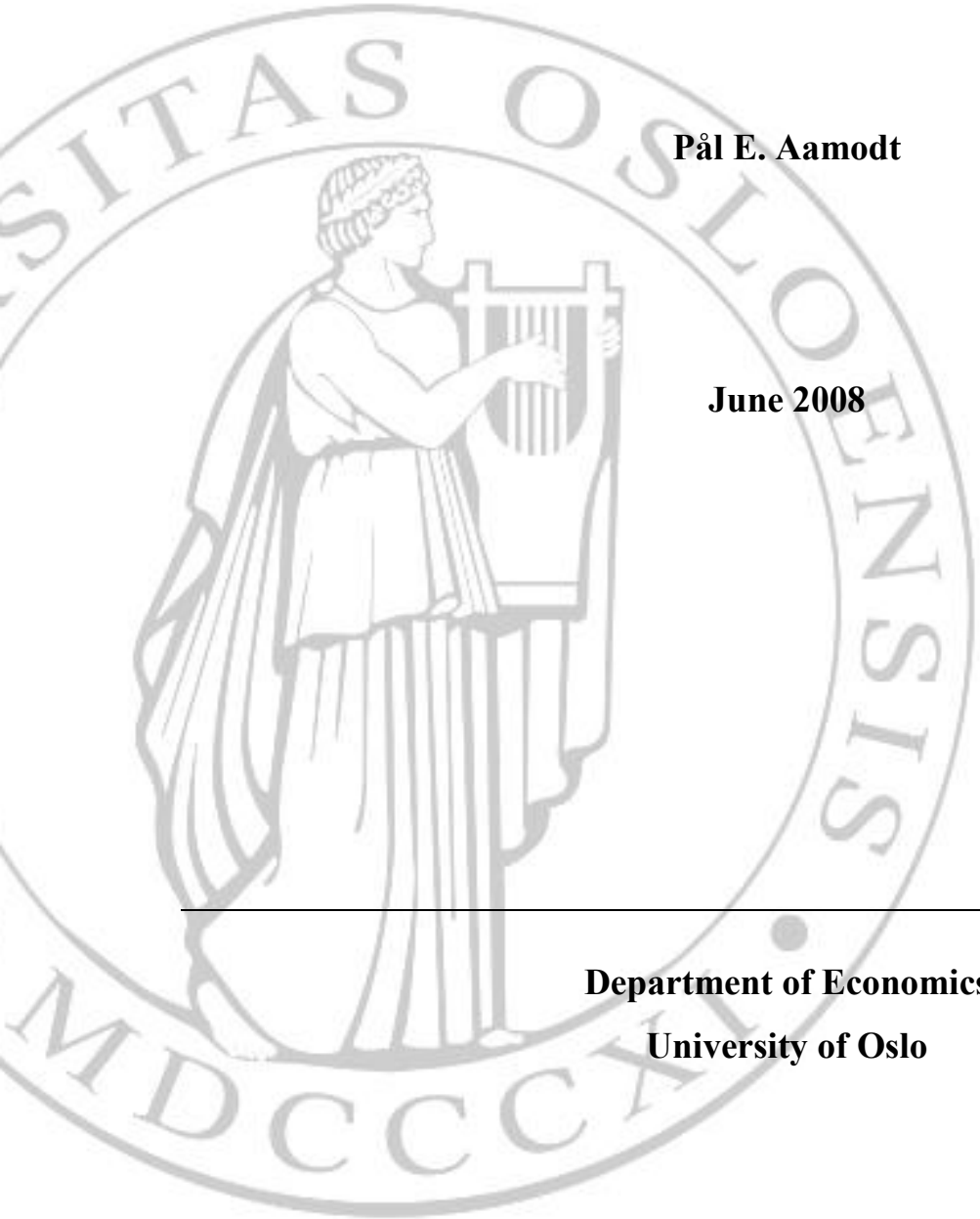
Master thesis for the Master of Philosophy in Economics degree

Currency

Carry Trade and Interest Rate Parity: Facts and Theoretical Implications



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Preface

I would like to thank my supervisor Kaiji Chen at the University of Oslo for his skilful advice and kind encouragement during the work on this thesis. His comments helped me find a way in the confusing landscape of data and theories. I would also like to thank my family and friends for their support and useful questions and comments during the process.

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Summary

This thesis looks at investments in low-risk assets denominated in foreign currencies and discusses theoretical implications related to the findings. Specifically, it looks at Japanese yen (JPY) and US dollars (USD).

Chapter 1 provides some background information about the phenomenon called carry trade, which has been mentioned in the public debate about economic affairs in general and exchange rate movements in particular. Since the term carry trade is often used in a vague or undefined manner, I start out by gathering some information from various sources in order to present a short overview of what carry trade actually is. This is done in the first part of Chapter 1. I then continue by describing some aspects of the Japanese financial market in order to justify the choice of Japanese yen and US dollars for the empirical study made in the thesis.

In the main part of Chapter 1, I go on to check whether uncovered interest parity (relating interest rates and expected exchange rate changes) are supported using the data on Japanese yen and US dollars. I then proceed to explore if there was a forward discount bias in the period 1993 to 2008 in order to look at uncovered interest parity from another angle. This is done by removing currency exchange risk through the use of forward contracts.

My empirical findings do not support uncovered interest parity. In fact, the results are opposite of what the uncovered interest parity hypothesis suggests. In the case of uncovered interest parity, I find that when a currency gave a higher interest return than another, this tended to lead to an increase rather than a decrease in the value of the same currency over the same period. I also find that although shorter three-year periods within the 1993-2008 period exhibited mixed results, uncovered investments in USD three-month bonds tended to yield higher return over the longer 1993-2008 period when compared to similar uncovered three-month bond investments in JPY.

I find that covered investments in Japanese yen gave higher return than similar investments in US dollars. This result is robust in the sense that it applied to the observed period 1993-2008 as a whole, and also to shorter three-year time-spans within this period. This shows that the forward rate was distorted, or biased. I relate this to the forward discount bias which has been described in economic literature.

In the last part of Chapter 1, I discuss potential reasons for these findings and compare the findings to other studies by reviewing some of the literature in this field. I also look at the development of the Japanese financial market from the 1980s. That review indicates that although the Japanese financial market may have been less liquid in the past than the US market, deregulations and reforms have made the markets more similar.

Chapter 2 of the thesis goes a step further into a theoretical paradox called the Siegel paradox. The Siegel paradox describes investments in foreign currencies and predicts a forward discount bias. I study the Siegel paradox for currency movements by using a simplified example with USD and JPY. The rationale leading to the paradox is analyzed, and alternative ways of thinking are investigated by looking at a simple version of the two-envelope problem. I try to find similarities and differences between the Siegel paradox and the two-envelope problem in order to gain some insight into what may be the common cause of the two paradoxes. I find that Jensen's inequality applies to both paradoxes. I find that the lack of a total value in the Siegel paradox and the existence of such a total value in the two-envelope problem may be one of the important differences between the two problems.

In Chapter 3, I discuss the relevance of the findings related to the paradoxes in Chapter 2 to interest rate parity and the forward discount bias found in Chapter 1. I suggest that the Siegel paradox is a purely theoretical misstatement which does not explain the forward discount bias observed in the market. Rather, I suggest that the forward discount bias is the result of other rational choices made by investors, like a risk premium and risk aversion among the investors combined with tax differences, trading costs and differences in liquidity. I suggest that investors that base their investment choices on the Siegel paradox are probably allocating their capital in an inefficient manner.

Finally, I indicate that further investigation should be made into resolving the Siegel paradox as this could possibly lead to a deeper understanding of risk, return and capital allocation in the financial markets.

The data in this thesis have been retrieved from the websites of the Bank of Japan and the Federal Reserve Bank of St. Louis. The spreadsheet application Microsoft Office Excel has been used for the processing of data and for the regressions.

1. Interest Rate Parity

In this chapter I start by looking at carry trade, which is an issue that comes up in the media from time to time. Since the term is often used quite loosely, I mention some possible definitions and data from reliable sources in order to get an overview of the phenomenon. I then look at some aspects of the Japanese financial markets in order to get an understanding of how it works. In order to see if the phenomenon of carry trade may be profitable, I spend the main part of this chapter checking if uncovered interest parity has held for three-month maturity bonds in the US and Japan. I also check if the forward rate has been an unbiased estimator of the future exchange rate. I use separate regression analyses for the two currencies in order to shed light on the Siegel paradox and two envelope problem in Chapter 2 (where the importance of the numéraire is investigated). In Chapter 1, I also discuss potential reasons for the findings I have made. I then continue by looking at some aspects of the Japanese economy in the 1980s and onward in order to understand why investment flows have been so large out of Japan and into currencies like the US dollar. By discussing the quality of the data, I make some suggestions about how to improve the analysis that has been made. In the end of the chapter, I review some literature about interest rate parity and try to relate the results that I have found to these papers.

1.1 Carry Trade

During the last few decades, two of the most widely traded currencies in the world have been the US dollar and the Japanese yen. These currencies are used in the largest (USA) and the second largest (Japan) national economies in the world as measured by nominal GDP[1]. During the last few years, some attention has been given to the phenomenon called carry trade. The reason is that movements in the currency exchange rates tend to trigger withdrawals of leveraged investments in foreign currency assets. This may further affect currency exchange rates and other prices.

Definitions of carry trade

There are several possible ways of defining carry trade. Some consider carry trade in the narrow sense of the term to be the act of borrowing in a currency with low interest rates to

[1] Gross Domestic Product (current prices, in USD) for 2007 from the International Monetary Fund

fund deposits in a high-interest yielding currency. Others may consider any financial transaction that increases one's high-yielding assets relative to one's low-yielding assets to be carry trade[2].

The International Monetary Fund (IMF) defines[3] carry trade in the following way: "A leveraged transaction in which borrowed funds are used to take a position in which the expected return exceeds the cost of the borrowed funds."

One can also separate between different types of investors. Financial investors may invest in the hope of increasing their financial return while commercial investors may act with the aim of protecting their business activities from losses.

Examples of carry trade

One example of carry trade is investments through the exchange of Japanese yen (JPY, which for a long time have offered low interest rates) into US dollars (USD, which for a long time have offered considerably higher interest rates). When looking at the short-term impact on currency exchange rates, it may be important to differentiate between investments derived from borrowed yen (leveraging) and investments based on savings or surplus liquidity. The latter will not normally set off large sell-offs when the exchange rate moves as there is no need to withdraw the investments in order to repay loans.

Because the rest of the world has large net liabilities in Japanese yen, one can expect that many investors are willing to protect themselves against yen appreciation.

If the JPY have been borrowed, then the loans may be subject to conditions that are shaped in order to ensure that the borrowers will be able to repay the borrowed yen. These lending conditions could force the investors to reduce or liquidate their holdings of USD assets and exchange the USD back into JPY if their value (measured in yen) falls below a certain threshold. This is often referred to as unwinding of carry trade. This has typically taken place when the JPY has suddenly strengthened compared to foreign currencies, but it could also happen because of large declines in the foreign currency value of particular assets.

Borrowing JPY and investing in USD means going short in JPY (betting that the value of the Japanese yen will decrease) and going long in USD (betting that the value of the US dollar assets will increase).

Hedge funds and to some extent pension funds, investment banks and individual investors, are among the market participants that engage in carry trade. As a net foreign asset

[2] Gagnon and Chaboud (2007)
[3] IMF (2007b, 102)

holder with a net long position in foreign assets, the Japanese official sector could (in the wider definition of the term) be said to be heavily engaged in carry trade. Japan's official reserve assets surpassed USD 1000 billion in February 2008 to become USD 1015.6 billion[4] at the end of March 2008. 97 percent of this was foreign currency reserves. This is the second largest stock of foreign currency assets in the world after China.

Capital export and import

According to the IMF[5], Japan accounted for 12.2 percent of countries' net export of capital in 2006 as measured by countries' current account surplus. The largest net importer of capital was USA, accounting for an estimated 63.7 percent of capital imports. These figures indicate that Japan is a major exporter and the US a major target for investment flows. Henceforth, looking at the case of JPY and USD seems to be justified.

1.2 The Scope of Carry Trade

When investors make investment choices, they also choose which currencies to invest in and borrow in. For small investors, it is often easier to invest in assets denominated in their country's own currency than to invest in assets denominated in other currencies. However, for people, institutions and firms with more resources, the trading costs as a proportion of the value of the assets they hold will be small or insignificant. They may also have costs that are more directly related to prices in foreign markets. Many of them consequently invest in assets denominated in foreign currencies in order to protect or increase the value of their assets.

The Bank of Japan and the Ministry of Finance Japan have estimated short-term JPY borrowings related to carry trade to be in the order of USD 20-40 billion[6]. When including individual Japanese investors, the total may be close to USD 170 billion.

Several high yielding currencies like the New Zealand dollar (estimated to be around NZD 2 million per month[7]), Turkish lira, Icelandic króna, Brazilian real, Latvian lat and Korean won have been investment targets for carry trade. Private individuals in various countries have mortgages denominated in Japanese yen.

[4] Ministry of Finance Japan (2008)
[5] IMF (2007b, 141)
[6] Financial Times (14 March 2007)
[7] IMF (2007a, 27)

Another estimate[8] for net carry trade (defined as being short in JPY and long in foreign currency positions) is USD 915 billion in December 2006.

