Bank of Japan Working Paper Series

Negative Interest Rates under the Quantitative Monetary Easing Policy in Japan:

The Mechanism of Negative Yen Funding Costs in the FX Swap Market

Shinichi Nishioka*
shinichi.nishioka@boj.or.jp

Naohiko Baba**
naohiko.baba@boj.or.jp

No.04-E-8
July 2004

Bank of Japan
2-1-1 Nihonbashi Hongoku-cho, Chuo-ku, Tokyo 103-8660

* Financial Markets Department
** Financial Markets Department

Bank of Japan Working Paper Series No.04-E-8

July 2004

Negative Interest Rates under the Quantitative Monetary Easing Policy in Japan:

The Mechanism of Negative Yen Funding Costs in the FX Swap Market

Shinichi Nishioka* and Naohiko Baba**

Abstract

This paper aims to reconsider the mechanism of the negative yen funding costs for foreign banks in the foreign exchange (FX) swap market, almost constantly observed since the adoption of the quantitative monetary easing policy in March 2001. Our main findings are as follows. First, if the no-arbitrage conditions for both domestic and foreign banks' foreign currency funding costs between the foreign currency market and the FX swap market hold, then the yen funding costs for foreign banks in the FX swap market can be written as the sum of (i) the yen risk-free interest rate, (ii) the credit risk premium for foreign banks, and (iii) the difference in the credit-risk premium for domestic banks between the yen and the U.S. dollar markets. Second, the recent negative yen funding costs for foreign banks result from the fact that the credit-risk premium for domestic banks is higher in the U.S. dollar market than in the yen market. Third, the difference in credit-risk premium between the yen and the U.S. dollar markets has existed at least since the beginning of the 1990s. As the yen risk-free interest rate has declined under the quantitative monetary easing policy, however, the difference in credit-risk premium has become marked, yielding the negative funding costs. Finally, the yen funding costs are expected to return to zero percent if foreign banks could invest in the risk-free Bank of Japan's current account balances without limits. In reality, however, the yen funding costs have remained below zero percent since foreign banks face credit lines, which limit the holdings of the current account balances.

Keywords: Yen Funding Cost, Foreign Exchange Swap Market, Credit-Risk Premium, No-arbitrage Condition, Quantitative Monetary Easing Policy

*Financial Markets Department, Bank of Japan E-mail: shinichi.nishioka@boj.or.jp
**Financial Markets Department, Bank of Japan E-mail: naohiko.baba@boj.or.jp

We benefited greatly from discussions with staff members of the Bank of Japan. We are also grateful to Meitan Tradition Co. for providing us with data of the Euro-market interest rates, and to Mr. Takayuki Sueyoshi, Mr. Yoshihiko Hogen, and Miss Asami Watanabe for excellent research assistance. Remaining errors are solely ours. Views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Japan.

1. Introduction

This paper aims to reconsider the mechanism of the negative yen funding costs for foreign banks in the foreign exchange (FX) swap market, almost constantly observed since the adoption of the quantitative monetary easing policy in March 2001.

A yen (dollar) funding transaction in the FX swap market means that foreign (domestic) banks borrow yen (U.S. dollars) from, and lend U.S. dollars (yen) to, domestic (foreign) banks at the same time. Thus, the yen (U.S. dollar) funding costs are defined as the funding costs when foreign (domestic) banks exchange U.S. dollars (yen) with yen (U.S. dollars) in the FX swap market. So far, we have explained that they are determined by the so-called "Japan premium", which is typically defined as the difference in the credit risk premium between foreign and domestic banks in the U.S. dollar market. Hanajiri [1999] explains that during the period of financial instability in Japan from 1997 to 1998, the Japan premium emerged significantly particularly in the U.S. dollar market, thereby considerably reducing domestic banks' access to uncollateralized U.S. dollar funds. Thus, domestic banks turned to the FX swap market for their U.S. dollar funding, which widened the Japan premium in the FX swap market, yielding the negative yen funding costs for foreign banks.

Since the Bank of Japan (BOJ) adopted the "zero interest rate policy" in February 1999 and the subsequent "quantitative monetary easing policy" in March 2001, as the yen risk-free interest rate has declined, the yen funding costs for foreign banks, both in the yen market and the FX swap market, have been almost constantly negative. Foreign banks can make a risk-free arbitrage profit by investing the yen funds thus raised in the BOJ's current accounts with zero interest rates. This fact is consistent with the phenomenon reported by Baba et al. [2004] that the non-negligible portion of an increase in the BOJ's current account balances has been satisfied by an increase in foreign banks' holdings.[1] It should be noted, however, that due to the existence of credit lines on the dealings with the BOJ, foreign banks are not allowed to accumulate current account balances without limits, thus releasing the extra funds in the call market at negative interest rates.

Another interesting fact under the quantitative monetary easing policy is that in various markets trading credit risks, the risk premium for domestic non-financial companies narrowed significantly. The narrowing was larger in Japan than the U.S. counterparts of the same credit ratings. It suggests that the credit risk perceived by domestic investors became lower and lower than that perceived by overseas investors.[2] This finding motivated us to reconsider the determinants of the yen (dollar) funding costs for foreign banks in the FX swap market, paying particular attention to a possible difference in the credit-risk premium for domestic and foreign

[1] Foreign banks' holdings of the BOJ's current account balances increased from 0.1 trillion yen as of the end of March 2003 to 5.4 trillion yen as of the end of March 2004, which corresponds to one quarter of the holdings of the BOJ's current account balances by all financial institutions.

banks between the yen and the U.S. dollar markets.

Our main findings are summarized as follows. First, if the no-arbitrage conditions for both domestic and foreign banks' foreign currency funding costs between the foreign currency market and the FX swap market hold, the yen funding costs for foreign banks in the FX swap market can be written as the sum of (i) the yen risk-free interest rate, (ii) the credit risk premium for foreign banks, and (iii) the difference in the credit-risk premium for domestic banks between the yen and the U.S. dollar markets. Second, the recent negative yen funding costs for foreign banks result from the fact that the credit-risk premium for domestic banks is lower in the yen market than in the U.S. dollar market. Third, the difference in the credit-risk premium between the yen and the U.S. dollar markets has existed at least since the beginning of the 1990s. As the yen risk-free interest rate has declined under the quantitative monetary easing policy adopted in March 2001, however, the difference in credit-risk premium has become marked, yielding the negative funding costs. Finally, the yen funding costs are expected to return to zero percent if foreign banks could invest in the risk-free BOJ's current accounts without limits. In reality, however, the yen funding costs have remained below zero percent since foreign banks face credit lines, which limit the holdings of the BOJ's current account balances.

The rest of the paper is organized as follows. Section 2 briefly reviews the FX swap transactions. Section 3 derives the no-arbitrage conditions for both domestic and foreign banks' foreign currency funding costs and empirically tests them. Section 4 reconsiders the mechanism for determining the yen funding costs based on the no-arbitrage conditions. Section 5 concludes the paper by referring to the implications for monetary policy. The Appendix reports details of the data and results of empirical analysis.

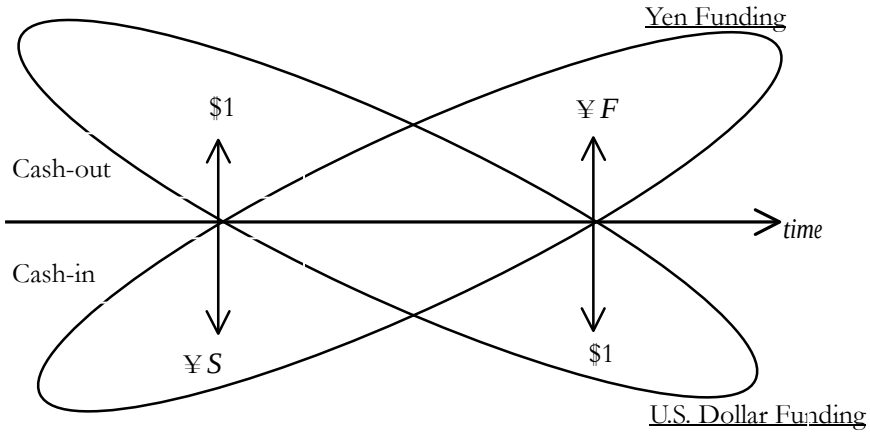
[2] See Nishioka and Baba [2004] for more details.

2. Overview of the FX Swap Transactions

A typical FX swap transaction is a contract in which domestic banks borrow U.S. dollars from, and lend yen to, foreign banks at the same time. For instance, 3-month yen funding in the FX swap market means that foreign banks lend U.S. dollars and borrow yen for three months. Figure 1 illustrates the flow of funds generated by the yen (dollar) funding transaction of foreign (domestic) banks in the FX swap market.

