Requiem for a Market: An Analysis of the Rise and Fall of a Financial Futures Contract

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Futures contracts often include a variety of delivery options that allow participants flexibility in satisfying the contract. These options have the potential to broaden the appeal of the contract. However, if these options are valuable, they may reduce the hedging effectiveness of the contract. This article analyzes the GNMA CDR futures contract that appears to have failed because of flaws in the contract's design. For the first 6 years following its introduction, the contract attracted significant and increasing volume, but, subsequently, the volume declined to almost zero. Over the years during which the volume experienced its most dramatic decline, the Treasury-bond futures contract provided a better hedge for current coupon GNMA securities than did the GNMA CDR futures contract. And, over this same period, the value of the quality option embedded in the contract often exceeded 5 percent of the futures price and reached a level of 19 percent at one point. We interpret the evidence to indicate that the contract failed because the delivery options reduced the hedging effectiveness of the contract for current coupon mortgage securities.

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Futures exchanges constantly search for new contracts that will generate sufficient interest to sustain a profitable level of trading volume for the exchange. Thus, the determinants of a futures contract's success or failure are a significant concern for futures exchanges.[1] Still, despite much careful analysis before the fact, approximately three-fourths of all futures contracts that are introduced never attract more than limited trading volume. These contracts soon fade from existence. Contrarily, if a newly introduced contract does attract significant interest, the contract typically continues to trade successfully. It is unusual for a contract to experience initial popularity and to fail subsequently.

In 1975, the Chicago Board of Trade introduced the Government National Mortgage Association (GNMA) Collateralized Depositary Receipt (CDR) futures contract. The GNMA CDR is a contract on mortgage-backed securities and, as such, was the first interest rate futures contract. As shown in Table 1, for the first six years following its introduction, this contract attracted significant and increasing volume. By 1980, annual trading volume had climbed to over 2.3 million contracts. However, in the following years, volume declined precipitously. By 1985, annual volume was less than 90,000 contracts. During 1987, fewer than 10,000 contracts traded. The decline of the GNMA CDR futures contract, during a period in which not only the market for mortgage-backed securities, but also the market for other interest rate futures contracts were growing rapidly, is puzzling. This article investigates the demise of the instrument.

The next section presents a hypothesis to explain the eventual failure of the GNMA CDR futures contract. We hypothesize that, at the outset, the hedge provided by the contract was effective for current coupon (i.e., newly produced) mortgage securities, but that the hedge's effectiveness subsequently deteriorated. To test this hypothesis, a measure of hedging effectiveness is calculated in Section 2. The results indicate that the absolute quality of the hedge provided by the GNMA CDR contract for current coupon mortgages declined after 1982, and that the quality of the hedge also declined relative to that provided by the Treasury-bond futures contract, so that, by 1983, the Treasury-bond futures contract provided a superior hedge for current coupon mortgages. Section 3 argues that the decline in the hedging effectiveness of the GNMA CDR contract can be attributed to the delivery options embedded in the contract, which can drive a wedge between the futures price and the cash price of current coupon mortgages, thereby reducing the effectiveness of the hedge for these securities. Three of the GNMA CDR contract's delivery options are considered in detail: the quantity option, which permits the short to determine the delivery quantity within a specified range; the perpetuity option, which permits the long to

[1] Academicians also have investigated the determinants of successful futures contracts. Black (1986) has developed an empirical model to predict whether a newly introduced contract will succeed. Duffie and Jackson (1988) present a theoretical analysis of the same question. In a slightly different spirit, Silber (1981) documents minor evolutionary changes in various futures contracts. In the struggle for survival, evolutionary modifications are often made to produce a contract with greater staying power.

Table 1
Annual trading volume of the GNMA CDR futures contract, 1975–1987

Year	Volume, thousands of contracts
1975[1]	20
1976	129
1977	422
1978	953
1979	1371
1980	2326
1981	2293
1982	2056
1983	1693
1984	862
1985	84
1986	24
1987	8

[1] Trading in the GNMA CDR futures contract began on the Chicago Board of Trade on October 20, 1975.

postpone transfer of the delivery asset indefinitely in exchange for a fixed monthly payment; and the quality option, which permits the short to deliver securities bearing any available coupon interest rate. We conclude that the quality option is most likely responsible for the loss of hedging effectiveness of the GNMA CDR for current coupon mortgages. Section 4 provides a commentary on the empirical results. A final section concludes.

1. Hypothesis

It is generally presumed that hedging demand is an important determinant of a futures contract's success. Hedgers are investors who plan to engage in a future sale or purchase of an asset and wish to reduce their uncertainty regarding the future price of the asset. They typically have a disproportionate share of their wealth (or their production needs) invested in a particular asset and wish to reduce the exposure of their portfolio to the price variability of this particular asset.

To assess the hedging effectiveness of the GNMA CDR contract, it is necessary to identify the asset that is being hedged. Mortgage bankers, who are likely to be the largest holders of undiversified mortgage portfolios, are institutions which originate mortgage loans and package them for resale in the secondary market. They are exposed to interest rate risk on mortgages written at the current market interest rate between the time when the loans are made and the time when they are sold in the secondary market. Thus, their hedging demand is concentrated in current coupon mortgages or current coupon mortgage-backed securities.[2]

[2] The belief that hedging demand in mortgage securities is concentrated in the current coupon security is widely held among practitioners. For example, "The current coupon GNMA is the bellwether of the mortgage-backed securities market. A key feature of the new CBOT [futures] contracts is their unique ability to track current coupon GNMA prices. By tracking the current coupon, they provide mortgage-backed securities dealers, mortgage bankers, and savings and loans with a simple, effective risk-management tool." [*The Financial Futures Professional* (1988, p.4)].

Following the introduction of the GNMA CDR futures contract, several other interest-sensitive futures contracts were introduced. Our hypothesis for the rise and fall of the GNMA CDR futures contract is that, initially, the contract provided a superior hedge for current coupon mortgages and mortgage-backed securities, but that during the early 1980s the hedging effectiveness of the GNMA CDR futures contract declined in both absolute terms and relative to that of another futures contract. This reduced the demand by current coupon hedgers and the resulting reduction in liquidity reduced the attractiveness of the contract to other investors as well. To test this hypothesis, we estimate the hedging effectiveness of the GNMA CDR contract over time and compare it with the hedging effectiveness of competing contracts.

