USING PPP DEVIATIONS AS A TRADING RULE: AN INDIRECT JOINT TEST OF PPP AND FOREIGN EXCHANGE MARKET EFFICIENCY.

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We accept this thesis as conforming to the required standard

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Abstract

In this thesis an international investment filter rule is used to test both the tendency for Purchasing Power Parity (PPP) to hold in the long run and the hypothesis of foreign exchange market efficiency for the four most actively traded currencies in the world vis-à-vis the United States dollar: the British pound, the Japanese yen, the German mark, and the Canadian dollar. One way to examine whether there is a tendency for PPP to hold in the long run and whether the foreign exchange market is efficient, is to place more money in the 'undervalued' currency according to PPP deviations or to invest according to PPP deviations, putting more money into interest bearing securities in the 'undervalued' currency, the more this currency is undervalued. The return can then be compared with a reference rule which does not use this filter, but instead puts an equal value of money into the currencies or the securities of each country.

This thesis has produced three results. First, using the PPP filter in the exchange money market yields no significantly abnormal rate of return compared with the reference rule. The result suggests that we can not reject the hypothesis that the tendency for PPP to hold in the long run does not exist. Second, using the PPP filter to invest in securities also yields no significantly higher rate of return compared with the reference rule. And third, when comparing the domestic (or foreign) interest rates with the rates of return for the domestic (or foreign) investor who uses the PPP filter, there is no significant difference between these rates in the long run. The last two results suggest that we can not reject the hypothesis that the foreign exchange market is efficient.
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Chapter 1

Introduction

In this thesis, an international investment filter rule has been developed to test both the tendency of Purchasing Power Parity (PPP) to hold in the long run and the hypothesis of foreign exchange market efficiency. Since PPP and the hypothesis of foreign exchange market efficiency play very important roles in any understanding of the behavior of exchange rates and the building of economic models, a great deal of research has been done in testing these two propositions. However, these two propositions are still controversial and have not been completely validated.

A new way to examine whether there is a tendency for PPP to hold in the long run, and whether the exchange market is efficient is to place more money into a 'undervalued' currency\(^1\) according to PPP deviations, or to invest according to PPP deviations, putting more money into interest bearing securities in the 'undervalued' currency, the more the currency is undervalued. The return can then be compared to a reference rule which does not use this filter, but instead puts an equal value of money into currencies or securities of each country. If the tendency for PPP to hold does not exist in the long run, the PPP filter should not work, i.e. we can not use the PPP filter to get higher rates of return than the reference rule. This filter rule, in fact, is a joint test of PPP and the hypothesis of foreign exchange market efficiency, especially when the filter rule involves investing money in interest-bearing securities in the 'undervalued' currency. This test strategy

\(^1\)If the exchange rate is defined as the price of foreign currency per unit of the domestic currency and the exchange rate is above the PPP rate, the foreign currency is undervalued.
is based on the fact that there is ample evidence\textsuperscript{2} that monetary authorities use foreign exchange intervention to 'lean against the wind' when they believe rates are changing too swiftly. If the exchange market is operating efficiently, the exchange rates should already reflect all available information about future events and monetary policy, and the PPP filter should not make any unexploited profit compared with the reference rule. If the test results show that the rates of return of the PPP filter are not significantly higher than the rates of return of the reference rule, we can not reject the null hypothesis that the foreign exchange market is efficient.

There are some new features associated with the PPP filter. First, the PPP filter is more accurate than the normal filter\textsuperscript{3}. The normal filter does not tell how much exchange we should buy when the exchange rate is above a trough. In contrast to the normal filter, the PPP filter not only tells us when we should buy an exchange, but also tells us how much we should buy because the PPP filter is not only based on which currency is undervalued, but more specifically, is based on how much that currency has been undervalued. Second, the PPP filter uses the information of the accumulated PPP deviations rather than the current PPP deviations. In this way, the PPP filter takes account of the aggregate effect of PPP deviations over time. When an investor uses the PPP filter to speculate in the foreign exchange market, he expects that the tendency for PPP to hold in the long run exists. The larger the accumulated PPP deviations, the stronger the market forces will be to push the exchange rates back to the PPP rates. Therefore, according to the PPP filter, the investor puts money into an undervalued currency in proportion to the extent of the accumulated PPP deviations to maximize his profits.

\textsuperscript{2}Branson (1984) \textsuperscript{[9]} found evidence of the 'leaning against the wind' policy for most countries, including the U.S.

\textsuperscript{3}Dooley and Shafer (1976, 1984) \textsuperscript{[14]} \textsuperscript{[15]} have used the normal filters to examine the evidence for economic profit in the exchange market.
Chapter 1. Introduction

Most previous studies\(^4\) which test the hypothesis of foreign exchange market efficiency measure profitability by the accumulated profit. However, the accumulated profit may not be a correct measure of the profitability of a trading rule because the accumulated profit is not independent of time. For example, a one year loss may not cause a negative accumulated profit to the investor if the previous accumulated profit is greater than the amount of loss. Therefore, the conclusion of the studies using the accumulated profit to measure the profitability of a trading rule may be misleading. In our opinion, a better measure of the profitability is the rate of return, because the rate of return is independent of time. For example, even if the accumulated profit is positive, the rate of return will be negative if there is a loss in a particular period of time. Accordingly, in our test we will use the rate of return brought by the PPP filter to measure the profitability of the PPP filter.

Furthermore, in this thesis, we have constructed a reference rule which does not take PPP deviations into consideration. The differences between the rates of return in these two trading rules are examined with reference to their standard deviations, which allow us to fully evaluate the real profitability of the PPP filter. This step is actually very important in testing the hypothesis of foreign exchange market efficiency. Most previous studies in this area have not constructed a reference rule. Therefore, even if profits are made by trading rules, it is difficult to judge whether or not the profits are risk premium. In this thesis, the reference rule is constructed such that the only difference between the reference rule and the PPP filter is whether or not the information from PPP deviations is used. Thus, comparing the rates of return between these two rules should give us a clear picture of whether or not the information from PPP deviations provides a useful signal for speculations. If the PPP filter has significantly higher rates of return than the reference

\(^4\)These studies include Dooley and Shafer (1976, 1984)[14][15], Bilson (1981) [3], Bilson and Hsieh (1983) [4], Hodrick and Srivastava (1984) [29], Boothe (1983) [5], Longworth et al. (1983) [32] and Boothe and Glassman (1987) [7].
rule, we then can use a method, such as Stochastic Dominance⁵, to judge whether the abnormal rates of return is a risk premium. If the exchange market is efficient, we cannot expect that the PPP filter will work. In summary, our null hypotheses are:

1. The tendency for PPP to hold in the long run does not exist.⁶

2. The exchange market is efficient.

If the PPP filter can not make significantly abnormal rates of return compared with the reference rule, we cannot reject these two hypotheses.

The thesis is organized as follows: Chapter 2 presents the rationale for using the PPP filter to test the two hypotheses. Chapter 3 describes the methodology of the test procedure and data description. In this chapter, the principles of the test procedure are presented first; then some statistical considerations are described, and finally, the data description is given. Chapter 4 presents the results and discussions, and Chapter 5 presents the conclusion.

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⁶Alternatively, the null hypothesis could have been defined as the tendency for PPP to hold rather than not to hold.
Chapter 2

Rationale

This chapter discusses the rationale for the filter rule used in testing the tendency of PPP to hold in the long run and the hypothesis of foreign exchange market efficiency. Why has PPP been chosen as a benchmark for the filter rule? Is this testing procedure reliable? Section 2.1 and Section 2.2 discuss the rationale for this test.