In the recent Tokyo FX swap market, domestic banks mainly play the role of a broker for (i) Japanese exporters with hedging needs for their foreign currency-denominated earnings, (ii) institutional investors investing in foreign bonds, and so on. Foreign banks, on the other hand, actively conduct speculative transactions as well as brokerage transactions, based on their prediction of the future course of U.S. dollar interest rates,[3] for instance. Also, most of the transactions in the Tokyo FX swap market are short-term, whose maturities are equal to or less than three months.

Figure 1: Flow of Funds in a Transaction in the FX Swap Market



Spot Time　　Forward Time

S : Spot FX Rate　　F : Forward FX Rate

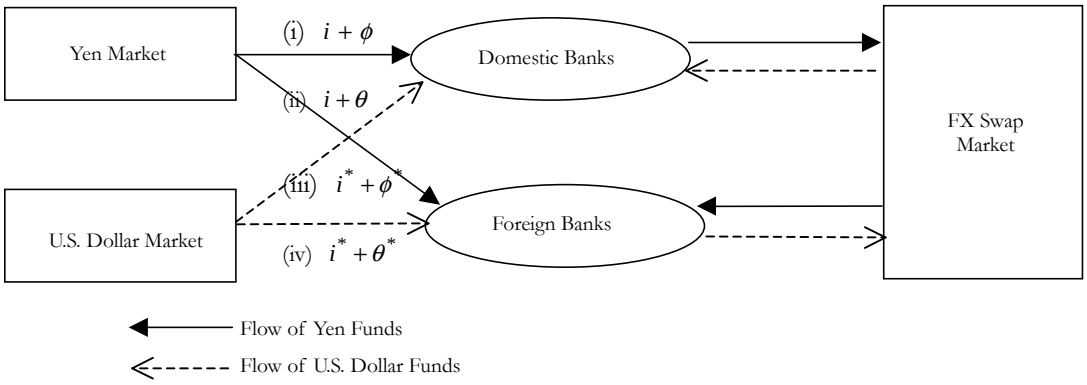
[3] Specifically, if they predict U.S. interest rates will decline in the future, they will build long-term yen-funding/dollar-investing positions anticipating a narrowing of the dollar discount. They will book their profits by closing out the positions after the interest rate is actually lowered.

3. Equilibrium Condition of the FX Swap Market Implied by the No-Arbitrage Conditions for Foreign Currency Funding Costs

3.1 Funding Structures of Domestic and Foreign Banks

We start by deriving the no-arbitrage conditions for domestic and foreign banks' foreign currency funding costs through the following three markets: (a) the yen market, (b) the U.S. dollar market, and (c) the FX swap market.[4] Figure 2 describes the funding structure of domestic and foreign banks. The funding costs in the yen and the U.S. dollar markets are the sum of the risk-free interest rates and the credit-risk premium for domestic or foreign banks. Let i (i^*) denote the yen (the U.S. dollar) risk-free interest rate, ϕ (ϕ^*) the credit-risk premium for domestic banks in the yen (U.S. dollar) market, and θ (θ^*) the credit-risk premium for foreign banks in the yen (U.S. dollar) market.

Figure 2: Funding Structure of Domestic and Foreign Banks



3.2 Equilibrium Condition of the FX Swap Market Implied by the No-Arbitrage Conditions for Foreign Currency Funding Costs

Domestic banks have two alternative funding sources for U.S. dollars: (i) raising U.S. dollars directly from the U.S. dollar market, and (ii) exchanging yen raised in the yen market with U.S. dollars in the FX swap market. Then, supposing that these funding sources are perfect substitutes for domestic banks, the following no-arbitrage condition holds in gross terms:

$$1+i^*+\phi^*=\frac{S}{F}(1+i+\phi)\,. \tag{1}$$

The left-hand side of equation (1) is the U.S. dollar interest rate for domestic banks, while the right-hand side is the U.S. dollar funding cost in the FX swap market for domestic banks.

Similarly, foreign banks have two yen-funding sources: (i) raising yen directly from the yen

[4] See Inaba et al.[2001] for the arbitrage relationship between the FX swap market and various yen markets.

market, and (ii) exchanging U.S. dollars raised in the U.S. dollar market with yen in the FX swap market. Then, supposing that these two funding sources are perfect substitutes for foreign banks, the following no-arbitrage condition holds:

$$1+i+\theta=\frac{F}{S}(1+i^{*}+\theta^{*}). \tag{2}$$

The left-hand side of equation (2) is the yen interest rate for foreign banks, while the right-hand side is the yen funding cost in the FX swap markets for foreign banks. Equilibrium in the FX swap market requires the following condition to hold[5]

$$\frac{1+i+\theta}{1+i+\phi}=\frac{1+i^{*}+\theta^{*}}{1+i^{*}+\phi^{*}}. \tag{3}$$

Equation (3) can be approximated as

$$\theta^{*}-\theta=\phi^{*}-\phi. \tag{4}$$

The left-hand side of equation (4) shows the difference in the credit-risk premium for foreign banks between the U.S. dollar and the yen markets, while the right-hand side shows the difference in the credit-risk premium for domestic banks between the U.S. dollar and the yen markets. Thus, we can derive the following proposition:

Proposition 1: *The difference in the credit-risk premium for domestic banks between the U.S. dollar and the yen markets must be equivalent to the difference in the credit risk premium for foreign banks between the U.S. dollar and the yen markets, if the no-arbitrage conditions for domestic and foreign banks' foreign currency funding costs between the foreign currency market and the FX swap market hold.*

Also, equation (4) can be rewritten as follows:

$$\phi-\theta=\phi^{*}-\theta^{*}. \tag{4}'$$

The left-hand side of the above equation shows the difference in the credit-risk premium in the yen market between foreign and domestic banks, while the right-hand side shows the difference in the U.S. dollar market, which is referred to as the Japan premium. Thus, we can rewrite the above proposition as follows:

Proposition 2: *The difference in the credit-risk premium in the yen market between foreign and domestic banks must be equivalent to the difference in the dollar markets, if the FX swap market is in equilibrium, satisfying the no-arbitrage conditions for domestic and foreign banks' foreign currency funding costs between the foreign currency market and the FX swap market.*

[5] Equation (3) is derived by substituting equation (1) into equation (2).

Figures 3-1 and 3-2 compare domestic banks' two U.S. dollar funding costs described by equation (1) and foreign banks' two yen funding costs described by equation (2), respectively.[6] No-arbitrage conditions seem to hold[7] except for the period of financial instability in Japan from 1997 to 1998.[8]

Also, Figure 4-1 shows the credit-risk premium for domestic and foreign banks in the U.S. dollar and the yen markets, while Figure 4-2 shows the difference in the credit-risk premium between the U.S. dollar and the yen markets. Figure 4-1 indicates that the credit-risk premium for domestic banks has been higher than that for foreign banks since the mid-1990s, particularly during the period of financial instability from 1997 to 1998. Figure 4-2 indicates that the difference in the credit-risk premium between the U.S. dollar and the yen markets have tended to move together except for the period of financial instability, which means that the equilibrium condition of the FX swap market (4) is satisfied on the whole.

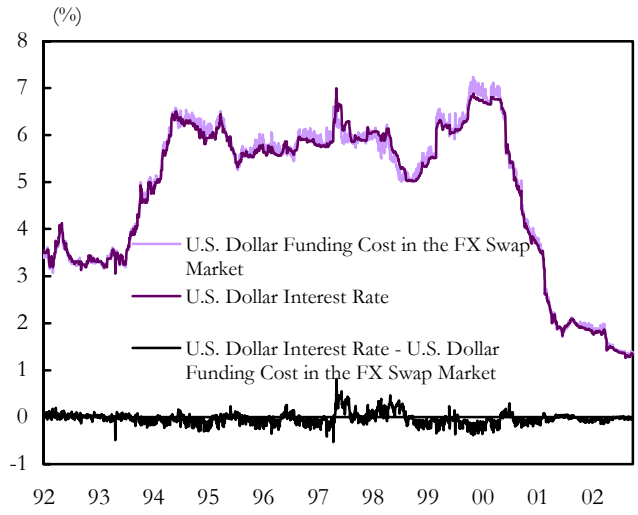
[6] See Appendix A for details of the data. In what follows, we report only the results of three-month transactions due to the limitation of space. For empirical results of transactions with other maturities, see Appendix B. Generally, the yen funding costs with short-term maturities such as T/N (tomorrow/next) and 1W (one-week) fluctuate widely for seasonal factors. They include (i) the final day of the U.S. reserve maintenance period, (ii) the tax payment day in the U.S., (iii) the end of quarters, and (iv) the settlement day of the U.S. treasuries, all of which temporarily lower the yen funding costs for foreign banks.

[7] The results for unit root tests show that the differences in both the yen rates for foreign banks and the U.S. dollar rates for domestic banks are stationary around non-zero constant terms. For details on the unit root tests, see Appendix B.