As mentioned, different definitions of carry trade lead to very different estimates of its size depending on what kind of investments one chooses to include. Figures that are much higher than those stated above may include non-leveraged assets. These investments are consequently less interesting for those who follow short-term movements in the exchange rates unless they are exchanged quickly in large amounts.

1.3 Empirical Tests on Japanese Yen and US Dollars

USA and Japan are the largest and second largest national economies in the world respectively. The two countries are major trading partners. From the 1970s, Japanese financial markets were gradually deregulated and the operating procedures of the US Federal Reserve and the Bank of Japan converged[9]. This facilitated higher liquidity in various asset markets, including the markets for foreign exchange, forward contracts and treasury bills.

Having a risk-free short term asset in a currency is considered important in order to tempt foreign investors into keeping some of their assets in a given currency. Such a short term asset in a liquid market makes it possible for investors to quickly shift their investments between currencies and investment types. Low trading costs give small losses in the transaction processes when they are combined with narrow spreads between the bid and ask prices on assets.

The functioning of the US currency market has been facilitated by high liquidity government bonds through the Treasury bill market. The three-month bill is often used as an approximation of the risk-free interest rate, that is, the interest rate one can get without any default risk. After all, the likelihood of a state going bankrupt is usually miniscule, since the central bank can print more money.

Such liquid markets, the fact that many products on the world market are priced in USD and the links to other markets have contributed to making the US dollar the most popular storage medium for surplus liquidity.

In Japan, government securities were for a long time absent from the short-term financial market[10]. The Tegata market and the Gensaki market have been important for the short-term financial market in Japanese yen, especially from the 1970s. Certificates of Deposit (CDs)

[8] Gagnon and Chaboud (2007, 21-22)
[9] Kasa and Popper (1996)
[10] Ito (1992, 121-125)

grew quickly from they became available in 1979, partially at the cost of the Gensaki market, but alongside growth in the Tegata market. Six-month Japanese Government Bonds were introduced in 1986 and three-month bonds in 1989. Combined with financial deregulation, this has led to higher liquidity. Because of this, and the fact that they are both developed economies with large financial markets, it has probably become easier to compare returns on risk-free assets in USA and Japan.

1.3.1 Uncovered Interest Parity and the Forward Rate

One way of checking the return on Japanese yen assets compared to US dollar assets is to look at the return on assets that are considered to be risk-free. This is typically the case for three-month interest rate bonds (often referred to as bills) in the two currencies. These are traded in highly liquid markets. Two ways have been used here in order to check the return:

1. Check if **uncovered interest parity** holds.
   a) Invest the initial holding of JPY in Japanese interest rate bonds.
   b) Exchange the initial amount of JPY into USD at the current JPY/USD spot rate, invest the USD one receives in a risk-free US asset like three-month treasury bills and then exchange the money back into JPY at the end of the three-month period at the JPY/USD spot rate.

   By comparing the returns on such investments over time, one can find out if uncovered interest parity has held.

2. Check if there has been a **forward discount bias**.
   a) Do the same as in 1a.
   b) Do the same as in 1b. However, when investing in USD assets, fix the JPY/USD exchange rate by buying a forward contract that gives a right to exchange the resulting USD back into JPY at a certain exchange rate.

   By comparing the return on these investment alternatives over time, one can find if the forward rate has been an unbiased estimator of the future exchange rate.

The data have been retrieved from the websites of the Bank of Japan (BoJ) and the Federal Reserve Bank of St. Louis. The data are on a monthly basis.

Let the definitions be as follows:

r = the return in percent on Japanese three-month bills from the end of month t-3 until the end of month t (source: BoJ)

r* = the return in percent on US Treasury bills from the end[11] of month t-3 until the end of month t (source: Federal Reserve Bank of St. Louis)

$F_{t-3,t}$ is the JPY/USD forward rate at time t bought at the end of month t-3 (source: BoJ)

ε_{t-3} is the JPY/USD spot rate at the end of month t-3 (source: BoJ)

ε_t is the JPY/USD spot rate at the end of month t (source: BoJ)

1.4 Uncovered Interest Parity

In the case of uncovered interest rate parity, an investor has two options:

a) Invest in JPY at time t-3 and gain r percent return until the end of month t. The value measured in JPY at time t is then (1+r) multiplied by the initial holding.

b) Exchange the same amount of JPY into USD at spot rate ε_{t-3} and invest in three-month USD treasury bills with r* percent return over the three month period. The resulting amount in USD is then exchanged back at time t into JPY at spot rate ε_t. The value measured in JPY at the end of month t is then $(1+r^*)\varepsilon_t/\varepsilon_{t-3}$ multiplied by the initial holding.

If investment strategies a) and b) tend to give the same return over time, that is if

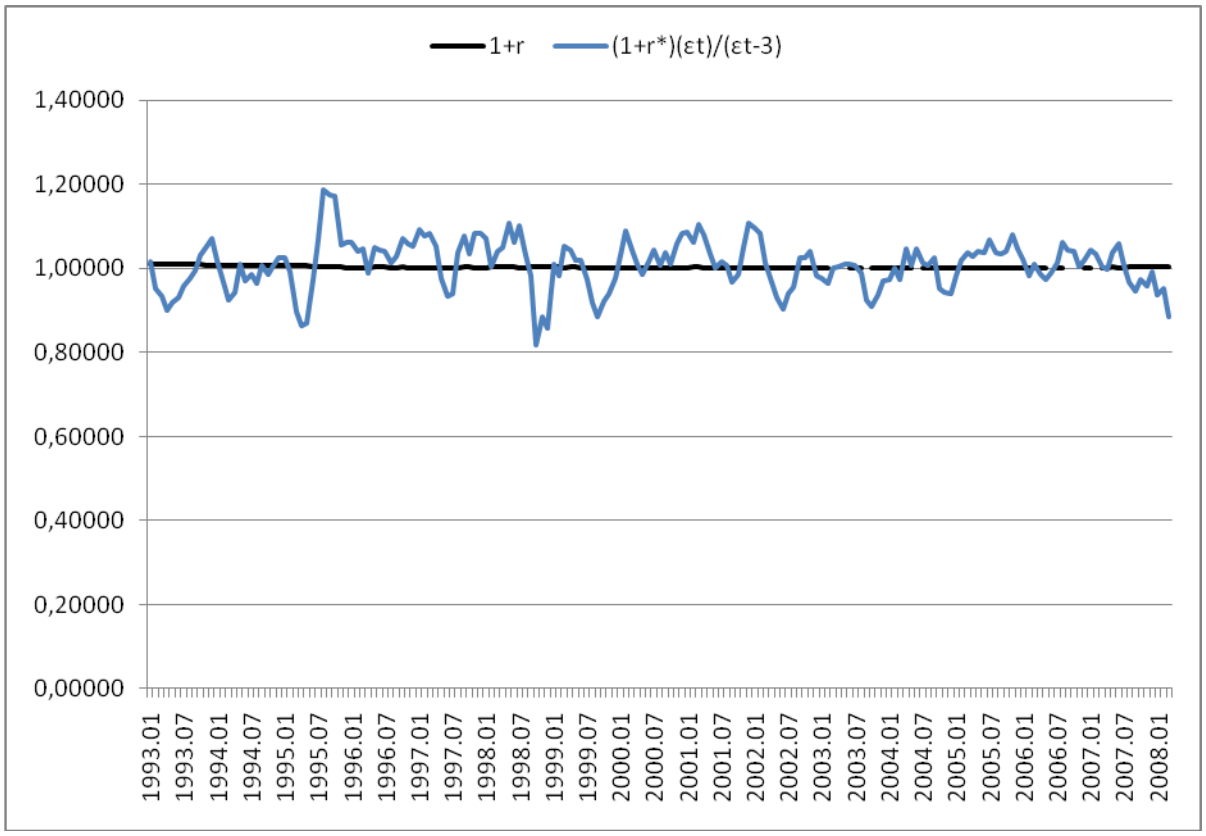
$$\mathbf{(1+r) = (1+r^*)\varepsilon_t/\varepsilon_{t-3}}$$

then uncovered interest rate parity holds.

Figure 1 on the next page shows the return for someone who measures return in JPY. We can see that the return on uncovered investments in USD fluctuates wildly around the return gained by keeping the investments in JPY. From a visual perspective, there does not seem to be any consistent tendency for any of the currencies to give higher return than the other. The USD investments sometimes give higher and sometimes lower return than JPY investments.

[11] Here, the actual interest rate figures from the Federal Reserve Bank of St. Louis are from the beginning of the next month (month t-2) and are therefore an approximation of the value of the end of month t-3.

Figure 1: Uncovered Interest Parity Measured in JPY. *For monthly three-month investment periods finalized from the end of January 1993 to the end of March 2008 (sources: Bank of Japan and Federal Reserve Bank of St. Louis)*



One can test if the difference between the two graphs is as random as it looks by checking the difference between the two sides in the uncovered interest parity equation. Let d_{1t} be the difference

$$1+r = (1+r^*)\varepsilon_t/\varepsilon_{t-3} + d_{1t}$$

$$d_{1t} = (1+r) - (1+r^*)\varepsilon_t/\varepsilon_{t-3}$$

By adding up all the values of d_{1t} and dividing by the number of observations, we get

$$\sum d_{1t} /175 = -0.64 \text{ percentage points}$$

In other words, when we measure return in JPY, monthly uncovered investments in three-month USD treasury bills gave an average of 0.6 percentage points higher return than investments in three-month JPY interest bills for investments that were settled from the end of January 1993 to the end of March 2008.

In order to complete the picture, one can look at the same investment strategy as seen from the perspective of an investor who measures return in USD. That is, we want to find out if the following equation holds:

$$1+r^* = (1+r)(1/\varepsilon_t)/(1/\varepsilon_{t-3})$$

$$1+r^* = (1+r)(\varepsilon_{t-3}/\varepsilon_t)$$

The two sides of the equation are depicted in figure 2. The data which have been used are the same as before.

Figure 2: Uncovered Interest Parity Measured in USD. *For monthly three-month investment periods finalized from the end of January 1993 to the end of March 2008*

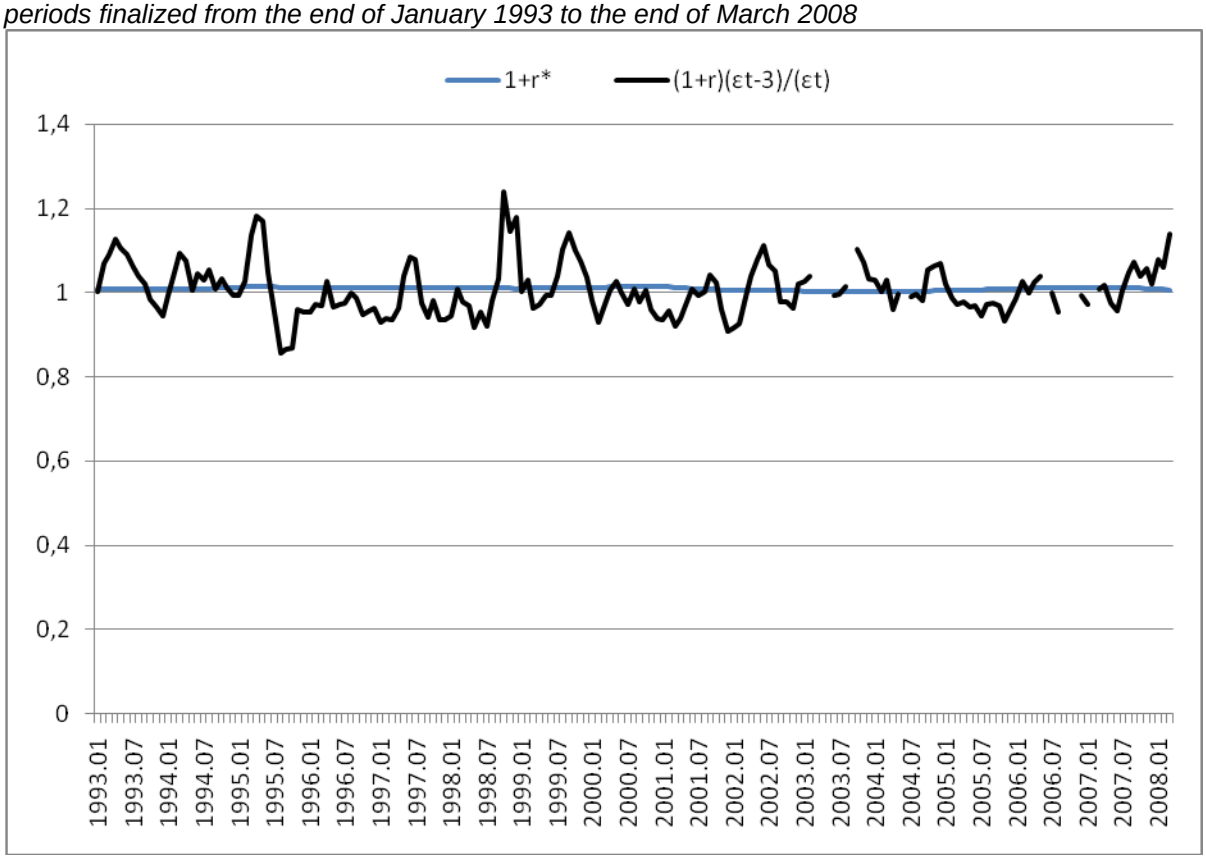


Figure 2 shows the return for someone who measures return in USD. Since this is basically the inverse version of figure 1, there does not from a visual perspective seem to be any consistent pattern here either.

