firm, one of the nation's largest discount brokerage firms, has as normal requirements to open an account: $5,000 in liquid assets, an annual income of at least $25,000, and $50,000 in equity excluding one's primary residence. These requirements are meant to insure that if the initial margin is depleted, then subsequent margin calls can be met. Note that sharp decreases in interest rates would lead to large losses on the short futures position, thus prudence dictates that at least $10,000 in liquid assets be dedicated to a futures account. Of course, the decrease in interest rates means that a larger mortgage can be qualified for at the same monthly payment, offsetting the loss in the futures position. Moreover, the costs associated with both opening and closing a futures position, i.e., the round trip commissions, are only $29 for a futures contract and $35 for an options contract and are paid when the position is liquidated. A full service broker, however, may charge as much as $200 per contract and impose much stricter liquidity and equity requirements. Although the Smiths seem to have sufficient liquidity by virtue of the $25,000 available for their down payment, they may not have enough equity to establish a futures trading account. If, however, the Smiths restrict their hedging activities to purchasing put options then it may be possible to establish a trading account with the $25,000 in cash. Creation of such an account would be at the discretion of the brokerage house, and is by no means a certainty. On the other hand, the Jones, who are constructing a $250,000 house, have accumulated a $50,000 down payment, enough to satisfy normal equity requirements for establishing a futures trading account.

3.3. Alternative goals

The Smiths and Jones potentially have two alternative goals for their mortgage hedging strategies. The Jones, who are committed to taking out a mortgage to fund their newly-constructed home, may have a goal of minimizing the uncertainty of their mortgage capacity. This goal may be met by hedging with futures contracts at a low effective cost. The Smiths, who are planning on buying a house at some indefinite future time, may be uncomfortable with the knowledge that hedging with futures means foregoing the opportunity to obtain a mortgage at a lower interest rates if rates decline before they find their home. Yet the Smiths are concerned about an unforeseen increase in mortgage rates ruining their chances of obtaining their dream home. Furthermore, the Smiths may decide to not buy a house at all. The Smiths' goal is to ensure that the effective mortgage rate they pay is no greater than the current rate. This goal may be met by purchasing a put option and effectively paying an insurance premium against an increase in rates. If the Smiths decide against buying a home, they forfeit the price of the put option, but have no further financial obligation.

3.4. Data

The data underlying the analysis are from Breeden and Giarla (1992) who present mortgage interest rates for 30-year fixed-rate mortgages and futures contracts on 20-year Treasury Bonds for each month from January 1984 through December 1990. This period of time is one that was especially difficult for a hedger and therefore provides a powerful test of the potential effectiveness of hedging. First, interest rates were quite volatile, sometimes changing more than 3% over a 12-month period. Second, the rates were on a long-term downward trend, meaning that on average, waiting to take out a mortgage would reward the individual with lower rates, albeit with the risk of sharp, sudden increases. This better-than-average performance of the unhedged mortgage makes a tough standard of comparison for the use of a hedge. Finally, this period of time includes the time span when the GNMA futures contract was failing, presumably because of ineffective hedging performance.

Fig. 1 displays the data for the fixed rate (GNMA) mortgage interest rates and the short term T-bill rates for this period. These data are derived from market prices, rather than survey data as shown in Templeton, Main and Orris (1996) that seems to be somewhat smoothed. There were a number of sizable reversals of interest rate trends during this period.

4. Results

4.1. Hedging individual mortgages with futures

Several different scenarios are examined to test the feasibility of hedging an individual's mortgage origination using futures contracts. These scenarios differ in the time from the initiation of the hedge until the mortgage is taken down.

