EUROPEAN CENTRAL BANK

EUROSYSTEM

ECB WORKSHOP
ON THE ANALYSIS OF
THE MONEY MARKET

WORKING PAPER SERIES
NO 980 / DECEMBER 2008

EXTRACTING MARKET EXPECTATIONS FROM YIELD CURVES AUGMENTED BY MONEY MARKET INTEREST RATES

THE CASE OF JAPAN

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In 2008 all ECB publications feature a motif taken from the €10 banknote.

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ECB WORKSHOP ON THE ANALYSIS OF THE MONEY MARKET

On 14 and 15 November 2007, Alain Durré, Huw Pill and Diego Rodriguez-Palenzuela of the ECB's Monetary Policy Stance Division organised a central bank workshop titled "The Analysis of the Money Market: Role, Challenges and Implications from the Monetary Policy Perspective". This workshop provided an opportunity for participating central bank experts to exchange views and foster debate, also in interaction with international organizations and academic institutions. The first day of the workshop addressed issues related to the macro-perspective of the money market, drawing on the experiences of a large number of countries. The second day adopted a micro-perspective on the money market, looking in particular at trading behaviour in the overnight money market and its implications for the evolution of spreads.

A first version of this paper was presented at this workshop. The papers presented at the time of the workshop did not consider the potential implications of the financial turmoil for the results of the paper, given that the tensions in money markets emerged in August 2007. The published version of these papers represents an update of the original paper, which incorporates the discussion which took place at the workshop and in most cases a discussion on the developments in the money markets since August 2007.

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CONTENTS

Abstract

This paper attempts to extract market expectations about the Japanese economy and the BOJ's policy stance from the yen yield curves augmented by money market interest rates, during the period from the end of the quantitative easing policy in March 2006. We use (i) the swap yield curves augmented by OIS interest rates (OIS/Swap), and (ii) the JGB yield curve augmented by FB/TB interest rates. First, using the Nelson-Siegel [1987] model, we estimate three latent dynamic factors, which can be interpreted as reflecting market expectations. Second, we investigate the relative importance of price discovery for each factor between OIS/Swap and FBTB/JGB, and find that the former has a more dominant role of price discovery for all factors. Third, we estimate the efficient price for each factor common to both yield curves using a time-series structural model, which enables us to decompose each factor into the efficient price and idiosyncratic factor.

Keywords: yield curve, overnight index swap, price discovery, structural time-series model, swap spread

JEL Classification: E43, E52, G12

Non-Technical Summary

Under the quantitative easing policy (QEP) adopted by the Bank of Japan (BOJ) in March 2001, the Japanese yen money markets ceased to function properly. The level and volatility of short-term interest rates became so low that almost nothing about the future course of interest rates has been priced into those rates. As the end of the QEP approached, however, the yen money markets started to become active again and to price in future hikes of the policy rate by the BOJ. In particular, around 2006, overnight index swap (OIS) trading emerged in yen markets. In the OIS contracts, the compounded uncollateralized overnight call rate is exchanged for the fixed rate. Since the uncollateralized overnight call rate is the BOJ's policy rate, the OIS rates should reflect market expectations about the BOJ's monetary policy stance.

Motivated by the above observation, this paper attempts to extract market expectations, particularly with regard to the future state of the Japanese economy, as well as the BOJ's monetary policy stance, from the following two sets of Japanese yen yield curves augmented by money market interest rates on a daily basis: (i) the swap yield curves augmented by the OIS rates (OIS/Swap) and (ii) the Japanese government bond (JGB) yield curve augmented by Financial bill/Treasury bill interest rates (JGB/FBTB). We focus on the period after the end of the QEP in March 2006 until the financial market turmoil erupted in August 2007.

First, using the Nelson-Siegel [1987] model, we estimate the daily time-series of three latent factors, namely, long-term, short-term, and curvature factors. Following Diebold and Li [2006], we interpret those factors as capturing the expectations component about (i) the long-term nominal growth rate of the Japanese economy or the long-term neutral interest rate, (ii) the pace of the BOJ's policy rate hikes, and (iii) the medium-term risk relative to the pace of rate hikes by the BOJ, respectively.

Second, we investigate the relative importance of price discovery for each factor between OIS/Swap and FBTB/JGB curves using the price discovery measures based on the vector error correction model. We find that for all the factors, the OIS/Swap yield curve has a more dominant role of price discovery than the FBTB/JGB yield curve.

Third, we estimate the efficient price for each latent factor common to both yield curves using a time-series structural model, and decompose the changes in each factor into the changes in the efficient price and idiosyncratic factor specific to each yield curve. We find that each efficient price shows a more close movement to the OIS/Swap factors than the FBTB/JGB factors, and the idiosyncratic component is more volatile for the FBTB/JGB factors than the OIS/Swap factors.

Overall results suggest that in terms of the information contents about the Japanese economy and the BOJ's monetary policy stance, the OIS/Swap yield curve plays a more relevant role than the JGB/FBTB yield curve. This possibly reflects the fact that generally speaking, liquidity is higher in the interest rate swap markets than the corresponding cash bond markets since investment in cash bonds entail the funding needs and so global investors such as leveraged hedge funds tend to prefer to build their positions using the swap markets.

1. Introduction

This paper attempts to extract market expectations about the Japanese economy and the Bank of Japan's (BOJ) monetary policy stance from the Japanese yen yield curves augmented by money markets interest rates. We focus on the period from the end of the quantitative easing policy (QEP) in March 2006 until the onset of the financial market turmoil in August 2007. Since the end of the QEP, the BOJ has raised its policy rate twice (July 2006 and February 2007), and yen money and fixed income markets have experienced large swings caused by fluctuations in expectations following such events as the CPI rebasing in August 2006.

As argued by Baba et al. [2005], the yen money markets had almost lost their function under the zero interest rate policy (ZIRP) and QEP.[1] The level and volatility of short-term interest rates became so low that almost nothing about the future course of interest rates seemed to have been priced into those rates. As the end of the QEP approached, however, the yen money markets started to become active again and to price in future hikes of the policy rate by the BOJ. In fact, a new derivatives transaction named the overnight index swap (OIS), in which the compounded uncollateralized overnight (O/N) call rate is exchanged for the fixed rate, emerged around the spring of 2006. The volume of OIS transactions has grown rapidly and substantially, and the amount outstanding of OIS as of the end of May 2007 reached 971 trillion yen, corresponding to 20-30 percent of interest rate swaps including OIS (Bank of Japan [2007]).[2]

As market liquidity of OIS transactions improved, many market participants started to see the OIS rate as one of the most important reference rates in the yen money markets. In particular, they use the OIS rate to extract market expectations about a near-term policy rate hike by the BOJ based on the grounds that the underlying floating rate of OIS is the BOJ's policy rate

1 The BOJ initiated the ZIRP in April 1999, when it promised to keep the policy interest rate at zero until deflationary concerns are dispelled. The BOJ adopted the QEP in March 2001, when the policy target was changed from the uncollateralized call rate to the outstanding balance of current accounts held by financial institutions at the BOJ. The BOJ lifted the QEP in March 2006 and ZIRP in July 2006.

2 For more details of the yen OIS market, see Ooka, Nagano, and Baba [2006] and Bank of Japan [2007].

itself.[3]

It should also be noted that as the end of the QEP approached, non-Japanese investors, particularly hedge funds, started to invest in the yen interest rate markets very actively. Their presence has substantially increased, chiefly in the market for yen interest rate derivatives including interest rate swaps and options. As a result, their transaction volumes exceeded those of domestic investors in such markets as interest rate swaps, Euroyen futures, and interest rate options. Their investment strategy is typically based on their so-called normalization scenario of interest rates by the BOJ, backed by the recovery of the Japanese economy. Hence, they place considerable importance on the extraction of market expectations about the future state of the Japanese economy and the BOJ's monetary policy stance.

In light of the improvement in market liquidity in the overall yen money markets and non-Japanese investors' strategy since the end of the QEP, this paper attempts to extract market expectations about the Japanese economy and the BOJ's monetary policy stance from the yield curves augmented by money market interest rates. We use the daily yield curves, which are the highest frequency available, to analyze the daily fluctuations of market expectations that have been heavily influenced by a series of data releases and the policy-related press reports since the end of the QEP. In this paper, we use the Nelson and Siegel [1987] model to estimate three latent dynamic factors, and follow Diebold and Li [2006] to interpret those as reflecting market expectations about the future state of the Japan's economy and BOJ's monetary policy stance.

We also compare the possible information content between the following two yen yield curves from a perspective of price discovery.[4] One is constructed from the cash bond yields of

[3] Liquidity in the yen OIS market is generally high at short-term maturities up to one month, particularly for the so-called inter-meeting trades, which starts on the next day of the BOJ's MPM and matures on the next MPM. The trades for next four to five inter-meeting are usually very active. As for the longer maturities, transactions with 3- and 6-month maturities are relatively liquid due chiefly to the use of OIS for hedging and arbitrage purposes in relation to FBs and TBs.

[4] Attempts to extract market expectations have been done so far with a view to extracting the expected

FB/TB (financial bills/Treasury bills) and JGB (Japanese government bond), and the other is constructed from the OIS and interest rate swaps. Specifically, from these yield curves we first extract the market expectations about (i) the long-term nominal growth rate of the economy or the long-term neutral interest rate, (ii) the pace of rate hikes by the BOJ, and (iii) medium-term risk. Each expectations component corresponds to the long-term level factor, short-term slope factor, and medium-term curvature factor estimated by the Nelson-Siegel model, respectively.

Second, we compare the relative importance of price discovery for each expectations component between the two yield curves. Information content from the swap markets may be different from those from the cash bond markets, particularly for short-term money markets in Japan. The OIS market is more liquid than the FB/TB market. However, the OIS market participants are predominantly non-Japanese investors, and hence the OIS rate may not reflect the views of domestic investors. As for the FB/TB market, market participants are more diversified, but the liquidity is fairly limited in the secondary market. In this sense, both markets have advantages and disadvantages in extracting market expectations, and for monitoring the daily market development, it is crucial to understand which market rate reflect fundamentals more closely from a perspective of price discovery. To that end, this paper uses both a reduced-form model proposed by Gonzalo and Granger [1995] and Hasbrouck [1995], and a time-series structural model based on the state space model.