By using the same error term as before, we have

$$d_{2t} = (1+r^*) - (1+r)\varepsilon_{t-3}/\varepsilon_t$$

By adding up all the values of d_{2t} and dividing by the number of observations, we get

$$\sum d_{2t} / 175 = 0.28 \text{ percentage points}$$

This indicates that for investments that were settled in the period from the end of January 1993 to the end of March 2008, there was a 0.3 percentage point excess return on average for

the period as a whole on three-month USD Treasury bills compared to similar investments in JPY when we measure the return in USD.

From these two perspectives (return measured in JPY and USD), it may seem like uncovered interest parity did not hold for the three-month investments periods that were finalized in the period from the end of January 1993 to the end of March 2008.

One way of checking the figures, is to look at several shorter periods instead of only at the aggregate result. By dividing the period into three-year periods, one can get an impression of the development over time. The table below shows the differences between the two currencies in these periods.

We get the following average excess return in percentage points as seen from the perspective of an investor that measures return in JPY and from the perspective of an investor that measures return in USD:

Table 1: Checking Uncovered Interest Parity *(monthly investments in three-month bonds)*

Period	*Excess return on JPY measured in JPY (percentage points)*	*Excess return on USD measured in USD (percentage points)*
1993 – 1995	+0.93	–1.5
1996 – 1998	–2.6	+2.1
1999 – 2001	–1.7	+1.5
2002 – 2004	+ 1.2	–1.5
2005 – 2007	–1.6	+1.5
1993 - March 2008	**–0.64**	**+0.28**

From table 1, we can see that the data from the period January 1993 to February 2008 indicate that there was an excess return on USD three-month bills compared to JPY three-month bonds in the period as a whole. However, when the whole period is divided into three-year periods, these show a much more volatile development. Three periods gave excess return on USD investments and two periods gave excess return on JPY investments.

1.4.1 Regression Analysis

In order to gain more insight into uncovered interest parity, we can use a linear regression. We start with the uncovered interest parity condition, rearrange and then take the logarithm:

$$(1+r) = (1+r^*)\varepsilon_t/\varepsilon_{t-3}$$

$$\varepsilon_t/\varepsilon_{t-3} = (1+r)/(1+r^*)$$

$$\log(\varepsilon_t/\varepsilon_{t-3}) = \log[(1+r)/(1+r^*)]$$

$\log(\varepsilon_t) - \log(\varepsilon_{t-3}) = \log(1+r) - \log(1+r^*)$

The linear regression can then be written as:

$$\mathbf{\log(\varepsilon_t) - \log(\varepsilon_{t-3}) = \alpha_1 + \beta_1[\log(1+r) - \log(1+r^*)] + e_{1t}}$$

where e_{1t} is the expectation error. If $\alpha_1 = 0$ and $\beta_1 = 1$, then there is equality between the percentage reduction in the value of the yen and the interest rate differential (r*- r) over the same period. Consequently, we would like to test if the H_0 hypothesis that $\beta_1 = 1$ can be rejected. The results are listed in table 2.

We can also do a regression analysis with USD as numéraire. Again, we rearrange the uncovered interest parity condition and take the logarithm:

$1+r^* = (1+r)(1/\varepsilon_t)/(1/\varepsilon_{t-3})$

$(1+r^*)/(1+r) = (1/\varepsilon_t)/(1/\varepsilon_{t-3})$

$\varepsilon_{t-3}/\varepsilon_t = (1+r^*)/(1+r)$

$\log(\varepsilon_{t-3}) - \log(\varepsilon_t) = \log(1+r^*) - \log(1+r)$

The regression can then be written as

$$\mathbf{\log(\varepsilon_{t-3}) - \log(\varepsilon_t) = \alpha_2 + \beta_2[\log(1+r^*) - \log(1+r)] + e_{2t}}$$

The null-hypothesis is now that $\beta_2 = 1$. The results are listed in table 2.

Table 2: Regression Results for Uncovered Interest Parity

Para-meter	*Estimate*	*95 % confidence interval*	R^2	*t-value*	*p-value*	*Standard-error*	*Obser-vations*
α_1	–0.01479	[–0.0252, –0.0071]	0.81	–3.78	0.00022	0.0039	175
β_1	–4.07233	[–6.1278, –2.0168]	0.81	–3,91	0.00013	1.0414	175
α_2	+0.01479	[0.0071, 0.0225]	0.81	3.78	0.00022	0.0039	175
β_2	–4.07233	[–6.1278, –2.0168]	0.81	–3.91	0.00013	1.0414	175

The 95 % confidence intervals for β_1 and β_2 are the same, and they are far from including the value 1. The t-value (–3.91) for the βs is acceptably high in terms of absolute value. The sum of squares due to error is $R^2 = 0.81$ and fairly close to the value 1 that one could ideally hope to get and can therefore be considered satisfactory. This indicates that we can be quite confident in rejecting the null hypothesis.

The remarkable thing is that we do not only get an estimate for β for that is significantly different from 1, but in fact clearly negative ($\beta_1 = \beta_2 = –4.07$). This implies that instead of having a weakening of the currency where the interest rate increases (as would have been the case with $\beta = 1$), the currency with the increasing interest rate actually had a

tendency to strengthen. This means that we can clearly reject that uncovered interest parity held in the period 1993 to March 2008.

1.5 Forward Discount Bias

The method used in this section looks at interest rate parity from another perspective by using forward contracts to fix the future interest rate. It also points towards Siegel's original formulation of the Siegel paradox with the forward rate. In order to protect/cover the value of the investments, the investor may use forward contracts to eliminate the exchange rate risk. Let us assume that the investor has the following two investment options

a) Invest in JPY three-month bills. The value measured in JPY at the end of the period is then as before (1+r).
b) Do like in the case of uncovered interest rate parity, but in addition buy a JPY/USD forward contract at the end of month (t-3) which gives a right to exchange the resulting amount of USD back into JPY at exchange rate $F_{t-3,t}$ at the end of month t. The return on this investment is then $(1+r^*)(F_{t-3,t})/(\varepsilon_{t-3})$.

If investment strategies a) and b) tend to give the same return over time, that is if

$$\mathbf{(1+r) = (1+r^*)(F_{t-3,t})/(\varepsilon_{t-3})}$$

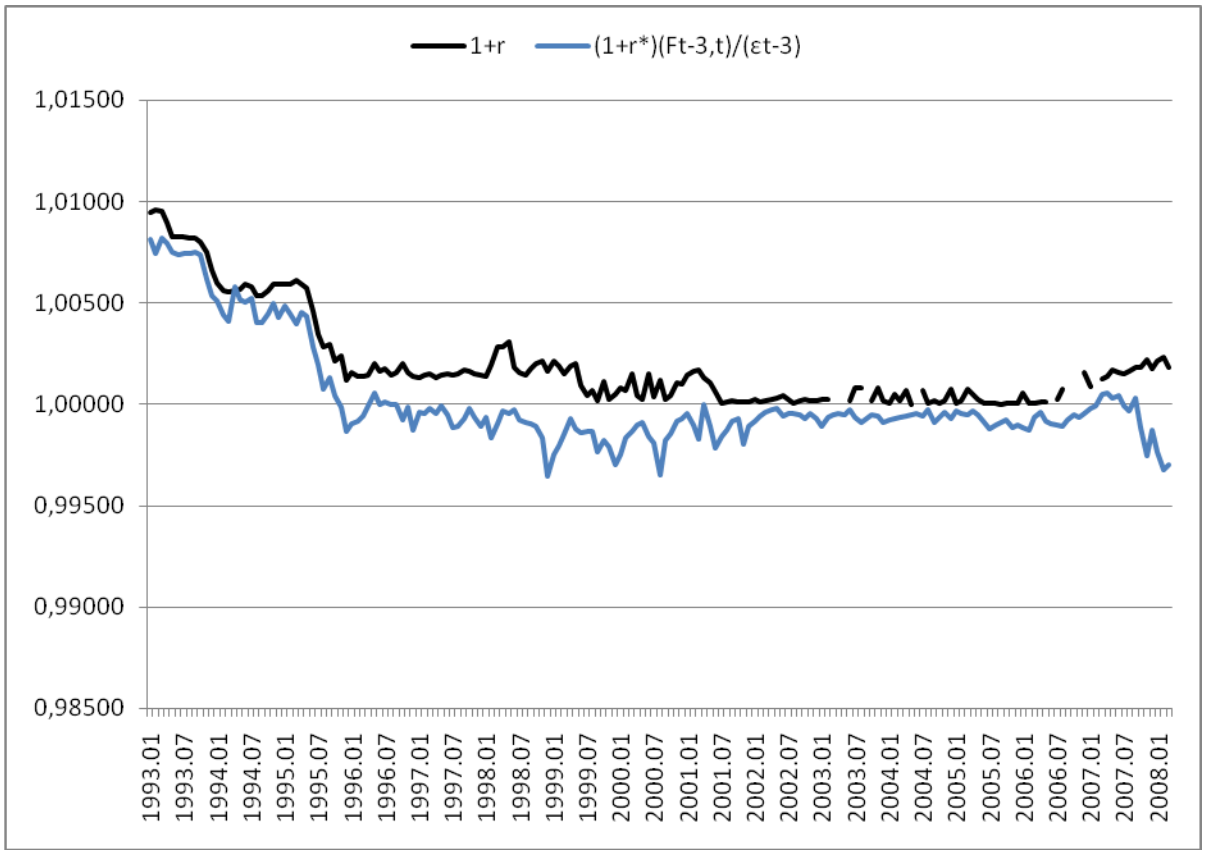
then the forward rate has been an unbiased estimator of the future exchange rate.

It has been pointed out[12] that covered interest rate parity must hold. The reason is that the entire operation can be conducted at time t-3 by exchanging the initial holding of JPY into USD at rate ε_{t-3} , invest the USD in three-month USD interest rate bills paying $1+r^*$ and then lock in a future JPY payout by selling the forward contract at rate $F_{t-3,t}$. The entire operation can be conducted at time t, without risk. So if covered interest rate parity does not hold, there has been an arbitrage opportunity.

Figure 3 shows that for someone who measures the return on covered investments in JPY, the return on USD tended to be systematically lower than the return on JPY.

[12] Obstfeld and Rogoff (1996, 585-586)

***Figure 3. Covered Investments Measured in JPY**. For monthly three-month investment periods finalized from the end of January 1993 to the end of March 2008*



Investments in JPY gave an average of 0.17 percentage point higher return in the period as a whole than similar covered investments in USD.

For the period 1995 to 2002 the graph indicates that there was a higher risk premium on Japanese yen than in the time before and after. Some have described the 1990s as Japan's lost decade as the Japanese economy performed less well than expected. Hayashi and Prescott (2002) study the performance in the Japanese economy from 1984 to 2000 and find that there was a fall in the growth rate of total factor productivity (TFP) in the 1990s and a reduction in the average hours worked per week from 1988 to 1993.

We can also see that there was a widening towards the end of the period which coincided with the weakening of the dollar during the financial turbulence which originated in the US mortgage market[13].

In order to look at the situation in another way, we can use the same data and use USD as the measuring rod. That is, we want to test if the following equation holds:

$$(1+r^*) = (1+r)\cdot(1/F_{t-3,t})/[(1/\varepsilon_{t-3})]$$

[13] The subprime crisis

$$(1+r^*) = (1+r)(\varepsilon_{t-3}/F_{t-3,t})$$

The two sides of the equation are drawn in figure 4.

Figure 4. Covered Investments Measured in USD. *For monthly three-month investment periods finalized from the end of January 1993 to the end of March 2008*

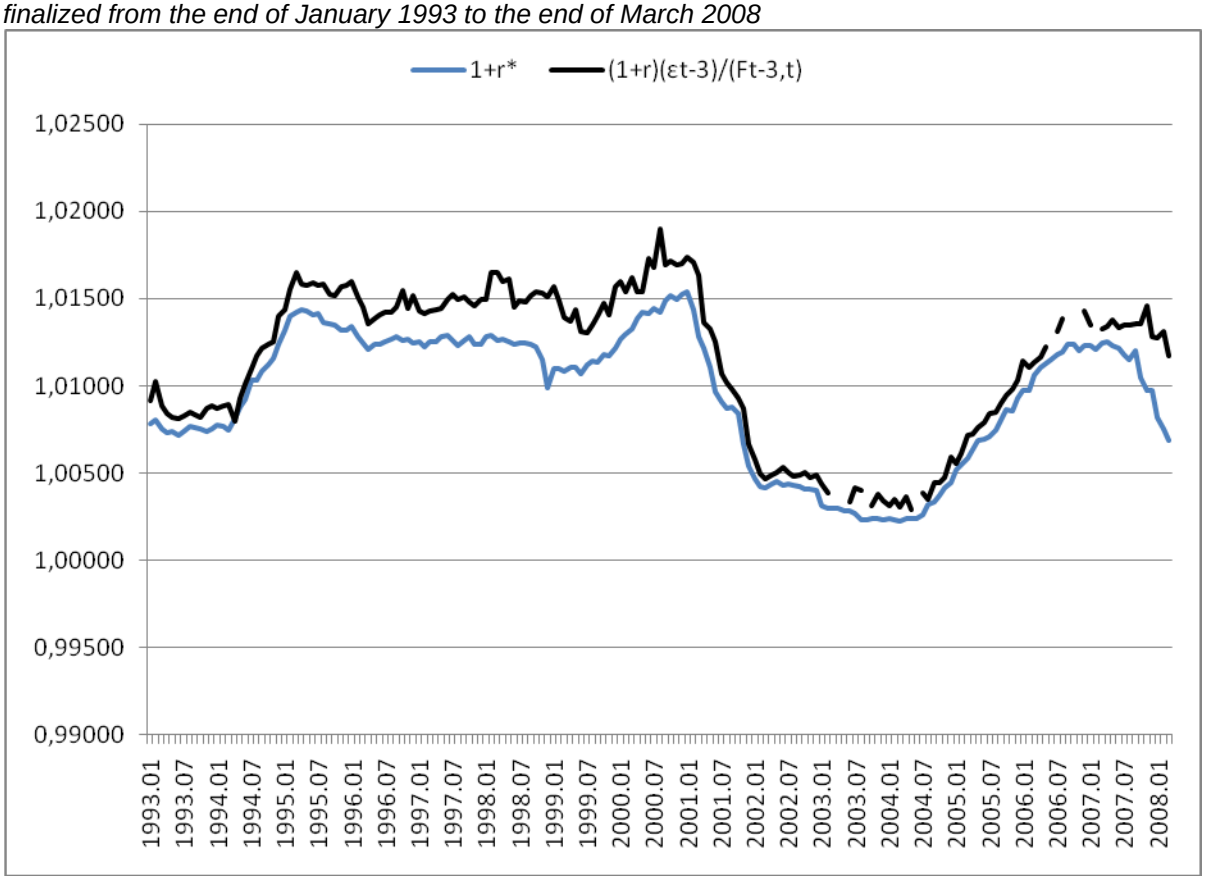


Figure 4 shows the covered returns for someone who measures the return in USD. Again, we find that investments in JPY have systematically tended to be higher than for USD for investments that were completed in the period January 1993 to March 2008.