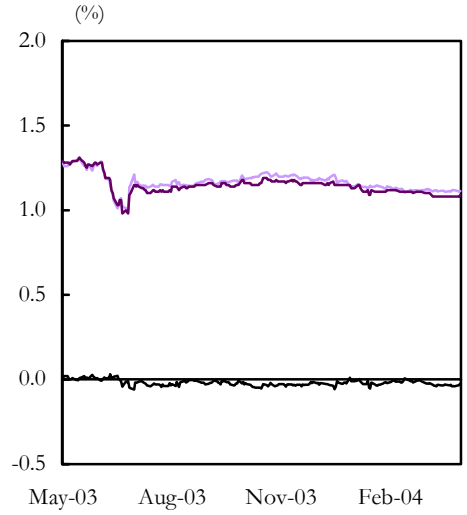
[8] Hanajiri [1999] concludes that in the period of financial instability from 1997 to 1998, the arbitrage relationship collapsed since domestic banks excessively turned to the FX swap market for dollar funding resulting from the increased difficulty in directly raising foreign currency from the markets. Also, note that although in Figures 3-1 (ii) and 3-2 (ii) we use the funding (bid) rates that directly reflect the creditworthiness of fund-raising financial institutions as the dollar rates for domestic banks and the yen rates for foreign banks, in Figures 3-1(i) and 3-2(i) we use the ask (offer) rates (TIBOR and LIBOR) due to the lack of the bid rates. On the other hand, the spot and forward FX rates used in computing the yen (dollar) funding costs are denominated in terms of mid-prices. These technical issues are possibly a main cause of the existence of non-zero constant terms that the differences in the yen rates for foreign banks and the U.S. dollar rates for domestic banks have.

Figure 3-1: U.S. Dollar Funding Costs in the FX Swap Market and the U.S Dollar Interest Rates for Domestic Banks (3-month)

(i) August 1992 to April 2003



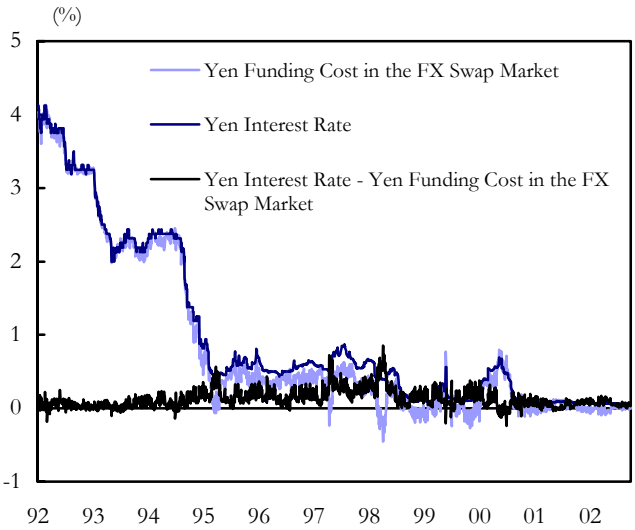
(ii) May 2003 to March 2004



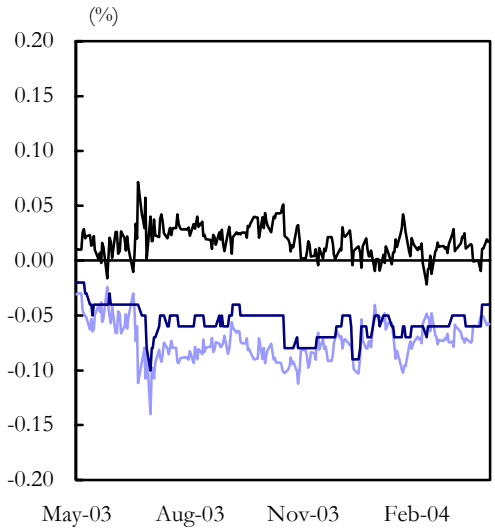
Note: For details of the data, see Appendix A.

Figure 3-2: Yen Funding Costs in the FX Swap Market and the Yen Interest Rate for Foreign Banks (3-month)

(i) August 1992 to April 2003



(ii) May 2003 to March 2004

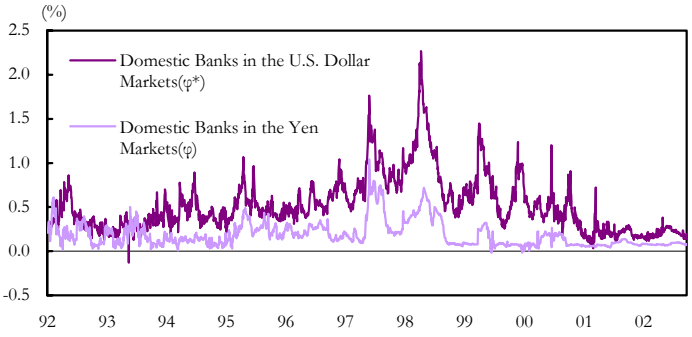


Note: For details of the data, see Appendix A.

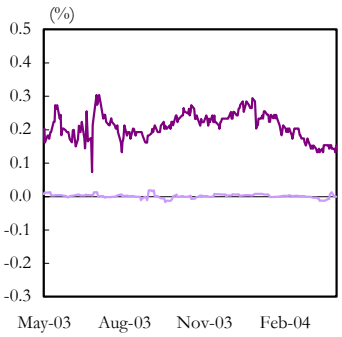
Figure 4-1: Credit Risk Premium (3-month)

(i) Credit Risk Premium for Domestic Banks.

(a) August 1992 to April 2003

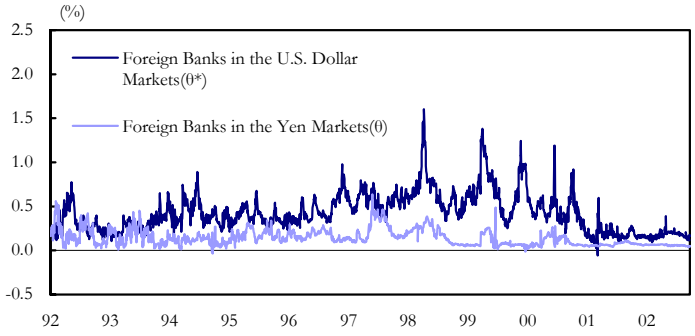


(b) May 2003 to March 2004

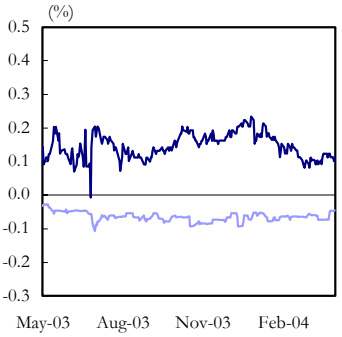


(ii) Credit Risk Premium for Foreign Banks.

(a) August 1992 to April 2003



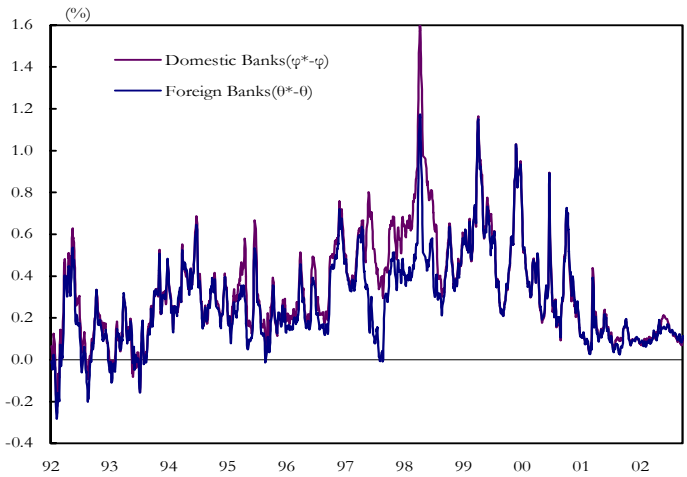
(b) May 2003 to March 2004



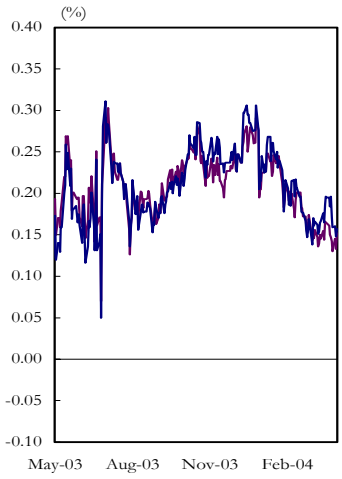
Note: For details of the data, see Appendix A.

Figure 4-2: Difference in the Credit-Risk Premium between the U.S. Dollar and the Yen Markets (3-month)

(a) August 1992 to April 2003



(b) May 2003 to March 2004



Note: For details of the data, see Appendix A.