Third, we decompose the changes in each expectations component into the changes in the efficient price common to both yield curves and idiosyncratic components specific to each curve. This type of decomposition enables us to closely monitor the market expectations after controlling for the temporary supply-demand balances specific to the markets.

The rest of the paper is organized as follows. Section 2 estimates three latent dynamic

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duration of the ZIRP when the ZIRP was put in place. See Ueno, Baba, and Sakurai [2006].

factors that likely capture specific aspects of market expectations from the yield curves augmented by money market interest rates: OIS and FB/TB rates, using the Nelson-Siegel model. Section 3 compares the relative role of price discovery for each latent factor between swaps (OIS/Swap) and cash bonds (FBTB/JGB) using the reduced-form model. Section 4 estimates the efficient price for each latent factor common to both yield curves using a time-series structural model, and decomposes the changes in each latent factor into the changes in the efficient price and idiosyncratic factors specific to each yield curve. Section 5 concludes the paper.

2. Estimation of Latent Dynamic Factors Capturing Market Expectations

2.1 Nelson-Siegel Model

As stated by Söderlind and Svensson [1997], yield curves can be estimated either by a structural model for interest rate dynamics or by simple curve fitting. The former is more appropriate when the purpose is to predict future changes in the yield curve, while the latter is more appropriate when the purpose is to extract market expectations about future interest rates without making additional assumptions about the model structure. Since our purpose is to extract market expectations, we use the latter approach. Among others, we use the following Nelson and Siegel [1987] model to extract three latent dynamic factors from the yield curves augmented by money market interest rates:

$$f_t(\tau) = \beta_{0t} + \beta_{1t} e^{-\tau/\lambda_t} + \beta_{2t}\, \tau/\lambda_t\, e^{-\tau/\lambda_t}, \qquad (1)$$

$$y_t(\tau) = \beta_{0t} + \beta_{1t}\left(\frac{1-e^{-\tau/\lambda_t}}{\tau/\lambda_t}\right) + \beta_{2t}\left[\frac{1-e^{-\tau/\lambda_t}}{\tau/\lambda_t} e^{\tau/\lambda_t}\right], \qquad (2)$$

where $f_t(\tau)$ and $y_t(\tau)$ denote the forward rate and the corresponding spot rate for time t and maturity τ, respectively. The main reasons for choosing the Nelson-Siegel model are its handiness and ease of interpreting the parameters in economic terms, as will be described later.[5] As shown in Nelson and Siegel [1987], the shape of yield curve model (2) may be upward sloping, downward sloping, humped, or inverted, depending on the values of β_{1t} and β_{2t}.

Diebold and Li [2006] reinterprets the Nelson-Siegel model as a dynamic three latent factor model by fixing λ_t as a pre-specified constant. Based on this reinterpretation, Diebold, Rudebusch, and Aruoba [2006] and Fabozzi, Martellini, and Priaulet [2005] examine the empirical and forecasting performance of the model using U.S. dollar yield curve data. Diebold, Piazzesi, and Rudebusch [2005] and Christensen, Diebold, and Rudebusch [2007] deepen the model from a theoretical perspective by imposing the no-arbitrage condition. Following Diebold and Li [2006], we extract three latent factors using the Nelson-Siegel and interpret each factor as follows.[6]

First, the loading on β_{0t} is one, a constant that does not decay to zero in the limit. Hence, it can be viewed as a long-term level factor. Diebold, Rudebusch, and Aruoba [2006] find that this factor is closely related to bond market's perception of long-term inflation and real macroeconomic conditions. In line with this finding, hedge fund managers in London we interviewed regard it as the long-term nominal growth rate of the economy or the long-term neutral interest rate perceived by market participants.[7]

Second, the loading on β_{1t} is a function that starts at one, but decays monotonically

[5] Another possible way to extract market expectations about monetary policy stance is to look at the futures interest rate. Kuttner [2001] decomposes the change in Federal funds futures rates into anticipated and unanticipated components. In the Japanese case, Euroyen interest futures rates are available, but since the sole maturity is 3 months and the underlying rate is TIBOR (Tokyo Interbank Offered Rate), we cannot directly gauge market expectations about the BOJ's near-term monetary policy changes with the uncollateralized overnight call rate as its policy target.

[6] An alternative approach to estimating the latent factors is proposed by Diebold, Rudebusch, and Aruoba [2006]. They fit the yield curve at each point in time and estimate the underlying dynamics of the factors represented as the VAR(1) system simultaneously, using the state space model. A major advantage of this approach is that it suffers less from the overfitting problem. A major disadvantage is that it requires a tough numerical optimization with a more complex VAR system, and hence it may not be able to efficiently capture a high persistence in yields over time.

[7] The definition of the long-term (nominal) neutral interest rate differs across market participants. The most common definition is the interest rate that can be achieved in the long run, and that is neutral to cyclical factors including monetary policy.

and quickly to zero. Hence, it can be viewed as a short-term slope factor. Diebold, Rudebusch, and Aruoba [2006] find the close link between this factor and market expectations about monetary policy. Our interviews also show that hedge fund managers typically use it to gauge market expectations about the pace of rate hikes by the BOJ.

Third, the loading on β_{2t} is a function that starts at zero, increases, and then decays to zero. Hence, it can be viewed as a medium-term curvature factor, which is likely to reflect the medium-term risk relative to the pace of rate hikes perceived by market participants. Diebold, Rudebusch, and Aruoba [2006] does not find any explicit link between this factor and relevant macroeconomic variables, so it is more likely to be related to risk premium stemming from investors' risk tolerance.

Below, we estimate three latent factors by the following two steps: (i) estimating λ_t and three latent factors by calibrating the spot yield curve model (2) to the daily interest rate data, treating each parameter including λ_t as a free parameter, and (ii) re-estimating model (2) by fixing λ_t at the average value of λ_t estimated in the first step. The fixed value of λ we use throughout the paper is found to be 4.60.[8]

2.2 Data

Throughout the paper, we use the following two combinations of money market yields with maturities shorter than one year and longer-term yields to construct the full yield curves: (i) OIS and interest rate swap yields and (ii) FB/TB and JGB yields. We call each one the OIS/Swap yield curve and the FBTB/JGB yield curve, respectively.

We use the daily spot rates of these instruments. The sample period is from April 3,

[8] This corresponds to the average of λ_t estimated from OIS/Swap yield curve and λ_t from FBTB/JGB yield curve.

2006 until July 31, 2007, and the number of observations is 329.[9] We do not include the period after the onset of the turmoil that began in early August, 2007 since each factor diverge substantially between OIS/Swap curve and the FBTB/JGB curve, indicating that a regime shift evidently happened from that time. This divergence is due chiefly to heightened concern over liquidity and counterparty risk in the markets. The maturities consist of (i) 12 shorter-than-one-year maturities (1, 2, …, 12 months) and (ii) 21 longer maturities (1.5, 2, …, 9.5, 10 and 12, 15, and 20 years).

For the OIS/Swap yield curve, we use the OIS closing rates reported by Meitan Tradition Co., Ltd. and the zero-coupon swap rates estimated from the Tokyo Swap Reference Rate released by Reuters. Both rates are as of 15:00 Tokyo time. It should be noted that the underlying floating rate of OIS is the uncollateralized call rate (O/N), and that of interest rate swaps is 6-month LIBOR.[10] This difference in the underlying rates inevitably causes a discontinuous kink on the yield curves. Hence, we adjust the rate differential by deducting the sample-average rate differential (14.2 basis points) between the 1-year OIS rate and the 1-year swap rate from all the swap rates.[11]

For the FBTB/JGB yield curve, we use the FB/TB yields and the JGB zero-coupon yields.[12] FBs are currently issued with 3- and 6-month maturity, and TBs are issued with 6- and 12-month maturities as discount bonds, not paying periodic coupons. The 3-month FBs are issued at weekly auctions and the 6-month FB/TBs and 12-month TBs are issued at monthly auctions. We estimate one to eleven month spot rates by linearly interpolating the FB/TB yields of nearby maturities using the newly issued 12-month TB yields as the 1-year money market rate.

[9] The OIS rate is available only from April 3, 2006 since the yen OIS market emerged in the spring of 2006.

[10] LIBOR is London Interbank Offered Rate.

[11] This differential is quite stable throughout our sample period, but after the onset of turmoil, it become very unstable due to heightened concern over liquidity and counterparty risk.

[12] JGB zero-coupon yields are estimated from the price of coupon bonds with 5-, 10-, and 20-year maturities at issue by McCulloch's [1971, 1990] method.

As is the case with the OIS/Swap yield curve, a rate differential remains between the TB yield and the JGB yield at 1-year maturity. This mainly comes from the difference in funding costs for each bond. Investors typically use repo transactions (repurchase agreement, spot/next) for funding FB/TBs, while they purchase JGBs using their own yen cash. The Japanese repo rate is constantly higher and more volatile than the uncollateralized call rate, despite the fact that repo transactions are collateralized.[13] Hence, we deduct the spread between the repo rate (S/N) and the call rate (O/N) from the FB/TB rates for adjustment. The above-mentioned adjustments enabled us to smoothly draw both the OIS/Swap and FBTB/JGB yield curves without any kinks.

2.3 Estimation Result of Latent Factors

Chart 1 (i) shows a fitting example of the Nelson-Siegel model to both the OIS/Swap and FBTB/JGB yield curves, and Chart 1 (ii) shows the average pricing errors over the full sample period. Evidently, the Nelson-Siegel model performs well in tracing both yield curves, and the performance is significantly better for the OIS/Swap yield curve than the FBTB/JGB yield curve for almost all of the maturities at the 1 percent level.[14]

Next, Chart 2 (i) compares the average pricing errors of the OIS/Swap and FBTB/JGB yield curves (full yield curves) to those of the Swap and JGB yield curves that are not augmented by money market interest rates. The average pricing errors of the OIS/Swap and FBTB/JGB yield curves are lower than those of the Swap and JGB yield curves for maturities equal to or shorter than one year. Chart 2 (ii) shows that the O/N rates implied by the yield curves augmented by money market rates are closer to the policy target rates, suggesting that the augmented yield curves more properly capture the term structure of short-term money market

[13] For the reasons for higher and volatile repo rates, see the Bank of Japan [2006], and Baba and Inamura [2004].

