Hedging with Bond Futures—A Way to Prepare for Rising Interest Rates

By Hideaki Chida
Financial Research Group
chida@nli-research.co.jp

Termination of the zero-interest rate policy has made it necessary to prepare for rising interest rates. Bond futures are a common hedging method in the bond market. However, because of the difference in characteristics between the underlying bonds and bond futures, risks cannot be completely eliminated. We assess three hedging methods, and note the limitations of each method.

1. Introduction

In July 2006, the Policy Board of the Bank of Japan ended the zero-interest rate policy by raising the uncollateralized overnight call rate target to approximately 0.25%. As a result, short-term interest rates rose for the first time in five years, impacting the bond market significantly. With short-term rates expected to continue rising, investors must prepare for the new interest rate environment.

When interest rates rise, bond prices fall and cause bondholders to suffer a capital loss. To hedge against this risk without having to unwind bond positions, investors often sell bond futures. Depending on the hedging method they use, the gain or loss (hedge error) can vary significantly. Moreover, due to differences in the characteristics of bonds and bond futures, hedging cannot completely eliminate price movement risk.

In this paper, we compare three methods of hedging with bond futures. Based on simulation results, we then assess the hedging effectiveness and note the limitations of each method.

2. Hedging Methods

While bond futures exist for both 5-year and 10-year government bonds, only the latter are considered to be practical due to liquidity and other considerations (Exhibit 1). Other maturities such as the 3-year and 7-year bond are also not deemed practical for bond futures. As a result, when using bond futures to hedge a bond position with various maturities, investors must adjust the transaction size (calculate the hedge ratio). Below we describe three major methods used to calculate the hedge ratio.

Exhibit 1 5- and 10-Year Bond Futures

	Medium-term JGB futures	Long-term JGB futures
Contract	Standardized 3% 5-year JGBs	Standardized 6% 10-year JGBs
Deliverable grade	Interest-bearing 5-year JGBs with at least 4 but less than 5.25 years to maturity	Interest-bearing 10-year JGBs with at least 7 but less than 11 years to maturity
Contract months	March, June, September, December (nearest 3 contract months are simulltaneously available; max. contract length 9 months)	
Delivery date	20th of contract month (or next business day)	
Last trading day	7th business day before delivery date	
Trading unit	JGBs with face value of ¥100 million	
Minimum fluctuation	0.01 point per 100 points (¥10,000 per contract)	
Settlement method	Seller may deliver any deliverable JGB	
Margin requirement	Approx. 0.5%	Approx. 1%
Trading volume <2005.09～2006.08>	¥0	¥1,074 trillion

Note: Margin requirement is periodically updated to reflect price movements. Unrealized gain or loss is settled separately on a daily basis.

(1) Conversion Factor (CF) Method [1]

The conversion factor is a ratio to adjust the price difference between the futures price and cash bond price at the delivery date:

Futures price × CF ＝ Cash bond price

If the futures price changes by one unit, the cash bond price changes by the amount of the CF. In other words, the CF determines the amount of bond futures needed to hedge the bond position (hedge ratio ＝ CF).

While the CF adjusts for the price difference, it does not adjust for time to maturity, and is effective only for the most heavily discounted deliverable cash bond (whose maturity is around 7 years).[2] For bonds with other maturities, the interest rate risk remains unhedged.

(2) Duration Method [3]

Duration is an indicator of how strongly bond prices respond to the same interest rate movement. Normally, duration increases with time to maturity, so that the interest rate risk increases.

To hedge against interest rate risk, bond durations need only be matched.[4] That is,

$$\text{Hedge ratio} = \frac{\text{Duration of cash bond}}{\text{Duration of futures}}$$

As long as interest rate movements are the same, bonds of all maturities can be completely hedged against interest rate risk. However, this method assumes that the interest rate movement is the same. If interest rate movements differ, the price movement risk is not hedged (the yield curve changes as in Exhibit 5).