4. Determination of the Yen Funding Costs in the FX Swap Market

4.1 Factor Decomposition of the Yen Funding Costs in the FX Swap Market

We restate the yen funding costs in net terms, c, for foreign banks in the FX swap market as follows:

$$1+c=\frac{F}{S}(1+i^*+\theta^*). \qquad (2)'$$

If proposition 1 holds, equation (2)' can be rewritten as

$$\begin{aligned} 1+c &= \frac{F}{S}(1+i^*+\theta^*) \\ &= \frac{1+i+\phi}{1+i^*+\phi^*}(1+i^*+\theta^*), \end{aligned}$$

$$\Leftrightarrow \quad c \approx i+\theta^*-[\phi^*-\phi]. \qquad (5)$$

Now, we can derive the following proposition:

Proposition 3: *The yen funding costs for foreign banks in the FX swap market can be decomposed into the following three factors: (i) the yen risk-free interest rate, (ii) the credit-risk premium for foreign banks in the U.S. dollar market, and (iii) the difference in the credit-risk premium for domestic banks between the U.S. dollar and the yen markets.*

If the difference in the credit-risk premium for domestic banks between the two markets is zero, that is, $\phi^*=\phi$, the yen funding costs for foreign banks boil down to the usual form of funding costs: the sum of the yen risk-free interest rate and the credit-risk premium for foreign banks. Put differently, the fact that the yen funding costs differ from the usual funding costs stems from the difference in the credit-risk evaluation of domestic banks between the U.S. dollar and the yen markets.

Also, we can rewrite equation (5) as

$$c \approx i+\phi-[\phi^*-\theta^*]. \qquad (6)$$

The above equation is another form of the factor decomposition of the yen funding costs in the FX swap market. The yen funding costs can be decomposed into (i) the yen risk-free interest rate, (ii) the credit-risk premium for domestic banks in the yen market, and (iii) the Japan premium. Figures 5-1 and 5-2 show the results of factor decomposition based on equations (5) and (6), respectively[9]. Figure 5-1 (ii) shows that the difference in the credit-risk premium for domestic banks between the yen and the U.S. dollar markets causes the yen funding costs for foreign banks to be negative. This suggests that foreign banks evaluate the credit-risk for domestic banks more rigorously than domestic banks do. This fact is consistent with the findings in Nishioka and Baba

[9] See Appendix C for the decomposition of the U.S. dollar funding costs for domestic banks in the FX swap market.

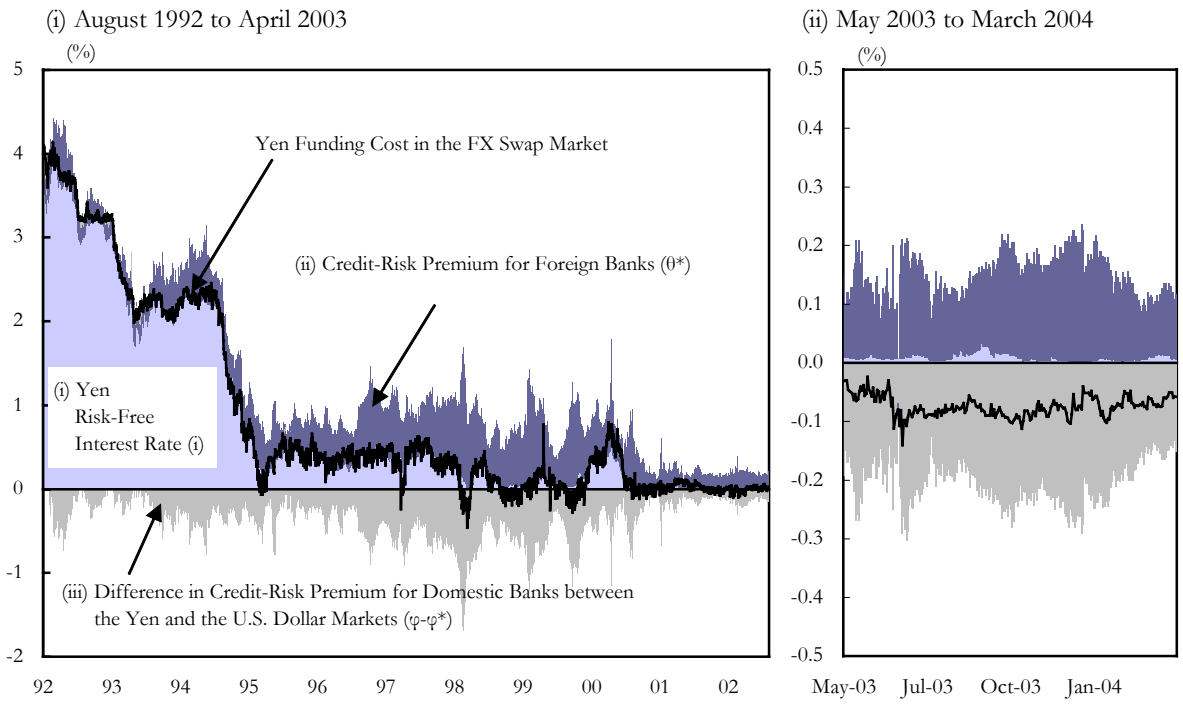
[2004], who empirically found significant differences in evaluation of credit-risk between domestic and overseas investors in the corporate bond markets.

Also, a look at the time series of the above-mentioned decomposition reveals something interesting. Figure 5-1 (i) shows that the difference in the credit-risk premium for domestic banks between the yen and the U.S. dollar markets has been negative at least since the beginning of the 1990s[10]. This finding tells us that as the yen risk-free interest rate declined to almost zero percent after the adoption of the zero interest rate policy and the subsequent quantitative monetary easing policy, the difference between the two markets exceeded the sum of the yen risk-free interest rate and the credit-risk premium for foreign banks in the U.S. dollar market, turning the yen funding costs negative.

Next, Figure 5-2 shows the factor decomposition based on equation (6). We find that the widening of the Japan premium significantly lowered the yen funding costs during the period of financial instability from 1997 to 1998. Although the recent negative yen funding costs also tended to be caused by the Japan premium, the Japan premium has not always been the main cause of the low yen funding costs since the beginning of the 1990s.

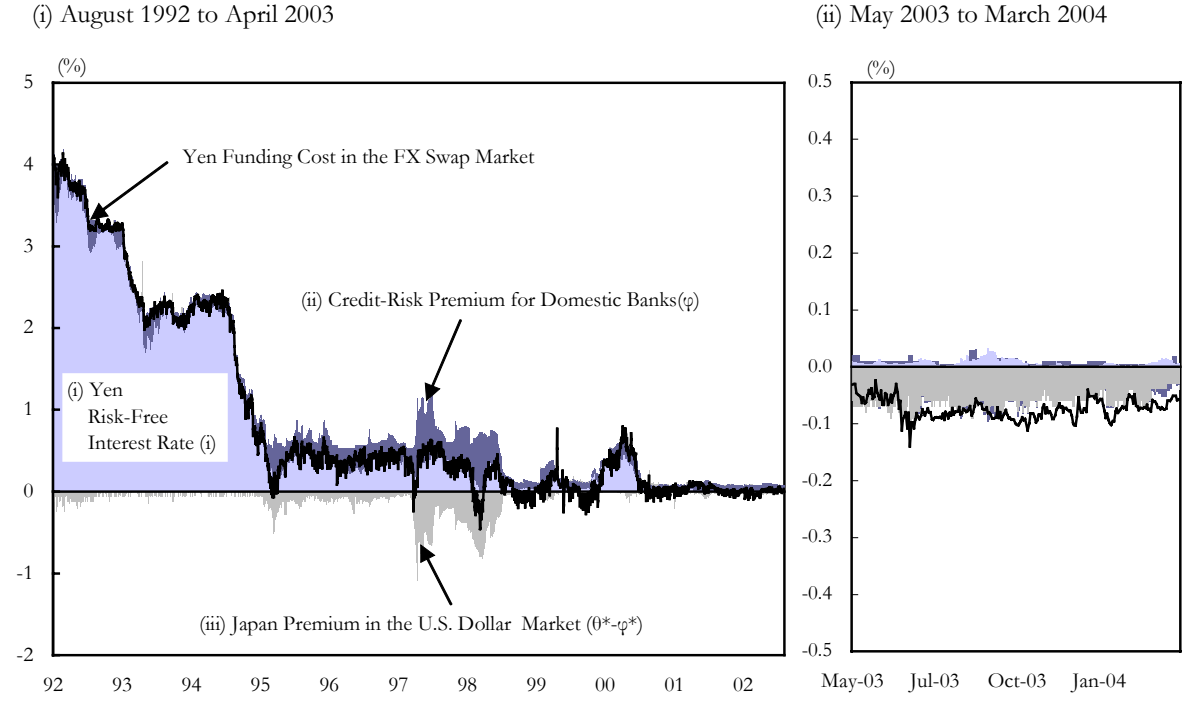
[10] The data is available only from August 1992.

Figure 5-1: Factor Decomposition of the Yen Funding Cost (3-month)



Note: For the data source, see Appendix A.

Figure 5-2: Factor Decomposition of the Yen Funding Cost Using the Japan Premium (3-month)



Note: For the data source, see Appendix A.