When using the US dollar as numéraire, one finds that covered investments in JPY gave 0.18 percentage points higher return on average than USD investments.

From these two perspectives, it is natural to conclude that there has been a forward discount bias for monthly, three-month long investment periods that were finalized in the period from the end of January 1993 until the end of March 2008. However, although the figures both indicate the same level of excess return on JPY three-month bonds over three-month Treasury bills, the difference is small.

By once again dividing the investment period into three shorter three-year periods, one can check the development over time. This is shown in table 3.

Table 3: Checking Covered Investments *(monthly investments in three-month bonds)*

Period	*Excess return on JPY measured in JPY (percentage points)*	*Excess return on USD measured in USD (percentage points)*
1993 – 1995	+0.13	–0.13
1996 – 1998	+0.24	–0.24
1999 – 2001	+0.24	–0.24
2002 – 2004	+0.09	–0.09
2005 – 2007	+0.14	–0.14
1993 - March 2008	**+0.17**	**–0.18**

We can see from figure 3, figure 4 and from table 3 that when the foreign currency investments were covered, then investments in JPY denominated three-month bonds consistently gave higher return than investments in USD denominated three-month bills. This applied to the period as a whole, measured in both currencies and for three-year sections within this period.

1.5.1 Regression: Prediction Bias in the Forward Rate

We can test further by using the forward premium ($F_{t-3,t} - \varepsilon_t$) as the independent variable[14]. The linear regression then becomes:

$$\log \varepsilon_t - \log \varepsilon_{t-3} = \alpha_3 + \beta_3 \cdot [\log(F_{t-3,t}) - \log(\varepsilon_{t-3})] + e_{3t}$$

We can change the numéraire to USD and test if the following equation holds:

$$\log \varepsilon_{t-3} - \log \varepsilon_t = \alpha_4 + \beta_4 \cdot [\log(\varepsilon_{t-3}) - \log(F_{t-3,t})] + e_{4t}$$

If the interception points of the regressions are 0 and the slopes 1, then there is equality between the spot rate at time t and the prediction made at time (t-3) by the forward rate. Consequently, we would like to test if the null-hypothesis $\beta = 1$ can be rejected. The results are listed in table 4.

[14] According to Froot and Thaler (1990), the linear regression $\log \varepsilon_t - \log \varepsilon_{t-3} = \alpha + \beta \cdot [\log(r^*) - \log(r)] + e_t$ is sometimes replaced by the forward discount which is the formulation used here: $\log \varepsilon_t - \log \varepsilon_{t-3} = \alpha + \beta \cdot [\log(F_{t-3,t}) - \log(\varepsilon_{t-3})] + e_t$ under the assumption that by arbitrage, the forward discount must equal the interest rate differential. If not, it would be possible to get a riskless profit. Some market participants including banks allow forward rates to be set by interest rate differentials. When r and r* are small, $F_{t-3,t}/\varepsilon_{t-3} = (1+r)/(1+r^*)$ can be approximated by $\log(F_{t-3,t}) - \log(\varepsilon_{t-3}) = r^* - r$

Table 4: Regression Results for Covered Investments

Para-meter	*Estimate*	*95 % confidence interval*	R^2	*t-value*	*p-value*	*Standard-error*	*Obser-vations*
α_3	-0.01305	[–0.02105, –0.00504]	0.055	–3.22	0.0015	0.00406	183
β_3	-2.91102	[–4.68225, –1.13979]	0.055	–3.24	0.0014	0.89766	183
α_4	0.01305	[0.00504, 0.02105]	0.055	3.22	0.0015	0.00406	183
β_4	-2.91102	[–4.68225,–1.13979]	0.055	–3.24	0.0014	0.89766	183

We see from table 4 that the beta values are both estimated to be (–2.91). The 95 % confidence intervals for β_3 and β_4 are equal to each other in the case of covered investments. The confidence intervals for the βs do not include the value 1. The absolute t-value (–3.24) is satisfactory. The sum of squares due to error is $R^2 = 0.055$. Such a low R-squared value is not uncommon in time-series data. However, if one wants to make a more rigorous analysis, one can use other methods[15].

The remarkable thing is again that we do not only get estimates for the βs that are significantly different from 1, but clearly negative ($\beta_3 = \beta_4 = –2.91$). This implies that the forward rate was not a good estimator of the future spot rate. This means that we can reject the null-hypothesis and conclude that there was a forward discount bias.

The results mean that for USD/JPY investments that were finalized in the period January 1993 to March 2008, the forward rate did not fit the JPY/USD spot rate three months later when taking into account interest rate differentials between the two currencies. There was a bias. The failure of regressions like these to get an estimate of $\beta = 1$ is often referred to as the forward discount bias[16].

This is somewhat surprising. One would expect that when there is a systematic pattern where covered investments in one of the currencies give higher return over time because of a bias in the forward rate, then some investors would discover this pattern and make use of the arbitrage opportunity. They would do so in the periods following after the discovery for instance by offering or buying forward contracts until the pattern disappeared. Still, when this does not happen, there must be some good reason for this. This is discussed in the following section.

[15] Models like autoregressive conditional heteroscedasticity (ARCH) and other ARCH models with cointegration or methods developed by Engle and Granger are possible methods for this purpose.
[16] Froot and Thaler (1990)

1.6 Potential Reasons

If the risk premium on JPY assets is higher than on USD assets, then the result (that there has been a forward discount bias) could make sense.

Although the yen gave higher covered return over the period surveyed here, it is possible that such excess returns are wiped out in the event of rare phenomena. The "peso problem"[17] is a name that has been used about a situation in the early 1970s when the Mexican peso was tied to the US dollar. Since USD bank accounts gave lower interest than the peso, this provided an arbitrage opportunity. However, Milton Friedman noted that this may have been a reflection of market participants worrying that the peso would be devalued. In August 1976, the peso was allowed to float and fell sharply in value. That wiped out the gains of investors that were still unfortunate to be long in pesos. The anomaly became easier to understand when the risk of devaluation was taken into account. As the Japanese and the US both have well developed financial markets and are more similar than the US economy and the Mexican economy in the 1970s, the return differentials are more difficult to explain in this case.

It is possible that the JPY treasuries market is still somewhat less liquid than the USD treasuries market, leading to a higher risk premium for JPY denominated bonds. Differences in taxes and regulation may also be relevant.

Japanese savers may be interested in channeling savings into assets denominated in other currencies than JPY in order to find more interesting assets than the three-month bills we have looked at here. For instance, Japanese investors may be interested in higher yielding assets like shares. They may be acting rationally if they succeed in finding such assets. However, this does not explain the forward discount bias for low-risk assets.

Investors may require a higher return on JPY as a compensation for investing in JPY and virtually other currencies since the USD remains the world's leading foreign reserve currency[18] and the main price setting currency for important tradable products on the world market. On the other hand, this claim does not fit well with periods where the USD had high

[17] For more about the peso problem, see Sill (2000).

[18] Although the US dollar has been the favorite currency of many governments and central banks, statistics from the US Department of the Treasury show that Japan was one of the countries that reduced the holdings of US Treasury securities from February 2007 to February 2008. This may have to do with the weakening of the US dollar and the relative rise of the euro and other currencies relative to the USD. Some foreign countries have consequently increased the shares invested in other currencies and assets like foreign equities and corporate bonds.

interest rates and a simultaneous strengthening of the dollar, as was the case in the period from late 1980 until 1985[19].

The forward discount bias may also be an indication that capital mobility is imperfect[20]. Although the currency exchange rate markets are often described as very liquid with high volumes being traded every minute of the day around the globe, there are related assets like forward contracts that are sometimes traded in thinner volumes. Although the total volume of a particular asset is traded in large numbers worldwide, the markets are fragmented into different locations, with different firms carrying out the trades and at different costs. Investors will normally demand to be compensated for the risk they take when offering prices in markets that sometimes take time to clear. These liquidity risks may be difficult to capture in the models and could lead to a difference between the observed trading prices and the idealized prices predicted by the models.

If investors are risk averse over the three-month investment periods that have been checked here, and if they are predominantly worried that the exchange rate will move in the opposite direction of what is predicted by the interest parity condition, then the investors may be willing to buy contracts that protect them against such currency exchange rate movements. This could potentially distort the forward rate and give the observed bias. However, this does not explain why investors with other preferences do not correct for this by entering into forward contracts that make use of this arbitrage opportunity. One would expect them to do so until the forward discount bias disappears.

The findings that have been made here are in agreement with the majority of similar studies. However, there are some studies that have looked at longer maturity bonds and some studies that have looked at short-term data[21].

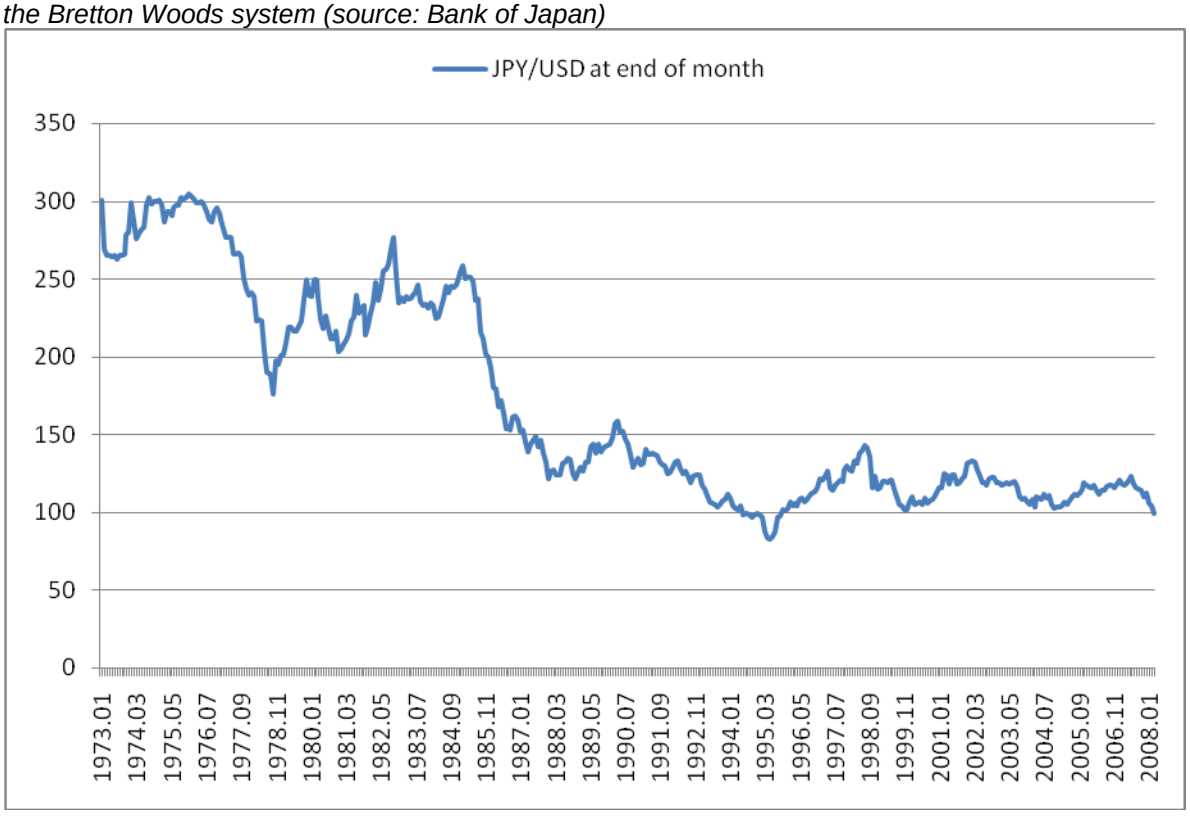
1.7 Background: The Japanese Economy

In order to shed light on the outflow of capital from Japan, we can look at a few aspects of the development of the Japanese economy from the 1980s until today. I will do this in the following part by considering some events internationally and some changes that were made in the Japanese financial markets. This could contribute to explain why some Japanese investors over the years have been tempted to place their money abroad.