(3) Regression Analysis Method [5]

In regression analysis, the historical price correlation between cash bonds and futures is calculated, and the correlation coefficient is used as the future hedge ratio.

Hedging works even if the shape of the yield curve changes, as long as the shape continues to change in the same way in the future. However, sudden changes in the market environment render the method unusable. Another problem is determining the appropriate regression period, which significantly affects results.

3. Hedge Effectiveness

To examine the various hedging methods, we ran simulations using historical data. Our assumptions are shown in Exhibit 2.

Exhibit 2 Simulation Assumptions

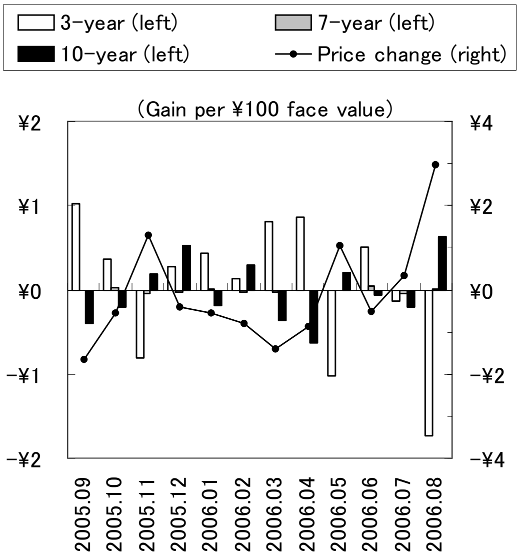
Simulation period	2003.04～2006.08 (approx. 3.5 years)
Investment strategy	Buy bonds and sell futures
Bonds	Long-term JGBs with 3, 7, or 10 years to maturity (*1)
Futures contracts	Main contract month of long-term JGB futures (*2)
Rebalancing	Adjust futures hedge ratio at end of month; replace bonds and futures when contract month shifts
Trading unit	Not established (*3)
Transaction cost	None (*3)
Regression analysis time period	4 periods of 10, 20, 40, 60 days; if data is unavailable, use previous contract month for futures, and shorten maturity of bonds
Hedge error	Bond price gain + Coupon income − Bond futures gain

Notes: (*1) Time to maturity refers to maturity at delivery. But for the10-year bond, we used the JGB with the longest maturity. (*2) Refers to contract month with highest volume. Usually, this is the nearest contract month, which is replaced with the next contract month just prior to delivery. (*3) This helps to refine measurement of hedging effects.

(1) Effectiveness of CF Method

The hedge error generated by the conversion factor method is shown for the past one-year period in Exhibit 3. Although the 7-year is almost completely hedged, the hedge error increases for the 3-year and 10-year. Also, the 10-year shows a positive hedge error in rising markets, and negative error in declining markets (the reverse is true for the 3-year). This occurs because a fixed ratio of futures is held regardless of the maturity of the cash bond (in the CF method, price differences between cash bonds and futures cannot be adjusted). These results confirm that in the CF method, interest rate risk can be hedged only for the 7-year maturity.

Exhibit 3 Hedge Error (CF Method)



Note: Price change refers to gain in futures price per ¥100 face value.

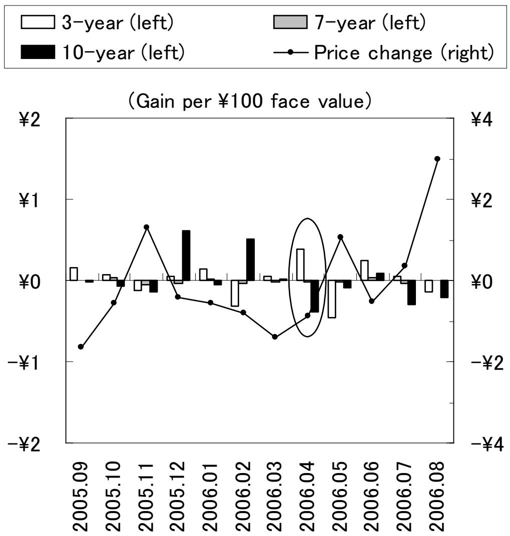
(2) Effectiveness of Duration Method

The hedge error generated with the duration method is shown in Exhibit 4. Compared to the CF method, the hedge error small overall. This occurs because by matching durations, interest rate risk can be hedged for the 7-year maturity as well as other bonds.