[14] The statistical test result is available upon request.

yields.

Chart 3 plots the estimates of the three latent dynamic factors from each full yield curve. First, Chart 3 (i) shows that the long-term level factors from both yield curves are largely within the range between 2.4 and 3.2 percent. More specifically, the long-term level factor from the OIS/Swap yield curve is largely within the range of 2.8–3.2 percent, while that from the FBTB/JGB curve is within the range of 2.4–3.0 percent. Market participants suggest that the long-term nominal neutral interest rate is in the range of 2.5–3.0 percent in this period, so the estimated long-term level factors seem to be consistent with the market views. They are on an uptrend until October 2006, turned to a downtrend toward the end of 2006, and move without a clear direction since then. Also, the factor is constantly higher for the OIS/Swap yield curve than for the FBTB/JGB yield curve, particularly in 2006. One possible reason for this differential is the counterparty risk associated with OIS/Swap transactions, but the difference in the composition of market participants between the OIS/Swap and FBTB/JGB markets also likely plays a role. We will examine this issue later.

Second, Chart 3 (ii) shows that the short-term slope factor is constantly negative, and the negativity is larger for the OIS/Swap yield curve than for the FBTB/JGB yield curve. The negative short-term slope factor means an upward-sloping yield curve, and hence this result shows that the OIS/Swap yield curve constantly has a steeper slope than the FBTB/JGB yield curve. The short-term slope factors from both curves are almost directionless until October 2006, on an uptrend toward the end of 2006, and move without a clear direction since then. Since this factor can be interpreted as the pace of rate hikes by the BOJ perceived by market participants, these results have the following implications.

As emphasized by Ooka, Nagano, and Baba [2006] and Bank of Japan [2007], the yen OIS market is dominated by non-Japanese participants, while cash bond markets like FB/TBs have a more balanced composition of investors between Japanese and non-Japanese market participants. Anecdotal evidence suggests that non-Japanese market participants have expected the BOJ to hike its policy rate at a more rapid pace than their Japanese counterparts, backed by strong expectations of higher growth of the Japanese economy. The difference in the short-term slope factor may reflect such a perception gap between Japanese and non-Japanese market participants. From our interviews with non-Japanese market participants, their expectations of the BOJ's rate hike peaked around May 2006, lost steam between October and December 2006 when the CPI inflation rates were successively weaker than expected, and heightened again toward the monetary policy meeting (MPM) in February 2007, when the policy rate was actually hiked. The movement of the short-term slope factor seems to capture such a swing of market expectations.

Third, Chart 3 (iii) shows that the medium-term curvature factors are on a consistent downtrend until October 2006, and move without a clear direction since then. This result seems to be consistent with the market sentiment that the expectations of higher interest rates based on the upbeat outlook for the Japanese economy peaked around the spring of 2006, and have substantially receded since the CPI rebasing in August 2006.[15]

Furthermore, to examine more closely the market expectations priced into the money market interest rates, we also estimate the short-term slope factor and the medium-term curvature factor only from the OIS and FBTB yield curves whose maturities are up to one year. We call them money market yield curves. In doing so, we fix the long-term factor at 2.92, which is the mean of the factor estimated from OIS/Swap and FBTB/JGB yield curves over the full sample period.

Chart 4 (i) and Chart 4 (ii) plot the thus-estimated short-term slope factor and the medium-term curvature factor, respectively. The medium-term curvature factor shows a similar

[15] As a result of the CPI rebasing in August 2006, the national core CPI inflation rate was revised downward by 0.4 percentage points.

time-series pattern to that estimated from the full yield curves, but the short-term slope factor has a more striking time-series pattern than that from the full yield curves. Since the time horizon of the money market yield curves is up to one year, the immediate rate hikes can be more easily priced in as the flattening of the curves.[16] We can see that each slope factor rapidly rises toward the MPMs when the BOJ raised the policy rate (July 14, 2006 and February 21, 2007), which suggests that money market yield curves price in the immediate rate hikes in the form of the flattening of the curve.[17] Evidently, the OIS yield curve has led the FBTB curve in pricing in the immediate rate hikes thus far.

3. Evaluating Price Discovery Using a Reduced-Form Model

3.1 Price Discovery Measures under a Reduced-Form Model

In this section, we investigate which yield curve, the OIS/Swap or FBTB/JGB yield curve, has a more dominant role of price discovery for each factor using a reduced-form model.

Broadly speaking, there are two empirical approaches that have attracted academic attention for investigating price discovery. One is the permanent-transitory (PT) model developed by Gonzalo and Granger [1995], and the other is the information share (IS) model developed by Hasbrouck [1995]. Both models start with the estimation of the vector error-correction model (VECM) of market prices:

$$\Delta\beta_t^{OIS} = \lambda_1\left(\beta_{t-1}^{OIS} - \alpha_1\beta_{t-1}^{FB} - C\right) + \sum_{j=1}^{p}\gamma_{1j}^{OIS}\Delta\beta_{t-j}^{OIS} + \sum_{j=1}^{p}\eta_{1j}^{FB}\Delta\beta_{t-j}^{FB} + \varepsilon_t^{OIS} \quad (6)$$

$$\Delta\beta_t^{FB} = \lambda_2\left(\beta_{t-1}^{OIS} - \alpha_1\beta_{t-1}^{FB} - C\right) + \sum_{j=1}^{p}\gamma_{2j}^{OIS}\Delta\beta_{t-j}^{OIS} + \sum_{j=1}^{p}\eta_{2j}^{FB}\Delta\beta_{t-j}^{FB} + \varepsilon_t^{FB}\,. \quad (7)$$

Here, β_t^{OIS} (β_t^{FB}) denotes the latent factor in time t estimated from the OIS/Swap

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[16] Diebold, Rudebusch, and Aruoba [2006] also emphasize this tendency by noting that "an increase in the funds rate almost immediately pushed up the slope factor so the yield curve is less positively sloped."
[17] We can also see the rises in the short-term slope factors toward the MPM in January 2007. In this period, the yen money markets, the OIS market in particular, were substantially disturbed by noisy media releases about the timing of the immediate policy rate hike.

(FBTB/JGB) yield curve, and ε_t^{OIS} (ε_t^{FB}) is the corresponding i.i.d. residual. For simplicity, we drop the subscript i for latent factors. An underlying assumption is that there is an unobservable efficient price for each factor that is common to both yield curve factors.

Based on the VECM above, the PT model decomposes the efficient price itself, and attributes a more dominant role of price discovery to the market that adjusts less to price movements in the other market. As stated in Engle and Granger [1987], the existence of cointegration assures that at least one market has to adjust. Specifically, price discovery for the OIS/Swap yield curve factor under the PT model can be measured by

$$\mathrm{PT} = \frac{\lambda_2}{\lambda_2 - \lambda_1}. \tag{8}$$

When this measure is larger than 0.5, we can judge that the OIS/Swap yield curve has a more dominant role in price discovery.

On the other hand, the IS model decomposes the variance of the efficient price under the assumption that price volatility reflects new information flows, and hence the market that contributes more to the variance of the innovations to the efficient price is considered to contribute more to price discovery. Specifically, price discovery for the OIS/Swap yield curve factor under the IS model can be measured by

$$\mathrm{IS}_1 = \frac{\lambda_2^2\left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2} \quad \text{and} \quad \mathrm{IS}_2 = \frac{\left(\lambda_2\sigma_1 - \lambda_1\frac{\sigma_{12}}{\sigma_1}\right)^2}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2}, \tag{9}$$

where σ_1^2, σ_2^2, and σ_{12} are factors in the covariance matrix of ε_t^{OIS} and ε_t^{FB}. IS_1 and IS_2 measure the lower and higher bounds of information share, where the difference between two bounds is positively related to the correlation between residuals. Baillie et al. [2002] argue that the average of these two bounds provides a sensible estimate of price discovery when the data frequency is high. Again, the threshold value of a more dominant role in price discovery is 0.5, beyond which the OIS/Swap yield curve is judged as having a more dominant role in price discovery. Also note that PT ignores the correlation between the residuals, and hence if the residuals are strongly correlated, then both models can provide substantially different results.

3.2 Estimation Result of Price Discovery Measures

Chart 5 shows the estimation results of price discovery measures for the three latent factors estimated from the two full yield curves.[18] First, Chart 5 (i) reports the result of the Johansen cointegration test. The same factors estimated from the two yield curves have a cointegration relationship at the 10 percent significance level for the long-term level factor and the slope factor, and at the 5 percent level for the medium-term curvature factor.[19] We also test the restriction of the theoretically complete relationship characterized as a vector (1, –1) between the two yield curves, and find that the restriction is not rejected significantly.

Second, Chart 5 (ii) shows the estimation result of the two price discovery measures. Both PT and IS measures of price discovery suggest that the OIS/Swap yield curve has a more dominant role of price discovery than the FBTB/JGB yield curve for all three latent factors.

Third, Chart 6 shows the generalized impulse responses of each factor.[20] For each factor, the responses of the FBTB/JGB factor to the OIS/Swap factor are generally larger than vice versa. In particular, the responses of the FBTB/JGB factor to the OIS/Swap factor become larger than the responses of the FBTB/JGB factor to itself several days after the shock.

Next, Chart 7 shows the estimation result of price discovery measures for the short-term slope factor and the medium-term curvature factor estimated from the money market yield curves. First, Chart 7 (i) shows that each factor has a cointegration relationship between OIS

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[18] Both the Augmented Dickey-Fuller and the Phipps-Perron tests (not shown) suggest that all three factors are I(1) at least at the 5 percent significance level. The estimation result is available upon request.