[19] See Froot and Thaler (1990) for more about the strengthening of the USD in the first half of the 1980s.
[20] Feldstein and Horioka (1980) found that savings and real investments were correlated in various countries, which indicates that capital mobility is imperfect.
[21] See section 1.9 for more about what others have found

In the 22 September 1985 Plaza Accord, the G5 countries agreed on a concerted effort to depreciate the US dollar compared to the Japanese yen and the German mark. The main purpose was to reduce the US trade deficit. In the period from 1985 to 1987, the JPY/USD exchange rate fell from around JPY 250/USD to around JPY 122/USD. The following strengthening of the JPY led to massive investments by JPY investors in the USA and other countries.

Figure 5: JPY/USD Exchange Rate 1973–2008. *1949–1971: Approximately JPY 360/USD under the Bretton Woods system (source: Bank of Japan)*



The G6 Louvre Accord was signed 22 February 1987 in order to stop the decline in the value of the USD. After the October 1987 stock market crash, the Japanese stock market rose back to record levels more quickly than US stocks did[22].

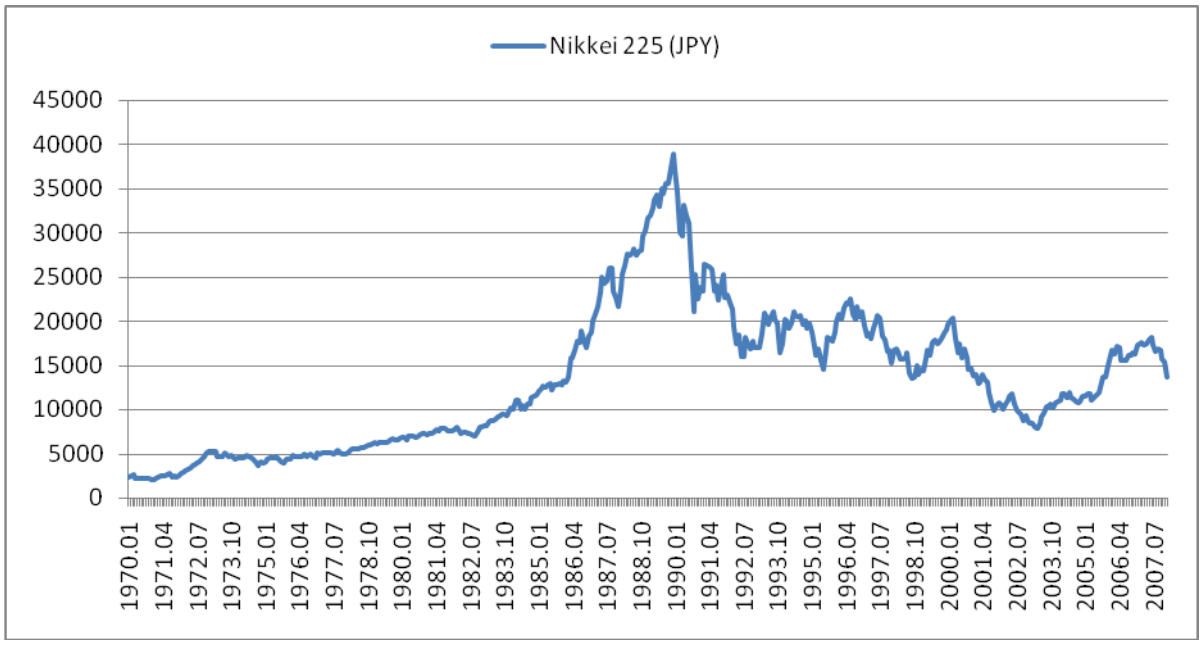
In the late 1980s, Japanese banks extended loans under a collateral system based on property values. The banks were more than willing to lend money to the public when property prices rose. This led to more lending to finance real estate investments. Property prices were pushed up further to unprecedented levels. The share prices of Japanese firms also rose when the increase in property prices made asset values in the balance sheets of

[22] Ito (1992, 426-438)

firms rise, facilitating even more lending from Japanese banks which by then had come to dominate the list of the biggest banks in the world.

In the beginning of the 1990s, there was a sense among analysts that Japanese stock prices had increased too much in the 1980s during the bubble years following the Plaza Accord. There was a growing sense among analysts that Japanese stocks were overvalued based such indicators as firms' q-ratio[23] and the price earnings ratios (P/E) of shares. The end of the 1980s is often referred to as the bubble years.

Figure 6: The Tokyo Stock Exchange - Nikkei 225. *(Source: Bank of Japan)*



On 29 December 1989, the Nikkei 225 index on the Tokyo Stock Exchange reached an intraday high of 38 957.44. In August 1990 the Nikkei 225 dropped 16 % and around this period, the bubble started to burst. After that, Japanese stocks fell to below 10 000 in 2001. This depressive Japanese stock market (as seen from a Japanese investor's perspective, since the Japanese share prices may have decreased less when measured in some other currencies because of strengthening of the JPY) coupled with low interest rates on Japanese bank accounts, made the foreign currency market look increasingly attractive to Japanese investors.

The Japanese Government deregulated financial markets further in the period 1997 to 2001 when the most important parts of the Japanese 'financial Big Bang' were implemented.

[23] Q-ratio: A firms market value divided by the firms asset value

The aim of this deregulation process was to make Tokyo regain its position as a major financial centre like London and New York.

Bank of Japan started to cut the key interest rate in 1991 in order to revive growth. The interest rate was gradually reduced towards the middle of the 1990s, but growth remained sluggish. As mentioned, the 1990s have often been referred to as Japan's lost decade.

The bad loan problem in Japanese banks reached a climax in the beginning of the new millennium before it was gradually resolved and the majority of the bad loans were written off. During the 1990s and the beginning of the new millennium, many analysts were negatively surprised by the lack of recovery in the Japanese economy. The stock market remained at a low level and economic growth was low. In spite of this, unemployment was relatively low and social stability high. The savings rates were high[24] and consumption growth was moderate.

The combination of lack of increase in domestic share prices, frustration with low interest rates on Japanese bank accounts, continued financial deregulation and high stocks of savings, may all have contributed to making investments in foreign currencies look tempting to many Japanese investors in the 1990s.

1.8 Data Quality

In the following section, I will discuss some of the implications the data quality may have had on the findings in the thesis.

Time differences

The data have been used in this thesis have been retrieved from two different sources, namely the Bank of Japan (BoJ) and the Federal Reserve Bank of St. Louis. They have collected the data from various markets. While the BoJ data are from the end of each business month, the Federal Reserve Bank's data are from the beginning of the next month. When these data (which are separated by up to a few days depending on the weekends and holidays) are coupled, then one risks that intermediate events and new information could change the expectations of investors. This makes the prices somewhat different from to what they would have been if they had all been collected at the same time.

[24] Katayama (2006) points out that the saving rate in Japan was above 10 percent in the 1980s and early 1990s. This was higher than in any other developed country. From around 1999, the saving rate started to decline rapidly.

Because of the location of Japan and USA on the Earth, the Japanese markets always open earlier on the same date. Tokyo is nine hours[25] ahead of Coordinated Universal Time (UTC, which is roughly equal to Greenwich Mean Time) all year, since Japan has not observed daylight saving time since the period 1948-1951. New York is four hours after UTC in the summer and five hours after in the winter. This means that the time difference between Tokyo and New York is 13 hours in the summer half of the year and 14 hours in the winter half. Because of this time difference, the Tokyo financial markets and the New York financial markets do not in general have overlapping trading hours. Information that flows to the markets will therefore sometimes change prices in the Tokyo market first and sometimes in the New York markets first[26].

Ito (1992, 338) shows how various news impacted the JPY/USD exchange rate in March 1985. The opening exchange rates in the Tokyo market in this month were approximately the same as the closing exchange rates in the New York market (which closed two to three hours earlier). This supports the efficient market hypothesis which says that the prices on traded assets reflect all known information.

Because there is a time difference between the New York and Tokyo markets, the prices will have changed between the two moments or opening periods from which the data have been collected. However, it is probably fair to assume that the price movements are not systematically going in one direction and that the movements do not change the main conclusions in this thesis.

Ways of Improving the Data

Since we have data from the turn of each month while the interest rate papers and forward contracts both point three months into the future, there is an overlap of two months between succeeding data and of one month when there is a two month period in between them. Because of this, the prices are partially overlapping in terms of information content and variation. This overlapping can be reduced by using one-month treasury bills instead of three-month treasury bills. The reason why three-month bills have been used here is that liquidity is high and that they are considered to be a good estimate of the risk free rate. Also, it may be more difficult to find data for one-month forward exchange rate contracts than for the three-month forward contracts that have been used here.

[25] Time and Date AS: Time zone changes and daylight saving time start/end dates

[26] For more about the settlement rules and functioning of the financial markets, see Chaboud and Wright (2003) and Rose and Lyons (1995)

One could possibly improve the data set by for instance selecting mid-week data for days on which the Tokyo financial markets and the New York markets are both open. This would reduce the time gap compared to the situation here, where some data are from the end of the month and others (the data for the US three month treasury bills) are from the beginning of the next month.

1.9 Discussion and Literature Review

In this section, I look at some of the findings presented in other papers. The purpose is to compare the results that have been obtained here with what others have found.

According to Froot and Thaler (1990), the average estimate of the coefficient for the slope β is (–0.88) across 75 published estimates. A few are positive, but none is equal to or greater than the null hypothesis of $\beta = 1$. A negative value of β means that when the annual interest rate in a currency increases by one percentage point, the value of the same currency increases by $|\beta|$ percent per year. This is the opposite of what one would expect from the unbiasedness hypothesis. According to Froot and Thaler, two interpretations are common: 1. There is a time-varying risk premium on foreign exchange (implying that when the value of a currency increases, it becomes more risky and this requires a higher risk premium). 2. Expectational errors explain the bias in the forward discount and the interest differential.

In a survey of the advances made in research on forward rate bias, Engel (1996) also finds that the change in the future exchange rate is generally negatively related to the forward discount.

Both of the above surveys are in agreement with the findings in this thesis. This is comforting since it indicates that the fact that the data are collected at different times for the Japanese and US markets does not lead to any systematic distortion in the data and the results derived from them.

Chinn and Meredith (2004) look at longer maturity government bonds and find some support of the uncovered interest parity hypothesis for the Group of Seven (G7) countries.

For uncovered interest parity I found a beta value of (–4.07) which is fairly similar to the (–2.887) found by Chinn and Meredith in their estimate three month bonds in Japan and the US. This indicates that the result obtained in this thesis is reasonable. Since the underlying data are not available, it is not possible to explain the difference that still remains between the results here and their result.

Chaboud and Wright (2003) go in the opposite direction and look at shorter time horizons, taking into account the settlement procedures in the spot foreign exchange market. Their results are supportive of uncovered interest parity over very short spans. When having overnight positions, investors can be compensated for devaluation risks through the interest rate which is only paid overnight.

Rose and Lyons (1995), study intraday movements (when investors are not paid interest rates) and find that currencies that are under attack tend to appreciate during the trading day. This may be interpreted as a compensation for the risk of holding those currencies.

The three articles mentioned above are consequently a support for the uncovered interest rate parity hypothesis in spite of the lack of support for it in the studies related to intermediate length investments.

Siegel (1972) writes that even in the simple case where investors are risk-neutral, it can be shown that the forward price of the foreign currency is not an unbiased estimator of the anticipated future exchange rate. Since the Siegel paradox deals with forward rates and foreign currencies, it may be relevant to the results obtained in Chapter 1. A simple version of the Siegel paradox is described in Chapter 2 of this thesis.

2 Theoretical Implications

In this chapter, I look at the Siegel paradox and the two-envelope problem in order to gain some insight into these two puzzles. I do this by using simple examples, looking at potential reasons for the paradoxes and relating these to the simple examples. By investigating some other ways of looking at the problems, I compare them and try to find differences and similarities between them. The purpose is to find out if there is some connection between the forward discount bias observed in Chapter 1 and the Siegel paradox.

2.1 Siegel's Paradox

Siegel (1972, 1975) studied risk, interest rates and forward exchange rates. He stated that it can be shown that even when investors are risk neutral, the forward price of the foreign currency is not an unbiased estimator of the anticipated future spot price. Rather than following his notation and description, a simplified example will be provided that gives some intuitive connotations to the JPY/USD market which has been used as an example in Chapter 1 of this thesis.

2.1.1 A Simple Version

Assume that the exchange rate is JPY 100 per USD in period one. There are two periods and there is no interest rate paid in any of the currencies. Let there be two possible outcomes with equal probability: The value of the currency either halves or doubles compared to the other. The example is chosen for the sake of simplicity – this makes it possible for us to study a simple calculation problem – and because the investment choice looks symmetric regardless of which currency is used as numéraire. The example is symmetric since a doubling of the value of the USD means a halving of the value of the JPY and vice versa.

Let an investor start out with JPY 100 in period one. The investor can then think in the following way: I have JPY 100. If I keep the JPY 100, I will end up with the same amount in period two.