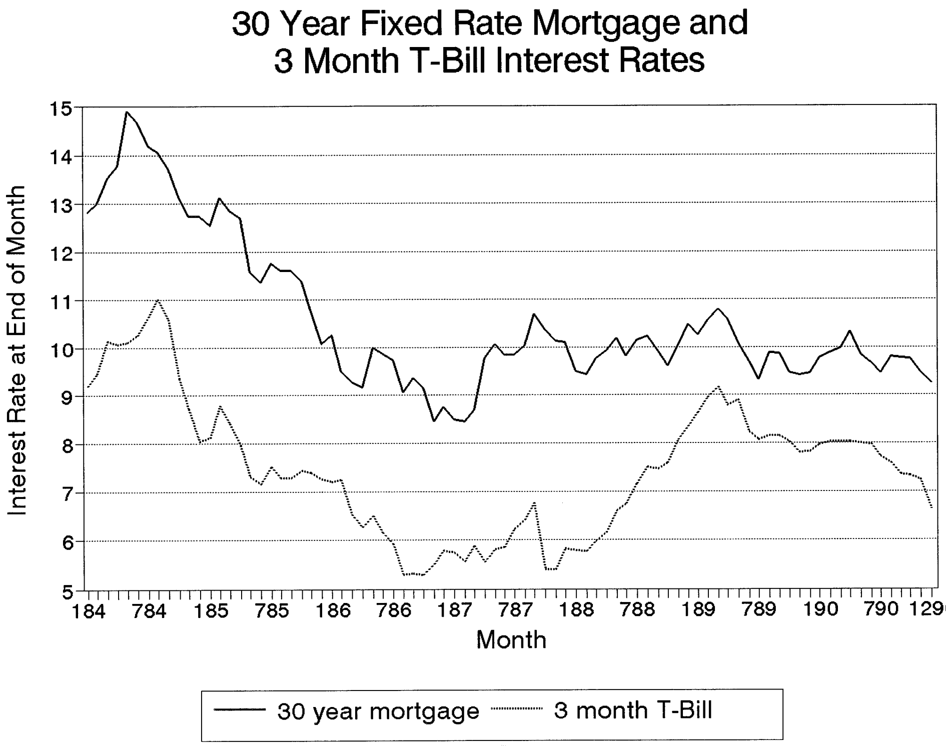

Fig. 1. Historical end of month interest rates for mortgages and Treasury bills.

Each month, the Smiths are assumed to form a twelve month hedge in anticipation of taking out a 30-year fixed-rate mortgage sometime during the forthcoming year. The hedge is formed by selling one futures contract on a Treasury bond. This contract has a face, or notional, value of $100,000, that nicely dovetails with the Smiths' plans for taking out a $100,000 mortgage. Together with their savings of $25,000 for the down payment, the Smiths will be able to afford a $125,000 home. At the beginning of this simulation, January 1984, the price of the one year futures contract is 69.16 (T-Bond futures prices are expressed in decimal form with par being equal to 100) and the Smiths established a short position in T-Bond futures by selling a futures contract for $69,160. This steep discount from the T-Bond future's $100,000 face value is caused by market interest rates being far above the 8% rate underlying the futures contract. If the Smiths finally take out a mortgage in December, and buy back the futures contract at its then current price of 71.06, or $71,060, they will lose $1900 on their futures transactions. Meanwhile, 30-year mortgage rates have declined slightly, from 12.82% in January to 12.74% in December. The monthly payments they would have faced on the January mortgage would pay for a slightly larger mortgage in December, $100,570. Thus, the additional $570 in leverage gained from the declining interest rates mitigated the $1900 loss in the futures market so that on balance the Smiths are $1330 worse off from hedging in this example.

Suppose, however, the Smiths had found their dream house somewhat earlier in the year, and had closed on their mortgage in June. In June, 1984, fixed-rate mortgages had increased to 14.67%! The original monthly payments projected in January could now support only an $88,210 mortgage, exactly what the Smiths feared. Fortunately, increasing interest rates had caused the price of the Treasury bond futures contract to fall to 58.56, or $58,560. This means that when the Smiths closed out their short futures position, they netted $10,600 in their margin account. As a result of their hedging activity, the Smith's total financing available for their house is $88,210 plus $10,600 plus the $25,000 savings, or $123,810. The Smiths only had to raise an additional $1190 to move into their home. The analysis here ignores the interest earned on the $25,000 down payment while awaiting the closing of the transaction. The interest earned would increase the purchase capacity in both the hedged and unhedged cases, but would raise the apparent ending purchase capacity.