[19] We include a trend term in the cointegration test since the differences in the same factors estimated from the two yield curves constantly become narrower throughout the sample period.

[20] We use the generalized impulse responses proposed by Pesaran and Shin [1998] instead of the impulse responses derived from the conventional orthogonalized Cholesky decomposition. The generalized impulse responses have an advantage in that they are invariant to the ordering of the variables in the VAR system.

and FBTB yield curves at least at the 5 percent significance level, and the theoretical restriction of the vector (1, –1) was not significantly rejected for the medium-term curvature factor.

Second, Chart 7 (ii) shows that the OIS yield curve has a more dominant role of price discovery for both factors. Last, Chart 8 shows the impulse responses. A similar tendency can be observed as is the case of the full yield curves. The dynamic effects of the OIS factors on the FBTB factors are larger than vice versa, particularly for the short-term slope factor.

4. Extracting Market Expectations Using a Structural Time-Series Model

4.1 Structural Model

Next, we use a structural time-series model (state space model) to extract market expectations in the form of the efficient price that is common to OIS/Swap and FBTB/JGB full yield curves or OIS and FBTB money market yield curves. Various specifications exist for structural time-series models. In this paper, we adopt the specification that is an extension of the so-called local level model into the setting of multiple market prices with a common factor as a state variable, following Lehmann [2002] and others:

$$\begin{pmatrix} \beta_t^{OIS} \\ \beta_t^{FB} \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} m_t + \begin{pmatrix} T_t^{OIS} \\ T_t^{FB} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{OIS} \\ \varepsilon_t^{FB} \end{pmatrix} \qquad \varepsilon_{it}^{OIS} \sim N\left(0, \sigma_{\varepsilon OIS}^2\right), \varepsilon_{it}^{FB} \sim N\left(0, \sigma_{\varepsilon FB}^2\right) \quad (10)$$

$$m_{t+1} = m_t + s_{t+1}^m \qquad s_t^m \sim N\left(0, \sigma_m^2\right) \quad (11)$$

$$T_{t+1}^{OIS} = b^{OIS} + c^{OIS} T^{OIS} + s_{t+1}^{OIS} \qquad s_{t+1}^{OIS} \sim N\left(0, \sigma_{sOIS}^2\right) \quad (12)$$

$$T_{t+1}^{FB} = c^{FB} T_t^{FB} + s_{t+1}^{FB} \qquad s_t^{FB} \sim N\left(0, \sigma_{sFB}^2\right) \quad (13)$$

$$0 < c^{OIS} < 1, \ 0 < c^{FB} < 1.$$

Here, we drop the subscript i for latent factors. Each latent factor consists of the following three price components: (i) the efficient price (m_t), (ii) the idiosyncratic factor (T_t^{OIS} or T_t^{FB}), and (iii) the idiosyncratic temporary noise (ε_t^{OIS} or ε_t^{FB}).

First, m_t is the efficient price that is common to OIS/Swap and FBTB/JGB yield curve factors. As discussed in section 2, this corresponds to the pure expectations component of: (i) long-term nominal growth rate of the economy for the long-term factor; (ii) pace of rate hikes by the BOJ for the short-term factor; and (iii) risk relative to the pace of rate hikes for the medium curvature factor. m_t is assumed to follow a random walk process (11), following a conventional practice in finance literature.[21]

Second, T_t^{OIS} and T_t^{FB} represent the idiosyncratic factors specific to the OIS/Swap and FBTB/JGB factor, respectively. These factors are assumed to follow a mean-reverting process.[22] Under this specification, a swap spread for each factor can be written as

$$E_t[Swap\,Spread_{t+1}] = b^{OIS} + c^{OIS}T_t^{OIS} - c^{FB}T_t^{FB}. \qquad (14)$$

Recent studies on interest rate swaps, such as Duffie and Singleton [1997] and Kambhu [2006], point out that the swap spreads tend to converge to their normal level, and hence follow an I(0) mean-reverting process. Moreover, Kambhu [2006] argues that both idiosyncratic factors specific to swaps and government bonds influence the swap spreads. Our specification of the swap spread follows these findings. As for the specification of the OIS and FBTB money market yield curves, b^{OIS} is assumed to be zero because the average level of the swap spread has already been adjusted by applying the same long-term level factor, 2.92, in calculating the two latent factors.

Third, ε_t^{OIS} and ε_t^{FB} are the idiosyncratic temporary noises, possibly reflecting transient market-microstructure shocks arising from temporary supply-demand shocks at auctions, for instance.

Note that the above model has a path through which a shock in one market does

21 The random walk representation of the efficient price dates back to Samuelson [1965].

22 A constant parameter, b, is included only in the OIS/Swap process because the swap spread is the spread added to the FBTB/JGB curve by definition, and hence the long-run average of each T_i^{FB} can be safely treated as zero.

transmit to the price in another in the following way. Suppose that a positive shock occurs in one market. As far as this shock is a non-stationary permanent shock, it is identified as a shock to affect the efficient price and then influence the factors in both markets. Simultaneously, a negative idiosyncratic shock is identified in the other market. Hence, the factor rises in one market and remains the same in the other market after the shock. Since an idiosyncratic shock is stationary, its effect gradually diminishes and the factor in the other market also rises over time. In this manner, a permanent shock transmits from one market to the other dynamically. On the other hand, an idiosyncratic shock does not transmit each other.

In what follows, we assume that each shock is mutually independent. The parameters in the model are well identified, and are estimated by maximizing the log-likelihood that can be evaluated by the Kalman filter.[23]

4.2 Estimation Result: Full Yield Curves

Chart 9 reports the estimation result of the structural model for each latent factor estimated from the full yield curves. All the coefficients except c^{OIS} for β_2 are significant at least at the 5 percent level. The long-run mean level of T_t^{OIS} calculated as $b^{OIS}/\left(1-c^{OIS}\right)$ is 0.220 for β_0, –0.182 for β_1, and –0.227 for β_2, respectively. This result suggests that in the long run, (i) the long-term level factor of the swap spread converges to the 0.220 percent level, (ii) the swap spread has a positive slope, and (iii) a negative curvature.

Furthermore, we compute the following signal-to-noise ratio to assess the relative importance of price discovery between the two yield curves, which is defined as the share of the efficient price variance in the total variance for each factor:[24]

[23] See Durbin and Koopman [2001] for details of the state space model and the Kalman filter.

[24] The conventional definition of the signal-to-noise ratio is the ratio of the efficient price variance to stochastic noise variance. We use our form of the signal-to-noise ratio primarily for ease of comparison.

$$SIS(i) \equiv \sigma_m^2 / \left(\sigma_m^2 + \sigma_{si}^2 + \sigma_{\varepsilon i}^2\right). \quad \text{For } i = \text{OIS/Swap or FBTB/JGB} \tag{15}$$

We call this measure "structural information share (SIS)" in this paper. As shown in Chart 9, SIS is higher for the OIS/Swap than the FBTB/JGB for each factor. The result is consistent with the estimation result of price discovery measures using the reduced-form model reported in Section 3.

4.3 Factor Decomposition: Full Yield Curves

Using the estimation result above, we can decompose a change in each factor into the changes in the efficient price and the idiosyncratic factor as follows:

$$\beta_{t+1}^{OIS} - \beta_t^{OIS} = \left(\overline{m}_{t+1} - m_t\right) + \left(\overline{T}_{t+1}^{OIS} - \overline{T}_t^{OIS}\right) + \varepsilon_{t+1}^{OIS} - \varepsilon_t^{OIS} \tag{16}$$

$$\beta_{t+1}^{FB} - \beta_t^{FB} = \left(\overline{m}_{t+1} - \overline{m}_t\right) + \left(\overline{T}_{t+1}^{FB} - \overline{T}_t^{FB}\right) + \varepsilon_{t+1}^{FB} - \varepsilon_t^{FB}, \tag{17}$$

where $\overline{m}_t$, $\overline{T}_t^{OIS}$, and $\overline{T}_t^{FB}$ are filtered state variables. The first term on the right-hand side of equations (16) and (17) indicates the forecast errors of the efficient price, and the remaining terms correspond to those of the total idiosyncratic factors. Note here that this is *not* the decomposition of forecast errors, but just a simple factor decomposition.

Chart 10 shows the result of the factor decomposition for each latent factor. The left figures show the decomposition of daily factor changes, and the right ones show the accumulated daily changes from the second date of our sample period, April 3, 2007. The efficient price for each factor shows a very similar time-series pattern to each latent factor itself shown in Chart 3. An interesting point here is that the idiosyncratic factors for FBTB/JGB seem to have a trend, and fluctuate much more widely than those for OIS/Swap. This result suggests that the efficient price follows the factor estimated from the OIS/Swap yield curve much more closely, which is consistent with the result that the OIS/Swap yield curve has a more dominant role in price discovery than the FBTB/JGB yield curve.

4.4 Estimation Result: Money Market Yield Curves

Next, Chart 11 shows the estimation result for the short-term slope factor estimated from the money market yield curves.[25] All the coefficients except $\sigma^2_{\varepsilon OIS}$ are significant at the 1 percent level. This result suggests that the idiosyncratic temporary noises are statistically negligible in the OIS market. Also note that c^{OIS} is estimated to be closer to 1 (0.944), which is higher than the case of the full yield curves (0.609). SIS is higher for the OIS slope factor than the FBTB slope factor, suggesting that the OIS slope factor has a more dominant role in price discovery than the FBTB slope factor. The result is consistent with the case of the full yield curves.

Chart 12 shows the result of the factor decomposition. The time-series pattern of the efficient price has a distinctive feature. Specifically, from about one month before the MPMs where market participants strongly expected the BOJ to raise the policy rate, the efficient price started to rise rapidly, and hence flattened the short-term yield curve. Then, once the policy rate was raised, it remained or gradually declined until market expectations about the next rate hike were reignited. Also note that the idiosyncratic factor is more volatile for FBTB than OIS throughout the sample period. This result is consistent with the case of the full yield curves and probably reflects temporary supply-demand imbalances in the bond markets, as has often suggested by market participants.