The investor also has another option: To exchange the JPY 100 into USD 1 in period one. There would be two possible outcomes in period two: The USD 1 will be worth either JPY 50 or JPY 200.

The investor can then think in the following way if he measures the value of his assets in JPY: Since there is 50 % chance of a halving and 50 % chance of a doubling of the value of the USD, the expected value in period two of exchanging the JPY 100 into USD 1 in period one is:

E(X) = 50 % ·JPY 50 + 50 % ·JPY 200 = JPY 25 + JPY 100 = JPY 125.

In other words: The expected return on leaving the initial JPY 100 in Japanese yen is 0 % while the expected return when exchanging the money into US dollars in period one is 25 %.

However, this argument can also be used by an investor who measures the value of her assets in USD. She can argue that if she keeps her initial US dollar, she will get no return, but if she exchanges the US dollar into JPY 100 in period one, the expected value would be:

E(Y) = 50 % ·USD 2 + 50 % ·USD(½) = USD 1¼.

Again, the investor would expect no return on the domestic currency, but 25 % return on the other currency. Only very risk-averse investors would then choose not to exchange their currency into the other in period one. Both risk-seeking and risk neutral investors would exchange their assets into other currencies if this way of thinking was correct. Obviously, there must be something wrong with the argument.

2.2 The Two-Envelope Problem

It is possible to give an example of the so-called two envelope paradox which resembles the above version of the Siegel paradox.

Consider the following situation: Two persons are given one envelope each. One envelope contains twice as much as the other. The two persons are asked if they want to switch envelopes.

Let us assume that each player thinks in the following way:

Assume that my envelope contains x. Then the other envelope contains either $y_1=x/2$ or $y_2=2x$. The expected, certain value I will end up with if I keep my envelope, is x. On the other hand, the expected value in the other envelope is 50 % · x/2 + 50 % · 2x = 1¼ x.

Because the expected return from switching is x/4, I should switch.

Like in the simplified example with the Siegel paradox (where both investors would switch into the other currency), both persons would here choose to switch into the other envelope.

In fact, the two players would continue to switch envelopes indefinitely if it was possible. However, this is a zero sum game (the sum of the players' payoffs must be zero) so both the players cannot expect positive return. Obviously, there is again some serious flaw in the rationale leading to the paradox.

2.3 Reasons

The Siegel paradox is by Jeremy Siegel (1972) ascribed to Jensen's inequality which states that the inverse of the expectation of the exchange rate is less than or equal to the expectation of the inverse of the exchange rate. The following indicates some reasons for the paradox.

2.3.1 Jensen's Inequality

Jensen's inequality can in this case be described in the following way[27]:

F_t = the JPY/USD forward exchange rate at time t

ξ_t = the USD/JPY forward exchange rate at time t

ε_{t+3} = the JPY/USD spot exchange rate in the US market at time t+3

$¥_{t+3}$ = the USD/JPY spot exchange rate at time t+3

Assume that investors have the same access to information and that they form their expectations based on all information available at time t under the rational expectation hypothesis. Assume that both covered and uncovered interest parity holds so that the forward rates equal the expected spot rates

$F_t = E[\varepsilon_{t+3}]$

$\xi_t = E[¥_{t+3}]$

Arbitrage should ensure[28] that the following consistency conditions hold for all t in the spot markets and the forward markets:

$\varepsilon_t = 1/¥_t \quad \leftrightarrow \quad \varepsilon_t ¥_t = 1$

$F_t = 1/\xi_t \quad \leftrightarrow \quad F_t \xi_t = 1$

Consequently, we should also have

$1/F_t = 1/E[\varepsilon_{t+3}]$ and $1/F_t = \xi_t = E[¥_{t+3}] = E[1/\varepsilon_{t+3}]$ (since $¥_{t+3} = 1/1/\varepsilon_{t+3}$)

Putting these together, we get

$1/E[\varepsilon_{t+3}] = E[1/\varepsilon_{t+3}]$

[27] The thought sequence follows Chu (2005) with some additional intermediate steps

[28] If not, investors would be able to sell currency in one market and sell the currency with a profit in another market. Forward rates would be distorted (biased) and provide arbitrage opportunities

However, the above equation violates Jensen's inequality[29] which states that the value of the value of the integral of a convex function to the integral of the convex function:

$$1/E[\varepsilon_{t+3}] \leq E[1/\varepsilon_{t+3}]$$

If Jensen's inequality holds, then we cannot at the same time have

$$1/ F_t = E[1/\varepsilon_{t+3}]$$

Because $1/\varepsilon_{t+3}$ is a strictly convex function and ε_{t+3} is a random variable with positive variance.

The above result can be used in the example that I have given about the Siegel paradox. We can see from that example and also from the example with the two envelope problem that Jensen's inequality holds in those cases.

First, I do the calculation in the example with the Siegel paradox and get:

$$1/E(\varepsilon_{t+3}) = 1 / (50\ \% \cdot \text{JPY } 200/\text{USD} + 50\ \% \cdot \text{JPY } 50/\text{USD}) = 1 / (\text{JPY } 125/\text{USD})$$
$$= (1/125)\ \text{USD/JPY}$$
$$<$$
$$E(1/\varepsilon_{t+3}) = 50\ \% \cdot 1 / (\text{JPY } 200/\text{USD}) + 50\ \% \cdot 1 / (\text{JPY } 50/\text{USD})$$
$$= 1 / (\text{JPY } 400/\text{USD}) + 1/ (\text{JPY } 100/\text{USD}) = (1+4) / (\text{JPY } 400/\text{USD})$$
$$= (1/80)\ \text{USD/JPY}$$

Similarly, in the simple version of the two envelope paradox, we get the following result for Jensen's inequality:

$$1/E(X) = 1 / (50\ \% \cdot x/2 + 50\ \% \cdot 2x) = 1/(x/4 + x) = 1/(5x/4) = (4/5)/x$$
$$<$$
$$E(1/Z) = 50\ \% \cdot 1/(x/2) + 50\ \% \cdot 1/(2x) = 1/x + (1/4)/x = (5/4)/x$$

These two results indicate that the paradoxes may have a common cause.

2.3.2 Purchasing Power Parity (PPP)

The following condition says that expected real return[30] is equal to zero

$$E[(F_{t,t+3} - \varepsilon_{t+3})/ P_{t+3}] = 0$$

When substituting $\varepsilon_{t+3} \cdot P^*_{t+3} = P_{t+3}$ into the equation above, one gets

$$E[(F_{t,t+3} - \varepsilon_{t+3})/(\varepsilon_{t+3} \cdot P^*_{t+3})] = 0$$

[29] For more about Jensen's inequality, see for instance Jensen (1905) and Needham (1993)
[30] Real return: The expected real increase in value. The subsequent lines follow the description in Obstfeld and Rogoff (1996, 587)

Multiplying numerator and denominator by $(-1)/(F_{t-3,t}\cdot\varepsilon_{t+3})$ gives

$$E[(1/F_{t,t+3} - 1/\varepsilon_{t+3})/P^*_{t+3}] = 0$$

Since $F_{t,t+3}$ is known at time t, all the equations hold when PPP holds. Then it does not matter which currency is used as numéraire. However, the equivalence between the equations above break down when PPP does not hold. There is also an unexplained difference between the forward rate and the expected future exchange rate when one uses a logarithmic function.

If purchasing power parity holds, then in does not matter which currency is used as numéraire, but the problem returns if PPP ceases to hold.

2.4 How to Avoid the Problem

Siegel (1972) states that if one changes numéraire, the forward discount bias would not materialize. In spite of this, it is then stated that the natural numéraire is the domestic currency so that the analysis made in the article is the proper formulation. However, based on the following line of reasoning, this could be problematic. The reason is that the formulation using only one of the currencies as fixed, does not take into account all the possible perspectives, resulting in this case to a lack of symmetry.

Langan (2000a, 2000b) looks at the two envelope paradox and suggests various ways of resolving it. A flaw in the argument used above is that both players imagine that only the content of their own envelope is fixed while they let only the content of the other envelope vary. However, there is no reason to give one's own envelope special treatment. Not all arithmetic possibilities have been taken into account when a player considers the contents of only one of the envelopes as fixed. If the rationale used previously had been correct, then each player could have considered the content of the other player's envelope as fixed and thereby end up with the opposite conclusion: That one would actually lose from switching.

By introducing the objective total value $|G|$ of the envelope game, the result is[31] that one's own envelope contains either $|G|/3$ or $2|G|/3$ whereas the other envelope contains either $2|G|/3$ or $|G|/3$. The expected value in the other envelope is then

$$E(x) = 50\ \% \cdot |G|/3 + 50\ \% \cdot 2|G|/3 = |G|/2$$

The expected return is then zero for both players.

In the incomplete reasoning in section 2.3, symmetry can be restored by also taking into account the situation where the other currency is fixed. One will then find that when considering all the arithmetic possibilities, the expected return from switching envelope

[31] The following deliberations can be found in a more stringent form in Langan (2000b)

becomes zero. This can be seen from the following way of thinking. Subscripts 1 and 2 after the x or y indicate that the variable in question is allowed to take on two different values (and therefore dependent) while the x or y written without subscript indicates that the variable is fixed and independent. When |G| is the total value of the game, then the conditionally dependent variable can take on half or double the value |G|/3. That is, the conditionally dependent value can take on the value |G|/6 or 2|G|/3. Actually, this tells us that there is something problematic with the formulation that leads to the two-envelope paradox. By implicitly choosing |G|/6 or 2|G|/3, the player does not only try to switch envelopes, but games (which is obviously impossible). The value spread is twice what it should be, as the higher of the two values is only twice as high as the lower value, not four times as high. The following method is used by Langan to get an acceptable result. Symmetry is restored by taking into account both possible subjective frames:

Subjective frame 1:

Assume that my envelope contains the fixed amount x and that the other envelope contains either $y_1=x/2$ or $y_2=2x$.

If I lose, then $gain_1 = -x/2$. If I win, then $gain_2$ is x.

My expected gain is $50\ \% \cdot (-x/2) + 50\ \% \cdot x = x/4$.

As mentioned above, this is not the only arithmetic possibility. The picture can be completed by adding the subjective frame where y is fixed and x is the conditionally dependent.

Subjective frame 2:

Assume that the other envelope contains the fixed amount y and that my envelope contains[32] *either $x_1= 2y$ or $x_2=y/2$.*

If I lose, then $gain_1 = -y = -x_1/2$. If I win, then $gain_2 = y/2 = x_2 = x_1/4$

My expected gain is $50\ \% \cdot (-x_1/2) + 50\ \% \cdot x_1/4 = -x_1/8 = -x/4$

Since none of the two subjective frames has precedence over the other, the true expectation is $x/4 + (-x/4) = 0$

[32] The relationship between x_1 and x_2 is $x_1/2 = 2x_2 \leftrightarrow x_2= x_1/4$. The last equality sign ($-x_1/8 = -x/4$) follows from the above deliberation where the conditionally dependent value is expressed in terms of |G|/3 by taking on half or double this value so that $x_1 = 2x = 4x_2$. As mentioned above, this stems from the problematic formulation in the original thinking leading up to the paradox. Langan (2000b) offers additional solutions in the latter half of his article.

One can also formulate the gain in terms of y and end up with the same result[33].

However, there is one challenge: Although there is a total value for the content of the two envelope paradox, no such total value seems to exist for the example with the Siegel paradox. The exchange rate case does not necessarily imply a zero sum game as in the case of the two envelope paradox[34]. A resolution of both paradoxes must consequently allow for this upper boundary to be discarded or described. If it is possible to generalize the solutions, then some insight could be gained into the forward exchange discount bias.

[33] First subjective frame: 50 %·(gain1+gain2) = 50 %·($-y_1+2y_1$) = $y_1/2$. Second subjective frame: 50 %·(gain1+gain2) = 50 %·(-y+y/2) = -y/4 = $-y_1/2$. The true expectation is then $y_1/+(-y_1/2) = 0$

[34] Langan (2000b) suggests that value and expectation may be relativistic rather than "absolutes". He explains further by among other things introducing $E_{max} = 2\ E_{min}$ instead of a third value which is implicitly used in the thinking leading up to the paradox.

3 Paradox from the Perspective of Interest Rate Parity

Siegel's paradox says that when using JPY as numéraire, then the expected return on investments in another currency (like USD) will have a tendency to be higher than the expected return on JPY investments. Also, this paradox should hold both ways (giving higher return on USD when using JPY as numéraire, and giving higher expected return on JPY when using USD as numéraire).

In Chapter 1, the returns on uncovered USD investments were found to be higher (both when using JPY and when USD as numéraire).

For covered investments, the return on the USD assets were found to be lower than on similar investment in low risk three-month assets denominated in JPY (both when using JPY and when USD as numéraire).

Since the Siegel paradox implies a tendency of higher expected return in the currency which is not used as numéraire, the Siegel paradox does not hold more than one way in the aggregated data that we have seen from the US and Japanese financial markets. Consequently, Siegel's paradox does not seem to give meaningful predictions in the real world, unless the distortions caused by the paradox are too small to be visible in the data.

Assuming that the market provides us with the correct prices that we should try to explain, and assuming that the theory may contain errors, it is natural to search in the theory for the answer to why the Siegel paradox does not hold.

It is probable that the forward discount bias that has been observed is caused by for instance differences in the liquidity in the various markets, the peso problem (requiring compensation to take on risk), settlement rules or tax differences.