2. Hedging Effectiveness of the GNMA CDR Futures Contract

Following Ederington (1979), Figlewski (1985), and Black (1986), we measure hedging effectiveness as the reduction in price variation that results when the asset to be hedged is combined with a futures contract in such a way as to minimize the variance of the two-asset portfolio.[3] Ederington (1979) demonstrates that the percentage reduction in variation that is achieved by combining the variance-minimizing quantity of a futures contract with the asset to be hedged is the square of the correlation between changes in the price of the asset to be hedged and changes in the futures price. Let $\tilde{R}_S$ be the return on the asset to be hedged (i.e., the spot asset) over the time period that the hedge is in effect and let $\tilde{R}_F$ be the "return" on the futures contract over the same period.[4] The percentage reduction in variation that can be gained by hedging is equal to the square of the correlation between $\tilde{R}_S$ and $\tilde{R}_F$. This quantity can be estimated by the coefficient of determination (i.e., the R-squared) of the regression

$$\tilde{R}_S = \beta_0 + \beta_1 \tilde{R}_F + \tilde{\epsilon} \quad (1)$$

where the returns are computed over the time period that the hedge is in effect.

Three different futures contracts are considered as potential hedging instruments for current coupon mortgage securities: the GNMA CDR, the Treasury bill, and the Treasury-bond futures contracts. Each of these contracts has four maturities each year—March, June, September, and December—and the underlying security for each contract is a debt instrument backed by the U.S. government.

The underlying assets for the GNMA CDR futures contract are GNMA

[3] For earlier work exploring the portfolio approach to choosing a hedging strategy, see Johnson (1960) and Stein (1961).

[4] Because no dollar investment occurs when an investor purchases a futures contract, futures contracts have no return in the proper sense. We define the "return" on a futures contract as the change in the futures price divided by the initial price.

mortgage-backed securities. Deliverable securities are backed by pools of single-family mortgages with initial terms-to-maturity of 29 or 30 years. Every mortgage in the pool may be prepaid (i.e., may be called) by the mortgagor at any time and every mortgage in the pool is insured by either the Federal Housing Administration (FHA) or the Veteran's Administration (VA). Both prepayments by mortgagors and prepayments by insurers in case of default are passed through to investors on a pro rata basis.

The stated (or par) delivery asset for the GNMA CDR futures contract is $100,000 of remaining principal balance on GNMA securities bearing an 8 percent coupon.[5] However, the seller of the contract (the short) may deliver securities with any available coupon rate. When securities bearing coupon rates other than 8 percent are delivered, the dollar amount of remaining principal balance is adjusted by predetermined "conversion factors."

The conversion factors were developed when the GNMA CDR contract was initially designed. At that time, the conventional procedure for computing yields on mortgage-backed securities assumed that only regularly scheduled principal and interest payments would be made during the first 12 years following issuance of the security.[6] At the end of 12 years, the remaining principal balances on the underlying mortgages were assumed to be repaid in full (i.e., all the mortgage loans were assumed to be called at the end of 12 years). With this assumption, a mortgage security's yield is that discount rate that equates the security's market price with the assumed set of future cash flows.

The conversion factors for securities with coupon interest rates other than 8 percent were determined as if the yield on securities of all coupon rates would be the same as the yield of an 8 percent GNMA security selling at par. That is, the market value of a security with $100,000 of principal balance remaining was estimated for securities of every coupon rate by discounting their assumed future cash flows (i.e., their regularly scheduled principal and interest payments for 12 years and their remaining principal at the end of 12 years) with a monthly discount rate of 8.0/12 percent.[7] Then, the conversion factor for each security was determined by dividing $100,000 by the present value of the assumed future cash flows. The principal balance that the short must deliver is equal to $100,000 times the

[5] The coupon rates on the certificate are 0.5 percent below the rate on the underlying mortgages. Of the 0.5 percent, 0.44 percent is retained by the servicer who collects and distributes the mortgage payments and 0.06 percent is paid to GNMA for insuring the pool against default by the servicer. Thus, an 8 percent certificate represents a claim to a pool of 8.5 percent mortgages.

[6] In actuality, yield calculations for all mortgage-backed securities, even those that have been outstanding for some period of time, assumed that the loans would be outstanding for the next 12 years and that all loans would be called at the end of 12 years. For further discussion of this procedure, see Curley and Guttentag (1977).

[7] In actuality, because of a two-week delay between the time when the mortgagor makes a monthly payment and the time at which the investor receives the cash flow, the annual yield of an 8 percent GNMA security selling at par is 7.96 percent and the monthly discount rate used to determine the conversion factors is 7.96/12 percent.

conversion factor. This procedure ignores the propensity for high coupon mortgages to be called earlier than low coupon mortgages. Thus, the assumption that all securities will be called at the end of 12 years causes the call option on high coupon mortgages to be undervalued relative to the call option on low coupon mortgages. Because the call option reduces the value of a security, the conversion factors overstate the value of high coupon securities relative to low coupon securities. Under this convention, with all else equal, the short position will find it advantageous to deliver high coupon securities to satisfy the futures contract.

The Treasury-bill futures contract, by comparison, is relatively simple. The underlying security is a short-term (a 90-, 91-, or 92-day) pure discount bond. The delivery quantity is $1 million.

The Treasury-bond futures contract is similar in many respects to the GNMA CDR. Like the GNMA CDR futures contract, the par asset is an 8 percent coupon bond and the delivery quantity is $100,000 of par bonds. Treasury bonds with 15 years to maturity or to first call are eligible for delivery. Like the GNMA contract, the Treasury-bond contract contains a provision allowing for delivery of bonds with coupon rates other than 8 percent. Conversion factors are used to determine the price to be paid when securities with coupon rates other than 8 percent are delivered to satisfy the contract. However, unlike GNMA securities, because the date of first call must be at least 15 years in the future, the call option has almost no effect on the price of deliverable Treasury bonds.