5. Concluding Remarks

This paper has extracted market expectations about the Japanese economy and the BOJ's policy stance from the Japanese yen yield curves augmented by money market interest rates on a daily

[25] The result for the medium-term curvature factor is available upon request.

basis. We focused on the period after the end of the quantitative easing policy in March 2006. We used (i) the swap yield curves augmented by OIS interest rates (OIS/Swap), and (ii) the JGB yield curve augmented by FB/TB interest rates. The main findings are summarized as follows.

First, using the Nelson-Siegel [1987] model, we estimated three latent dynamic factors. Following Diebold and Li [2006], we interpreted those as capturing the expectations component about (i) the long-term nominal growth rate of the Japanese economy or the long-term neutral interest rate, (ii) the pace of the BOJ's rate hikes, and (iii) the medium-term risk relative to the pace of rate hikes by the BOJ.

Second, we investigated the relative role of price discovery for each factor between OIS/Swap and FBTB/JGB, and found that for all the factors, the OIS/Swap yield curve has a more dominant role of price discovery than the FBTB/JGB yield curve.

Third, we estimated the efficient price for each latent factor common to both yield curves using a time-series structural model, and decomposed the changes in each latent factor into the changes in the efficient price and idiosyncratic factors specific to each yield curve. We found that each efficient price follows each OIS/Swap factor more closely than the corresponding FBTB/JGB factor, and the idiosyncratic component is more volatile for the FBTB/JGB factors than the OIS/Swap factors.

References

Baba, N., and Y. Inamura [2004], "The Japanese Repo Market: Theory and Evidence," *Bank of Japan Monetary and Economic Studies*, 22, pp. 65-90.

Baba, N., S. Nishioka, N. Oda, M. Shirakawa, K. Ueda, and H. Ugai [2005], "Japan's Deflation, Problems in the Financial System, and Monetary Policy," *Monetary and Economic Studies*, Bank of Japan, 23, pp. 47-111.

Baillie, R., G. Booth, Y. Tse, and T. Zabotina [2002], "Price Discovery and Common Factor Models," *Journal of Financial Markets*, 5, pp. 309-321.

Bank of Japan [2006], *Financial Markets Report – Developments during the First Half of 2006*.

Bank of Japan [2007], *Survey on Yen-OIS Market in May 2007*.

Christensen, J. H. E., F. X. Diebold, and G. D. Rudebusch [2007], "The Affine Arbitrage-Free Class of Nelson-Siegel Term Structure Models," Federal Reserve Bank of San Francisco Working Paper Series*,* 2007-20.

Diebold, F. X., M. Piazzesi, and G. D. Rudebusch [2005], "Modeling Bond Yields in Finance and Macroeconomics," *American Economic Review*, 95, pp. 415-420.

Diebold, F. X., G. D. Rudebusch, and S. B. Aruoba [2006], "The Macroeconomy and the Yield Curve: A Latent dynamic factor Approach," *Journal of Econometrics*, 131, pp. 309-338.

Diebold, F. X., and C. Li [2006], "Forecasting the Term Structure of Government Bond Yields," *Journal of Econometrics,* 130, pp. 337-364.

Duffie, D., and K. J. Singleton [1997], "An Econometric Model of the Term Structure of Interest Rate Swap Yields," *Journal of Finance*, 52-4, pp. 1287-1321.

Durbin, J., and S. J. Koopman [2001], *Time Series Analysis by State Space Models*, Oxford, Oxford University Press.

Engel, R., and C. Granger [1987], "Cointegration and Error-correction Representation, Estimation and Testing," *Econometrica*, 55, pp. 251-276.

Fabozzi, F. J., L. Martellini, and P. Priaulet [2005], "Predictability in the Shape of the Term Structure of Interest Rates," *Journal of Fixed Income*, June 2005, pp. 40-53.

Gonzalo, J., and C. Granger [1995], "Estimation of Common Long-memory Components in Cointegrated Systems," *Journal of Business and Economic Statistics*, 13, pp. 27-35.

Hasbrouck, J. [1995], "One Security, Many Markets: Determining the Contributions to Price Discovery," *Journal of Finance*, 50, pp. 1175-1199.

Kambhu, J. [2006], "Trading Risk, Market Liquidity, and Convergence Trading in the Interest Rate Swap Spread," *FRBNY Economic Policy Review*, May 2006.

Kuttner, K. N. [2001], "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market," *Journal of Monetary Economics*, 47, pp. 523-544.

Lehmann, B. [2002], "Some Desiderata for the Measurement of Price Discovery Across Markets," *Journal of Financial Markets*, 5, pp. 259-276.

McCulloch, J. [1971], "Measuring the Term Structure of Interest Rates," *Journal of Business*, 44, pp. 19-31.

McCulloch, J. [1990], "U.S. Government Term Structure Data, 1947-1987," in B. M. Friedman and F. Hahn, eds., *Handbook of Monetary Economics* (vol. 1), North Holland, pp. 672-715.

Nelson, C. R., and A. F. Siegel [1987], "Parsimonious Modeling of Yield Curve," *Journal of Business*, 60, 473-489.

Ooka, E., T. Nagano, and N. Baba [2006], "Recent Developments of the OIS (Overnight Index Swap) Market in Japan," *Bank of Japan Review Series*, 06-E-4, Bank of Japan.

Pesaran, M., and Y. Shin [1998], "Generalized Impulse Response Analysis in Linear Multivariate Models," *Economics Letters*, 58, pp. 17-29.

Samuelson, P. [1965], "Proof that Properly Anticipated Prices Fluctuate Randomly," *Industrial Management Review*, 6, pp. 41-49.

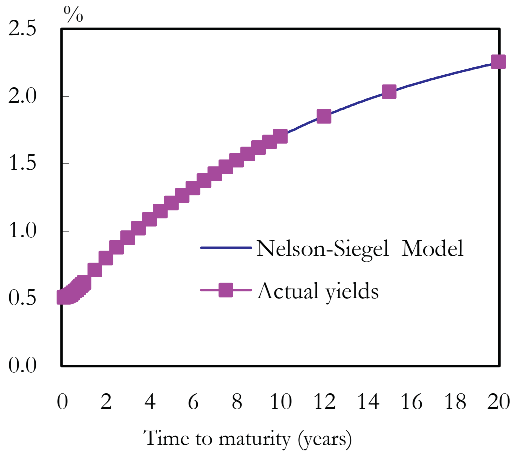
Söderlind, P., and L. Svensson [1997], "New Techniques to Extract Market Expectations from Financial Instruments," *Journal of Monetary Economics*, 40, pp. 383-429.

Ueno, Y., N. Baba, and Y. Sakurai [2006], "The Use of the Black Model of Interest Rates as Options for Monitoring the JGB Market Expectations," Bank of Japan Working Paper Series No. 06-E-15.

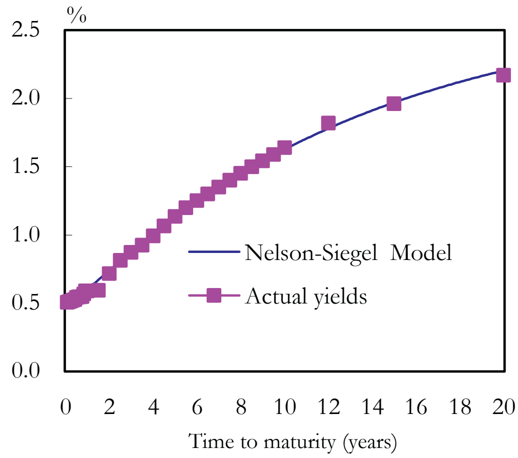
Chart 1: Fitting Performance of the Nelson-Siegel Model

(i) Fitting Example of the Nelson-Siegel Model

a. OIS/Swap Yield Curve

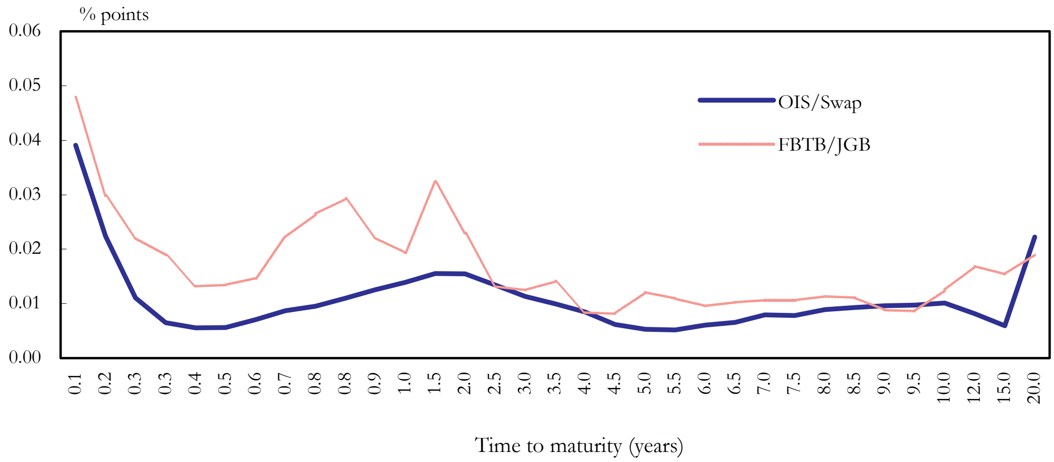


b. FBTB/JGB Yield Curve



Note: The fitting example is as of March 30, 2007.