However, a large hedge error still occurs in some months for the 3-year and 10-year (Exhibit 4). For example, in April 2006, a positive hedge error arises for the 3-year and negative hedge error for the 10-year. As Exhibit 5 shows, the yield curve (years to maturity on the horizontal axis and yield on the vertical axis) grows steeper from March to April. Thus the smaller interest rate increase of the 3-year (smaller bond price decline) results in a positive hedge error, while the larger interest rate increase (larger price decline) of the 10-year results in a negative hedge error.

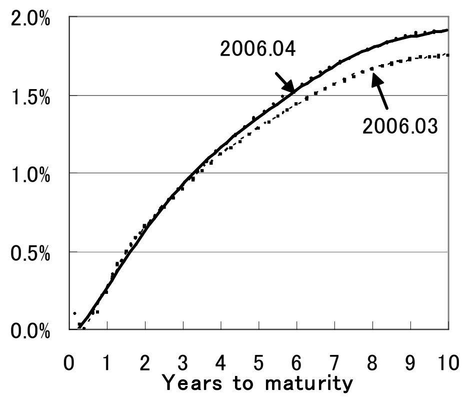
The duration method works well for a parallel shift of the yield curve (same interest rate change for all maturities). But if the shape of the yield curve changes, price movement risk arises for maturities other than the 7-year.

Exhibit 4 Hedge Error (Duration Method)



Note: Price change refers to gain in futures price per ¥100 face value.

Exhibit 5 Yield Curve (long-term JGB)



(3) Regression Analysis Method

Exhibit 6 shows the hedge error generated using regression analysis. The tracking error, shown below the hedge error, measures the variation of the hedge error.[6] A small tracking error indicates a relatively stable hedge error, meaning that the hedge is more effective. Our results show that the hedge error and tracking error vary significantly depending on market conditions in the period under study. For example, from June to August 2003, the long-term interest rate rose sharply, departing from the previous downtrend (Exhibit 7). As a result, the hedge error is quite different if this period is included (full period results) compared to when it is not (last 3-month period).

By years to maturity, the 7-year again shows the best correlation, followed by the 3-year and 10-year. This is because with bond futures, the 7-year is ultimately chosen for delivery.

By regression period, short periods such as 10 days pose a high risk because of a possible large one-time loss. This is because under fast market conditions, short-term regression analysis immediately reflects these conditions in the hedge ratio, making the ratio volatile and unstable.

On the other hand, results are poor for long regression periods such as one year. Reasons include: (1) market conditions cannot be adequately reflected; (2) data is unavailable for part of the period; and (3) as time passes, both the time to maturity and duration of bonds decrease. According to our results, the most appropriate regression period is 20 to 60 days.

In addition, our results for the past 1-year period were affected by the decision of the BOJ to end the zero-interest rate policy, causing short-term rates to fluctuate widely. As a result, the 3-year hedge error became more volatile, as seen by the large tracking error.

4. Comparison of Hedging Methods

Hedge error and tracking error results for the three methods are compared in Exhibit 8. Since tracking error size expresses the correlation between cash bonds and bond futures, the method that generates the smallest tracking

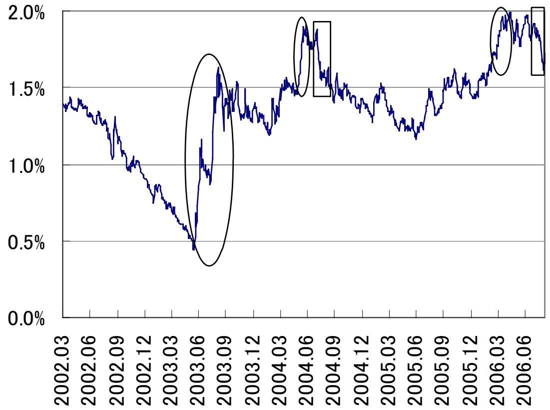
Exhibit 6 Hedge Error (Regression Analysis)