Tests of the ability of each of the three futures contracts to provide hedging protection for current coupon GNMA securities are conducted by estimating the regression in Equation (1). In the regressions, the dependent variable is the return of the current coupon GNMA security over a specified holding period. The independent variable is the return on one of the three futures contracts over the same holding period.

Daily GNMA cash prices were obtained from Data Resources, Inc., for the period January 1976 through August 1985.[8] Prior to December 1, 1983, the FHA and VA set maximum interest rates for mortgages which they insured. For this time period, the current coupon rate is based on the maximum allowable mortgage rate. After November 30, 1983, FHA ceilings were abolished. From December 1, 1983, onward, the current coupon is chosen to be the GNMA coupon rate which corresponds most closely to the average rate reported in the concurrent Federal Home Loan Bank Board mortgage interest rate survey.

Daily futures prices were obtained from Dunn and Hargitt, Inc. The futures prices are taken from contracts which have at most three months to maturity, but which are not in the delivery month. Because each contract

[8] The data consist of daily offering prices for each coupon with sufficient volume in the secondary market for a price to be quoted. The prices are averages of large dealer quotations and are timed to coincide with the closing of the New York Stock Exchange.

Table 2
Hedging performance of the GNMA CDR, Treasury-bond, and Treasury-bill futures contracts for the period 1976–1985 for hedges of 1, 5, 10, and 20 trading days

Time period[1]	Length of hedge, (days)	Number of observations[2]	Coefficient of determination: GNMA[3]	Coefficient of determination: Treasury bill/ Treasury bond[4]
A. Treasury bills				
1976–1985	1	2376	.59	.03
	5	485	.81	.13
	10	243	.83	.19
	20	116	.89	.45
1976–1979	1	987	.43	.01
	5	201	.72	.03
	10	100	.76	.05
	20	48	.93	.31
1980–1982	1	735	.66	.05
	5	151	.90	.32
	10	75	.92	.44
	20	36	.95	.67
1983–1985	1	654	.48	.00
	5	133	.56	.00
	10	66	.54	.05
	20	32	.64	.04
B. Treasury bonds				
1975–1985	1	1967	.61	.58
	5	401	.83	.83
	10	202	.83	.83
	20	96	.89	.90
1977–1979	1	575	.53	.50
	5	117	.86	.76
	10	58	.91	.85
	20	28	.96	.90
1980–1982	1	735	.66	.58
	5	151	.90	.85
	10	75	.94	.86
	20	36	.95	.92
1983–1985	1	657	.47	.58
	5	133	.55	.78
	10	67	.61	.81
	20	32	.64	.86

[1] The Treasury-bill sample begins in January 1976; the Treasury-bond sample begins in August 1977; both samples end on August 30, 1985.

[2] The difference between the number of daily observations for one-trading-day hedges in panels A and B for the period 1983 through 1985 reflects missing observations for the Treasury-bill contract.

[3] The R-squared of regression (1) when the GNMA CDR futures contract is the hedging instrument.

[4] In panel A, the R-squared of regression (1) when the Treasury-bill futures contract is the hedging instrument. In panel B, the R-squared of regression (1) when the Treasury-bond futures contract is the hedging instrument.

matures quarterly, this procedure yields a single futures price for each day of the sample period.

To ensure comparability across competing contracts, an observation is included in the regressions only if price data are available for the current coupon GNMA security, for the GNMA CDR futures contract, and for the competing or cross-hedge futures contract, both on the trading day on which the hedge is initiated and Δt trading days later, where Δt is the number of days the hedge is maintained. Thus, the observations in the GNMA CDR futures contract regression and in the cross-hedge futures contract regression are contemporaneous. Hedges are initiated sequentially, with a new hedge established on the first trading day following the close of the previous position. Hedging effectiveness is estimated for holding periods of 1, 5, 10, and 20 trading days.

Panel A of Table 2 contains the results for GNMA and Treasury-bill futures contracts for the entire sample period, January 1976 through August 1985, and for three nonoverlapping subperiods: January 1976–December 1979, January 1980–December 1982, and January 1983–August 1985. Panel B contains a parallel set of results for GNMA and Treasury-bond futures contracts. The Treasury-bond sample encompasses the period August 1977 through August 1985. Differences in sample periods for panels A and B are the result of different initiation dates for Treasury-bill and Treasury-bond futures contracts. The Treasury-bill and Treasury-bond contracts began trading in January 1976 and August 1977, respectively. The fourth and fifth columns of the table contain the R-squared obtained from the regression in Equation (1) for the GNMA CDR contract and either the Treasury-bill contract (panel A) or the Treasury-bond contract (panel B).

For the entire sample period, 1976 through 1985, the GNMA CDR futures contract's hedging effectiveness is fairly good: The R-squared exceeds 80 percent for hedges of one week or longer. However, hedging effectiveness varies substantially across the various subperiods. For the period 1976 through 1979 the reduction in variation exceeds 70 percent for hedges of one week or longer. For the period from 1980 through 1982, the reduction in variation exceeds 90 percent for hedges of one week or longer. For the period 1983 to 1985, however, the R-squared is less than 65 percent for hedges of the same length.

For the entire sample period, hedges with the Treasury-bill futures contract reduce the GNMA cash price variation by at most 45 percent. For the period 1976 to 1979, the reduction in variation is less than 32 percent for all hedges. Even for the period 1980 through 1982, where the Treasury-bill contract is most effective, the R-squared is less than 68 percent for all holding periods. For the critical period 1983 through August 1985, when the GNMA CDR volume declined precipitously, the R-squared provided by the Treasury-bill futures contract is at most 5 percent, regardless of the length of the hedge. In no time period, for hedges of any length, is the hedging effectiveness of the Treasury-bill contract for current coupon mortgage securities greater than that of the GNMA futures contract.