Repeating this example for the hedging periods available in our data shows that the average wealth at the end of the 11-month hedging period is 99.20% of the beginning home buying capacity. Furthermore, as expected with hedging, the extreme outcomes declined dramatically. Unhedged, the Smiths faced a worst case shortfall of 15.21% in that era, and a standard deviation (SD) of capacity of 10.42%. Standard statistical interpretation of the SD means that approximately 16% of the time the home buyer would likely be more than 10.42% short of the purchase price of the house. Hedged, the worst case shortfall is 10.90%, whereas the SD is 5.02%. Thus, hedging greatly improves the likelihood of the Smiths being able to afford their dream home.

Repeating the analysis for the shorter hedge periods gives similar results. For the 79 five-month hedge periods, the unhedged worst case shortfall is 11.79% with a SD of 7.23%. Hedged, the worst case shortfall is 12.36% (100 − 87.64) with a SD of 4.08%. The average purchase capacity at the end of the hedging period is 99.96% of the beginning capacity.

When comparing the worst case shortfalls, the reader should note that the hedged and unhedged worst cases do not coincide. In general, the worst case hedged shortfall occurs when rates drop dramatically over the hedged period. The increased loan capacity is more than offset by the losses on the futures transaction. The worst case unhedged shortfall occurs when interest rates increase so that although the loan capacity is diminished no offsetting gain is available from the hedge not taken.

The last column in Table 1 shows the benefit that the borrower obtained via the hedge. This column portrays the change in the dispersion of the hedger's borrowing capacity and the numbers are calculated as the percentage difference between the SD of the hedged position versus the unhedged position. For example, the 5.02% SD of the 11-month hedge is roughly half the 10.42% SD associated with the unhedged 11-month position. This lower SD represents a 51.8% improvement over the unhedged position. The data in this column reveal that the hedges reduced the SD of mortgage capacity for every hedge period. This reduces the Smith's exposure to changing interest rates, reducing the uncertainty about their borrowing capacity by between 43.1% to 51.8%. This finding is in accord with that of Breeden (1994) for the effectiveness of hedging mortgage-backed securities in the more recent 1992–1994 period.

Table 1
Hedging mortgage using futures[a]

Months delay	Unhedged				Hedged with Treasury bond futures				Percent reduction
	Average	SD	Maximum	Minimum	Average	SD	Maximum	Minimum	SD with hedge
0	100.00	0	100.00	100.00	100.00	0	100.00	100.00	0
1	100.39	3.23	108.43	90.84	100.09	1.80	104.75	94.13	44.3
2	100.80	4.81	110.96	88.63	100.17	2.56	105.46	90.47	46.8
3	101.22	5.88	112.94	86.70	99.69	3.08	107.72	88.73	47.6
4	101.66	6.63	116.68	86.92	99.81	3.59	109.58	90.78	45.9
5	102.21	7.23	118.84	88.21	99.96	4.08	112.61	87.64	43.6
6	102.78	7.69	120.97	84.16	99.42	4.35	110.13	85.75	43.4
7	103.29	8.09	122.26	82.32	99.50	4.60	111.29	87.50	43.1
8	103.80	8.59	122.36	82.70	99.61	4.82	110.16	89.26	43.9
9	104.24	9.11	123.69	84.77	99.04	4.87	109.66	87.97	46.5
10	104.69	9.79	128.59	82.47	99.14	4.94	108.47	89.47	49.5
11	105.12	10.42	130.97	84.79	99.20	5.02	108.36	89.10	51.8

[a] Percent of original mortgage capacity based on monthly mortgage payments remaining constant when there is a delay in closing mortgage. Hedging is accomplished by selling one Treasury bond futures contract at time 0 and closing the position when the mortgage is obtained. The contract sold is the fourth nearest contract. Percent reduction refers to the percentage decrease in the standard deviations of mortgage capacity when hedged.