2.1 The Rationale for Testing the Tendency for PPP to Hold in the Long Run

The filter rule is based on deviations from Purchasing Power Parity. Before we describe the filter rule, let us look at why PPP has been chosen as a benchmark for the filter rule. PPP exists in two forms: the absolute and the relative (Levi, 1984) [30]. The absolute version of PPP states that the equilibrium exchange rate between domestic and foreign currencies equals the ratio between domestic and foreign price levels. In other words, a unit of currency should have the same purchasing power around the world. If \( P(A) \) and \( P(B) \) represent the prices of a standard basket of wholesale goods in country A and country B, and \( S(A, B) \) is the spot exchange rate measured as units of currency A per unit of currency B, we have:

\[
P(A) = S(A, B) \times P(B)
\]  

The relative version of PPP states that proportionate changes in the ratio of domestic and foreign prices will equal proportionate changes in the exchange rate between domestic
and foreign currencies or that the adjustment of exchange rates should follow national inflation differentials closely. The relative version of PPP is:

$$\frac{S(A, B, t)}{S(A, B, t - 1)} = \frac{1 + \dot{P}(A, t)}{1 + \dot{P}(B, t)}$$

or

$$\dot{S}(A, B, t) = \frac{\dot{P}(A, t) - \dot{P}(B, t)}{1 + \dot{P}(B, t)}$$

where $S(A, B, t)$ is the exchange rate at time $t$. $\dot{P}(A, t)$ and $\dot{P}(B, t)$ are the price changes at time $t$ in country A and B respectively. $\dot{S}(A, B, t)$ is the exchange rate change at time $t$.

In a world of perfect information, uniform price changes, identical consumption preferences, all goods tradable, and no transportation costs and barriers to trade, PPP would hold. However, in a multicommodity world with relative price changes, different consumption preferences across countries, nontraded goods, transaction costs and uncertainties, PPP may not hold. Indeed, recent experience with floating exchange rates has shown that PPP does not hold in the short term. There are two major explanations for these departures from PPP: the index problem and the different behavior of pricing in goods and assets markets.

The index problem is caused by the different weights of the same commodity in constructing the price indices in different countries which reflect the different national consumption preferences. Shapiro (1983)[40] gives a detailed review of the index problem. A change in relative prices that increases (or decreases) country B’s price index relative to country A’s index will cause a decrease (or increase) in the value of currency A relative to currency B. The net result can be a change in the equilibrium exchange rate even though each country’s own price level remains the same.

The second explanation of deviation from PPP is the different pricing behavior of
goods and assets markets. Exchange rates, like asset prices, react quickly to 'news,' whereas goods market prices react more slowly to the same 'news'. The 'news,' which causes instantaneous exchange rate adjustment, should cause an immediate one-to-one PPP deviation since prices adjust slowly. Over time, as prices adjust, the PPP deviation may diminish; however, it need not diminish to the extent that the exchange rate change is caused by real disturbances.

There is no doubt that PPP is inadequate as a short term hypothesis. Although deviation from PPP can be observed for most currencies at any instant, is PPP better as a long-run theory? Gaillot (1970)[25], Hodgson and Phelps (1975)[28] argue that there must be a tendency for real exchange rates to revert to parity. Economic forces such as international commodity arbitrage and the mechanism of slow price adjustment create a countervailing tendency for the exchange rate to return to parity. In this hypothesis, a long-run version of PPP is therefore consistent with two principles: first, the oscillating behavior of real exchange rate fluctuation; second, the tendency of PPP deviations to revert to zero over sufficiently long periods.

However, this argument is controversial. Frenkel (1981a)[23] pointed out that over sufficiently long time periods, when there are substantial movements in relative national prices levels, exchange rate movements are consistent with the relative version of PPP. But when the economy experiences real structural changes, PPP may not hold even in the long run.

On the basis of the above discussion, departures from PPP in the short run are inevitable. On the other hand, the oscillatory behavior of real exchange rate fluctuation gives us a way to test whether the tendency for PPP to hold exists in the long run. By using PPP as a benchmark to measure which currency is overvalued, an investor could

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make abnormal profits because an overvalued currency has more purchasing power than it should have. Therefore, the filter rule is developed as follows: at the beginning when the exchange rate is supposed to be in equilibrium, the investor puts an equal value of money in both domestic and foreign currencies. Afterwards, if the foreign currency is overvalued, he trades foreign currency for domestic currency in proportion to the extent to which the currency is overvalued. Conversely, if the domestic currency is overvalued, the investor buys foreign currency. The return from the filter rule at each investment period can be compared with that from use of a reference rule, called the 50-50 rule, in which the investor puts an equal value of money in each of two currencies. It is clear that if the tendency for PPP to hold does not exist in the long run, for example, if the deviation from PPP appears large over a long time period, the filter rule will not have any advantage compared with the 50-50 rule. In this situation, if the foreign currency ultimately has a greater value, the investor is better off if he sells all foreign currency at the end of the period instead of selling it successively as the filter rule dictates. Therefore, if the PPP filter can not make significantly higher rates of return than the 50-50 rule, we can not reject the hypothesis that the tendency for PPP to hold in the long run does not exist.

2.2 The Rationale for Testing Exchange Market Efficiency

The foundation for most of the modern studies of market efficiency was laid by Fama (1970)[18] who defines an efficient market as one that does not allow 'economic profit'\(^2\) to be made based only on information readily available to market participants.\(^3\) If the foreign exchange market is operating efficiently, there should be no opportunities for a speculator to make any unexploited profits by using publicly available information.

\(^2\)Economic profit is profit calculated after adjustment for risk bearing.

\(^3\)This is the semi-strong version of market efficiency.
Interest rates react to 'news' quickly. If the exchange market is operating efficiently, exchange rates should react to 'news' as quickly as the interest rates. It would be impossible for an abnormal return to be made if an investor uses the filter rule to speculate in interest-bearing securities. Therefore, it is interesting to link the filter rule also to financial markets to examine if the exchange market is efficient. Before we describe the rationale of using the PPP filter for this test, it is useful to recall the theory of the relationship between exchange rates and interest rates.

There are two kinds of relationships between the exchange rate and the interest rate. One is called Uncovered Interest Rate Parity (UIP), which predicts a positive association between the two rates. The other may be called 'liquidity effect' which predicts a negative relationship between them. Uncovered Interest Rate Parity refers to the equilibrium in international interest rates after adjustment for expected exchange rate movements. The relationship can be written:

\[
\frac{S^*(t+n) - S(t)}{S(t)} = \frac{r(d) - r(f)}{1 + r(f)}
\]

where \( S(t) \) is the spot rate at time \( t \), \( S^*(t+n) \) is the market expectation at time \( t \) regarding the future spot rate at time \( t + n \), and \( r(d) \) and \( r(f) \) are the domestic and foreign interest rates for \( n \) month's financial allocations. The UIP is valid when prices are perfectly flexible.\(^4\) Changes in the nominal interest rate reflect changes in the expected inflation rate. When the domestic interest rate rises relative to the foreign interest rate, it is because the domestic currency is expected to lose value through inflation. The demand for domestic currency falls relative to the foreign currency, causing the domestic currency to depreciate immediately. There is a rise in the exchange rate when exchange rate is defined as the units of domestic currency per unit of foreign currency. Thus there is a positive relationship between them.

\(^4\)See Frankel's paper [20].
In contrast, 'liquidity effect' predicts a negative relationship between exchange rates and interest rates. The 'liquidity effect' is realistic when prices are sticky, at least in the short term. Changes in the nominal interest rate reflect changes in the tightness of monetary policy. When the domestic interest rate rises relative to the foreign interest rate, it is because there has been a contraction in the domestic money supply relative to the domestic money demand. A higher interest rate attracts foreign capital, which in turn induces a surplus in the capital account of the balance of payments and thereby induces appreciation of the domestic currency (i.e. a lower spot exchange rate). A higher rate of interest also lowers spending and thus induces a surplus in the current account of the balance of payments, which in turn results in a lower spot exchange rate. Thus there is a negative relationship between exchange rates and interest rates. The 'liquidity effect' plays an important role in the short run behavior of exchange rate movements. Hardouvelis (1985) has found that the liquidity effect dominates the reactions of short term interest rates and exchange rates.

Another important factor that affects the short run behavior of exchange rates is the policy reaction by central banks (Branson 1983) which is called 'leaning against the wind' in which the authorities intervene in the foreign exchange market to oppose changes in the exchange rate, especially changes that they view as economically inappropriate. Branson (1984) has found evidence of this 'leaning against the wind' policy in most countries including the United States. A drop in the real exchange rate, immediately followed by an increase in the short-term interest rate differential, is explained by Solnik (1987) as the result of the 'leaning against the wind' policy.