4.2 The Mechanism of the Negative Yen Funding Costs

Given our assumptions, the yen funding costs for foreign banks in the FX swap market can be negative, if and only if

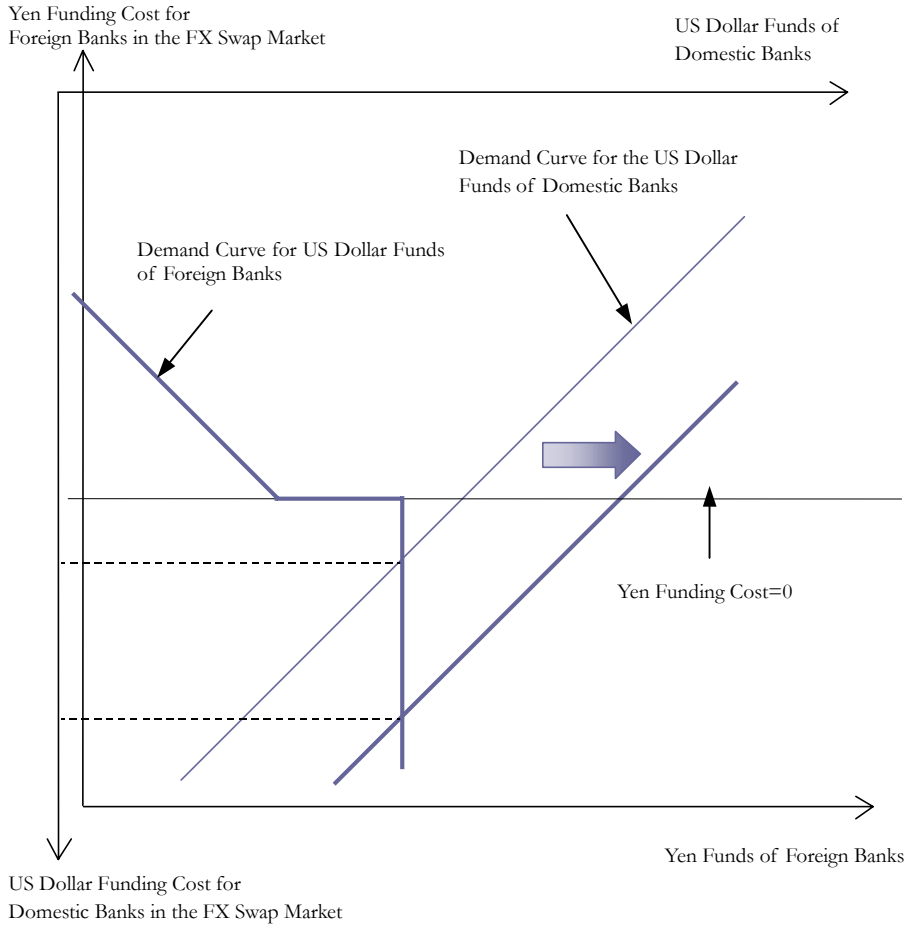
$$i + \theta^* < \phi^* - \phi .$$

When we consider the possibility that foreign banks can invest in risk-free assets such as the BOJ's current accounts without limits, however, the lower bound of the yen funding costs should become zero percent through the following mechanism: the negative yen funding costs enable foreign banks to enjoy positive returns without taking additional risk by investing the yen funds raised at the negative rates in the BOJ's current accounts. Thus, as long as the yen funding costs are negative, foreign banks would continue to raise the yen funds through the FX swap markets. This process would continue until the equilibrium is restored, that is, the yen funding costs rise to as high as zero percent.

In reality, however, foreign banks usually impose restrictions on the BOJ's current account holdings in the form of credit lines for risk management reasons. It means that foreign banks miss the risk-free arbitrage opportunities. This is why the yen funding costs have remained negative.

Figure 6 summarizes the mechanism of the negative yen funding costs. The slope of the demand curve for yen funds of foreign banks in the FX swap market is assumed to be negative in the area of the positive funding costs, flat at zero percent, and vertical at the credit line limits on the BOJ's currency account holdings. On the other hand, the demand curve for U.S. dollar funds of domestic banks in the FX swap market is assumed to have a positive slope irrespective of the funding costs for simplicity. Thus, a rightward shift of the demand for U.S. dollar funds, driven by the widening of the difference in credit-risk premium for domestic banks between the U.S. dollar and the yen markets $\phi^* - \phi$ for instance, further widens the negative yen funding costs.

Figure 6: Demand Curve for Yen and U.S. Dollar Funds in the FX Swap Market



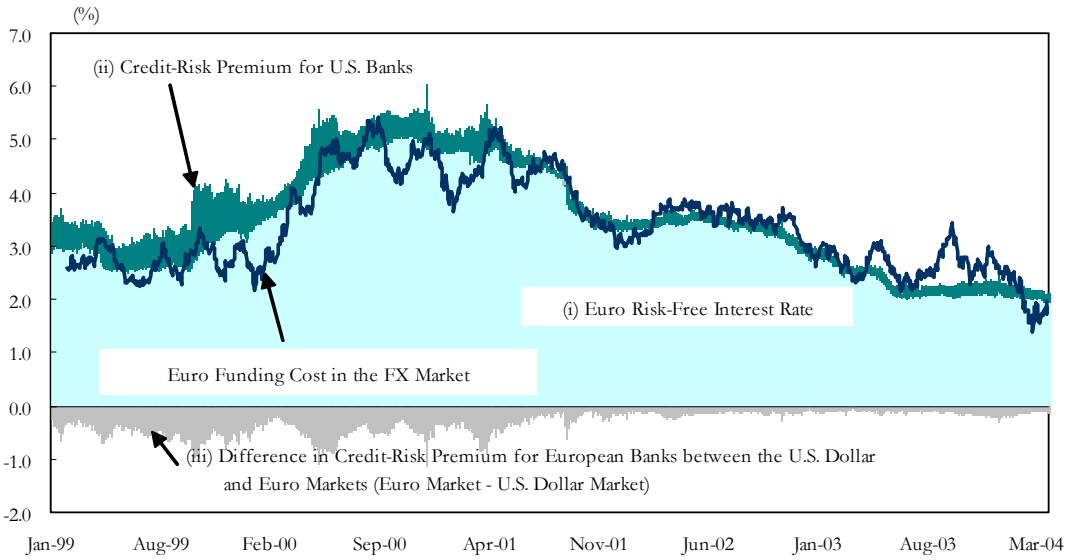
4.3 Euro Funding Costs for U.S. Banks in the FX Swap Market

The previous discussion tells us that although the difference in credit-risk premium for domestic banks between the U.S. dollar and the yen markets has existed at least since the beginning of the 1990s, we did not notice its importance until the yen risk-free interest rate declined to almost zero percent. Now, we examine whether this phenomenon is peculiar to Japan by examining the factor decomposition of the Euro funding costs for U.S. banks in the FX swap market.

Equation (5) shows that the euro funding costs for U.S. banks can be decomposed into: (i) the euro risk-free interest rate, (ii) the credit-risk premium for U.S. banks in the U.S. dollar market, and (iii) the difference in the credit-risk premium for European banks between the U.S. dollar and the euro markets. Figure 7 shows the result of the factor decomposition. Similar to the case of the yen funding costs, factor (iii) has contributed to lowering the euro funding costs, in some phases, dominating factor (ii), the credit-risk premium for U.S. banks in the U.S. dollar market. Since the euro risk-free interest rate has been high enough to keep the euro funding costs from being negative, factor (iii) has not turned the funding costs negative. Note, however, that the euro

funding costs can be negative if the euro risk-free interest rate declines enough. Therefore, we can conclude that the negative funding costs are not peculiar to Japan and can potentially occur in any FX swap markets under low interest rate environments.

Figure 7: Euro Funding Cost for U.S. Banks in the FX Swap Market (3-month)



Note: For the data source, see Appendix A.

5. Concluding Remarks

This paper reconsidered the mechanism of the negative yen funding costs for foreign banks in the FX swap market, based on the no-arbitrage conditions between foreign currency market and the FX swap market. We conclude the paper by referring to some implications for monetary policy.[11]

We can point out the increase in the BOJ's current account balances held by foreign banks as a noteworthy phenomenon under the quantitative monetary easing policy. It has been often said that foreign banks tend to avoid holding excess reserves compared with domestic banks since foreign banks, relatively speaking, focus more on earning profits than domestic banks. Nevertheless, the negative yen funding costs have given incentives for foreign banks to hold excess reserves. Also, foreign banks have invested the portion of the yen funds exceeding the credit lines on the BOJ's current account balances in the call market at the negative interest rates.

The usual framework of macroeconomics assumes the constraints of non-negative nominal interest rates. Many macroeconomic researchers have had the idea that the non-negative constraints bring about a transmission mechanism through which a huge amount of excess reserves held by banks would flow into lending and other risky assets. However, foreign banks have chosen to hold the BOJ's current account balances up to the limits of the credit lines as a rational choice since the negative yen funding costs have provided the arbitrage opportunity even with the current account balances whose returns are zero percent.

[11] See Baba et al.[2004] for more details.