(Yen gain per ¥100 yen face value)

Years to maturity	3-year				7-year				10-year				Price change
Period (days)	10	20	40	60	10	20	40	60	10	20	40	60	
2003.04.30	0.13	0.12	0.11	0.11	0.02	-0.00	-0.00	0.00	0.42	0.34	0.34	0.34	0.54
2003.05.31	-0.08	0.02	0.02	-0.00	0.00	-0.06	-0.02	-0.02	-0.18	-0.54	-0.50	-0.50	1.20
2003.06.30	0.09	-0.13	-0.10	-0.09	-0.10	-0.21	-0.15	-0.05	-2.27	-0.24	-0.29	-0.29	-2.75
2003.07.31	0.14	0.14	0.14	0.14	0.03	0.03	0.03	0.03	-1.13	-1.13	-1.13	-1.13	0.29
2003.08.31	-0.33	-0.24	-0.21	-0.21	-0.18	-0.09	-0.07	-0.08	-1.03	0.15	0.14	0.15	-4.45
2003.09.30	-0.21	-0.15	-0.11	-0.04	-0.06	-0.09	-0.09	-0.11	0.00	-0.18	-0.17	-0.16	0.91
⋮	⋮				⋮				⋮				⋮
2006.06.30	0.19	0.18	0.20	0.21	0.02	0.04	0.04	0.03	-0.01	0.05	0.05	0.05	-0.52
2006.07.31	0.07	0.07	0.07	0.07	-0.03	-0.03	-0.03	-0.03	-0.19	-0.21	-0.23	-0.23	0.35
2006.08.31	0.06	0.07	0.07	0.08	0.03	0.03	0.06	0.04	0.03	0.38	0.48	0.36	2.98
All periods (2003.04.30～2006.08.31)													
Total hedge error	0.17	0.27	0.13	0.27	-0.72	-0.90	-0.72	-0.72	-5.85	-3.38	-3.27	-3.33	2.64
Tracking error (%)	0.49	0.47	0.47	0.46	0.17	0.18	0.16	0.15	1.80	1.19	1.15	1.15	
Last 3 years (2003.09.30～2006.08.31)													
Total hedge error	0.22	0.35	0.17	0.33	-0.49	-0.56	-0.51	-0.60	-1.65	-1.95	-1.82	-1.89	7.81
Tracking error (%)	0.47	0.46	0.47	0.46	0.14	0.14	0.15	0.15	1.14	1.03	0.98	0.98	
Last 1 year (2005.9.30～2006.08.31)													
Total hedge error	-0.01	-0.05	-0.16	-0.18	-0.06	-0.02	-0.01	-0.06	-0.71	0.01	0.19	-0.16	-1.07
Tracking error (%)	0.70	0.72	0.72	0.71	0.10	0.11	0.12	0.11	1.19	1.09	1.11	1.10	

Note: Price change refers to gain in futures price per ¥100 face value.

Exhibit 7 Yield on Newly Issued 10-year JGB (simple)



error is deemed best. The exception is when the hedge error is large and negative, indicating a large loss. This situation must be avoided regardless of tracking error size. Thus our criterion for ranking is tracking error size, unless it is accompanied by a large and negative hedge error.

For the 3-year, we found that regression analysis excels because it has the smallest tracking error and no conspicuous negative hedge error. For the 7-year, the CF method generates the smallest tracking error with no conspicuous negative hedge error. For the 10-year, although the duration method produces the smallest tracking error size, the large negative hedge error leads us to prefer regression analysis.

Overall, tracking errors are smallest for the 7-year, followed by the 3-year and 10-year maturities. Notably, however, when hedging long-term and very long-term bonds longer than 7 years, there is a high risk of hedge error.