Turning to panel B, for the entire sample period, 1977 through August 1985, the R-squared produced by the Treasury-bond futures contract exceeds 80 percent for hedges of one week or longer and is very similar to that produced by the GNMA contract. However, the more intriguing results are those for the three subperiods. In the first two subperiods, 1977 through

Table 3
Hedging performance of GNMA CDR futures contract and Treasury-bond futures contract by year for the period August 1977 through August 1985 for hedges of five trading days

		Coefficient of determination	
Year	Number of observations	GNMA[1]	Treasury bond[2]
1977	16	.74	.71
1978	50	.80	.75
1979	50	.90	.80
1980	50	.93	.89
1981	50	.94	.83
1982	50	.85	.83
1983	50	.54	.77
1984	50	.58	.77
1985	33	.62	.88

[1] The *R*-squared of regression (1) when the GNMA CDR futures contract is the hedging instrument.
[2] The *R*-squared of regression (1) when the Treasury-bond futures contract is the hedging instrument.

1979 and 1980 through 1982, the hedging effectiveness of the GNMA contract exceeds that of the Treasury-bond contract for hedges of every length. These results indicate that the GNMA CDR futures contract provided a superior hedge relative to that offered by the Treasury-bond contract in the first two subperiods. However, in the third subperiod, which corresponds to the period when GNMA CDR futures volume was declining, the hedging effectiveness of the Treasury-bond contract exceeds that of the GNMA contract for hedges of all maturities. That is, between 1983 and 1985, not only does the hedging effectiveness of the GNMA futures contract decline relative to that of the earlier time periods, but, additionally, the Treasury-bond futures contract provides a better hedge for the current coupon GNMA than does the GNMA CDR futures contract.

To investigate more closely the hedging effectiveness of GNMA and Treasury-bond contracts over time, the regressions are repeated for each year for holding periods of five trading days. The results are reported in Table 3. In 1981, the *R*-squared for the GNMA CDR regression reached its highest level, .94, then fell to its lowest level, .54, in 1983 and remained at about that level in 1984 and 1985. Additionally, for each year from 1977 through 1982 the *R*-squared of the GNMA contract exceeded the *R*-squared of the Treasury-bond contract. During 1983, 1984 and 1985, however, the ability of the Treasury-bond contract to reduce price variability of the current coupon mortgage substantially exceeded that of the GNMA contract. Thus, in every year prior to 1983, the GNMA CDR contract provided a hedge that was either superior to or at least as effective as the hedge provided by the Treasury-bond contract, but from 1983 onward, the Treasury-bond contract provided superior hedging effectiveness for current coupon mortgage securities.

It could be argued that the decline in the quality of the hedge provided by the GNMA CDR futures contract for current coupon mortgages and the concurrent superiority of the hedge provided by the Treasury-bond futures contract is not sufficient to explain the demise of the GNMA CDR futures

Table 4
Hedging performance of GNMA CDR futures contract in combination with the Treasury-bond futures contract for the period August 1977 through August 1985 for hedges of five trading days

		Coefficient of determination	
Year	Number of observations	GNMA & Treasury bond[1]	Treasury bond[2]
1977	16	.72	.71
1978	50	.80	.75
1979	50	.90	.80
1980	50	.93	.89
1981	50	.94	.83
1982	50	.87	.83
1983	50	.76	.77
1984	50	.77	.77
1985	33	.87	.88

[1] The adjusted R-squared of a two-variable linear regression in which both the GNMA CDR futures contract and the Treasury-bond futures contract are the hedging instruments.

[2] The R-squared of regression (1) when the Treasury-bond futures contract is the hedging instrument.

contract because it is possible that the two contracts in combination might provide a still better hedge than either one used alone. To investigate that question, a regression containing both the Treasury-bond and GNMA CDR futures contract is estimated. The dependent variable is the return for the current coupon GNMA security and the independent variables are the returns for the Treasury-bond and GNMA futures contracts.

Table 4 contains the results of the regression for a five-day hedge for annual time periods. In each year prior to 1983, the adjusted R-squared of the regression containing both the GNMA futures contract and the Treasury-bond futures contract exceeds the R-squared of the regression containing only the Treasury-bond contract. However, during 1983, 1984, and 1985 the R-squared of the regression containing only the Treasury-bond contract is at least as high as the adjusted R-squared of the regression containing both the GNMA and the Treasury-bond contract. These results indicate that in those years in which the trading volume of the GNMA futures contract declined most severely, not only did the Treasury-bond futures contract provide better hedging protection for current coupon mortgages than did the GNMA contract, but additionally, the GNMA contract did not improve the hedging performance of a current coupon hedger who used Treasury-bond futures alone to hedge his position.

3. The Effect of Selected Delivery Options on the GNMA CDR Futures Price

The foregoing analysis of hedging effectiveness is consistent with our hypothesis for the rise and fall of the GNMA CDR futures contract. However, this explanation for the demise of the contract raises a second issue: Why did the quality of the hedge provided by the GNMA CDR contract for current coupon mortgages decline after 1982?

The GNMA contract, like many other futures contracts, contains a variety of delivery options. Because the value of these options is reflected in the futures price, the futures price on the delivery date will differ from the cash price of the asset to be hedged. As a result, the link between the futures price and the cash price of the asset to be hedged may be weakened and the effectiveness of the hedge diminished.

To determine whether the delivery options embedded in the GNMA CDR futures contract were significant enough to have contributed to the contract's poor hedging performance, we derive expressions for the value of selected delivery options during delivery periods, when presumably the link between the futures and the price of the underlying cash instrument is strongest. Our method for estimating the values of the delivery options is straightforward. We estimate terminal payoffs for exercising the delivery option on each day during the delivery periods.