Now let us see why the filter rule can be used to test the hypothesis of exchange market efficiency. The filter rule in this test is actually based on the 'liquidity effect' and the 'leaning against the wind' policy. An investor uses the filter rule to speculate in

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5See Frankel (1979) and Frenkel (1981b).
this way: when a currency is undervalued, he invests more money in an interest bearing security which is denominated in the undervalued currency. The investor expects that the more the currency is undervalued, the stronger the 'leaning against the wind' policy will be. Whichever method monetary authorities use in intervention, a drop in the real exchange rate tends to be followed immediately by an increase in the short-term interest rate. If the foreign exchange market is operating efficiently, the exchange rate should already reflect the expectation of government intervention. The exchange market should not allow the investor to earn any abnormal profit. In our test, the null hypothesis is that the exchange market is efficient. We examine the rates of return produced by the PPP filter as compared with the rates of return of the reference rule. If the PPP filter can make higher rates of return than the reference rule and the results are statistically significant, we will reject this null hypothesis in favour of the alternative hypothesis that the foreign exchange market is not efficient. Otherwise, if the results are not statistically significant, then the null hypothesis can not be rejected.
Chapter 3

Methodology and Data Description

3.1 Introduction

This chapter describes the methodology and available data. Before describing the methodology of the PPP filter, in this introduction section, we discuss what is the differences between the PPP filter and other normal filters, and why our methodology can provide more reliable results.

The normal filters are popularly used for testing spot market efficiency. Filter rules are trading strategies based on specifically observed price movements. For example, an $X$ percent filter rule is: 'Buy a currency, and then an interest bearing asset denominated in that currency whenever the currency rises $x$ percent above its most recent trough. Sell the currency and the asset, and take a short position in both the currency and the asset whenever the currency falls $x$ percent below its most recent peak.' (Levich 1979) [31]. The basic idea behind the normal filter rule is that the exchange rate movements have trend patterns. If the exchange rate increases, it is likely to then continue to increase. This increase is interpreted in terms of bandwagons and technical corrections. In contrast to the normal filter, the PPP filter is more theoretically orientated. The PPP filter is based on the theory of Purchasing Power Parity (PPP), but more specifically, the accumulated percentage change of PPP deviations. If the tendency for PPP to hold exists in the long run, the larger the accumulated PPP deviation, the stronger the market forces to push the exchange rate back to its PPP rate. According to the PPP filter, an investor can put
money into an 'undervalued' currency, or interest-bearing security denominated in this 'undervalued' currency, the more this currency is undervalued. Therefore, the PPP filter is more accurate than the normal filter because the PPP filter not only tells us when to buy a currency, but also how much we should buy. Moreover, because the PPP filter is based on the PPP theory, it not only provides a tool to test the hypothesis of foreign exchange market efficiency, but also provides a way to test the tendency for PPP to hold in the long run.

In many previous studies which test exchange market efficiency, we have noticed that most of them had a hard time distinguishing the unexploited profit and the risk premium. One way to distinguish the unexploited profit and the risk premium is to directly compute the risk premium, but this computation is very difficult (Boothe and Longworth, 1986)[6]. Another way is to identify an opportunity cost associated with the trading strategy and then use a method, such as the stochastic dominance, to compare returns at every point in the probability distribution to see which trading rule is preferred by a risk-averse investor. When we use normal filter rules, it is difficult to identify the opportunity cost associated with the filter rule because we do not directly forgo income\(^1\). In this thesis, a reference rule has been constructed such that the only difference between the reference rule and the PPP filter is whether or not the information regarding the PPP deviation is used. Therefore, comparing the rates of return between these two rules should give us a clear picture about whether or not the information of PPP deviations provides a useful signal for speculations. If the PPP filter has significantly higher rates of return than the reference rule, we shall then judge whether the abnormal returns of the PPP filter are the risk premium. If the PPP filter does not work, we cannot reject the hypothesis that the exchange market is efficient.

When we design the methodology, another consideration which must be taken into

\(^1\)See footnote 14 in Dooley and Shafer's paper [15].
account is how to measure the profitability of the PPP filter. Most previous studies testing the hypothesis of foreign exchange market efficiency measure profitability by the accumulated profit. However, the accumulated profit may not be a correct measure of the profitability of a trading rule because the accumulated profit is not independent of time. For example, a one year loss may not cause a negative accumulated profit if the previous accumulated profit is greater than the amount of loss. Therefore, when we compare the profitabilities of two trading rules, the results will be erroneous. In our opinion, a better measure of the profitability is the rate of return, because the rate of return is independent of time. For example, even if the accumulated profit is positive, the rate of return will be negative if there is loss in a particular period of time. Accordingly, in our test we will use the rate of return brought by the PPP filter to measure the profitability of the PPP filter.

In this thesis, we have designed two test strategies. One of them, called Interest-Bearing Strategy, is based on the fact of the 'leaning against the wind' policy. This strategy is to examine whether an investor can make abnormal returns using the PPP filter by investing in interest bearing securities, because if a currency is undervalued, the 'leaning against the wind' policy will very likely cause an increase in the interest rate of a security denominated in the undervalued currency. The purpose of this strategy is to test hypothesis that the foreign exchange market is efficient such that the PPP filter can not make significantly abnormal rates of return. Another test strategy, called Pure-Cash Strategy, is only associated with the exchange money market. The purpose of this test strategy is to examine how well PPP holds in the long run when we exclude the effect of the change of interest rate on the returns of the trading rules. In this strategy, the null hypothesis is that the investor can not make an abnormal return using the PPP filter, i.e. the tendency for PPP to hold does not exist in the long run.

The methodology is described in detail in Section 3.2. Section 3.3 discusses the
3.2 Methodology

3.2.1 The Interest-Bearing Strategy

The filter rule allows an investor to speculate in both the foreign exchange money market and the financial market according to PPP deviations. The filter rule is constructed as follows: at the beginning of a quarter, the investor first calculates his wealth, and then constructs his portfolio according to the PPP filter. He invests more funds into a security which is denominated in an undervalued currency in proportion to the extent that the currency has been undervalued. The extent of the undervaluation of the currency is measured by the currently accumulated PPP deviation. At the beginning of the next quarter, he calculates his wealth again. Then the quarterly rate of return is calculated. The detailed algorithm of the filter rule is described below.

For the purpose of illustration, a simplified deviation chart is given in Figure 3.1.

Figure 3.1: An example of the PPP deviation chart

How to construct a deviation chart will be described in Section 3.2.3.
In Figure 3.1, the horizontal axis measures time and the vertical axis measures the accumulated PPP deviation of the exchange rates. The exchange rate is expressed as units of foreign currency per unit of domestic currency and the expected maximum accumulated deviations are assumed to be equal to ±b. The investor is expected to use three-month interest bearing securities because 'liquidity effect' dominates the reactions of short-term interest rates and exchange rates.

Before the algorithm is described, some notations are given as follows:

- $D_0$: value of the domestic currency that the investor held in time 0.
- $F_0$: value of the foreign currency that the investor held in time 0.
- $S(t)$: exchange rate at time 0, defined as foreign currency price per unit of home currency.
- $V(t)$: accumulated PPP deviation at time t.
- $DOM(t)$: value of the domestic currency in the domestic security at time t.
- $FN(t)$: value of the foreign currency in the foreign security at time t.
- $r^d(t)$: quarterly interest rate of the domestic security at time t.
- $r^f(t)$: quarterly interest rate of the foreign security at time t.
- $W(t)$: investor's wealth at time t.

At the beginning of the simulation, at time 0, the exchange rate is supposed to be in equilibrium. The investor puts an equal value of money into the domestic and foreign securities respectively.

\[
DOM(0) = D_0
\]
\[
FN(0) = F_0
\]
\[
F_0 = D_0 \times S(0)
\]

After 3 months, when the securities mature, the value of the money in both domestic
and foreign securities is:

\[
\begin{align*}
DOM(1) &= DOM(0) \times (1 + r^d(0)) \\
FN(1) &= FN(0) \times (1 + r^f(0))
\end{align*}
\]

At that moment, the investor first calculates his wealth:

\[
W(1) = DOM(1) + FN(1) \div S(1)
\]

Then he reconstructs his portfolio according to the extent of PPP deviation \( V(t) \).