(ii) Average Pricing Errors

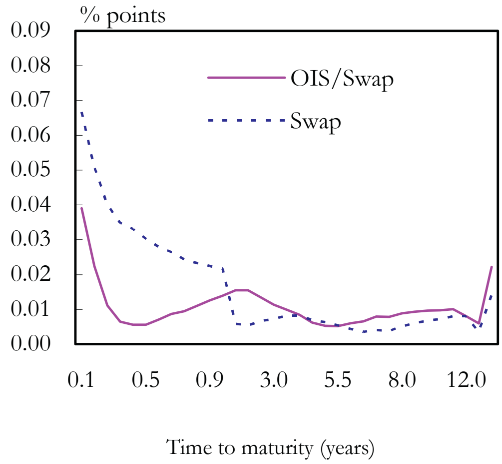


Note: Average pricing errors are calculated as the absolute values of pricing errors over the full sample period.

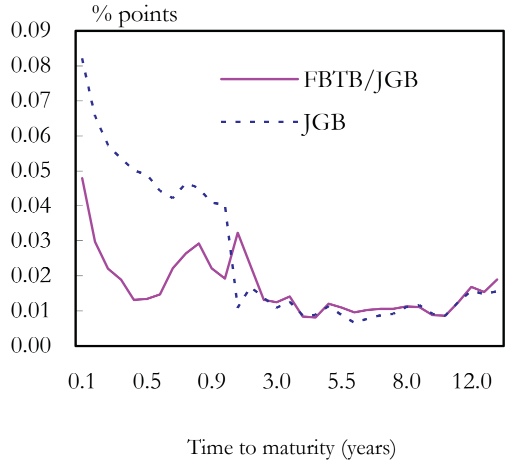
Chart 2: Comparison between Full Yield Curves and Yield Curves without Money Market Rates

(i) Average Pricing Errors

a. OIS/Swap vs. Swap Yield Curve



b. FBTB/JGB vs. JGB Yield Curve



Note: Average pricing errors are calculated as the absolute values of pricing errors over the full sample period.

(ii) Implied O/N Rates

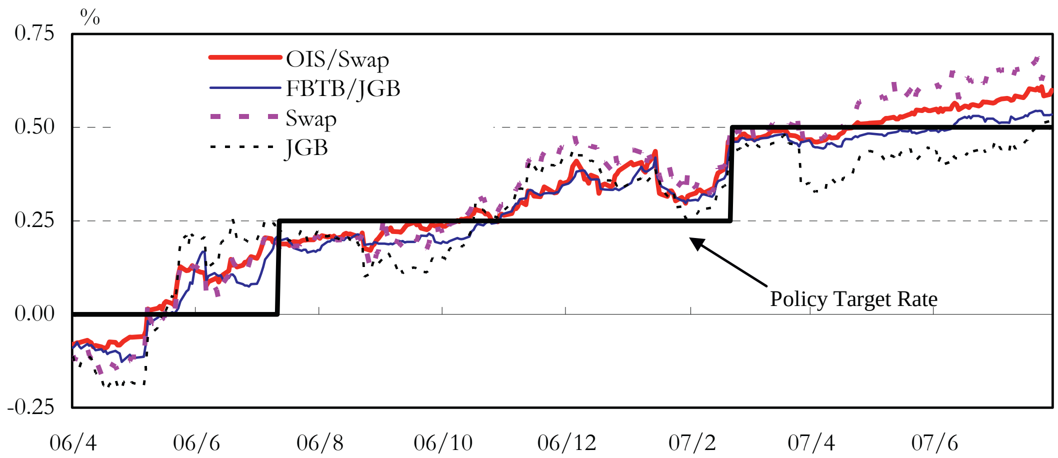


Chart 3: Three Latent Factors Estimated from Full Yield Curves

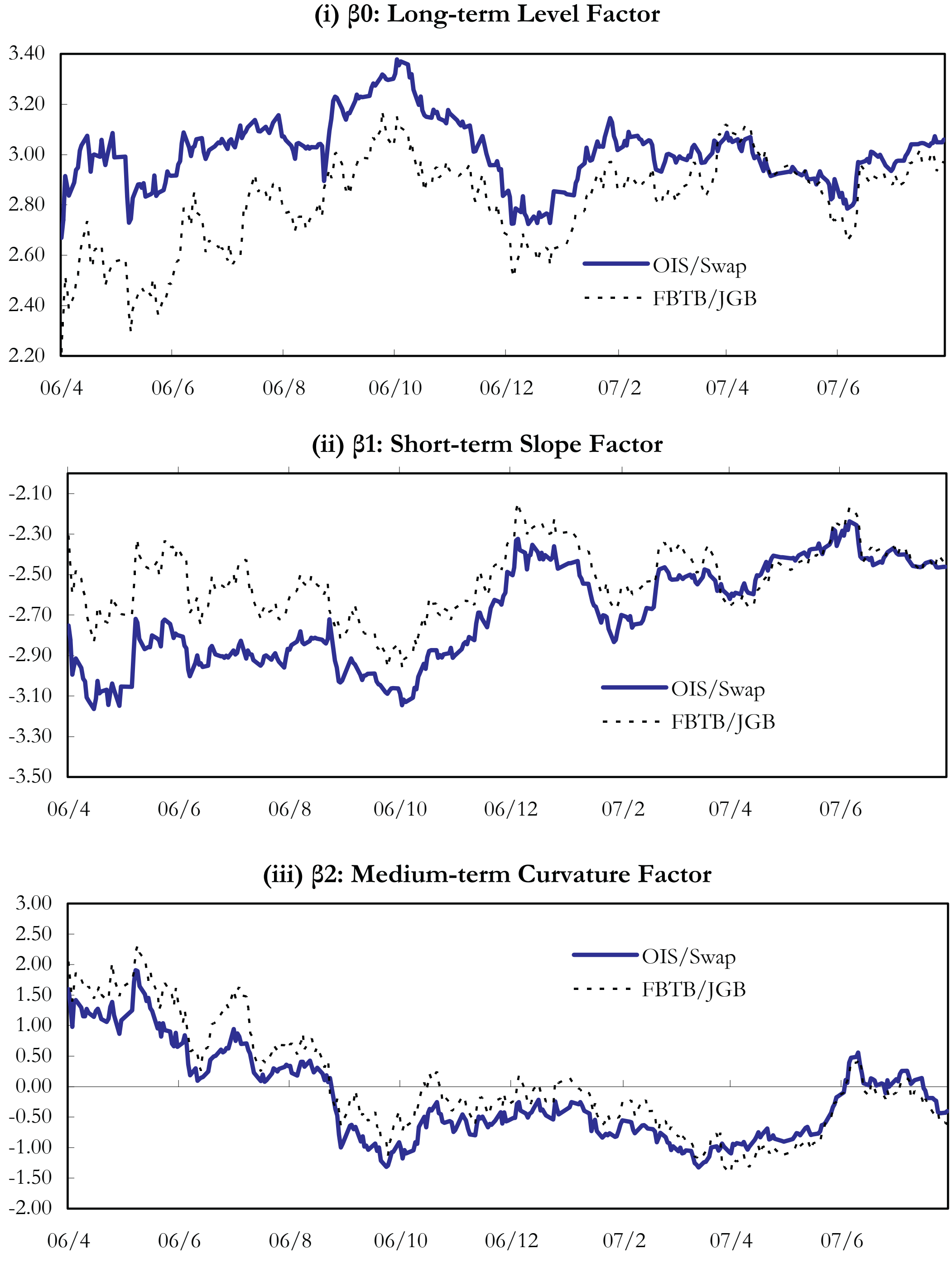
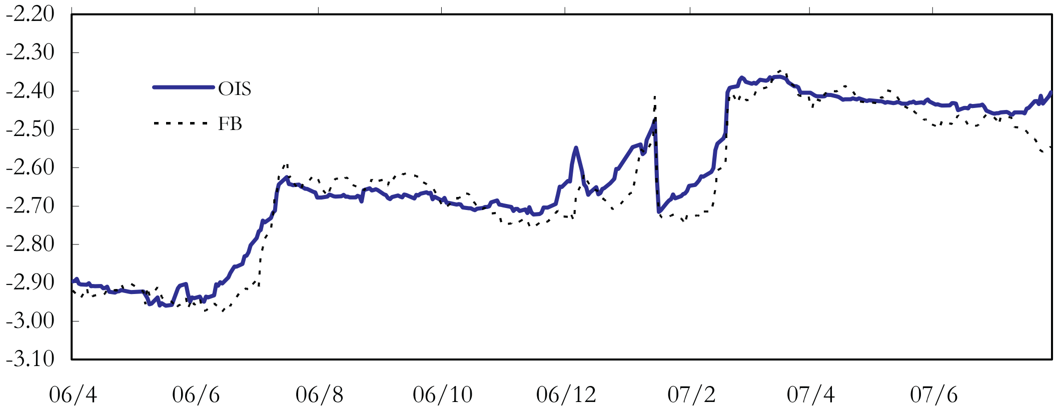
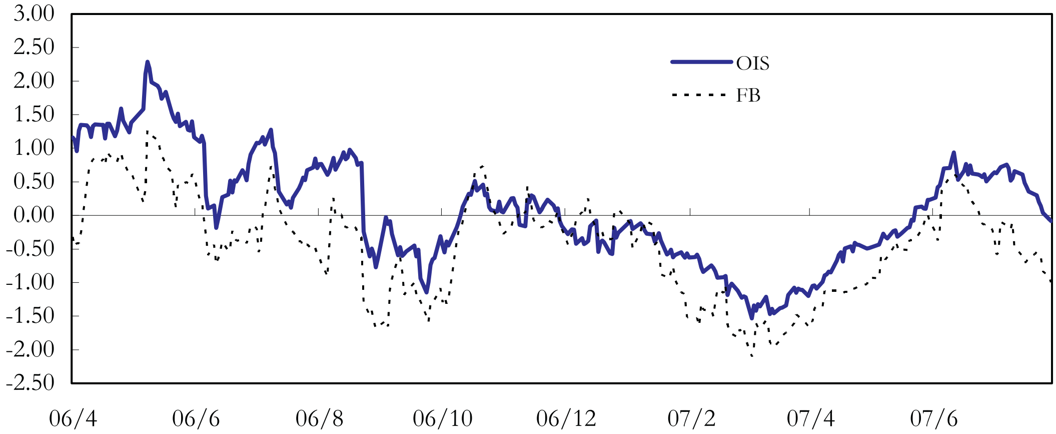


Chart 4: Two Factors Estimated from Money Market Yield Curves

(i) β1: Short-term Slope Factor



(ii) β2: Medium-term Curvature Factor



Note: β0 is fixed at 2.92.