The delivery procedure for the GNMA CDR futures contract is similar to the delivery procedure for the Treasury-bond futures contract. For both contracts, the delivery period lasts approximately one month. Trading continues in the contract until the last seven business days of the month when trading is suspended. All contracts that remain open when trading is suspended must be settled by delivery. Prior to the suspension of trading, contracts may also be fulfilled by taking an offsetting position in the futures market. The short may initiate delivery on any business day beginning two business days prior to the delivery month and ending one business day prior to the end of the delivery month. The delivery procedure gives the short a series of delivery options. The options which the GNMA and Treasury-bond contracts have in common are known as the wild card option (the option to exploit the timing difference between the closing of the futures and cash markets), the accrued interest option (the option to deliver either early or late in the month, depending upon the relationship between the rate at which interest accrues on the futures contract and the rate available on alternative investments), and the end-of-month option (which allows the short to benefit from price changes in the cash market after futures trading has been suspended).[9] While these three options are contained in both contracts, it is the differences between the GNMA CDR and the Treasury-bond contracts that are of interest here. These are two delivery options that are unique to the GNMA CDR: a quantity option and an option that we call a perpetuity option. A third difference involves a quality option which is similar to, but different, in a potentially important way, from the quality option contained in the Treasury-bond contract. The quantity option and the quality option are held by the short position in the contract. The perpetuity option is held by the long.

The quantity option allows the short to adjust the amount of principal balance to be delivered by as much as 2.5 percent above or below the

[9] Gay and Manaster (1986) provide a detailed exposition of these options and estimate their potential value to the short for the Treasury-bond futures contract.

contractually specified amount. The perpetuity option allows the long to receive a fixed interest payment each month in lieu of the actual GNMA securities—in essence, a nontransferrable perpetuity—until the long elects to receive the actual securities. The quality option allows the short to deliver securities bearing any of the available coupon interest rates.

While, in principle, the value of each delivery option depends upon how the others are exercised, we estimate the value of each in isolation. This neutralizes the effect of the other delivery options on the futures price and ignores any interactions between the various options.

To neutralize the accrued interest and the end-of-the-month options, we estimate the value of the other options on each business day during the delivery period. In doing so, we are assuming that the short has elected to initiate delivery on that day. To neutralize the wild card option, we assume that the decision to initiate delivery is made at the end of each trading day. These assumptions are maintained throughout the analysis of each of the three options of interest here. Additionally, when we estimate the values of the perpetuity and the quality options, we assume that the short delivers the exact amount of remaining principal balance required to satisfy the contract. This neutralizes the quantity option. We neutralize the effect of the perpetuity option by assuming that the long decides to accept delivery of the securities immediately and that the short delivers immediately. When we estimate the values of the quantity option and the perpetuity option, we neutralize the quality option by assuming that the short searches among all available coupons to determine which one minimizes the cost of purchasing the securities in the cash market on that day. In the vernacular of futures markets, the minimum cost security is the "cheapest-to-deliver."

3.1 Cheapest-to-deliver securities

Determination of the value of the quantity option and the perpetuity option on any given day requires that we determine which coupon rate GNMA security is cheapest to deliver on that day. Since the invoice price, the amount the long must pay to the short to settle the contract, is a fixed amount independent of which security the short delivers, the short will choose the security which minimizes the market value of the securities he actually delivers.

If S_{it} is the market price per dollar of remaining principal balance of a security with coupon rate i on day t, and C_i denotes the conversion factor for coupon rate i, the cost of delivering a security with coupon rate i on day t is \$100,000C_iS_{it}. For day t, the cheapest-to-deliver security is determined as

$$\min\{C_iS_{it}\} \tag{2}$$

The number of days between March 1976 and June 1985 on which each

Table 5
Frequency distribution of cheapest-to-deliver GNMA securities for the period March 1976 through June 1985

Year	Delivery month	Coupon 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	Mar	24	*														
	Jun	17	5	1*													
	Sep	19	3	*													
	Dec	23		*													
1977	Mar	24		*													
	Jun	23		*													
	Sep	22		*													
	Dec	22		*													
1978	Mar	4		19	*												
	Jun		10	13	*												
	Sep	21			*												
	Dec	21			*												
1979	Mar	23			*												
	Jun	20	2			*											
	Sep	20				*											
	Dec	18	3					*									
1980	Mar	5	13	4						*							
	Jun	18	4								*						
	Sep	17	2	3							*						
	Dec	8			4	1	2	4				4*					
1981	Mar		2	5	4	3	3	5	1			*					
	Jun	23												*			
	Sep	1		1					4	3	8	3				2*	
	Dec	16	4										1	1	1	*	
1982	Mar	22	1													*	
	Jun	21	2													*	
	Sep	22														*	
	Dec	23															*
1983	Mar	24															*
	Jun	23															*
	Sep	22															*
	Dec	22															*
1984	Mar	23														*	
	Jun	13									1	1		4	3		*
	Sep	20															*
	Dec	21															*
1985	Mar	22															*
	Jun	21															*

Coupon 1 represents the highest available coupon rate GNMA security. Coupon 2 is the second highest available coupon rate GNMA security and so on. The asterisks denote the lowest available coupon rate GNMA security. The numbers in the table represent the number of days during the delivery period on which the relevant coupon rate was cheapest to deliver.

available delivery instrument was cheapest to deliver is displayed in Table 5.[10] The results are organized by delivery month, with the permitted delivery instruments ranked from the highest coupon to the lowest. In the table, coupon 1 is the highest coupon security available throughout the delivery month and the asterisk denotes the lowest coupon rate. The number of

[10] The first delivery period, December 1975, is omitted because cash prices were not available.

available delivery instruments ranges from a low of two in March 1976 to a high of 16 from December of 1982 onward.

The table demonstrates that there is a strong relation between the highest coupon securities and the cheapest-to-deliver securities. Over the entire sample period, one of the two highest coupon securities is cheapest to deliver on 87 percent of the days, and the very highest coupon security is cheapest 81 percent of the time. Between March 1976 and September 1980, the cheapest-to-deliver security is always one of the three highest available coupon rates, with the highest coupon rate security being cheapest on 81 percent of the days.[11] From December 1980 through December 1981, the relation between the cheapest-to-deliver security and the highest coupon security is somewhat weaker. Over this period, the cheapest-to-deliver security is one of the two highest coupon rates only 47 percent of the time. However, from September 1982 onward, with the exception of June 1984, the cheapest-to-deliver security is always the one with the highest coupon.