For example, as shown in Figure 3.1, at time 1, the accumulated deviation is \(-a\). The domestic currency is undervalued. The investor expects that the government will use the 'leaning against the wind' policy and thus the interest rate of short-term domestic security is likely to increase. The investor will now invest more funds in domestic security, but not all the funds he holds because the accumulated deviation has not reached the expected maximum deviation. The additional funds that he will invest in domestic security are in proportion to the extent of PPP deviation. The proportion is measured by the ratio of currently accumulated deviation to expected maximum accumulated deviation. In this example, the ratio is equal to \( a \div b \). The investor's portfolio is reconstructed as follows:

\[
\begin{align*}
DOM(1) &= 0.5 \times W(1) \times (1 + \frac{a}{b}) \\
FN(1) &= 0.5 \times W(1) \times (1 - \frac{a}{b}) \times S(1)
\end{align*}
\]

and he reinvests these funds in domestic and foreign securities again.

After 3 months, at time 2, when the securities mature, the values of domestic and foreign securities are:

\[
\begin{align*}
DOM(2) &= DOM(1) \times (1 + r^d(1)) \\
FN(2) &= FN(1) \times (1 + r^f(1))
\end{align*}
\]
the investor’s wealth is:

\[ W(2) = DOM(2) + FN(2) \div S(2) \]

At this time, the accumulated deviation is \(-b\). Following the same rule, the investor then reconstructs his portfolio as:

\[ DOM(2) = 0.5 \times W(2) \times (1 + \frac{b}{b}) = W(2) \]
\[ FN(2) = 0.5 \times W(2) \times (1 - \frac{b}{b}) \times S(2) = 0 \]

This means that when the currently accumulated deviation is equal to the expected maximum accumulated deviation, the investor puts his total wealth in domestic security because he expects that in this situation the monetary authority might use the strongest policy to 'lean against the wind' and therefore the interest rate of domestic security might be very high.

At time 3, similar to the steps at time 1 and 2, when the accumulated deviation goes back to \(-a\), the portfolio is constructed as:

\[ DOM(3) = 0.5 \times W(3) \times (1 + \frac{a}{b}) \]
\[ FN(3) = 0.5 \times W(3) \times (1 - \frac{a}{b}) \times S(3) \]

At time 4, when the accumulated deviation is equal to zero, the portfolio is constructed as:

\[ DOM(4) = 0.5 \times W(4) \times (1 + \frac{0}{b}) \]
\[ FN(4) = 0.5 \times W(4) \times (1 - \frac{0}{b}) \times S(4) \]
\[ = 0.5 \times W(4) \times S(4) \]

At this moment, the investor again puts an equal value of money in domestic and foreign securities because the exchange rate is in equilibrium again.
At times 5, 6, 7 and 8, the domestic currency is overvalued. The speculation process is the reverse of the process when the domestic currency is undervalued, i.e. the more a foreign currency is undervalued, the more the investor puts funds in that foreign security. From the wealth that the investor holds at the beginning of each quarter, the quarterly rate of return can be calculated and compared with those in the 50-50 rule.

The 50-50 rule is simple: at the beginning of a quarter, the investor puts an equal value of money in 3-month domestic security and foreign security. Every 3 months, he first calculates his wealth, and then again puts an equal value of money in domestic and foreign securities without transferring any currency according to the PPP deviation. The quarterly rates of return will also be calculated as a reference for comparison with those in the filter rule.

3.2.2 The Pure Cash Strategy

The Pure Cash Strategy is very similar to the Interest Bearing Strategy. The difference is that in this strategy, the investor does not invest currencies into interest bearing securities. In the PPP filter, the investor just transfers funds from one currency to another currency according to the rule mentioned in the Interest Bearing Strategy. However, the investor's motivation now becomes to sell more foreign currency for domestic currency, the more the domestic currency is undervalued. In the 50-50 rule, the investor just puts an equal value of money into both currencies at the beginning of each quarter. The remaining part of the test procedure is the same as that in the Interest Bearing Strategy.

3.2.3 The Deviations from PPP

In the filter rule, the deviations from PPP provide crucial information. In general, over sufficiently long time periods, when there have been substantial movements in relative national price levels, exchange rate movements have been consistent with the relative
version of PPP (Mussa, 1979)[34]. Although in the 1970's and 1980's the variations in inflation differentials in industrialized countries were moderate, we still prefer to use the relative version of PPP to calculate the deviations from PPP. The percentage change of the PPP rate is calculated in the equation (2.3).

\[ S(A, B, t) = \frac{\hat{P}(A, t) - \hat{P}(B, t)}{1 + \hat{P}(B, t)} \]

The percentage change of the actual exchange rate is:

\[ \hat{X}(t) = \frac{X(t)}{X(t - 1)} - 1 \quad (3.5) \]

where \( \hat{X}(t) \) is the percentage change of the actual exchange rate at time \( t \), \( X(t) \) and \( X(t - 1) \) are the exchange rates at time \( t \) and \( t - 1 \) respectively.

Next, the accumulated percentage changes of PPP rates and the actual exchange rates can be calculated. The purpose of calculating the accumulated percentage change of PPP rates and the actual exchange rates is to see the aggregate effect of PPP deviations. If PPP holds in the long run, the larger the accumulated deviation, the stronger the economic forces which are supposed to bring the exchange rate back to PPP. After calculating the accumulated percentage changes of the PPP rates and the actual exchange rates, the accumulative deviations from PPP can be calculated. The PPP charts and deviation charts for the four major exchange rates are presented in Appendix A.

3.2.4 The Measurement of Prices

The wholesale price index has been chosen as a proxy of 'Purchasing Power' when we measure inflation rates because the wholesale prices tend to be more sensitive to market forces and less subject to politically motivated manipulation of the market baskets, commonly used in cost of living indices (Everett 1980)[17]. Another reason for selecting the
Chapter 3. Methodology and Data Description

wholesale price index is that the relative version of PPP holds better when national price levels are measured by wholesale price indices rather than by prices, such as consumer price indices, which are more heavily weighted with non-traded goods.\(^3\) In practice, the wholesale price indices for one month are released in the middle of that month. Therefore, if an investor speculates at the end of a month, it is easy for him to access the information to calculate the PPP deviation. In our test, all speculations take place at the end of the month.

3.2.5 The Choice of Standard Country

For a given country, the optimal standard country is the one with which the given country's trade and payment links are strongest (Officer, 1982)[36]. In our tests, we have selected the United States as the standard country because of the important role of that country in international trade.

3.2.6 The Time Period and Selecting of Samples

In any test of PPP, determining the base time of the analysis is very difficult. Theoretically, the correct time to begin the test is when the PPP rate coincides with the actual rate. In practice, it is unlikely that anyone can determine a point of time at which a given currency is in 'equilibrium' in relation to all other currencies. As the collapse of the fixed rate has begun a period of exchange rate turbulence, the base time has been chosen as the time when floating exchange rates began in most industrial countries. Canada was the earliest country to adopt a floating exchange rate in May, 1970, followed by the U.K. in June, 1972; Japan in February, 1973; and the U.S. and West Germany in March, 1973.\(^4\) Therefore, April, 1973, has been chosen as the base time for the test period. The

\(^3\)See Mussa’s paper[34].
\(^4\)See OECD (1985): Exchange Rate and Conduct of Monetary Policy [37].
whole sample period is from April, 1973 to March, 1988.

The investment period has been chosen for one quarter. Because the investor is supposed to access all information *ex ante*, the expected maximum accumulated deviations have been arbitrarily chosen as ±20%, ±30%, ±40% and ±50%. The arbitrarily chosen expected maximum deviations do not violate the conditions for testing market efficiency.

Three sets of data are required in order to test the tendency of PPP to hold in the long run: (1) monthly-average exchange rates which are used to calculate PPP deviations. (2) end-month market exchange rates which are used for exchanging currencies. (3) wholesale price indices. In the test of foreign exchange market efficiency, an additional set of data is needed: interest rates of securities.