Chart 5: Price Discovery Measures from Full Yield Curves (OIS/Swap vs. FBTB/JGB Yield Curve)

(i) Cointegration Analysis

(a) β0 Sample Period: April 3, 2006-July 31, 2007 (Number of Observations: 329)

Cointegration Rank Test				
H0	Eigenvalue	Trace	Max Eigen	Lags
None	0.05	24.08 *	17.57 *	2
At most 1	0.02	6.51	6.51	

Cointegration Vector			
OIS/Swap	FBTB/JGB	Constant	Trend
1.000	-0.917	-0.624	0.001
LR statistic for cointegration vector = (1, -1)		Chi-squared = 0.453	*p*-value = 0.501

(b) β1 Sample Period: April 3, 2006-July 31, 2007 (Number of Observations: 329)

Cointegration Rank Test				
H0	Eigenvalue	Trace	Max Eigen	Lags
None	0.05	25.10 *	18.24 *	2
At most 1	0.02	6.86	6.86	

Cointegration Vector			
OIS/Swap	FBTB/JGB	Constant	Trend
1.000	-0.941	0.550	-0.001
LR statistic for cointegration vector = (1, -1)		Chi-squared = 0.343	*p*-value = 0.558

(c) β2 Sample Period: April 3, 2006-July 31, 2007 (Number of Observations: 329)

Cointegration Rank Test				
H0	Eigenvalue	Trace	Max Eigen	Lags
None	0.07	27.48 **	23.61 **	2
At most 1	0.01	3.87	3.87	

Cointegration Vector			
OIS/Swap	FBTB/JGB	Constant	Trend
1.000	-1.077	0.737	-0.003
LR statistic for cointegration vector = (1, -1)		Chi-squared = 1.626	*p*-value = 0.202

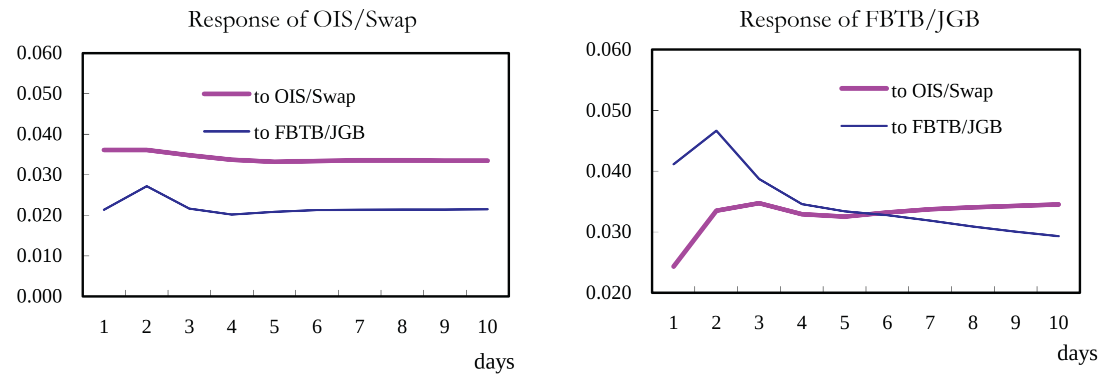
Notes: 1. The number of lags is chosen by SIC.
2. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.
3. LR (likelihood ratio) statistic examines the hypothesis that the parameters of OIS/Swap and FBTB/JGB in the cointegration vector are the same.

(ii) Price Discovery Measures: OIS/Swap vs. FBTB/JGB

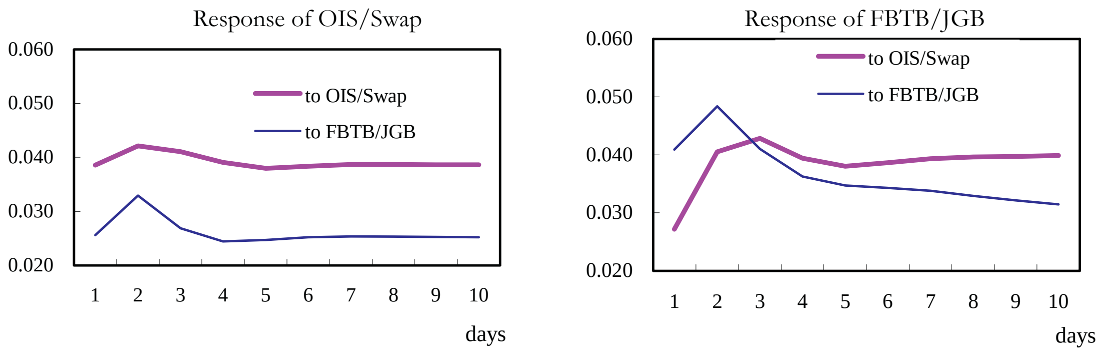
	PT	IS		
		Higher	Lower	Mean
β0	0.91	0.99	0.57	0.78
β1	1.02	1.00	0.58	0.79
β2	0.93	1.00	0.45	0.73

Chart 6: Impulse Reponses of Full Yield Curves

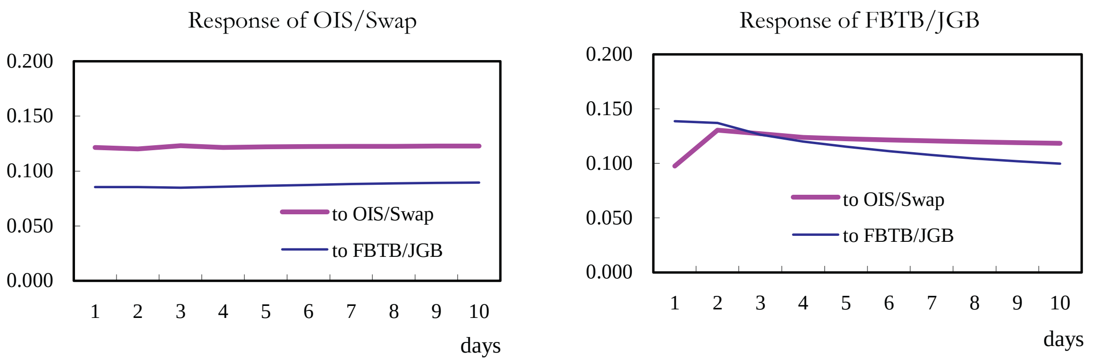
(i) β0: Long-term Level Factor



(ii) β1: Short-term Slope Factor



(iii) β2: Medium-term Curvature Factor



Note: Impulse responses are the responses of each factor to generalized one standard deviation of each factor.
See Pesaran and Shin [1998] for the estimation method.

Chart 7: Price Discovery Measures from Money Market Yield Curves (OIS vs. FBTB Yield Curve)

(i) Cointegration Analysis

(a) β1

Sample Period: April 3, 2006-July 31, 2007 (Number of Observations: 329)

Cointegration Rank Test				
H0	Eigenvalue	Trace	Max Eigen	Lags
None	0.11	46.09 ***	37.65 ***	1
At most 1	0.03	8.44	8.44	

Cointegration Vector			
OIS	FBTB	Constant	Trend
1.000	-0.720	0.819	-0.001
LR statistic for cointegration vector = (1, -1)		Chi-squared = 13.366	*p*-value = 0.000

(b) β2

Sample Period: April 3, 2006-July 31,2007 (Number of Observations: 329)

Cointegration Rank Test				
H0	Eigenvalue	Trace	Max Eigen	Lags
None	0.07	27.72 **	23.32 **	1
At most 1	0.01	4.40	4.40	

Cointegration Vector			
OIS	FBTB	Constant	Trend
1.000	-1.153	-0.651	0.000
LR statistic for cointegration vector = (1, -1)		Chi-squared = 0.974	*p*-value = 0.324

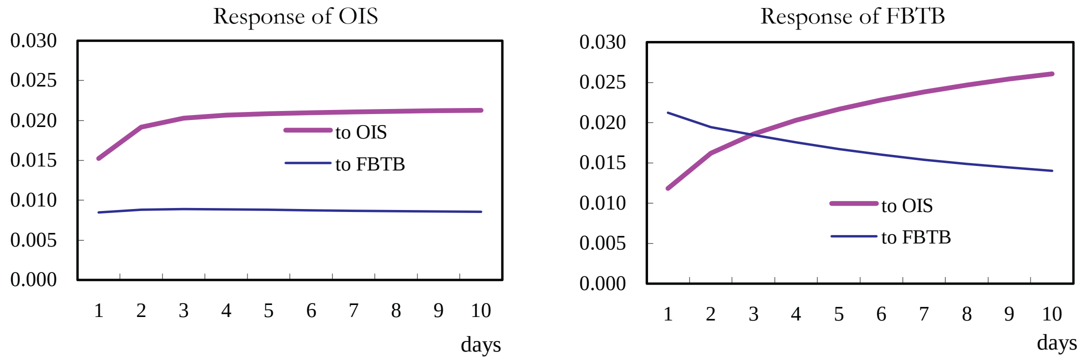
Notes:
1. The number of lags is chosen by SIC.
2. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.
3. LR (likelihood ratio) statistic examines the hypothesis that the parameters of OIS and FBTB in the cointegration vector are the same.