Although the forward discount bias does not hold both ways in the real world, the bias which is described in the theory still remains a problem. The reason is that the paradox could potentially lead to inefficient distortions in the allocation of capital if investment decisions are based on the incorrect reasoning underlying the Siegel paradox. Langan's resolution of the two-envelope problem may point to ways of resolving the Siegel paradox.

Edlin (2002) and Bolle (2003) are among those who have tried to link the two envelopes problem with the Siegel paradox. Edlin describes the Siegel paradox as being richer than the two envelopes problem. The lack of an easily recognizable total value may be one such source of richness in the Siegel paradox.

By trying to relate the total value |G| (which is used in the two-envelope example) to the Siegel paradox, some further insights could possibly be gained.

An interesting question is whether or not the Capital Asset Pricing Model (CAPM) and other models like derivatives models are built on assumptions that include aspects of the Siegel paradox. If there are such misguided assumptions in these models, then this could lead to discrepancies between the observed data and the predictions made by the models. Such shortcomings could lead to distortions in the allocation of capital. This would not necessarily be visible in the market prices as a whole (since arbitrage opportunities will eventually be discovered and utilized), but possibly for individual investors that follow unsound strategies based on these assumptions. Such misallocations of capital made by individual investors could also have consequences for the economy as a whole.

I suggest that further investigation should be made into resolving the Siegel paradox as I believe that this could provide new understanding about risk, return and capital allocation in the financial markets.

Conclusion

This paper looks into the phenomenon of carry trade, checks returns on investments in low-risk and low-interest yielding three-month bonds in the US and in Japan, describes the Siegel paradox and the two-envelope problem and tries to link the empirical findings with these two paradoxes.

I find that in the period 1993 to 2008, uncovered interest rate parity did not hold for three-month Japanese bonds and US bonds. USD investments tended to give higher return in the period as a whole, although shorter three-year periods within the period 1993-2008 showed mixed results. Still, the statistical analysis shows that there is a clear tendency for uncovered interest rate parity not to hold, both when using Japanese yen and USD as numéraire.

I find that there was a forward discount bias in the same period. The return on covered investments in JPY tended to be higher than on USD. This was the case both for the period 1993-2008 as a whole and for shorter three-year periods within this time interval. The results are fairly robust statistically.

When comparing the two-envelopes problem with the Siegel paradox, I find that there are similarities between the two, but also an important difference in the sense that the two-envelopes problem has a clearly defined total value (the total value of the contents of the two envelopes) while the Siegel paradox does not have such a clearly understood total value. I think the Siegel paradox is more complex than the two envelopes problem, and if the various aspects of the two puzzles are resolved and brought together, this could clarify whether forward discount bias is caused by other factors than by the Siegel paradox.

More research into the puzzles mentioned in this thesis could possibly shed light on various models in international finance.

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Appendix – Data Material

Exchange rate and forward rate

BoJ End of Month T	BoJ Interbank rates in Tokyo (JPY/USD) εt	BoJ Spot-forward spread (3 months) (negative = discount, positive = premium)	Calculated forward rate at time t-3 for time t
1992.09	**119,25**	0,22	
1992.10	**123,35**	0,04	
1992.11	**124,75**	-0,08	
1992.12	**124,65**	0,085	
1993.01	**124,3**	0,076	123,39
1993.02	**117,85**	0,015	124,67
1993.03	**115,35**	0,02	124,735
1993.04	**111,1**	0,005	124,376
1993.05	**107,45**	-0,025	117,865
1993.06	**106,51**	-0,013	115,37
1993.07	**105,6**	-0,017	111,105
1993.08	**104,18**	-0,125	107,425
1993.09	**105,1**	-0,228	106,497
1993.10	**108,23**	-0,285	105,583
1993.11	**108,82**	-0,348	104,055
1993.12	**111,89**	-0,37	104,872
1994.01	**109,55**	-0,255	107,945
1994.02	**104,3**	-0,37	108,472
1994.03	**102,8**	-0,425	111,52
1994.04	**102,38**	-0,52	109,295
1994.05	**104,38**	-0,65	103,93
1994.06	**98,95**	-0,663	102,375
1994.07	**99,93**	-0,665	101,86
1994.08	**99,57**	-0,65	103,73
1994.09	**98,59**	-0,786	98,287
1994.10	**97,37**	-0,802	99,265
1994.11	**98,98**	-0,93	98,92
1994.12	**99,83**	-1,015	97,804
1995.01	**98,58**	-0,96	96,568
1995.02	**96,93**	-0,955	98,05
1995.03	**88,38**	-0,985	98,815
1995.04	**83,77**	-1,01	97,62
1995.05	**83,19**	-1,06	95,975
1995.06	**84,77**	-1,023	87,395
1995.07	**88,17**	-1,135	82,76
1995.08	**97,46**	-1,28	82,13
1995.09	**98,18**	-1,407	83,747

1995.10	**101,9**	-1,445	87,035
1995.11	**101,66**	-1,375	96,18
1995.12	**102,91**	-1,33	96,773
1996.01	**106,92**	-1,28	100,455
1996.02	**104,58**	-1,22	100,285
1996.03	**106,49**	-1,305	101,58
1996.04	**104,29**	-1,281	105,64
1996.05	**108,37**	-1,365	103,36
1996.06	**109,88**	-1,4	105,185
1996.07	**107,13**	-1,416	103,009
1996.08	**108,4**	-1,373	107,005
1996.09	**111,45**	-1,509	108,48
1996.10	**113,27**	-1,448	105,714
1996.11	**113,44**	-1,423	107,027
1996.12	**115,98**	-1,465	109,941
1997.01	**122,13**	-1,562	111,822
1997.02	**120,88**	-1,545	112,017
1997.03	**123,97**	-1,639	114,515
1997.04	**126,92**	-1,728	120,568
1997.05	**116,43**	-1,543	119,335
1997.06	**114,3**	-1,505	122,331
1997.07	**117,74**	-1,519	125,192
1997.08	**119,39**	-1,535	114,887
1997.09	**121,44**	-1,617	112,795
1997.10	**120,29**	-1,604	116,221
1997.11	**127,66**	-1,83	117,855
1997.12	**129,92**	-1,74	119,823
1998.01	**127,34**	-1,641	118,686
1998.02	**126,72**	-1,628	125,83
1998.03	**133,39**	-1,668	128,18
1998.04	**131,95**	-1,729	125,699
1998.05	**138,72**	-1,826	125,092
1998.06	**139,95**	-1,849	131,722
1998.07	**143,79**	-1,896	130,221
1998.08	**141,52**	-1,84	136,894
1998.09	**135,72**	-1,805	138,101
1998.10	**116,09**	-1,546	141,894
1998.11	**123,83**	-1,588	139,68
1998.12	**115,2**	-1,405	133,915
1999.01	**115,98**	-1,351	114,544
1999.02	**120,32**	-1,465	122,242
1999.03	**119,99**	-1,438	113,795
1999.04	**119,59**	-1,486	114,629
1999.05	**121,37**	-1,53	118,855
1999.06	**120,87**	-1,641	118,552
1999.07	**115,27**	-1,544	118,104

1999.08	**110,19**	-1,503	119,84
1999.09	**105,66**	-1,576	119,229
1999.10	**104,89**	-1,566	113,726
1999.11	**102,42**	-1,482	108,687
1999.12	**102,08**	-1,476	104,084
2000.01	**106,9**	-1,572	103,324
2000.02	**110,27**	-1,646	100,938
2000.03	**105,29**	-1,633	100,604
2000.04	**106,44**	-1,716	105,328
2000.05	**107,3**	-1,871	108,624
2000.06	**105,4**	-1,728	103,657
2000.07	**109,52**	-1,798	104,724
2000.08	**106,43**	-1,658	105,429
2000.09	**107,75**	-1,693	103,672
2000.10	**108,81**	-1,7	107,722
2000.11	**111,07**	-1,688	104,772
2000.12	**114,9**	-1,653	106,057
2001.01	**116,38**	-1,406	107,11
2001.02	**116,44**	-1,398	109,382
2001.03	**125,27**	-1,466	113,247
2001.04	**124,06**	-1,304	114,974
2001.05	**119,06**	-1,18	115,042
2001.06	**124,27**	-1,18	123,804
2001.07	**124,79**	-1,126	122,756
2001.08	**118,92**	-1,009	117,88
2001.09	**119,29**	-0,77	123,09
2001.10	**121,84**	-0,664	123,664
2001.11	**123,98**	-0,595	117,911
2001.12	**131,47**	-0,587	118,52
2002.01	**132,94**	-0,606	121,176
2002.02	**133,89**	-0,624	123,385
2002.03	**132,71**	-0,643	130,883
2002.04	**127,97**	-0,606	132,334
2002.05	**123,96**	-0,583	133,266
2002.06	**119,22**	-0,556	132,067
2002.07	**119,82**	-0,565	127,364
2002.08	**117,97**	-0,528	123,377
2002.09	**121,79**	-0,566	118,664
2002.10	**122,48**	-0,503	119,255
2002.11	**122,44**	-0,443	117,442
2002.12	**119,37**	-0,405	121,224
2003.01	**119,21**	-0,397	121,977
2003.02	**117,75**	-0,388	121,997
2003.03	**119,02**	-0,367	118,965
2003.04	**119,46**	-0,393	118,813
2003.05	**118,63**	-0,378	117,362

2003.06	**119,82**	-0,353	118,653
2003.07	**120,11**	-0,348	119,067
2003.08	**117,13**	-0,338	118,252
2003.09	**110,48**	-0,348	119,467
2003.10	**108,99**	-0,333	119,762
2003.11	**109,34**	-0,324	116,792
2003.12	**106,97**	-0,305	110,132
2004.01	**105,88**	-0,306	108,657
2004.02	**109,08**	-0,313	109,016
2004.03	**103,95**	-0,293	106,665
2004.04	**110,44**	-0,343	105,574
2004.05	**109,56**	-0,378	108,767
2004.06	**108,69**	-0,456	103,657
2004.07	**111,67**	-0,485	110,097
2004.08	**109,86**	-0,495	109,182
2004.09	**110,92**	-0,564	108,234
2004.10	**105,87**	-0,578	111,185
2004.11	**103,17**	-0,609	109,365
2004.12	**103,78**	-0,655	110,356
2005.01	**103,58**	-0,688	105,292
2005.02	**104,58**	-0,765	102,561
2005.03	**106,97**	-0,833	103,125
2005.04	**105,87**	-0,874	102,892
2005.05	**108,17**	-0,905	103,815
2005.06	**110,37**	-0,981	106,137
2005.07	**112,18**	-1,043	104,996
2005.08	**111,42**	-1,071	107,265
2005.09	**113,28**	-1,153	109,389
2005.10	**115,67**	-1,238	111,137
2005.11	**119,46**	-1,297	110,349
2005.12	**117,48**	-1,306	112,127
2006.01	**117,18**	-1,329	114,432
2006.02	**116,35**	-1,392	118,163
2006.03	**117,47**	-1,448	116,174
2006.04	**114,32**	-1,447	115,851
2006.05	**111,85**	-1,442	114,958
2006.06	**114,66**	-1,485	116,022
2006.07	**114,47**	-1,462	112,873
2006.08	**117,23**	-1,466	110,408
2006.09	**118,05**	-1,483	113,175
2006.10	**117,74**	-1,462	113,008
2006.11	**116,12**	-1,402	115,764
2006.12	**118,92**	-1,402	116,567
2007.01	**121,34**	-1,438	116,278
2007.02	**118,59**	-1,409	114,718
2007.03	**118,05**	-1,372	117,518

2007.04	**119,41**	-1,403	119,902
2007.05	**121,63**	-1,424	117,181
2007.06	**123,48**	-1,432	116,678
2007.07	**118,99**	-1,37	118,007
2007.08	**116,24**	-1,413	120,206
2007.09	**115,27**	-1,26	122,048
2007.10	**114,78**	-1,196	117,62
2007.11	**110,29**	-1,171	114,827
2007.12	**113,12**	-1,108	114,01
2008.01	**106,63**	-0,634	113,584
2008.02	**104,34**	-0,551	109,119
2008.03	**99,37**	-0,482	112,012

Interest Rates

BoJ End of month t	BoJ JPY 3 months (t-3) to t r (annual)	Calculated JPY 3 months (t-3) to t 1+r (3 month)	St. Louis Fed Date	St. Louis Fed US treasury bill (t-3) to t r* (annual rate)	Calculated US treasury bill (t-3) to t 1+r* (3 month)
1993.01	3,78	1,009453	1993-02-01	**3,13**	1,007825
1993.02	3,84	1,009609	1993-03-01	**3,22**	1,008050
1993.03	3,81	1,009531	1993-04-01	**3,00**	1,007500
1993.04	3,59	1,008984	1993-05-01	**2,93**	1,007325
1993.05	3,31	1,008281	1993-06-01	**2,95**	1,007375
1993.06	3,31	1,008281	1993-07-01	**2,87**	1,007175
1993.07	3,31	1,008281	1993-08-01	**2,96**	1,007400
1993.08	3,28	1,008203	1993-09-01	**3,07**	1,007675
1993.09	3,28	1,008203	1993-10-01	**3,04**	1,007600
1993.10	3,22	1,008047	1993-11-01	**3,02**	1,007550
1993.11	3,00	1,007500	1993-12-01	**2,95**	1,007375
1993.12	2,66	1,006641	1994-01-01	**3,02**	1,007550
1994.01	2,41	1,006016	1994-02-01	**3,10**	1,007750
1994.02	2,25	1,005625	1994-03-01	**3,06**	1,007650
1994.03	2,22	1,005547	1994-04-01	**2,98**	1,007450
1994.04	2,25	1,005625	1994-05-01	**3,25**	1,008125
1994.05	2,28	1,005700	1994-06-01	**3,50**	1,008750
1994.06	2,37	1,005925	1994-07-01	**3,68**	1,009200
1994.07	2,33	1,005825	1994-08-01	**4,14**	1,010350
1994.08	2,15	1,005375	1994-09-01	**4,14**	1,010350
1994.09	2,15	1,005375	1994-10-01	**4,33**	1,010825
1994.10	2,25	1,005625	1994-11-01	**4,48**	1,011200
1994.11	2,37	1,005925	1994-12-01	**4,62**	1,011550
1994.12	2,37	1,005925	1995-01-01	**4,95**	1,012375
1995.01	2,39	1,005975	1995-02-01	**5,29**	1,013225
1995.02	2,39	1,005975	1995-03-01	**5,60**	1,014000