Appendix A: Data Source

Our arguments require us to use the bid-rates that directly reflect the credit-risk for banks as the yen/U.S. dollar interest rates. However, the bid-rates of the yen/U.S. dollar interest rates are available only from May 2003. Thus, before April 2003, we use TIBOR and LIBOR that are the average of offer-rates among reference banks as the proxy for the interest rates. Therefore, the left-hand sides of Figures 3 to 5 use TIBOR/LIBOR, while the right-hand sides use the yen/dollar bid interest rates.

Data sources in figures except Figure 7 are as follows.

		From August, 1992 to April, 2003	From May, 2003 to March, 2004
$i+\phi$	: Yen Interest Rate for Domestic Banks	Japanese Bankers' Association (Yen-TIBOR)	Meitan Tradition Co. (Euro-yen interest rates for domestic banks)
$i+\theta$	: Yen Interest Rate for Foreign Banks	British Bankers Association (Yen-LIBOR)	Meitan Tradition Co. (Euro-yen interest rates for foreign banks)
$i^*+\phi^*$	: U.S. Dollar Interest Rate for Domestic Banks	QUICK (U.S. Dollar-TIBOR)	Meitan Tradition Co. (Euro-dollar interest rates for domestic banks)
$i^*+\theta^*$	: U.S. Dollar Interest Rate for Foreign Banks	British Bankers Association (U.S. Dollar-LIBOR)	Meitan Tradition Co. (Euro-dollar interest rates for foreign banks)
i	: Treasury Bill Rate in Japan	Bloomberg	Japan Bond Trading Co., Ltd.
i^*	: Treasury Bill Rate in the U.S.	FRB, *FRED*	
S	: Domestic Currency Value of the Spot Exchange Rates.	Bank of Japan	Meitan Traditional Co.
$F-S$	: Forward Premium	Bank of Japan	Meitan Traditional Co.

Also, data sources in Figure 7, the euro funding costs for U.S. banks, are as follows.

U.S. Dollar Interest Rate for U.S. Banks	British Bankers Association (the average of Dollar-LIBOR among U.S. banks)
U.S. Dollar Interest Rate for European banks	British Bankers Association (the average of Dollar-LIBOR among European banks)
Euro Interest Rate for U.S. Banks	British Bankers Association (the average of Euro-LIBOR among U.S. banks)
Euro Interest Rate for European Banks	British Bankers Association (the average of Euro-LIBOR among European banks)
U.S. Dollar Risk-Free Interest Rate	FRB, *FRED* (Treasury Bill Rate in the U.S.)
Euro Risk-Free Interest Rate	Bloomberg (Treasury Bill Rate in Germany)
Euro Currency Value of the Spot Exchange Rates	Bank of Japan
Forward Premium	Bank of Japan

The reference banks of TIBOR and LIBOR are as follows.

Yen-TIBOR	Mizuho Bank, Sumitomo Mitsui Banking Co., JP Morgan Chase, the Bank of Tokyo Mitsubishi, Saitama Resona Bank, UFJ Bank, Shinsei Bank, the Chuo Mitsui Trust and Banking Co., the Mitsubishi Trust and Banking Co., the Sumitomo Trust and Banking Co., Mizuho Corporate Bank, Mizuho Trust and Banking Co., the Shoko Chukin Bank, UBS AG, Shinkin Central Bank, the Norinchukin Bank
Dollar-TIBOR	Sumitomo Mitsui Banking Co., the Bank of Tokyo Mitsubishi, UFJ Bank, Mizuho Corporate Bank, the Norinchukin Bank, the Mitsubishi Trust and Banking Co., the Sumitomo Trust and Banking Co., the Chuo Mitsui Trust and Banking Co., Citibank NA, UBS AG
Yen-LIBOR	Bank of America, Barclays Bank Plc, Citibank NA, Deutsche Bank AG, HSBC, JP Morgan Chase, Lloyds TSB Bank Plc, Rabobank, The Royal Bank of Scotland Group, UBS AG, Westdeutsche Landesbank AG, the Bank of Tokyo Mitsubishi, Sumitomo Mitsui Banking Co., Mizuho Corporate Bank, UFJ Bank, the Norinchukin Bank
Dollar-LIBOR	Abbey National Plc, Bank of America, Barclays Bank Plc, Citibank NA, Credit Suisse First Boston, Deutsche Bank AG, HBOS, HSBC, JP Morgan Chase, Lloyds TSB Bank Plc, Rabobank, The Royal Bank of Scotland Group, UBS AG, Westdeutsche Landesbank, the Bank of Tokyo Mitsubishi, the Norinchukin Bank
Euro-LIBOR	Bank of America, Barclays Bank Plc, Citibank NA, Credit Suisse First Boston, Deutsche Bank, Halifax, HSBC, JP Morgan Chase, Lloyds TSB Bank Plc, Rabobank, the Royal Bank of Scotland Group, UBS AG, Westdeutsche Landesbank, the Bank of Tokyo Mitsubishi

Appendix B: No-Arbitrage Conditions and Factor Decomposition of the Yen and U.S. Dollar Funding Costs with Various Maturities

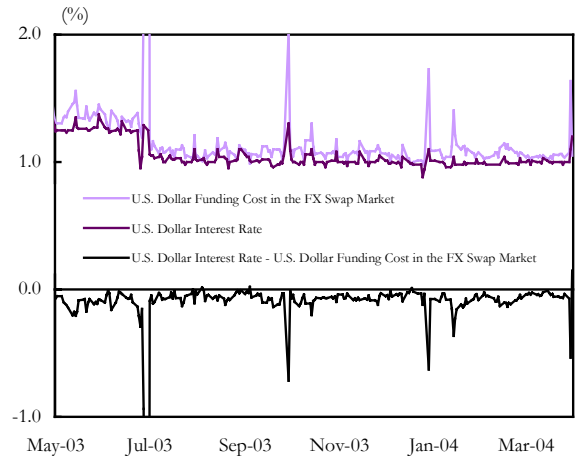
For reference, we show the data with various maturities except for three-month. Figures B-1 and B-2 show the U.S. dollar funding costs for domestic banks (equation (1)) and the yen funding costs for foreign banks (equation (2)). The differences between the U.S. dollar/yen funding costs in the FX swap market and the U.S. dollar/yen interest rates seem to be stationary around a constant term.[12] To statistically test whether the no-arbitrage conditions hold, we applied the ADF (Augmented Dickey-Fuller) test to the differences. The results are reported in Table B-1, which shows that in most cases, the no-arbitrage conditions between two markets hold, significantly rejecting the null-hypothesis of the existence of the unit roots at the one percent level.

Also, Figure B-4 shows the factor decomposition of the yen funding costs in the FX swap market for foreign banks based on equation (5). In the figure, irrespective of maturities, the differences in the credit-risk premium for domestic banks between the U.S. dollar and the yen markets yield the negative yen funding costs for foreign banks.

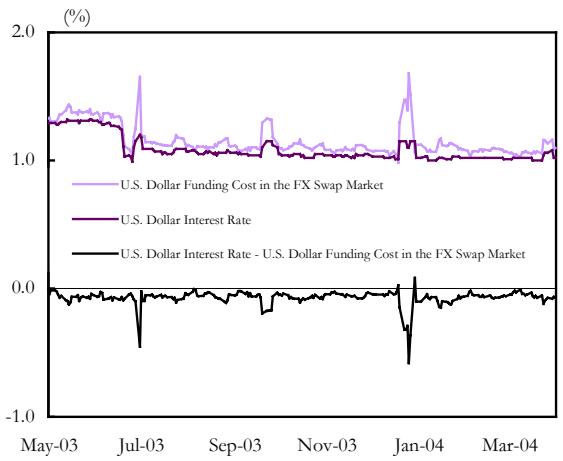
[12] The differences cannot be approximated as a perfectly stationary process around zero because the yen/dollar funding costs include transaction costs in the FX swap markets.