(ii) Price Discovery Measures of OIS relative to FBTB

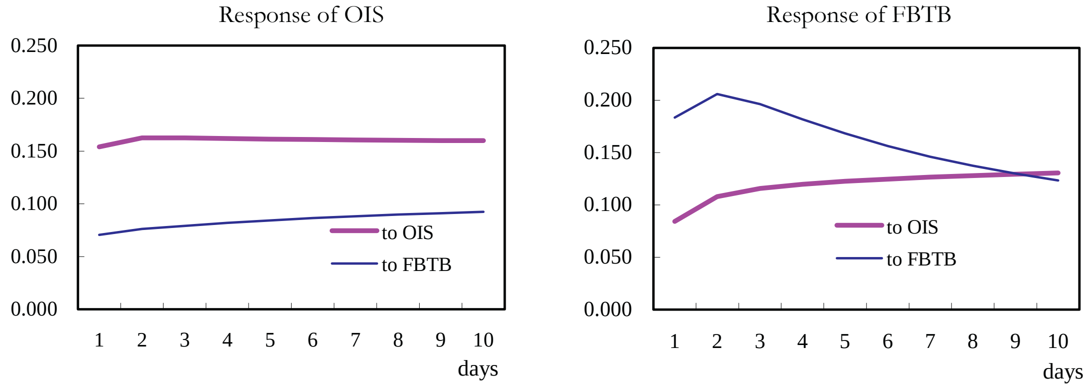
	PT	IS		
		Higher	Lower	Mean
β1	1.19	0.96	0.86	0.91
β2	0.84	0.97	0.63	0.80

Chart 8: Impulse Responses of Money Market Yield Curves

(i) β1: Short-term Slope Factor



(ii) β2: Medium-term Curvature Factor



Note: Impulse responses are the responses of each factor to generalized one standard deviation of each factor.
See Pesaran and Shin [1998] for the estimation method.

Chart 9: Estimated Result of Structural Model (Full Yield Curves)

Sample Period: April 4, 2006 to July 31, 2007 (Number of Observations: 329)

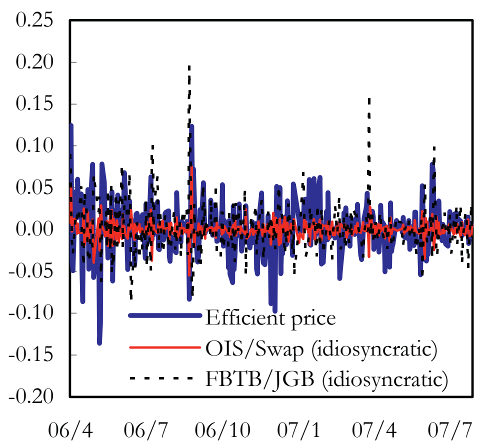
		β0		β1		β2	
b	OIS/Swap	0.009	***	-0.071	**	-0.157	**
		[0.035]		[0.033]		[0.077]	
c	OIS/Swap	0.590	***	0.609	***	0.308	
		[0.176]		[0.202]		[0.302]	
	FBTB/JGB	0.975	***	0.980	***	0.975	***
		[0.011]		[0.010]		[0.014]	
ln (σ^2)	m	-6.872	***	-6.649	***	-4.403	***
		[0.101]		[0.093]		[0.094]	
	s_{OIS}	-10.330	***	-9.872	***	-7.073	***
		[3.564]		[2.338]		[1.701]	
	s_{FB}	-7.204	***	-7.491	***	-5.528	***
		[0.176]		[0.225]		[0.248]	
	ε_{OIS}	-8.452	***	-8.575	***	-7.136	***
		[0.403]		[0.479]		[1.372]	
	ε_{FB}	-9.130	***	-8.944	***	-5.782	***
		[0.715]		[0.625]		[0.247]	
Log Likelihood		1244.22		1240.31		502.49	
SIS (OIS)		0.808		0.843		0.882	
SIS (FB)		0.549		0.653		0.634	
SIS(OIS)-SIS(FB)		0.259		0.191		0.247	

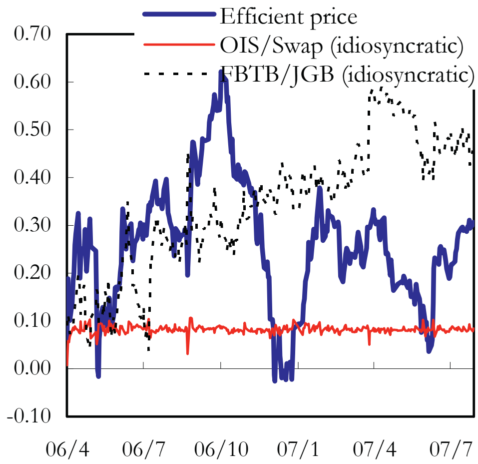
Note: ** and *** denote the 5% and 1% significance level, respectively.

Chart 10: Factor Decomposition (Full Yield Curves)

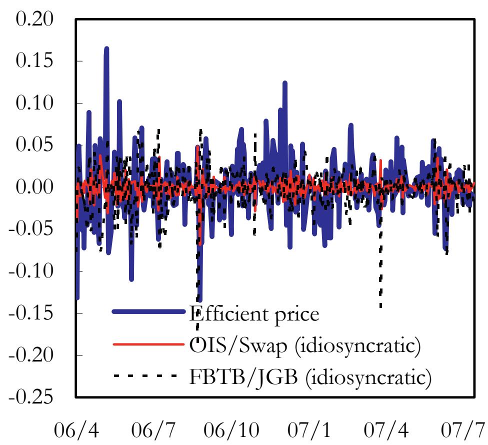
Decomposition of Daily Factor Changes | Accumulated Daily Changes

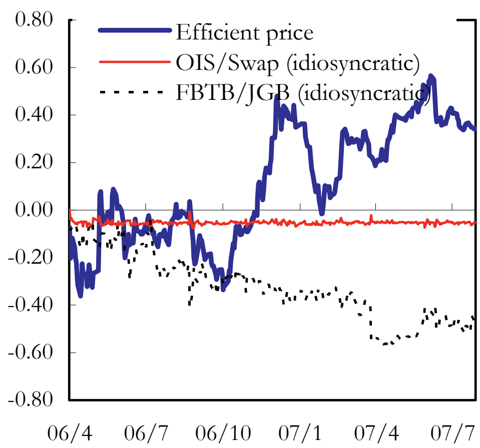
(i) β0: Long-term Level Factor



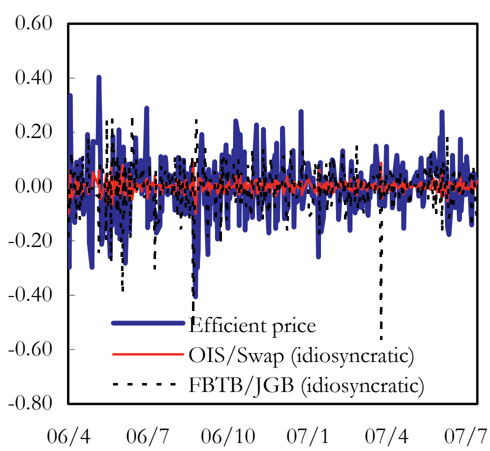


(ii) β1: Short-term Slope Factor





(iii) β2: Medium-term Curvature Factor



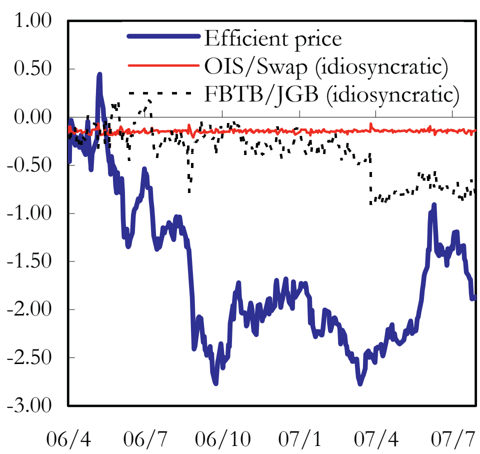


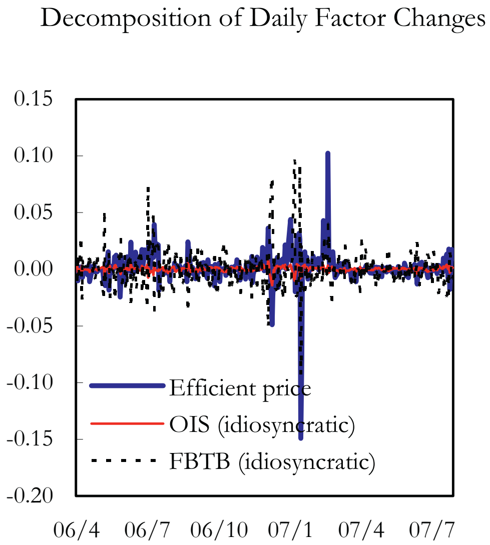
Chart 11: Estimated Result of Structural Model (Money Market Yield Curves)

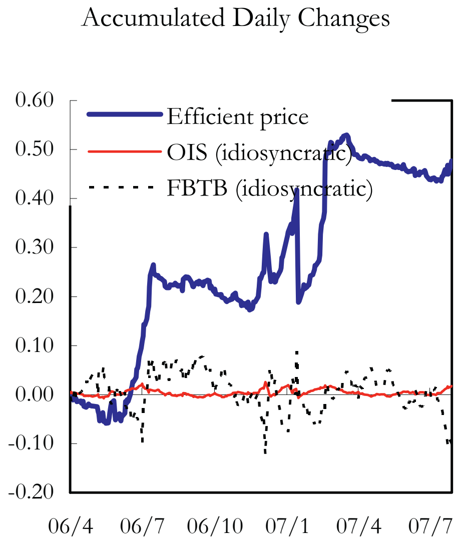
Sample Period: April 4, 2006 to July 31, 2007 (Number of Observations: 329)

		$\beta 1$	
c	OIS	0.944	***
		[0.081]	
	FBTB	0.956	***
		[0.021]	
ln (σ^2)	m	-8.434	***
		[0.106]	
	s_{OIS}	-10.250	***
		[0.451]	
	s_{FB}	-8.365	***
		[0.138]	
	ε_{OIS}	-28.100	
		[27.100]	
	ε_{FB}	-9.987	***
		[0.257]	
Log Likelihood		1732.49	
SIS (OIS)		0.860	
SIS (FB)		0.433	
SIS(OIS)-SIS(FB)		0.427	

Note: *** denotes the 1% significance level.

Chart 12: Factor Decomposition (Money Market Yield Curves)





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