When interest-bearing securities are chosen for investment, one essential condition must be that the securities have similar risks. Aliber (1973)[2] suggests that traditional investment pairs, such as treasury bills, are not always genuinely comparable. The political risk attached to treasury bills, for instance, can vary greatly. He also points out that ideally the comparison should include investments on external markets, rather than national markets, so that Euro-interest rates are also needed. However, since there are no Euro-interest rates available for the five currencies we are going to test, our investments are based on the next best thing: national markets. We chose short term interest bearing securities: three-month treasury bills for the United States, Britain, and Canada. Where the data for 3-month treasury bill rates were not available for other countries, we have used 3-month deposit rates for Japan and France, and 3-month interbank deposit rates for West Germany. For this class of short term investment, the political and default risk differential between the United States and the other four countries should be sufficiently small to guarantee comparability with respect to returns on investment.
3.3 Statistical Considerations

In order to fully evaluate the profitability of the filter rule, the mean and standard deviation of the returns need to be calculated for both filter rule and the 50-50 rule. In financial markets, the compound rate is a more appropriate measure and the geometric mean is a more precise measure of the average rate of return. The geometric mean, \( G \), for a set of values \( X_1, X_2, \ldots, X_n \), is the antilogarithm of the arithmetic mean of the logarithms of the values; that is

\[
\log G = \frac{\log X_1 + \log X_2 + \ldots + \log X_n}{n}
\]

or

\[
G = \sqrt[n]{X_1 X_2 \cdots X_n}
\]

Therefore, at the beginning of every quarter, we take the logarithm of the ratio of the wealth for an investor at this time to the wealth at the beginning of the previous quarter, that is, the logarithm of one plus the quarterly rate of return. The mean is calculated by taking the arithmetical average of the logarithm of the ratios.

\[
R(i) = \frac{1}{N} \sum_{n=0}^{N} r(i, n)
\]

where \( R(i) \) is the mean of the logarithm of one plus the rate of return for rule \( i \), and \( r(i, n) \) is the logarithm of one plus the rate of return at the \( n^{th} \) quarter for rule \( i \). The variance of the logarithm of one plus the rate of return for rule \( i \) is defined as:

\[
\sigma^2(i) = \frac{1}{N} \sum_{n=0}^{N} (r(i, n) - R(i))^2
\]

In order to test whether the PPP holds in the long run, and whether the exchange market is efficient, the abnormal return is needed. Because the samples are the logarithm of one plus the rate of return, the 'abnormal return' now is defined as the difference
between the logarithm of one plus the rate of return of the filter rule and that of the 50-50 rule.

\[ \pi(n) = r(i,n) - r(j,n) \]

Actually, the abnormal return is the logarithm of one plus the rate of return of the filter rule over one plus the rate of return of the 50-50 rule. If \( \pi(n) \) is greater than one, the filter rule has an abnormal rate of return. Then we can use the method of 'matched sample' t-test (Neter 1988)[35] to test the significance of the 'abnormal return'. Here, we use a one-tail t-test rather than two-tail t-test because we are interested in whether the PPP filter can make positive abnormal returns. Therefore, the null hypothesis is

\[ H_0 : \pi(n) = 0 \]

i.e. there is no abnormal rate of return, and the alternative hypothesis is

\[ H_1 : \pi(n) > 0 \]

It is possible that in some cases, there will be negative abnormal returns. This indicates that the PPP filter in these cases is worse than the reference rule. If we want to know whether these negative abnormal returns are statistically significant, we have to use a different alternative hypothesis, \( H_1 : \pi(n) < 0 \). However, our interest is in determining whether the PPP filter will produce positive abnormal returns.

### 3.4 Data Description

The data are all monthly observations that have not been seasonally adjusted. All data are taken from the International Monetary Fund Data Base.

*Monthly average exchange rates*

Data Source: IFM, line af or ag.
Chapter 3. Methodology and Data Description


Description: the monthly average market rate. The daily rate is the mid rate in the domestic market quotation.

*End-of-month exchange rate*

Data Source: IMF, line ae or ah.


Description: the end of the month market rate. The daily rate is the mid rate in the domestic market quotation.

*Wholesale price indices*

Data Source: IMF, line 63.


Description: monthly index with 1980 = 100.

*Short term interest rates*

U.S.

Data Source: IMF, line 60c.


Description: this is a discount rate on new issues of 3-month bills.

U.K.

Data Source: IMF, line 60c.


Description: the tender rate at which 91-day bills are allocated. Monthly data are the weighted averages of Friday data.

Japan

Data Source: IMF, line 60l.
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Series: 3-month time deposit rates; 1973:4-1988:3.
Description: this rate is set by the Bank of Japan.

Germany
Data Source: IMF, line 60bs.
Series: 3-month interbank deposit rates; 1973:4-1988:3.
Description: monthly data refer to the simple arithmetical average of the daily quotation reported by banks for the 3-month interbank rates.

Canada
Data Source: IMF, line 60c.
Description: this is the weighted average of the tender rates for the last Thursday of the month.
Chapter 4

Results and Discussion

This chapter presents and discusses the results of the filter rule used to test both the tendency of PPP to hold in the long run and the hypothesis of foreign exchange market efficiency. The four most actively traded currencies in the world, the British pound, the Japanese yen, the German mark, and the Canadian dollar, were tested vis-à-vis the United States dollar from April, 1973 to March, 1988. The results of the Pure-Cash Strategy are presented in Tables 4.1-4.4, while the results of the Interest-Bearing strategy are given in Tables 4.5-4.8. All these tables have the same form. The column 'Maximum Deviation' means the expected maximum accumulated PPP deviation. The investment periods are all quarterly which are successive and not overlapping. The test samples are the logarithm of one plus the rate of return which comes from the results of the simulations of either the filter rule or the 50-50 rule. The number of samples is fifty-nine.

4.1 Does the Tendency for PPP to Hold Exist in the Long Run

One way to discriminate between the short run and the long run PPP deviations is to identify 'long run' with a longer sample interval. The reason is obvious. It allows us to see if the filter rule will make an abnormal return on average over a sufficiently long period. In our test, the sampling period is from April 1973 to March 1988, which includes most of the period that the flexible exchange rate system has been in effect in industrial countries.
Tables 4.1-4.4 show that in the cases of Britain, Japan, and Germany, the filter rule has not made significantly abnormal returns. For example, when the expected maximum accumulated PPP deviations are ±20%, in the case of Britain, the mean of the abnormal rates of return for the American investor is 0.0008 at the significant level 0.38. In the case of Japan, the mean of the abnormal rates of return for the American investor is 0.0011 at the significant level 0.35. In the case of Germany, the mean of the abnormal rates of return for the American investor is 0.003 at the significant level 0.14. In the case of Canada, the filter rule is even worse than the 50-50 rule. The mean of the abnormal rates of return for the American investor is -0.0011 at the significant level 0.1394. Therefore, we cannot reject the null hypothesis that the tendency for PPP to hold in long run does not exist. The different expected maximum deviations do not alter the results very much.

Why does the filter rule not make an abnormal return? What is the implication of the tendency for PPP to hold in the long run? According to the studies of Gaillot (1970)[25], Hodgson and Phelps (1975)[28], the modern long run version of PPP is consistent with two empirical regularities: first, the oscillatory behavior of real exchange rate fluctuation and, second, the tendency of PPP deviation to average to zero over sufficiently long periods. A competing account of these aspects of exchange rate behavior is the martingale model of real exchange rate behavior (Rogalski and Vinso 1977)[38], (Roll 1979) [39]. As Adler and Lehmann (1983)[1] pointed out, the martingale model of real exchange rate behavior is also consistent with the pronounced but irregular cycles that the real exchange rate exhibits and with the observation that the mean PPP deviations tend to zero. Adler and Lehmann then tested whether the percentage change of real exchange rate is serially dependent and demonstrated that the deviations from PPP reveal consistency with martingale behavior based on financial arbitrage in bonds. Our results support

1The theory of martingale predicts this kind of oscillatory behavior. See Feller[21] chapter 6 and 12, Doob[13] chapter 7 and Chow and Teicher[10].
the finding of Adler and Lehmann. It implies that, based on financial arbitrage, prices adjust to the change of exchange rates quickly, and the deviations from PPP may follow a random walk. Therefore, the tendency of PPP to hold in the long run may not exist.