1995.03	2,45	1,006125	1995-04-01	**5,71**	1,014275
1995.04	2,38	1,005950	1995-05-01	**5,77**	1,014425
1995.05	2,30	1,005750	1995-06-01	**5,73**	1,014325
1995.06	1,84	1,004600	1995-07-01	**5,65**	1,014125
1995.07	1,39	1,003475	1995-08-01	**5,67**	1,014175
1995.08	1,15	1,002875	1995-09-01	**5,47**	1,013675
1995.09	1,19	1,002975	1995-10-01	**5,42**	1,013550
1995.10	0,85	1,002125	1995-11-01	**5,40**	1,013500
1995.11	0,95	1,002375	1995-12-01	**5,28**	1,013200
1995.12	0,49	1,001225	1996-01-01	**5,28**	1,013200
1996.01	0,64	1,001600	1996-02-01	**5,36**	1,013400
1996.02	0,56	1,001400	1996-03-01	**5,14**	1,012850
1996.03	0,56	1,001400	1996-04-01	**5,00**	1,012500
1996.04	0,58	1,001450	1996-05-01	**4,83**	1,012075
1996.05	0,82	1,002050	1996-06-01	**4,96**	1,012400
1996.06	0,65	1,001625	1996-07-01	**4,95**	1,012375
1996.07	0,70	1,001750	1996-08-01	**5,02**	1,012550
1996.08	0,58	1,001450	1996-09-01	**5,09**	1,012725
1996.09	0,63	1,001575	1996-10-01	**5,15**	1,012875
1996.10	0,82	1,002050	1996-11-01	**5,05**	1,012625
1996.11	0,63	1,001575	1996-12-01	**5,09**	1,012725
1996.12	0,56	1,001400	1997-01-01	**4,99**	1,012475
1997.01	0,53	1,001325	1997-02-01	**5,03**	1,012575
1997.02	0,57	1,001425	1997-03-01	**4,91**	1,012275
1997.03	0,60	1,001500	1997-04-01	**5,03**	1,012575
1997.04	0,54	1,001350	1997-05-01	**5,01**	1,012525
1997.05	0,58	1,001450	1997-06-01	**5,14**	1,012850
1997.06	0,60	1,001500	1997-07-01	**5,16**	1,012900
1997.07	0,58	1,001450	1997-08-01	**5,05**	1,012625
1997.08	0,61	1,001525	1997-09-01	**4,93**	1,012325
1997.09	0,68	1,001700	1997-10-01	**5,05**	1,012625
1997.10	0,67	1,001675	1997-11-01	**5,14**	1,012850
1997.11	0,62	1,001550	1997-12-01	**4,95**	1,012375
1997.12	0,57	1,001425	1998-01-01	**4,97**	1,012425
1998.01	0,56	1,001400	1998-02-01	**5,14**	1,012850
1998.02	0,78	1,001950	1998-03-01	**5,16**	1,012900
1998.03	1,15	1,002875	1998-04-01	**5,04**	1,012600
1998.04	1,15	1,002875	1998-05-01	**5,09**	1,012725
1998.05	1,23	1,003075	1998-06-01	**5,03**	1,012575
1998.06	0,73	1,001825	1998-07-01	**4,95**	1,012375
1998.07	0,63	1,001575	1998-08-01	**5,00**	1,012500
1998.08	0,57	1,001425	1998-09-01	**4,98**	1,012450
1998.09	0,70	1,001750	1998-10-01	**4,96**	1,012400
1998.10	0,80	1,002000	1998-11-01	**4,90**	1,012250
1998.11	0,85	1,002125	1998-12-01	**4,61**	1,011525
1998.12	0,65	1,001625	1999-01-01	**3,96**	1,009900

1999.01	0,85	1,002125	1999-02-01	**4,41**	1,011025
1999.02	0,75	1,001875	1999-03-01	**4,39**	1,010975
1999.03	0,62	1,001550	1999-04-01	**4,34**	1,010850
1999.04	0,75	1,001875	1999-05-01	**4,44**	1,011100
1999.05	0,80	1,002000	1999-06-01	**4,44**	1,011100
1999.06	0,38	1,000950	1999-07-01	**4,29**	1,010725
1999.07	0,18	1,000450	1999-08-01	**4,50**	1,011250
1999.08	0,28	1,000700	1999-09-01	**4,57**	1,011425
1999.09	0,08	1,000200	1999-10-01	**4,55**	1,011375
1999.10	0,45	1,001125	1999-11-01	**4,72**	1,011800
1999.11	0,09	1,000225	1999-12-01	**4,68**	1,011700
1999.12	0,20	1,000500	2000-01-01	**4,86**	1,012150
2000.01	0,33	1,000825	2000-02-01	**5,07**	1,012675
2000.02	0,28	1,000700	2000-03-01	**5,20**	1,013000
2000.03	0,60	1,001500	2000-04-01	**5,32**	1,013300
2000.04	0,17	1,000425	2000-05-01	**5,55**	1,013875
2000.05	0,10	1,000250	2000-06-01	**5,69**	1,014225
2000.06	0,61	1,001525	2000-07-01	**5,66**	1,014150
2000.07	0,15	1,000375	2000-08-01	**5,79**	1,014475
2000.08	0,49	1,001225	2000-09-01	**5,69**	1,014225
2000.09	0,11	1,000275	2000-10-01	**5,96**	1,014900
2000.10	0,19	1,000475	2000-11-01	**6,09**	1,015225
2000.11	0,44	1,001100	2000-12-01	**6,00**	1,015000
2000.12	0,41	1,001025	2001-01-01	**6,11**	1,015275
2001.01	0,59	1,001475	2001-02-01	**6,17**	1,015425
2001.02	0,66	1,001650	2001-03-01	**5,77**	1,014425
2001.03	0,68	1,001700	2001-04-01	**5,15**	1,012875
2001.04	0,54	1,001350	2001-05-01	**4,88**	1,012200
2001.05	0,43	1,001075	2001-06-01	**4,42**	1,011050
2001.06	0,26	1,000650	2001-07-01	**3,87**	1,009675
2001.07	0,02	1,000050	2001-08-01	**3,62**	1,009050
2001.08	0,05	1,000125	2001-09-01	**3,49**	1,008725
2001.09	0,08	1,000200	2001-10-01	**3,51**	1,008775
2001.10	0,06	1,000150	2001-11-01	**3,36**	1,008400
2001.11	0,04	1,000100	2001-12-01	**2,64**	1,006600
2001.12	0,06	1,000160	2002-01-01	**2,16**	1,005400
2002.01	0,11	1,000275	2002-02-01	**1,87**	1,004675
2002.02	0,05	1,000120	2002-03-01	**1,69**	1,004225
2002.03	0,07	1,000163	2002-04-01	**1,65**	1,004125
2002.04	0,10	1,000250	2002-05-01	**1,73**	1,004325
2002.05	0,14	1,000350	2002-06-01	**1,79**	1,004475
2002.06	0,18	1,000450	2002-07-01	**1,72**	1,004300
2002.07	0,10	1,000250	2002-08-01	**1,73**	1,004325
2002.08	0,02	1,000050	2002-09-01	**1,70**	1,004250
2002.09	0,08	1,000200	2002-10-01	**1,68**	1,004200
2002.10	0,10	1,000250	2002-11-01	**1,62**	1,004050

2002.11	0,08	1,000200	2002-12-01	**1,63**	1,004075
2002.12	0,07	1,000178	2003-01-01	**1,58**	1,003950
2003.01	0,09	1,000225	2003-02-01	**1,23**	1,003075
2003.02	0,09	1,000225	2003-03-01	**1,19**	1,002975
2003.03	0,00	0,000000	2003-04-01	**1,17**	1,002925
2003.04	0,01	1,000033	2003-05-01	**1,17**	1,002925
2003.05	0,00	0,000000	2003-06-01	**1,13**	1,002825
2003.06	0,09	1,000223	2003-07-01	**1,13**	1,002825
2003.07	0,33	1,000820	2003-08-01	**1,07**	1,002675
2003.08	0,33	1,000820	2003-09-01	**0,92**	1,002300
2003.09	0,00	0,000000	2003-10-01	**0,90**	1,002250
2003.10	0,09	1,000223	2003-11-01	**0,95**	1,002375
2003.11	0,34	1,000850	2003-12-01	**0,94**	1,002350
2003.12	0,08	1,000200	2004-01-01	**0,92**	1,002300
2004.01	0,02	1,000050	2004-02-01	**0,93**	1,002325
2004.02	0,21	1,000513	2004-03-01	**0,90**	1,002250
2004.03	0,08	1,000198	2004-04-01	**0,88**	1,002200
2004.04	0,29	1,000725	2004-05-01	**0,93**	1,002325
2004.05	0,00	1,000003	2004-06-01	**0,94**	1,002350
2004.06	0,00	0,000000	2004-07-01	**0,94**	1,002350
2004.07	0,28	1,000700	2004-08-01	**1,02**	1,002550
2004.08	0,02	1,000038	2004-09-01	**1,27**	1,003175
2004.09	0,08	1,000198	2004-10-01	**1,33**	1,003325
2004.10	0,02	1,000055	2004-11-01	**1,48**	1,003700
2004.11	0,09	1,000223	2004-12-01	**1,65**	1,004125
2004.12	0,31	1,000775	2005-01-01	**1,76**	1,004400
2005.01	0,02	1,000050	2005-02-01	**2,07**	1,005175
2005.02	0,09	1,000215	2005-03-01	**2,19**	1,005475
2005.03	0,31	1,000775	2005-04-01	**2,33**	1,005825
2005.04	0,20	1,000500	2005-05-01	**2,54**	1,006350
2005.05	0,10	1,000245	2005-06-01	**2,74**	1,006850
2005.06	0,02	1,000050	2005-07-01	**2,78**	1,006950
2005.07	0,02	1,000038	2005-08-01	**2,84**	1,007100
2005.08	0,03	1,000068	2005-09-01	**2,97**	1,007425
2005.09	0,01	1,000025	2005-10-01	**3,22**	1,008050
2005.10	0,03	1,000075	2005-11-01	**3,44**	1,008600
2005.11	0,03	1,000075	2005-12-01	**3,42**	1,008550
2005.12	0,02	1,000050	2006-01-01	**3,71**	1,009275
2006.01	0,23	1,000575	2006-02-01	**3,88**	1,009700
2006.02	0,03	1,000063	2006-03-01	**3,89**	1,009725
2006.03	0,03	1,000063	2006-04-01	**4,24**	1,010600
2006.04	0,06	1,000138	2006-05-01	**4,43**	1,011075
2006.05	0,06	1,000150	2006-06-01	**4,51**	1,011275
2006.06	0,00	0,000000	2006-07-01	**4,60**	1,011500
2006.07	0,10	1,000250	2006-08-01	**4,72**	1,011800
2006.08	0,30	1,000750	2006-09-01	**4,79**	1,011975

2006.09	0,00	0,000000	2006-10-01	**4,95**	1,012375
2006.10	0,42	1,001050	2006-11-01	**4,96**	1,012400
2006.11	0,00	0,000000	2006-12-01	**4,81**	1,012025
2006.12	0,63	1,001575	2007-01-01	**4,92**	1,012300
2007.01	0,35	1,000875	2007-02-01	**4,94**	1,012350
2007.02	0,00	0,000000	2007-03-01	**4,85**	1,012125
2007.03	0,51	1,001283	2007-04-01	**4,98**	1,012450
2007.04	0,55	1,001375	2007-05-01	**5,03**	1,012575
2007.05	0,68	1,001700	2007-06-01	**4,94**	1,012350
2007.06	0,63	1,001575	2007-07-01	**4,87**	1,012175
2007.07	0,62	1,001550	2007-08-01	**4,73**	1,011825
2007.08	0,65	1,001625	2007-09-01	**4,61**	1,011525
2007.09	0,73	1,001825	2007-10-01	**4,82**	1,012050
2007.10	0,75	1,001865	2007-11-01	**4,20**	1,010500
2007.11	0,89	1,002213	2007-12-01	**3,89**	1,009725
2007.12	0,70	1,001750	2008-01-01	**3,90**	1,009750
2008.01	0,87	1,002175	2008-02-01	**3,27**	1,008175
2008.02	0,93	1,002325	2008-03-01	**3,00**	1,007500
2008.03	0,73	1,001825	2008-04-01	**2,75**	1,006875