It is apparent that the structure of the conversion factors produces a bias toward delivery of high coupon rate securities. This is because the conversion factors understate the effect of the call option on high coupon mortgages so that the cost of delivering the required principal balance is lower for higher coupon securities.

3.2 The quantity option

Each month, the remaining principal balance of a GNMA security changes as principal payments are received. This may make it difficult to find a set of securities with the exact principal balance required to satisfy the futures contract. To alleviate this problem, the GNMA CDR futures contract contains a quantity option which allows for over- or underdelivery by 2.5 percent of the principal balance required to satisfy the contract. For an 8 percent coupon GNMA security, the short may satisfy the contract by delivering a set of securities whose remaining principal balance lies between \$97,500 and \$102,500. The principal balance required to satisfy the contract for any other security i must lie between \$97,500C_i and \$102,500C_i. Discrepancies between the actual principal balance delivered and the required principal balance, within the 2.5 percent tolerance limit, are settled by adjusting the invoice amount which the long must pay the short.

The adjustment is equal to the difference between the actual principal balance delivered divided by the conversion factor and \$100,000. The maximum adjustment is \$2500C_i. The short gains if \$2500 differs from \$2500C_iS_{it}. If \$2500C_iS_{it} is less than \$2500, the short will overdeliver and receive \$2500 for securities worth only \$2500C_iS_{it}. If \$2500C_iS_{it} is greater than \$2500, the short will underdeliver and reduce the payment he receives from the long by only \$2500 for securities which would have cost \$2500C_iS_{it}. If the short can locate securities with the right remaining principal balance

[11] These results are similar to those of Kilcollin (1982) for a similar time period.

to fully exploit the quantity option, its value on day t for the cheapest-to-deliver security can be estimated as

$$\$2500 | 1 - \min\{C_i S_{it}\} | \tag{3}$$

For each possible delivery day i during each delivery month, Equation (3) is used to estimate the value of the quantity option. This estimate is divided by that day's futures price to obtain the relative value of the option and these relative values are averaged across each delivery period. Table 6 presents the average values of the quantity option expressed as a percentage of the futures price for each delivery period in the sample. The estimated value of the option ranges from a low of 0.01 percent of the futures price in June 1977 to a high of 1.86 percent in September 1981.[12]

3.3 The perpetuity option

For most futures contracts, the usual methods of delivery are for the short either to deliver the underlying security to the long or to pay the long the cash equivalent of the underlying security. In contrast, the GNMA CDR futures contract has a delivery instrument called a collateralized depositary receipt (CDR) which entitles the long to receive \$635 in interest each month as long as he holds the CDR and to exchange the CDR for the actual GNMA securities at any time by giving 15 business days notice.[13]

When the futures contract matures, the short must deposit GNMA securities with the required principal balance in the hands of an approved depositary (usually a commercial bank). While the long holds the CDR, the short continues to receive the cash flows on the securities (less the interest payment to the long and a servicing fee to the depositary). If the principal balance of the securities held by the depositary should fall below the minimum delivery quantity, $\$97{,}500C_i$, the short must deposit additional securities.

At maturity, the long may either ask for delivery of the actual GNMA security or retain the CDR. If we ignore the option to exchange the CDR for GNMA securities at some future date, the CDR is essentially a perpetuity and its value is simply $\$635/r_t$, where r_t is the appropriate monthly discount rate for a risk-free perpetuity. If the value of the perpetuity exceeds the value of the cheapest-to-delivery security, the long should retain the CDR. Conversely, if the value of the perpetuity is less than the value of the cheapest-to-deliver security, the long should immediately notify the short that he wishes to receive the securities. The value to the long of the

[12] The short's ability to exploit the quantity option depends upon the availability of a set of securities that have precisely the desired remaining principal balance. To the extent that such securities do not exist, or that constructing such a set of securities entails transaction and search costs, the values in Table 6 represent an upper bound on the value of the quantity option.

[13] According to Garbade (1982), this unusual delivery procedure was introduced because GNMA securities are registered and cash settlement was illegal in Illinois at the time the GNMA futures contract was designed. Thus, a lag was built into the delivery process to permit the transfer to be registered.

Table 6
Average value of quantity option relative to the futures price during delivery months for the period March 1976 through June 1985

Year	Delivery month	Average option value/ futures price, in percent
1976	Mar	0.07
	Jun	0.09
	Sep	0.06
	Dec	0.03
1977	Mar	0.03
	Jun	0.01
	Sep	0.02
	Dec	0.08
1978	Mar	0.12
	Jun	0.21
	Sep	0.20
	Dec	0.31
1979	Mar	0.33
	Jun	0.34
	Sep	0.45
	Dec	0.67
1980	Mar	1.15
	Jun	0.65
	Sep	0.97
	Dec	1.17
1981	Mar	1.23
	Jun	1.41
	Sep	1.86
	Dec	1.49
1982	Mar	1.50
	Jun	1.57
	Sep	1.24
	Dec	1.29
1983	Mar	1.28
	Jun	1.31
	Sep	1.25
	Dec	1.21
1984	Mar	1.11
	Jun	1.29
	Sep	1.20
	Dec	1.10
1985	Mar	1.10
	Jun	0.97

perpetuity option at the maturity date of the futures contract can be estimated as[14]

$$\max\{0, \$635/r_t - \$100{,}000 \min(C_t S_{it}\} \qquad (4)$$

For each possible delivery day during each delivery month, the value of the perpetuity option is estimated with Equation (4) using the yield on a 20-year Treasury bond as a proxy for r_t. This estimate is divided by that

[14] This computation assumes payments begin one month after delivery. The actual procedure is somewhat more complicated, but has negligible effect on the value of the perpetuity.