5. Factors Causing Hedge Error

The hedge errors of the three methods are generally negative. In particular, the hedge error becomes increasingly negative for long bonds such as 10-year bonds. Below we examine the causes of the negative hedge error.

(1) Regression Analysis

In regression analysis, the negative hedge error is particularly large for the 10-year maturity (Exhibit 8). This hedge error arises when past price movements differ from future price movements, and especially when the former is smaller. When future price movements are smaller, the lack of correlation is not a problem. Future price movements can grow larger when interest rates either rise (bond prices fall) or fall

Exhibit 8 Comparison of Hedge Error (All Methods)

(Yen gain per ¥100 face value)

Years to maturity	3-year			7-year		10-year			Price
Hedge method	CF	Dur	Reg	CF	Reg	CF	Dur	Reg	change
2003.06.31～08.31	5.53	1.53	−0.23	−0.14	−0.27	−3.51	−1.19	−1.23	−6.91
2004.06.30	1.53	0.53	0.07	0.01	−0.03	−0.76	−0.26	−0.72	−1.73
2004.08.31	−2.10	−0.55	−0.02	−0.03	0.01	0.71	−0.05	0.57	2.80
2006.04.30	0.85	0.39	0.31	−0.01	−0.02	−0.63	−0.39	−0.59	−0.86
2006.08.31	−1.74	−0.14	0.07	0.01	0.03	0.62	−0.20	0.38	2.98
All periods (2003.04.30～2006.08.31)									
Total hedge error	−0.84	0.44	0.27	−0.71	−0.90	−3.21	−3.83	−3.38	2.64
Tracking error (%)	3.64	0.98	0.47	0.14	0.18	1.66	1.05	1.19	
Last 3 years (2003.09.30～2006.08.31)									
Total hedge error	−5.02	−0.76	0.35	−0.56	−0.56	−0.30	−2.64	−1.95	7.81
Tracking error (%)	2.97	0.83	0.46	0.13	0.14	1.27	0.89	1.03	
Last 1 year (2005.9.30～2006.08.31)									
Total hedge error	0.68	0.12	−0.05	−0.11	−0.02	−0.24	−0.03	0.01	−1.07
Tracking error (%)	2.92	0.81	0.72	0.09	0.11	1.33	1.03	1.09	

Notes: CF refers to conversion factor method, Dur to duration method, and Reg to regression analysis method. Regression period is 20 days. For 7-year time to maturity, Dur results are same as CF results and are not shown. Price change refers to futures gain per ¥100 face value.

(bond prices rise). When interest rates are rising, the 10-year rate increases more than the 7-year rate (for example, in the recent case where short-term interest rates have hovered near zero percent). As a result, the hedge error turns negative. Conversely, when interest rates are falling, the hedge error turns positive.

In the bond market, interest rates tend to rise quickly and decline slowly. In Exhibit 7, circles mark interest rate surges that caused the hedge error to turn negative, and rectangles mark interest rate declines that caused the hedge error to turn positive.

Since bonds become more volatile when interest rates rise, using regression analysis to hedge maturities longer than 7 years often results in a negative hedge error. On the other hand, for shorter bonds such as the 3-year bond, the hedge error tends to turn positive (Exhibit 8).

(2) Effect of the Basis

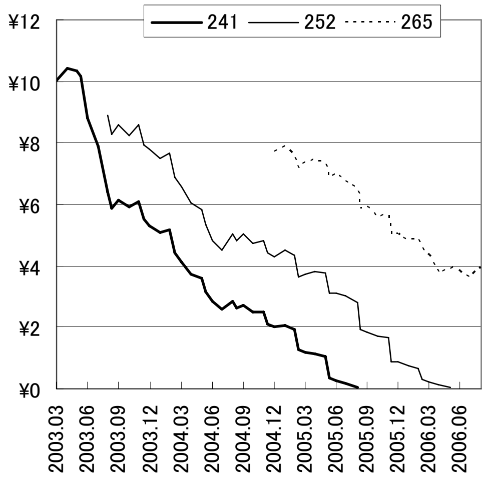
The basis, which refers to the difference between the spot (cash) price of a bond and cash settlement price calculated from the futures price, is generally positive. In other words, the basis indicates the degree of discounting of the cash bond with respect to the futures price.