4.2 Foreign Exchange Market Efficiency

The results of testing foreign exchange market efficiency are presented in Tables 4.5-4.8 and Tables 4.9-4.13 give the examination for the Uncovered Interest Rate Parity (UIP) to hold in the long run. Two findings are revealed in the tables. First, in all four cases, the filter rule cannot make significantly abnormal return\(^2\). For example, when the expected maximum accumulated PPP deviations are \pm 20\%, in the case of Britain, the mean of the abnormal rates of return for the American investor is 0.0011 at the significant level 0.35. In the case of Japan, the mean of the abnormal rates of return for the American investor is 0.0008 at the significant level 0.39. In the case of Germany, the mean of the abnormal rates of return for the American investor is 0.0018 at the significant level 0.25, and in the case of Canada, the mean of the abnormal rates of return for the American investor is 0.0003 at the significant level 0.37. Although there is ample evidence that monetary authorities have used foreign exchange intervention to 'lean against the wind' when they believe exchange rates are changing too swiftly, the filter rule, which is based on this expectation, cannot make an abnormal return. Therefore, we cannot reject the hypothesis of exchange market and financial market efficiency. In an efficient market, exchange rate should already reflect all available information about expected future activity and policy. For example, when a currency is undervalued, an investor may expect that the government will take the 'leaning against the wind' policy and the currency will appreciate. Like the investor, all market participants will also

\(^2\)Similar to the Pure Cash Strategy, the expected maximum accumulated deviations do not affect the results very much.
recognize the future event and every one will buy this currency. Consequently, the currency will appreciate immediately. Similarly, in the assets market, if the market expects that the government may take the 'leaning against the wind' policy and the interest rate of the security, denominated in the undervalued currency, will increase, then all market participants will buy the security and push the interest rate down. Therefore, it is not surprising that the filter rule in the Interest Bearing Strategy cannot succeed.

Second, as a by-product we have compared the interest rates of the domestic (or foreign) securities with the rates of return for the domestic (or foreign) investor in the 50-50 rule or the filter rule to see if there are significant differences between them. The Uncovered Interest Rate Parity can be expressed in the form:

\[ 1 + r(d) = \frac{s^*(t+n)}{s(t)}(1 + r(f)) \]  

If UIP holds, it is indifferent to whether the investor invests in domestic or in foreign securities. This implies that the market is efficient. If equation (4.6) does not hold, the international arbitrage will eliminate the profit opportunity immediately. The results in Tables 4.9-4.13 show that there are no significant differences between them. For example, we compare the domestic interest rates with the rates of return for the domestic investor who uses the PPP filter. When the expected maximum accumulated PPP deviations are ±20%, in the case of Britain, the mean of the difference is 0.0017 at the significant level 0.37. In the case of Japan, the mean of the difference is 0.0025 at the significant level 0.31. In the case of Germany, the mean of the difference is 0.0052 at the significant level 0.20 and in the case of Canada, the mean of the difference is 0.0004 at the significant level 0.43. These results are consistent with the hypothesis that the UIP holds in the long run and again provides the evidence that we cannot reject the hypothesis that the foreign exchange market is efficient. The fact that the standard deviations of the rate

3 The samples are the logarithms of one plus the quarterly rates.
of return in the 50-50 rule and the filter rule are much bigger than those of the interest rates indicates that UIP does not hold in the short run.

One thing that we have to mention is why we do not use the investor's accumulated wealth as a measure of profitability. We illustrate this problem by the data in the case of Britain, presented in Table 4.14 where the plus sign (or minus sign) indicates that the accumulated wealth (or one plus the rate of return) of the filter rule is greater (or less) than that of the 50-50 rule. From Table 4.14, we can see that there are 28 cases in which the rates of return of the filter rule are less than that of the 50-50 rule. If we use the investor's accumulated wealth as the measure of profitability, there are only 6 cases in which the investor's accumulated wealth in the filter rule is worse than that in the 50-50 rule. Therefore, the accumulated wealth is not an appropriate measure of the profitability because it is not independent from previous wealth.

Dooley and Shafer (1976,1984) applied the normal filters to daily exchange rates for nine currencies vis-à-vis the U.S. dollar. The period considered in the first paper was mid-March 1973 to early September 1975, while the period September 1975 to early November 1981 was dealt with in the second paper. In both sample periods, Dooley and Shafer found that small filters ($x = 1, 3, 5$ percent) had been profitable for all currencies over the entire sample period. There was no evidence of declining profit opportunities from the first to the second period as would be consistent with the market 'learning' and competing away this unexploited profit. Therefore, they concluded that the profitability of the filters suggests that exchange markets for many currencies are not efficient in the use of price information. However, in their test, there appears to be some element of risk in these trading rules since each filter generated losses in at least one currency during at least one subperiod. There are some weaknesses in their paper. First, because the asset and liability positions generated by the rule were largely offsetting, the investor did not directly forgo income. Thus the opportunity costs associated with a filter rule were
difficult to identify. Second, they did not compute the mean and variance of the profits generated by the filter rule over various holding periods. Therefore, they can not give a full evaluation of how the expected value and the variability of the investor's wealth were altered by the positions generated by trading rules. These shortcomings weaken their conclusion.

In our tests the filter rule has been compared with a reference rule and the rates of return are used as a measure of the profitability. Also, the mean and standard deviation of the profits generated by the filter rule have been calculated to give a full evaluation of the profitability. Therefore, our results are more reliable.

Finally, we have to mention that if we find that the PPP filter does not yield a higher return than the reference rule, we might still have an abnormal return if the PPP filter is less risky. However, unfortunately we do not know the relative risk of the two rules. In general, riskiness of any portfolio must be measured on the basis of systematic risk. For example, if portfolio A has less covariance with the market portfolio than portfolio B, then portfolio A has less systematic risk than portfolio B. Hence, A is considered to have less risk than B. However, the relative risk of the PPP filter and the reference rule cannot be computed for two reasons. First, the systematic risk of the world portfolio is difficult to measure. Second, portfolios constructed according to the PPP filter and the reference rule change every quarter. Therefore, the covariances between these portfolios and the world market portfolio also vary over time which makes us unable to compare the risks of the two portfolios.

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4See footnote 14 in their paper.
Table 4.1: The results of the pure-cash strategies. (British pound/U.S. dollar)

<table>
<thead>
<tr>
<th>Maximum Deviation</th>
<th>Investor</th>
<th>50-50 Rule</th>
<th>Filter Rule</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean STD.</td>
<td>Mean STD.</td>
<td>Mean STD.</td>
</tr>
<tr>
<td>+/-20</td>
<td>American</td>
<td>-0.0024 0.0315</td>
<td>-0.0015 0.0386</td>
<td>0.0008 0.0209</td>
</tr>
<tr>
<td></td>
<td>British</td>
<td>0.0034 0.0316</td>
<td>0.0042 0.0373</td>
<td>0.0008 0.0209</td>
</tr>
<tr>
<td>+/-30</td>
<td>American</td>
<td>-0.0024 0.0315</td>
<td>-0.0014 0.0371</td>
<td>0.0010 0.0188</td>
</tr>
<tr>
<td></td>
<td>British</td>
<td>0.0034 0.0316</td>
<td>0.0043 0.0344</td>
<td>0.0010 0.0188</td>
</tr>
<tr>
<td>+/-40</td>
<td>American</td>
<td>-0.0024 0.0315</td>
<td>-0.0015 0.0355</td>
<td>0.0009 0.0130</td>
</tr>
<tr>
<td></td>
<td>British</td>
<td>0.0034 0.0316</td>
<td>0.0043 0.0329</td>
<td>0.0009 0.0130</td>
</tr>
<tr>
<td>+/-50</td>
<td>American</td>
<td>-0.0024 0.0315</td>
<td>-0.0017 0.0344</td>
<td>0.0007 0.0104</td>
</tr>
<tr>
<td></td>
<td>British</td>
<td>0.0034 0.0316</td>
<td>0.0041 0.0322</td>
<td>0.0007 0.0104</td>
</tr>
</tbody>
</table>

Table 4.2: The results of the pure-cash strategies. (Japanese yen/U.S. dollar)