Figure B-1: Yen Funding Costs in the FX Swap Market and the U.S. Dollar Interest Rates for Foreign Banks

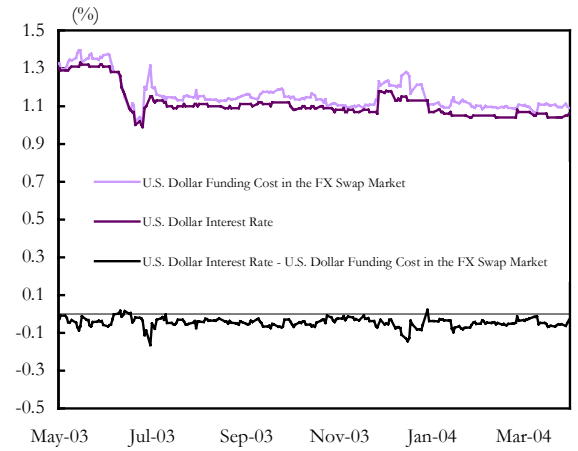
(i) T/N



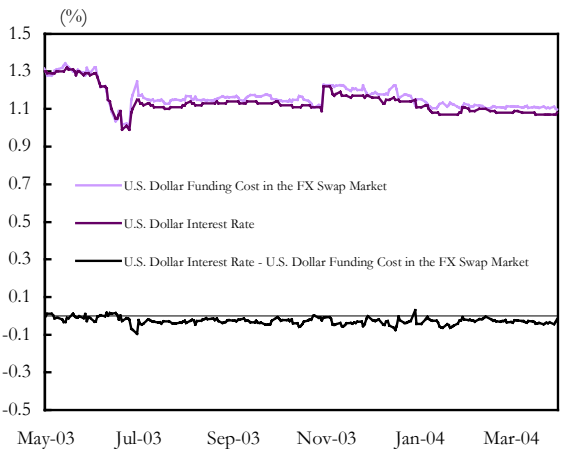
(ii) 1W



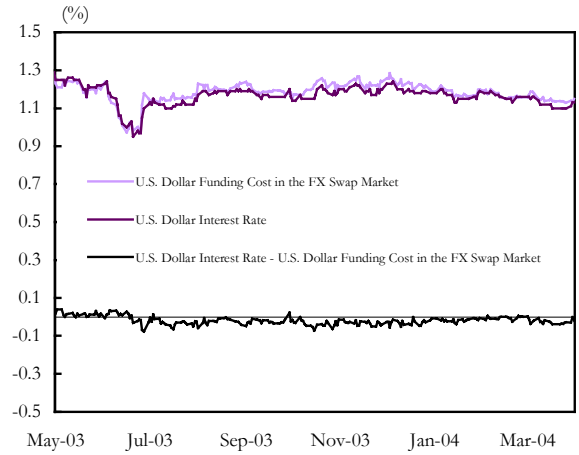
(iii) 1M



(iv) 2M



(v) 6M



(vi) 1Y

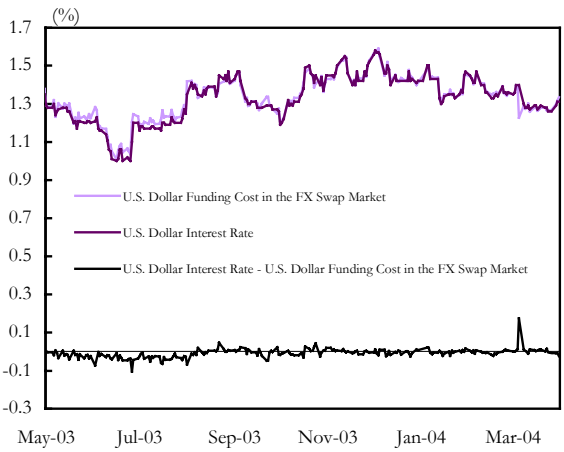
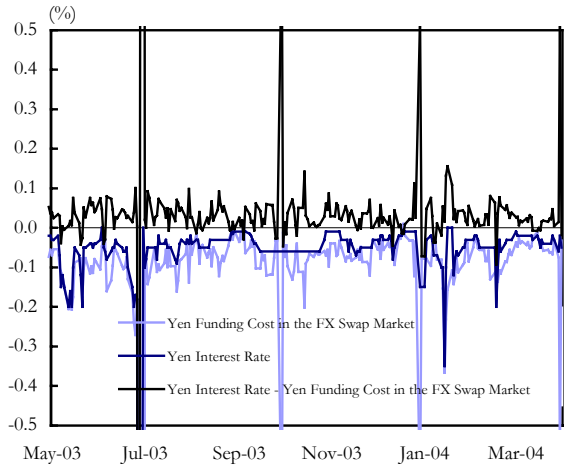
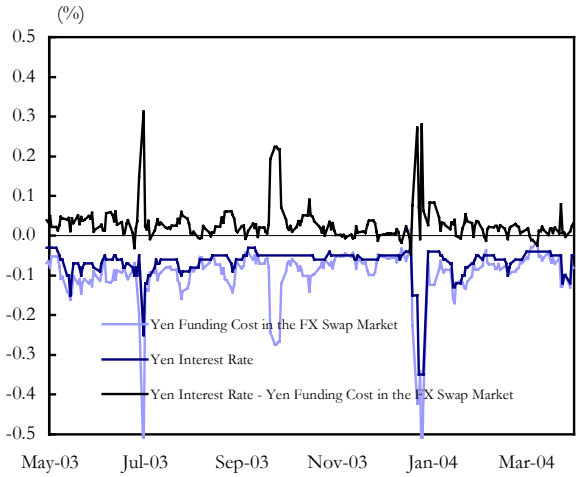


Figure B-2: Yen Funding Costs in the FX Swap Market and the Yen Interest Rates for Foreign Banks

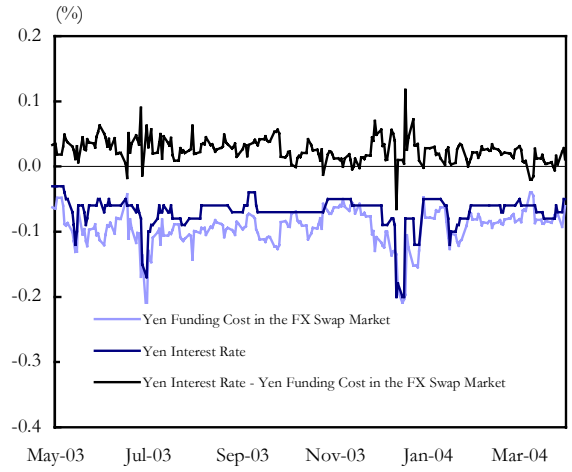
(i) T/N



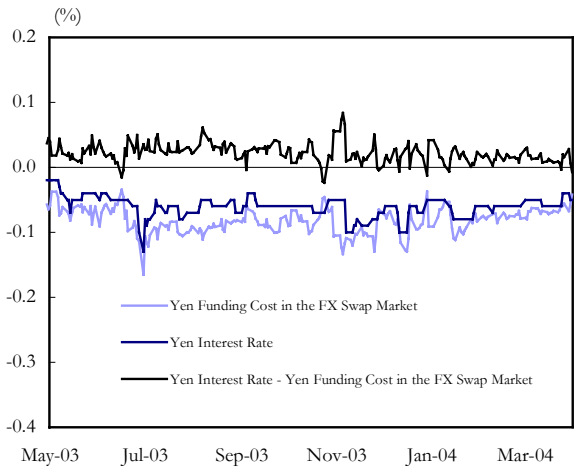
(ii) 1W



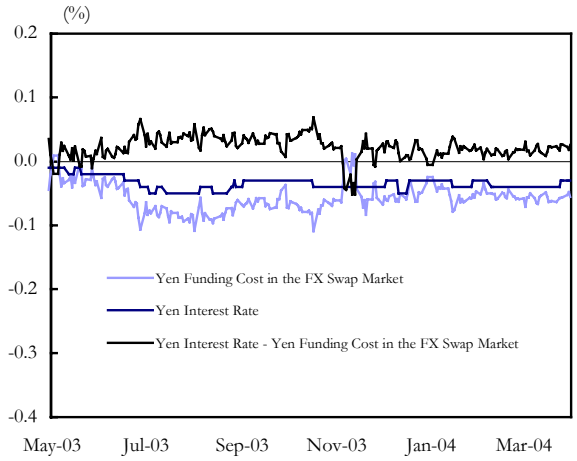
(iii) 1M



(iv) 2M



(v) 6M



(iv) 1Y

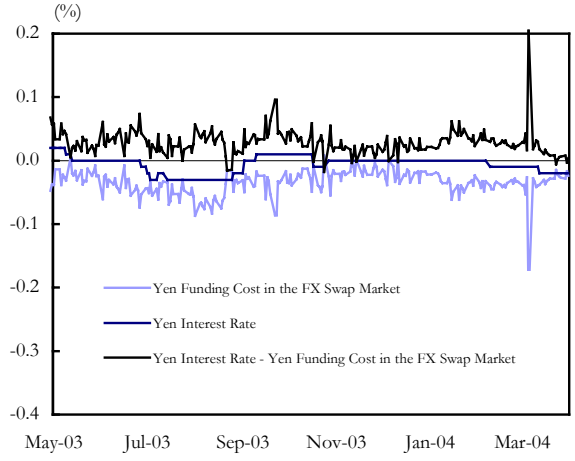


Table B-1: ADF Test Results

(i) Differences between the U.S. Dollar Funding Costs and the U.S. Dollar Interest Rates for Foreign Banks

	Number of Observations	Number of Lags	t -Value
From August, 1992 to April, 2003			
3M	2628	20	-4.733 ***
From May, 2003 to March, 2004			
T/N	239	0	-13.833 ***
1W	235	4	-6.334 ***
1M	239	0	-6.907 ***
2M	239	0	-6.728 ***
3M	236	3	-3.153 *
6M	237	2	-4.147 ***
1Y	233	6	-2.709