4.2. Put options as insurance against interest rate increases

The Smiths may wish to consider buying a put option as an alternative to forming a hedge with futures contracts. The CBOT trades put and call options on the Treasury bond and Treasury note futures contracts. There are no options available on the smaller Mid American futures contracts. Buying a Treasury futures contract put option would give the Smiths the opportunity to offset an increase in interest rates. If interest rates increase, then the right to sell the futures contract, that underlies the put option, would increase in value. The put option could then be resold to realize this increase in value. The value rises because the put option conveys the right to sell the underlying futures contract at specific price known as the exercise price. An increase in rates would cause the underlying futures contract price to fall below the previously established exercise price. The put option would then expire worthless, and the Smiths would lose the amount paid for the put option.

In general, the value of an option contract does not increase dollar for dollar with the value of the underlying futures contract. The most liquid contracts are for those options with the exercise price nearest the current futures price. For these puts the *delta* is typically about one-half. That is, a decrease in the futures contract of one dollar would result in an increase in the option contract of fifty cents. Therefore, to obtain a similar amount of hedging as obtained with one futures contract, the Smiths would need to purchase two put options.

If interest rates decline, the Smiths would not exercise their put contract, but would instead take out a mortgage at the new, lower rates. The net cost of the hedging position would be the cost of the put contracts and the commissions. If the Smiths decide against buying a house, they can simply sell the unnecessary put options for whatever the then-current price is. This price is guaranteed to be non-negative, and may even result in a large profit if interest rates have *increased* but the Smith's decide against buying a house. Note that if the Smiths had used futures contracts to hedge and decided against buying a house, they would likely reap a similar profit on unwinding their position when rates *increase*. If rates *decline*, however, then the Smiths would face substantial losses in unwinding their futures contracts without being able to use the offsetting gain in mortgage capacity caused by the declining rates.

As before, the Breeden and Giarla data from January 1984 through December 1990 for 30-year fixed-rate mortgages and 20-year Treasury bond futures are employed in different scenarios to test the feasibility of hedging an individual's mortgage origination by purchasing put options. Although liquidity for one year put options on Treasury futures contracts is virtually nonexistent, a complete analysis regarding the hedging alternatives potentially available to individual borrowers requires that we simulate the put option strategies. We used the Black commodity option model examined by Luft and Fielitz (1986) to approximate the price of the put options on the 20-year T-Bond futures contracts. The Black model for a put on a futures contract is:

$$P = e^{-rt}[XN(-d_2) - FN(-d_1)] \tag{1}$$

$$d_1 = \{\ln(F/X) + 0.5\sigma^2 t\}/\{\sigma\sqrt{t}\}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

where F is the price of the underlying futures contract, X is the exercise price, t is the time until maturity, r is the rate of return on a risk free bond that matches the option maturity, and σ is the volatility of the price changes for the underling futures contract. The Breeden and Giarla data provided us with the means to observe or compute all the required inputs except the risk free rates. Breeden and Giarla also provide rates on 1-year, 6-month, and 3-month Treasury bills that match their other observation dates. These rates are used during the simulations as required.

Volatility estimation always is a critical issue in option pricing. Given the amount of monthly data that we had, we chose to estimate the return volatility based on the prior year's worth of monthly returns. There are two consequences to this decision. First: it means that we calculate our annualized SD based on only 12 return observations. Second: it means that the first put option hedge could not be constructed until January of 1985. If we lengthen the estimation interval, then we obtain more degrees of freedom, but run the risk of a poor estimate of current volatility because of extremely old return data. Furthermore, we would have fewer hedging opportunities. If we shorten the estimation interval then we gain more opportunities to hedge, but our estimated SDs become unreliable because of too few degrees of freedom. We feel comfortable that one year's worth of return data is stable enough to captures the true volatility of the underlying futures contract, while providing us with an adequate number of hedging opportunities.