<table>
<thead>
<tr>
<th>Maximum Deviation</th>
<th>Investor</th>
<th>50-50 Rule</th>
<th>Filter Rule</th>
<th>Differences</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>Mean STD.</td>
<td>Mean STD.</td>
<td>Mean STD.</td>
</tr>
<tr>
<td>+/-20</td>
<td>American</td>
<td>0.0068 0.0328</td>
<td>0.0079 0.0370</td>
<td>0.0011 0.0218</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>-0.0057 0.0325</td>
<td>-0.0046 0.0415</td>
<td>0.0011 0.0218</td>
</tr>
<tr>
<td>+/-30</td>
<td>American</td>
<td>0.0068 0.0328</td>
<td>0.0078 0.0344</td>
<td>0.0010 0.0152</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>-0.0057 0.0325</td>
<td>-0.0047 0.0377</td>
<td>0.0010 0.0152</td>
</tr>
<tr>
<td>+/-40</td>
<td>American</td>
<td>0.0068 0.0328</td>
<td>0.0076 0.0333</td>
<td>0.0008 0.0114</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>-0.0057 0.0325</td>
<td>-0.0049 0.0359</td>
<td>0.0008 0.0114</td>
</tr>
<tr>
<td>+/-50</td>
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<td>0.0074 0.0329</td>
<td>0.0008 0.0092</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>-0.0057 0.0325</td>
<td>-0.0051 0.0349</td>
<td>0.0008 0.0092</td>
</tr>
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</table>
### Table 4.3: The results of the pure-cash strategies. (German mark/U.S. dollar)

<table>
<thead>
<tr>
<th>Maximum Deviation</th>
<th>Investor</th>
<th>50-50 Rule Mean</th>
<th>50-50 Rule STD.</th>
<th>Filter Rule Mean</th>
<th>Filter Rule STD.</th>
<th>Differences Mean</th>
<th>Differences STD.</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/-20</td>
<td>American</td>
<td>0.0050 0.0334</td>
<td>0.0080 0.0463</td>
<td>0.0030 0.0206</td>
<td>1.1021 0.1375</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>German</td>
<td>-0.0039 0.0326</td>
<td>-0.0010 0.0299</td>
<td>-0.0023 0.0185</td>
<td>0.9838 0.1696</td>
<td></td>
<td></td>
<td></td>
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<td>-0.0019 0.0285</td>
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<td>0.9822 0.1650</td>
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<tr>
<td></td>
<td>German</td>
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<td>-0.0021 0.0286</td>
<td>-0.0018 0.0138</td>
<td>1.0249 0.1548</td>
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### Table 4.4: The results of the pure-cash strategies. (Canadian dollar/U.S. dollar)

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<th>50-50 Rule STD.</th>
<th>Filter Rule Mean</th>
<th>Filter Rule STD.</th>
<th>Differences Mean</th>
<th>Differences STD.</th>
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<th>P</th>
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<td>-0.0011 0.0079</td>
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<td></td>
</tr>
<tr>
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<td>Canadian</td>
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<td>-0.0011 0.0079</td>
<td>-1.0932 0.1394</td>
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<tr>
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<td>American</td>
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<td>-0.0027 0.0155</td>
<td>-0.0007 0.0055</td>
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<td>0.0014 0.0087</td>
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<td>-1.0233 0.1552</td>
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<tr>
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<td>Canadian</td>
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<td>0.0017 0.0080</td>
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Table 4.5: The results of the interest-bearing strategies. (British pound/U.S. dollar)
Instruments: American: Treasury Bill.
Britain: Treasury Bill.

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<th>Filter Rule</th>
<th>Differences</th>
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<td>Mean STD.</td>
<td>Mean STD.</td>
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<td>0.0213 0.0395</td>
<td>0.0011 0.0217</td>
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<tr>
<td>British</td>
<td>0.0280 0.0323</td>
<td>0.0270 0.0385</td>
<td>0.0011 0.0217</td>
</tr>
<tr>
<td>+/-30 American</td>
<td>0.0202 0.0316</td>
<td>0.0213 0.0378</td>
<td>0.0011 0.0173</td>
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<tr>
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<td>0.0010 0.0136</td>
</tr>
<tr>
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<td>0.0010 0.0136</td>
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<tr>
<td>+/-50 American</td>
<td>0.0202 0.0316</td>
<td>0.0210 0.0348</td>
<td>0.0008 0.0109</td>
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<tr>
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<td>0.0268 0.0331</td>
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Table 4.6: The results of the interest-bearing strategies. (Japanese yen/U.S. dollar)
Instruments: American: Treasury Bill.
Japan: Time Deposit.

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<th>Filter Rule</th>
<th>Differences</th>
</tr>
</thead>
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<td>Mean STD.</td>
<td>Mean STD.</td>
</tr>
<tr>
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<td>0.0213 0.0316</td>
<td>0.0221 0.0380</td>
<td>0.0008 0.0219</td>
</tr>
<tr>
<td>Japanese</td>
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<td>0.0096 0.0429</td>
<td>0.0008 0.0219</td>
</tr>
<tr>
<td>+/-30 American</td>
<td>0.0213 0.0316</td>
<td>0.0221 0.0332</td>
<td>0.0008 0.0153</td>
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</tr>
<tr>
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<td>0.0219 0.0321</td>
<td>0.0006 0.0115</td>
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<tr>
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<td>0.0094 0.0374</td>
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<td>0.0218 0.0317</td>
<td>0.0005 0.0092</td>
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<tr>
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Table 4.7: The results of the interest-bearing strategies. (German mark/U.S. dollar)
Instruments: American: Treasury Bill.
Germany: Interbank Deposit.

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<th>Filter Rule</th>
<th>Differences</th>
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<td>Mean</td>
<td>STD.</td>
</tr>
<tr>
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<td>0.0322</td>
<td>0.0248</td>
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<td>German</td>
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<td>0.0349</td>
<td>0.0159</td>
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<td>0.0322</td>
<td>0.0243</td>
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<td>0.0322</td>
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<td>German</td>
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<td>0.0152</td>
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<tr>
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<td>0.0322</td>
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Table 4.8: The results of the interest-bearing strategies. (Canadian dollar/U.S. dollar)
Instruments: American: Treasury Bill.
Canada: Treasury Bill.

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<th>Filter Rule</th>
<th>Differences</th>
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<td>STD.</td>
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<td>0.0127</td>
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<td>0.0121</td>
<td>0.0239</td>
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Table 4.9: The examination of the UIP compared with the 50-50 rule.

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<td>0.0083</td>
<td>0.0213</td>
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<td>Time</td>
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<td>Deposit</td>
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<td>0.0083</td>
<td>0.0196</td>
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<tr>
<td>Canadian</td>
<td>T-Bill</td>
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Table 4.10: The examination of the UIP compared with the filter rule.
Instruments: American: Treasury Bill.
Britain: Treasury Bill.
Exchange rate: British pound/U.S. dollar.

<table>
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<th>Maximum Deviation</th>
<th>Investor</th>
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<th>STD</th>
<th>Return Mean</th>
<th>STD</th>
<th>Differences Mean</th>
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Table 4.11: The examination of the UIP compared with the filter rule.
Instruments: American: Treasury Bill.
Japan: Time Deposit.

<table>
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<th>Investor</th>
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<th>STD</th>
<th>Return Mean</th>
<th>STD</th>
<th>Differences Mean</th>
<th>STD</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 20</td>
<td>American</td>
<td>0.0196</td>
<td>0.0063</td>
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<td>0.0063</td>
<td>0.0221</td>
<td>0.0332</td>
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<td>0.0098</td>
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<td>0.0389</td>
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<td>0.0063</td>
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### Table 4.12: The examination of the UIP compared with the filter rule.

Instruments: American: Treasury Bill.
Germany: Interbank Deposit.
Exchange rate: German mark/U.S. dollar.

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<td>Mean STD.</td>
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<tr>
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</tr>
<tr>
<td>+/− 50</td>
<td>American</td>
<td>0.0196 0.0063</td>
</tr>
<tr>
<td></td>
<td>German</td>
<td>0.0164 0.0070</td>
</tr>
</tbody>
</table>

### Table 4.13: The examination of the UIP compared with the filter rule.

Instruments: American: Treasury Bill.
Canada: Treasury Bill.
Exchange rate: Canadian dollar/U.S. dollar.