Table 7
Average value of perpetuity option relative to the futures price during delivery months for the period March 1977 through June 1985

Year	Delivery month	Average option value/ futures price, in percent
1977	Mar	3.20
	Jun	3.74
	Sep	5.20
	Dec	3.47
1978	Mar	1.08
	Jun	0.59
	Sep	1.16
	Dec	0.18
1979	Mar	0.00
	Jun	0.95
	Sep	1.94
	Dec	0.00
1980	Mar	0.00
	Jun	2.35
	Sep	0.00
	Dec	0.00
1981	Mar	0.00
	Jun	0.00
	Sep	0.05
	Dec	0.00
1982	Mar	0.00
	Jun	0.00
	Sep	0.24
	Dec	14.89
1983	Mar	14.34
	Jun	11.76
	Sep	3.51
	Dec	0.90
1984	Mar	0.00
	Jun	0.00
	Sep	0.00
	Dec	0.09
1985	Mar	0.00
	Jun	6.71

day's futures price and the average of these relative values is computed for each delivery period.[15] The results are presented in Table 7.

In 21 of the 34 delivery months the estimated average value of the perpetuity option is less than 1 percent. During 1977, the average value of the option varied between 3 and 6 percent of the value of the futures price. From 1978 until December 1982, the average option value was less than 2.5 percent. In the following three delivery periods, the average option value exceeded 10 percent of the futures price. In December 1982, the option value reached its highest level of 14.89 percent. From December 1983 through March 1985, the option had negligible value.

[15] Treasury bond yields were provided by the Federal Reserve Bank of San Francisco. The yields were adjusted to account for monthly payments.

3.4 The quality option

The quality option, which permits the short to deliver securities that bear coupon rates other than 8 percent, was incorporated into the contract to attract hedgers holding mortgages with different coupon rates. The quality option is valuable because of differences in the market values of the required delivery quantity of the various coupon securities. To assess the value of the quality option it is necessary to compare it with an alternative benchmark security. For current coupon hedgers, a relevant comparison is between the cheapest-to-deliver coupon and the current coupon security. Thus, if we denote the current coupon by c, the value of the quality option to current coupon hedgers can be estimated as

$$\$100{,}000 C_c S_{ct} - \min\{\$100{,}000 C_i S_{it}\} \tag{5}$$

The quality option will have a value of zero if the conversion factors imply identical costs for the required delivery quantity for all the available securities or if the current coupon rate security is cheapest to deliver. From our earlier results relating the cheapest coupon security with the highest coupon security, it is apparent that the conversion factors do not drive the value of the quality option to zero. Furthermore, it is reasonable to expect that the option will be more valuable the greater the disparity between the current coupon rate and the highest one.[16]

Using Equation (5), the value of the quality option is estimated for each delivery day during each delivery month and is divided by that day's futures price. The average relative value is then computed for each delivery month. The results, which represent the average relative value to the short for delivering the cheapest security instead of the current coupon security, are presented in Table 8. For the 26 delivery periods from March 1976 through June 1982, the values are generally small: The value is zero in six of these periods, and less than 2 percent in all but two. For the 12 delivery periods from September 1982 through June 1985, the value exceeds 5 percent in 10 periods, and reaches a peak of 19.32 percent in March 1983.

4. Commentary

The pattern of mortgage interest rates over the life of the GNMA CDR futures contract appears to have had a significant impact on the contract's performance. In March 1976, the current coupon rate was 8.25 percent. From that time onward, the current coupon mortgage rate increased more or less steadily until it reached a peak of 17 percent during September 1981 and remained at 16 or 17 percent through the early part of 1982. Over this period, as over most periods, the cheapest-to-deliver security typically

[16] Our approach for estimating the value of the quality option differs from the approaches in Garbade and Silber (1983), Gay and Manaster (1984), or Kane and Marcus (1986). Each of those papers focuses on the value that accrues to the short position because the cheapest-to-deliver security changes over the life of the contract. We focus on the value of the quality option at maturity to a hedger who holds one particular grade of the deliverable security.

Table 8
Average value of quality option as a percentage of the futures price during delivery months for the period March 1976 through June 1985

Year	Delivery month	Average option value/ futures price, in percent
1976	Mar	0.42
	Jun	0.14
	Sep	0.47
	Dec	2.51
1977	Mar	0.68
	Jun	0.59
	Sep	0.37
	Dec	0.42
1978	Mar	0.02
	Jun	0.08
	Sep	0.00
	Dec	0.00
1979	Mar	0.00
	Jun	0.00
	Sep	0.00
	Dec	0.02
1980	Mar	0.29
	Jun	2.81
	Sep	0.52
	Dec	1.28
1981	Mar	0.47
	Jun	0.00
	Sep	1.86
	Dec	1.40
1982	Mar	0.83
	Jun	0.65
	Sep	4.34
	Dec	15.86
1983	Mar	19.32
	Jun	18.08
	Sep	11.17
	Dec	11.31
1984	Mar	5.99
	Jun	1.81
	Sep	5.44
	Dec	8.72
1985	Mar	6.02
	Jun	11.18

was also the one with the highest available coupon rate. Thus, the coupon rate of the cheapest-to-deliver security coincided with the current coupon rate, which we have argued is the rate that mortgage producers wished to hedge. During the latter half of 1982, the current coupon rate fell precipitously, reaching a low of 11 percent during mid-1983. Throughout the remainder of our sample period, current coupon rates remained well below 16 percent. Over this latter period, the cheapest-to-deliver securities continued to be those with coupon rates of 16 or 17 percent. Thus, from mid-1982 through the end of our sample period, the coupon rate that mortgage producers wished to hedge was substantially below that of the cheapest-to-deliver security.

If the assumptions underlying the calculation of the conversion factors had been met, the delivery options embedded in the GNMA CDR futures contract would have had no value and the futures price and the value of the dollar amount to be delivered would have converged during the delivery month for securities of all coupon rates. Because the assumptions were not met, the various delivery options had positive values which weakened the quality of the contract as a hedging instrument for current coupon mortgages.