Using the Breeden Giarlia data, we construct one year at the money put option hedges for the Smiths. We find that the average annualized put premiums are 4.36%, and that the put deltas are approximately 0.5 in absolute value as expected. These figures are generally

Table 2
Hedging mortgage using put options[a]

Months delay	Unhedged				Hedged with two Treasury bond futures puts				Percent reduction
	Average	SD	Maximum	Minimum	Average	SD	Maximum	Minimum	SD with hedge
0	100.00	0	100.00	100.00	100.00	0	100.00	100.00	0
1	100.39	3.23	108.43	90.84	103.14	10.52	130.04	82.77	−226.7
2	100.80	4.81	110.96	88.63	101.79	10.40	127.91	78.52	−116.2
3	101.22	5.88	112.94	86.70	101.46	9.84	125.33	79.58	−67.3
4	101.66	6.63	116.68	86.92	101.18	9.56	124.92	75.67	−44.2
5	102.21	7.23	118.84	88.21	100.98	9.56	124.35	76.07	−32.2
6	102.78	7.69	120.97	84.16	100.26	9.83	124.24	78.21	−27.8
7	103.29	8.09	122.26	82.32	99.96	9.60	123.74	80.30	−18.7
8	103.80	8.59	122.36	82.70	99.87	9.69	123.61	79.96	−12.8
9	104.24	9.11	123.69	84.77	99.38	9.87	123.60	80.75	−8.3
10	104.69	9.79	128.59	82.47	99.17	9.64	123.60	83.43	1.2
11	105.12	10.42	130.97	84.79	98.60	9.35	123.60	83.73	10.3

[a] Percent of original mortgage capacity based on monthly mortgage payments remaining constant when there is a delay in closing mortgage. Hedging is accomplished by buying two Treasury bond futures put options at time 0 and closing the position when the mortgage is obtained. The put option bought is the fourth nearest contract. The striking price is the nearest to the money. Percent reduction refers to the percentage decrease in the standard deviations of mortgage capacity when hedged.

Note: The negative percent reduction in standard deviation means that the short-term hedges increased the risk. The average premium paid for one put is 4.36 (a total of $8,720 for the two puts used in this example).

consistent with the average option values given by Maris and White (1989), Sharp (1989) and Kutner and Seifert (1991). The inverse of the put option delta's absolute value establishes how many put options must be purchased when attempting to hedge a drop in the futures contract price that is the result of rising interest rates. Given these deltas, the individual would need to buy two put contracts to give about the same protection as one futures contract. Thus, the individual would need to pay about 8.72% of the anticipated mortgage to provide protection against an increase in interest rates for one year. Individual borrowers may recover some of this premium, especially if they decide against taking out a mortgage. If interest rates increase, the individual may be able to sell the put option for more than the purchase price offsetting the lower mortgage they would qualify for. If rates, however, decline substantially, the put will become worthless.

Table 2 presents the results of the put option hedging simulations. The "Unhedged" results are identical to those presented in Table 1. The "Hedged" results reflect the outcomes of the put option strategies. Observe that on average, the put options preserve the borrowing capacity quite well. If the average hedging performance of the put options is compared with the average hedging performance of the futures contracts, the options dominate; however, when the percentage reduction columns are compared, the put options perform horribly.

Recall that the futures hedge reduces the borrower's exposure to changing interest rates in every hedge period. The data in the last column of Table 2 show that the put options reduce the dispersion associated with borrowing capacity for only two hedge periods: the 10-month and 11-month periods. Moreover, the improvement is minor when compared to the improvement achieved via the futures contracts: 10.3% versus 51.8% for the 11-month hedges, and 1.2% versus 49.5% for the 10-month hedges. Finally, the negative values indicate that the put option hedges actually increase the risk to the borrower. Why do the options perform so poorly?

We believe that the poor hedging performance is caused by the fundamental differences between the two types of instruments. First, when a futures hedge is constructed, only the initial margin deposit is required. This $2,700 requirement is only a fraction of the $8,720 required to establish a hedge via the purchase of two put options. Second, the at the money options provide the borrower with full insurance against falling interest rates for the life of the option. Thus, the longer the option's term, the more expensive the insurance coverage. Third, the put options also provide the flexibility to take advantage of more favorable rates. If rates fall sufficiently far, then the put option will expire worthless, and the borrower can capture the much lower rate, thus lowering the effective borrowing rate. Conversely, the futures contract locks in a borrowing rate when the hedge is established. Even if rates drop dramatically, the borrower's effective rate is determined by the futures hedge at the time it is created. The ability to capture a lower effective rate, coupled with the long term insurance makes the put option very expensive. Finally, if interest rates remain stable and prices do not change, then no gains or losses accrue to the futures margin account and the futures hedger neither suffers a loss nor enjoys a gain. The options hedger will lose the entire amount paid for the options, however. The reason is that if the market remains stable, then the put options never gain any intrinsic value and thus expire worthless. The potential gains and losses due to the put option's flexibility are reflected in the range of outcomes reported in Table 2. Note the relatively large differences, when compared to the futures values in Table 1, between the maximum and minimum values for all the put option hedges.