<table>
<thead>
<tr>
<th>Maximum Deviation</th>
<th>Investor</th>
<th>Interest Rate Return Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean STD.</td>
<td>Mean STD.</td>
</tr>
<tr>
<td>+/− 20</td>
<td>American</td>
<td>0.0196 0.0063</td>
</tr>
<tr>
<td></td>
<td>Canadian</td>
<td>0.0237 0.0072</td>
</tr>
<tr>
<td>+/− 30</td>
<td>American</td>
<td>0.0196 0.0063</td>
</tr>
<tr>
<td></td>
<td>Canadian</td>
<td>0.0237 0.0072</td>
</tr>
<tr>
<td>+/− 40</td>
<td>American</td>
<td>0.0196 0.0063</td>
</tr>
<tr>
<td></td>
<td>Canadian</td>
<td>0.0237 0.0072</td>
</tr>
<tr>
<td>+/− 50</td>
<td>American</td>
<td>0.0196 0.0063</td>
</tr>
<tr>
<td></td>
<td>Canadian</td>
<td>0.0237 0.0072</td>
</tr>
</tbody>
</table>
Table 4.14: The comparison of the accumulated wealth with the rate of return in the case of Britain

<table>
<thead>
<tr>
<th>No. (quarter)</th>
<th>50-50 Rule</th>
<th>Filter Rule</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wealth</td>
<td>1+r</td>
<td>Wealth</td>
</tr>
<tr>
<td>7</td>
<td>220.44</td>
<td>1.0137</td>
<td>223.49</td>
</tr>
<tr>
<td>12</td>
<td>227.43</td>
<td>1.0096</td>
<td>234.15</td>
</tr>
<tr>
<td>13</td>
<td>220.91</td>
<td>0.9710</td>
<td>226.02</td>
</tr>
<tr>
<td>14</td>
<td>221.03</td>
<td>1.0005</td>
<td>224.78</td>
</tr>
<tr>
<td>15</td>
<td>214.02</td>
<td>0.9683</td>
<td>211.70</td>
</tr>
<tr>
<td>22</td>
<td>264.73</td>
<td>1.0438</td>
<td>278.44</td>
</tr>
<tr>
<td>23</td>
<td>281.05</td>
<td>1.0616</td>
<td>291.75</td>
</tr>
<tr>
<td>25</td>
<td>292.34</td>
<td>1.0410</td>
<td>303.99</td>
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<td>26</td>
<td>315.98</td>
<td>1.0809</td>
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</tr>
<tr>
<td>28</td>
<td>333.87</td>
<td>1.0075</td>
<td>336.81</td>
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<tr>
<td>29</td>
<td>344.74</td>
<td>1.0326</td>
<td>345.56</td>
</tr>
<tr>
<td>30</td>
<td>362.73</td>
<td>1.0522</td>
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</tr>
<tr>
<td>31</td>
<td>380.64</td>
<td>1.0493</td>
<td>366.00</td>
</tr>
<tr>
<td>35</td>
<td>376.75</td>
<td>1.0302</td>
<td>404.94</td>
</tr>
<tr>
<td>38</td>
<td>402.74</td>
<td>1.0167</td>
<td>433.71</td>
</tr>
<tr>
<td>39</td>
<td>406.15</td>
<td>1.0085</td>
<td>435.61</td>
</tr>
<tr>
<td>40</td>
<td>396.81</td>
<td>0.9770</td>
<td>420.42</td>
</tr>
<tr>
<td>42</td>
<td>413.15</td>
<td>1.0085</td>
<td>438.16</td>
</tr>
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<td>43</td>
<td>418.83</td>
<td>1.0137</td>
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</tr>
<tr>
<td>44</td>
<td>414.60</td>
<td>0.9899</td>
<td>427.39</td>
</tr>
<tr>
<td>45</td>
<td>422.47</td>
<td>1.0190</td>
<td>434.42</td>
</tr>
<tr>
<td>46</td>
<td>417.74</td>
<td>0.9888</td>
<td>416.98</td>
</tr>
<tr>
<td>47</td>
<td>413.80</td>
<td>0.9906</td>
<td>398.93</td>
</tr>
<tr>
<td>48</td>
<td>408.05</td>
<td>0.9861</td>
<td>378.25</td>
</tr>
<tr>
<td>52</td>
<td>501.46</td>
<td>1.0110</td>
<td>527.32</td>
</tr>
<tr>
<td>57</td>
<td>603.24</td>
<td>1.0649</td>
<td>654.39</td>
</tr>
<tr>
<td>59</td>
<td>634.86</td>
<td>1.0563</td>
<td>684.29</td>
</tr>
<tr>
<td>60</td>
<td>657.87</td>
<td>1.0362</td>
<td>701.40</td>
</tr>
</tbody>
</table>
This thesis has tested the tendency of PPP to hold in the long run and the hypothesis of foreign exchange market efficiency through the filter rule based on deviations from PPP. There are several features in this thesis. First, the PPP filter gives a more accurate way than the normal filter to test these hypotheses because it is not just based on the currency which is undervalued. More precisely, it is based on the extent of the undervaluation of the currency. Moreover, the PPP filter uses the information of the accumulated PPP deviations which takes into account the aggregate effect of PPP deviation over time. Second, the profitability of trading rules is measured by rate of return rather than by accumulated profit (or wealth). Because the rate of return is independent on time, this measurement of profitability is more reliable. Third, a reference rule has been designed such that it is different from the PPP filter only in whether or not the information from PPP deviations is used. Therefore, the rates of return between the PPP filter and the reference rule can be compared to give us a clear picture of the usefulness of PPP deviation as a signal for speculations. The mean and standard deviation of the differences between the rates of return of the two rules can also be calculated to give a full evaluation of the real profitability of the PPP filter.

We tested several strategies and our results show that in the exchange money market, the PPP filter does not make significantly abnormal rates of return compared with the reference rule. Therefore, we cannot reject the null hypothesis that the tendency for PPP to hold in the long run does not exist. This result is probably consistent with the
martingale model of the real exchange rate behavior. It implies that based on financial arbitrage, prices adjust to the exchange rate quickly and the deviations from PPP may follow a random walk. In the exchange money market and the financial market, the filter rule still cannot produce significantly higher rates of return than the reference rule. Hence, we cannot reject the null hypothesis that the exchange market is efficient. This result is not surprising. Although there is ample evidence that the monetary authorities use foreign exchange intervention to 'lean against the wind' and that the 'liquidity effect' exists in short run, if the exchange market is operating efficiently, the exchange rates should already reflect all available information about future events and monetary policy. The PPP filter should not work. The finding that the UIP holds in the long run again supports the hypothesis of foreign exchange market efficiency.

There is a problem that has not been solved in this thesis. Although our results provide evidence against PPP theory, it is not clear why, before 1976, the PPP deviations were small and the exchange rates returned to PPP relatively rapidly. After 1976 the PPP deviations lasted longer and longer. The U.S. dollar, especially, continued to appreciate from 1980 to 1985 by approximately 50 and 40 per cent in normal and real terms, and then to depreciate after 1985. This phenomenon was an important reason for the failure of the PPP theory. If we can understand the reason for the change in PPP deviation behavior in the decade between 1976 and 1985, it will be very helpful to reveal the behavior of the exchange rates in the floating rate regime. It is an interest topic for further research.

In conclusion, after a careful examination of the profitabilities of two rules, the PPP filter rule and the reference rule, our results are consistent with the hypotheses that the exchange market is efficient and that the tendency for PPP to hold in long run does not exist.
Appendix A

The PPP Charts and the Deviation Charts

In Appendix A, the PPP charts and the deviation charts of these four exchange rates are presented in Figure A.1-A.8.

A PPP chart describes the actual exchange rate movement and the trend of the Purchasing Power Parity rate. The horizontal axis measures time from a suitable chosen-time origin. The vertical axis measures the accumulated percentage change in exchange rates and PPP rates. A deviation chart describes the movements of PPP deviations. The horizontal axis measures time and the vertical axis measures the accumulated percentage deviation of the actual exchange rates from PPP rates.
Figure A.2: PPP Chart (U.K. pound/U.S. dollar)

Figure A.3: Deviation from PPP (U.K. pound/U.S. dollar)
Figure A.4: PPP Chart (Japanese yen/U.S. dollar)

Figure A.5: Deviation from PPP (Japanese yen/U.S. dollar)
Appendix A. The PPP Charts and the Deviation Charts

Figure A.6: PPP Chart (DM/U.S. dollar)

Figure A.7: Deviation from PPP (DM/U.S. dollar)
Appendix A. The PPP Charts and the Deviation Charts

Figure A.8: PPP Chart (Canadian dollar/U.S. dollar)

Figure A.9: Deviation from PPP (Canadian dollar/U.S. dollar)
Bibliography


of Chicago Press.