The value of the quantity option, on average, never reached a level of more than 2 percent of the futures price during any delivery month. However, the average value of this option did reach its highest level during the latter part of 1981 and continued to be above 1 percent of the futures price during all delivery months (with one exception) thereafter. The perpetuity option had negligible value over most of the sample period. However, its value did exceed 10 percent of the futures price for a brief period in late 1982 and early 1983. It is, however, the quality option that appears to have had the greatest effect on the price of the futures contract. On average, the quality option had relatively little value until September of 1982. In that month, the average value of the quality option reached 4.34 percent of the price of the futures contract. In each of the five subsequent delivery months, the average value of the quality option exceeded 10 percent of the price of the futures contract. It was during this period that the quality of the hedge provided by the GNMA CDR futures contract for current coupon mortgages deteriorated both absolutely and relative to the quality of the hedge provided by the Treasury-bond futures contract. Furthermore, with the exception of one month, during the remainder of our sample period the average value of the quality option continued to exceed 5 percent. Thus, the quality option took on and maintained its largest relative values precisely during the period in which the hedging effectiveness of, and trading volume in, the GNMA CDR contract declined. For comparison, Hemler (1988) estimates that, over the period 1977 through 1986, the value of the quality option in the Treasury-bond futures contract averaged less than 2 percent.

We should note that the amount of the delivery option is, in itself, not sufficient to impair the quality of the hedge provided by a futures contract. For example, if the option value is a linear function of the futures price, hedging effectiveness would not be affected. However, the pattern of relative values displayed in Tables 6, 7, and 8 clearly rules out a simple linear relation between the value of any of the options and the futures price.

Our argument may appear to depend heavily upon the assumption that hedging is concentrated in current coupon mortgage securities. If, instead, hedging demand arises from holders of seasoned mortgage portfolios, the propensity of the GNMA CDR to track the highest available coupon security is still likely to be undesirable. Portfolios of seasoned mortgages have a representative or weighted average coupon rate which is less than the highest available coupon rate security. Since 1981, the cheapest-to-deliver security has been the 16 or 17 percent coupon. The FHA ceiling was 17.5

percent (which corresponds to a 17 percent security) for less than one month, and of the $260 billion in GNMAs issued between 1970 and 1985, only about $2.3 billion were 16 percent securities. The 16 percent coupon securities, which were last issued on March 1, 1982, experienced a greater than 50 percent prepayment rate over the period 1982 through 1985. Thus, the securities whose price the GNMA CDR contract follows most closely are unlikely to be the securities that comprised the bulk of seasoned mortgage portfolios over this period. As a consequence, the GNMA CDR contract would have provided poor hedging effectiveness even for seasoned mortgage portfolios.

There are, of course, other possible explanations for the decline of the GNMA CDR futures contract. For example, it might be argued that the GNMA CDR futures contract is a redundant security. Apparently, a significant portion of the mortgage hedging market has moved into the negotiated dealer market. Both forward contracts and options on GNMA securities are readily available. However, there are costs associated with dealer markets. Also, these instruments are less standardized, less liquid, and the market is less readily accessible to small investors.[17] Furthermore, there was an active GNMA forward market that coexisted with the GNMA futures market even in the futures contract's heyday, so the presence of these alternative securities appears to offer an incomplete explanation for the demise of the GNMA CDR futures contract.

5. Conclusion

The determinants of futures contract success or failure and optimal futures contract design are important considerations for futures exchanges as well as for traders and hedgers in futures contracts. In designing futures contracts, exchanges often include a variety of delivery options, which allow participants flexibility in the timing of delivery and the quality of the delivery asset. On the one hand, these options have the potential to broaden the appeal of the contracts and to make "squeezes" less likely. On the other hand, to the extent that these delivery options are valuable, they may reduce the hedging effectiveness of the contract. Thus, one goal of futures contract design can be viewed as constructing delivery options that have very small values, thereby increasing the appeal of the contract in general, while simultaneously preserving the quality of the contract as a hedging instrument.

This research is a case study of the GNMA CDR futures contract, which appears to have failed because of flaws in its design. After considerable success following its introduction in 1975, by 1987 trading in the contract had declined to the point where price quotations were no longer listed in the daily financial press. We find that over the period from 1983 to 1985,

[17] The benefits of organized futures markets are discussed in Telser (1981), Garbade (1982), and Miller (1986).

when trading volume experienced its most dramatic decline, the effectiveness of the GNMA CDR futures contract as a hedge for current coupon mortgages also declined. Furthermore, during the years in which the GNMA CDR volume declined, the Treasury-bond futures contract provided a better hedge for current coupon GNMA securities than did the GNMA CDR contract. We attribute the decline in the quality of the hedge provided by the GNMA futures contract to the effect on the futures price of the delivery options embedded in the contract.

Our empirical investigation suggests that the structure of the quality option, which allows the short to deliver any of the available coupon rate securities, is the most likely cause of the GNMA CDR contract's failure as a hedging instrument. The method used to convert the various deliverable coupon rates into a common, comparable basis presumes that the mortgages underlying the various coupon rate securities will have identical prepayment patterns. However, in the interest rate environment of the early 1980s, when rates first rose and then fell dramatically, the prepayment rate on high coupon securities was much higher than implicitly assumed in the contract. Consequently, the high coupon securities became relatively cheap to deliver, causing the futures price to follow the price of the high coupon securities, while, at the same time, hedging demand was concentrated in the considerably lower current coupon securities. We estimate that, over the period September 1982 through June 1985, the difference between delivering the cheapest and the current coupon securities was typically in excess of 4 percent of the futures price and at one point was as much as 19 percent of the futures price. The high value of the quality option drove a wedge between the futures price and the prices of current coupon mortgages that, in turn, caused the GNMA CDR futures contract to become a poor hedge for current coupon mortgages, where hedging demand is likely to be concentrated. As the contract became less useful to mortgage hedgers volume would have declined, thereby, creating a less liquid market. The loss of liquidity would have had the reinforcing effect of making the contract less appealing to other market participants as well, which, in turn, would have further reduced the appeal of the contract to mortgage hedgers.

The GNMA CDR futures contract appears to have been a victim of the conflicting needs to design a contract that has broad appeal while at the same time is useful to a particular class of hedgers. In this instance, the delivery options were intended to make the contract appealing to many different mortgage hedgers. The unfortunate unintended result was that these options appear to have rendered the contract appealing to few or, perhaps, no mortgage hedgers.

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