Given these results, we believe that the best alternative available to an individual borrower for hedging unwanted mortgage interest rate risk is provided by interest rate futures contracts. Mortgage interest rate hedges constructed via put options written on interest rate futures contracts do little to reduce a borrower's interest rate exposure, and are too expensive to justify the lower equity requirements.

4.3. Potential difficulties

All hedging programs face potential difficulties that may prevent the hedgers from completely meeting their objectives. One of these difficulties involves what is known as *tracking error*. Tracking error springs from the commodity underlying the futures contract being a different commodity than that traded in the spot market. In the case of hedging mortgages, no futures contract exists on newly issued mortgages (the spot commodity). Therefore, the hedger will need to use Treasury bond or Treasury note futures. Ten-year Treasury note futures have a very high, but not perfect, correlation with current mortgage rates. If T-note rates temporarily zig while mortgage rates zag, tracking error will occur.

Basis risk is another difficulty faced by a hedger. Basis risk occurs because the hedge is rarely held to maturity. When the futures contract expires, the spot and futures prices are certain to be equal; however, before maturity, the futures and spot prices can diverge.

Although the basis, the difference between the spot price and futures prices, tends to decline over time, this decline is not perfectly predictable except at the moment of delivery.

A third potential difficulty with a mortgage hedging program for individuals is that the individual may decide not to buy a house. This means that the individual will need to unwind the hedging position. In the case of the futures contract, this is easily done by entering an offsetting contract. This offsetting contract will lock in any gains or losses in the futures market. Because, however, the individual will not be taking out a mortgage, there is no offsetting loss or gain in the spot market. Thus, if interest rates have fallen when the individual decides to close out the futures position, there will be a net loss or decrease in wealth. This take-down risk is diversifiable in the case of the lender, but is not for the individual.

A hedge using options is also subject to volatility risk. Volatility risk causes the hedge option to less perfectly track the underlying asset's price. If interest rate volatility increases, as is often the case when rates increase, the value of the option increases explosively. Conversely, if rates stabilize, the volatility declines, dragging down the value of the option, so that less of the original premium will be recovered when the hedging position is unwound.

5. Conclusions

Simulation shows that hedging individual mortgage rate risk with futures contracts reduces the SD in wealth available for housing by about 50%. Although total variation is reduced, substantial downside risk remains. The expected cost of this hedge is near zero.

Hedging with put options on futures contracts is much less effective in reducing downside risk, and has a substantially greater cost. The typical annualized put premium (the cost of buying the put options) is about 5–10% of the mortgage value in our simulation time period. The actual cost could be greater or less, depending upon interest rate dynamics. Furthermore, there is minimal reduction in variation of wealth available for housing when hedging with put options.

This paper has established that hedging interest rate risk before taking out a mortgage is feasible for individuals, and potentially effective by normal financial measures. Yet, the practice is virtually unknown.

A possible explanation is that individuals are not aware of the potential advantages to entering a mortgage hedge and need education on the process. This paper provides a basis for a financial planner to aid an individual in making this choice; however, a financial planner may want to consider how this process would seem to an individual client.

A number of papers in behavioral finance have suggested that people perform mental accounting that segregates gains and losses. This means that, rather than integrating the gains and losses (the essence of a hedging policy), individuals focus on the losing side of the hedge. Because all effective hedges will have a losing side, the individual needs to be educated in financial thinking. This is a time-consuming project, that needs to be accomplished each time a client faces this prospect. Furthermore, about half of the time, an individual will observe *ex post* that they would have been better off without the hedge and perhaps blame the advisor.

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