Exhibit 9 shows the basis for major JGBs. For each bond, every time the contract month is renewed, the large positive value of the basis decreases, eventually approaching zero at the delivery date.

The premium on cash bonds and its decrease can be attributed to the cost of borrowing bonds. Since the owner of cash bonds can receive rent payments when lending the bond, doing so is more advantageous than holding (buying) bond futures.

This advantage is reflected in the price of cash bonds, making cash bonds higher in price than futures. However, because prices converge on the delivery date, cash bonds become cheaper as the delivery date approaches. From a different perspective, the price premium of futures increases as the delivery date approaches.

Exhibit 9 Basis of Selected JGB Issues



Thus for investors taking a long position on cash bonds and short position on futures, as cash bonds become cheaper relative to futures, the hedge error, which expresses the difference between the two, contributes negatively.[7]

(3) Effect of Short-term Interest Rates

Because of the need for cash financing to build a long position on cash bonds and short position on futures, short-term interest income is usually earned. However, since short-term rates were near zero percent during our simulation period, interest income did not arise. Nonetheless, in the past one-year period that includes the lifting of the zero-interest rate policy, we can confirm a positive tendency in the hedge error (Exhibit 8).

6. Conclusion

Our results indicate that the most effective method to hedge against bond price risk is regression analysis. However, we found the conversion factor method to be most effective for the 7-year maturity due to the strong correlation with futures.

However, we must note that regression analysis loses effectiveness under fast market conditions. In addition, results vary significantly depending on the regression period.

No matter how sophisticated the method, it is impossible to completely eliminate risk. Losses arising from the hedge error can be considerable at times. Thus investors must always choose the appropriate hedging method based on their purpose and the market environment.

Notes

[1] On the delivery date, the futures contract has a fixed coupon rate of 6% and maturity of 10 years. But the cash bonds can have various coupon rates and maturities, causing price disparities to arise. The conversion factor, which adjusts for this price disparity, is calculated as follows.

$$CF = \frac{C/0.06 \times ((1+0.06/2)^{N}-1)+100}{(1+0.06/2)^{n/6} \times 100} - C \times (6-d)/1{,}200$$

where:

C: Coupon rate of cash bond (%)
N: No. of interest payments after delivery
n: Time to delivery (months)
d: No. of months to next interest payment

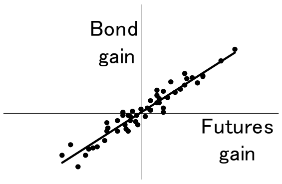
This equation shows the price of the cash bond at delivery when discounted at 6%.

[2] The deliverable bond can be chosen from interest-bearing 10-year JGBs with a time to maturity ranging from 7 years to less than 11 years. The futures seller will thus choose the most heavily discounted bond at the time of delivery. At present, with the interest rate on cash bonds far below the 6% rate on standardized futures, the most heavily discounted bond is the 7-year maturity.

[3] Duration can be measured in three ways.
McCauley = PV of cash flow × Period / price
Modified = McCauley duration / (1 + Yield)
Effective = Modified duration × Unit price with interest
Here we use effective duration.

[4] The duration of a futures contract can be expressed as the duration of the most heavily discounted bond divided by the conversion factor.

[5] Regression analysis measures the correlation between historical gains of cash bonds and bond futures. The slope of the regression line is the correlation coefficient, which can be used as a hedge ratio.



Slope = Hedge ratio

[6] Tracking error refers to the standard deviation of the difference in return from cash bonds and futures. In this case, it is the standard deviation of the hedge error, and is annualized.

[7] Taking the opposite position (selling bonds and buying futures) should make the hedge error turn positive. However, this requires borrowing the cash bonds to sell. The cost of borrowing effectively prevents the hedge error from turning positive.