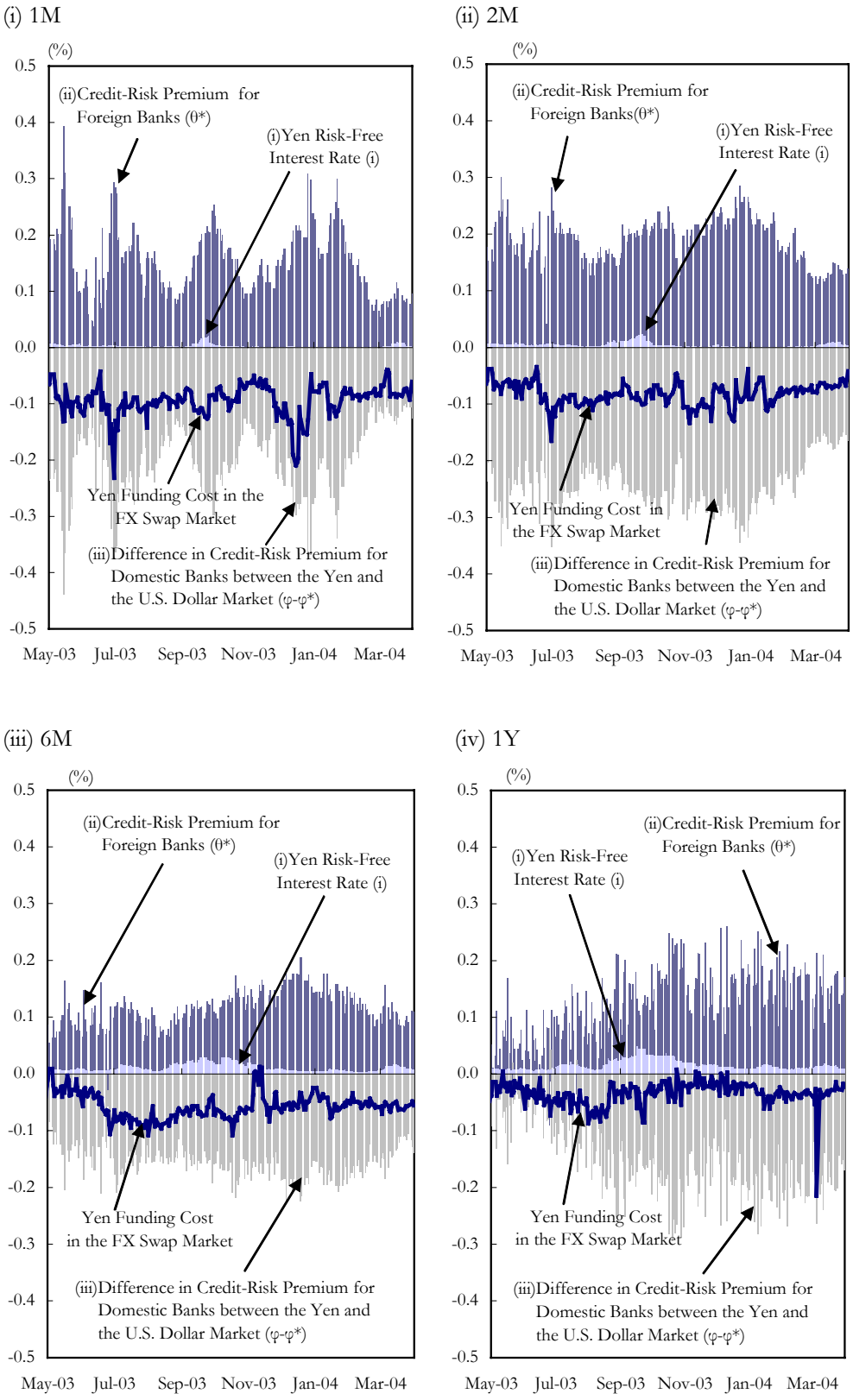
(ii) Differences between the Yen Funding Costs and Yen Interest Rates for Domestic Banks

	Number of Observations	Number of Lags	t -Value
From August, 1992 to April, 2003			
3M	2633	15	-4.675 ***
From May, 2003 to March, 2004			
T/N	238	1	-14.342 ***
1W	236	3	-6.030 ***
1M	231	8	-3.582 **
2M	239	0	-7.590 ***
3M	238	1	-5.037 ***
6M	232	7	-2.949
1Y	236	3	-4.457 ***

Notes: 1. ADF test is to test $H_1: \alpha_0 < 0$ in the following equation: $\Delta y_t = \mu + \alpha_0 y_{t-1} + \alpha_1 \Delta y_{t-1} + \cdots \alpha_N \Delta y_{t-N} + \varepsilon_t$ .We chose the number of lags whose AIC (Akaike Information Criteria) takes the smallest value among 0 to 20 lags.

2. ***, **, and * show that the null hypothesis is rejected at the 1, 5 and 10 percent significance level, respectively.

Figure B-4: Factor Decomposition of the Yen Funding Costs in the FX Swap Market for Foreign Banks



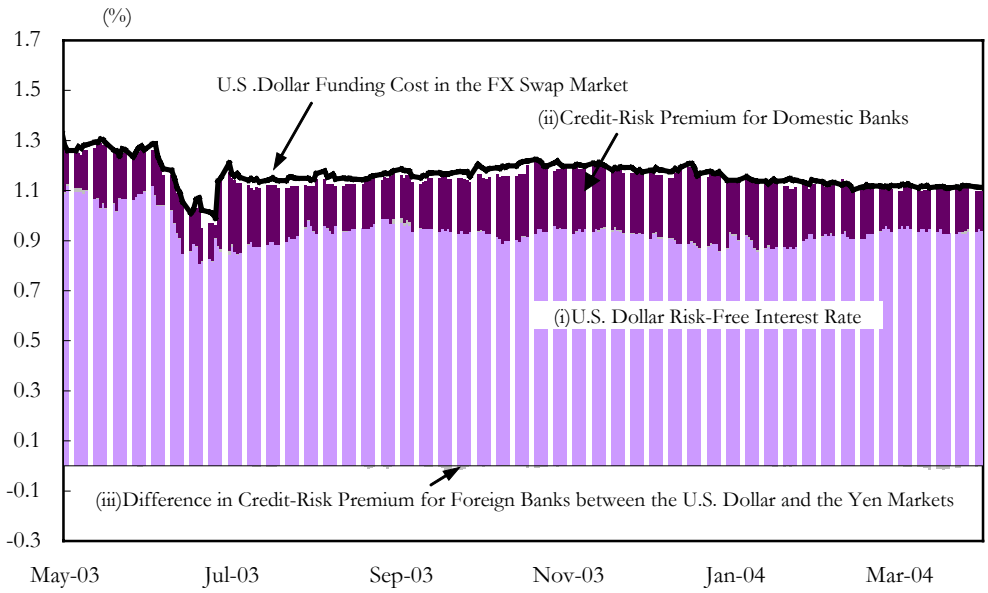
Appendix C: Factor Decomposition of the U.S. Dollar Funding Cost for Domestic Banks in the FX Swap Market

Similar to the yen funding costs for foreign banks, the U.S. dollar funding costs for domestic banks in the FX swap market c^* can be written as

$$c^* \approx i^* + \phi - [\theta - \theta^*].$$

Thus, the U.S. dollar funding costs can be decomposed into (i) the U.S. dollar risk-free interest rate (i^*), (ii) the credit-risk premium for domestic banks in the yen market, and (iii) the difference in the credit-risk premium for foreign banks between the yen and the U.S. dollar markets. Figure C-1 shows the decomposition of the recent U.S. dollar funding costs for domestic banks.

Figure C-1: Factor Decomposition of the U.S. Dollar Funding Cost for Domestic Banks in the FX Swap Market



Note: For details of the data, see Appendix A.

References

Baba, Naohiko, Shinichi Nishioka, Nobuyuki Oda, Masaaki Shirakawa, Kazuo Ueda, and Hiroshi Ugai [2004], "Japan's Deflation, Problems in the Financial System and Monetary Policy," presented at the third BIS Annual Conference "Understanding Low Inflation and Deflation," in Brunnen, Switzerland, forthcoming as BIS Working Paper.

Hanajiri, Tetsuro [1999], "Three Japan Premiums in Autumn 1997 and Autumn 1998: Why Did Premiums Differ between Markets ?," Financial Market Working Paper, Bank of Japan.

Inaba, Kei-ichiro, Sayako Konno, Noritaka Fukunaga, Tokiko Shimizu [2001], "The Structure of and Recent Developments in the Short-term Yen Money Markets: Arbitrage Relationship between the Uncollateralized Call market, the Euro-yen Market and the Dollar/Yen Swap Market," *Market Review*, 2001-E-3, Financial Markets Department, Bank of Japan.

Nishioka, Shinichi and Naohiko Baba [2004], "Credit Risk Taking by Japanese Investors: Is Skewness Risk Priced in Japanese Corporate Bond Market?," BOJ Working Paper Series 04-E-8, Bank of Japan.