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TESTING THE FORWARD RATE UNBIASEDNESS
HYPOTHESIS IN LEBANON

BY

VIKEN KEVORK KESHISHIAN

A thesis

Submitted in partial fulfillment of the requirements for the degree of

Master of Business Administration

To the faculty of Business Administration and Economics

At Haigazian University

Beirut, Lebanon

June 2011

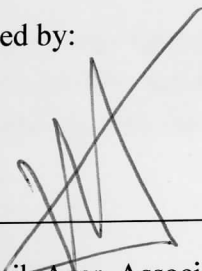
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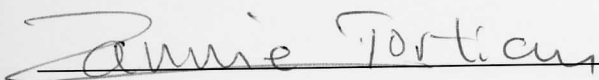
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AN ABSTRACT OF THE THESIS OF

Viken Keshishian for Master of Business Administration and Economics

Title: Testing the Forward Rate Unbiasedness Hypothesis in Lebanon

After November 1998, the adjustable peg of the Lebanese pound to the US dollar played a major role in maintaining financial and price stability in the country. It also helped in the expansion of the economy and in massive capital inflows to the Lebanese market. Moreover, the high stock of assets in foreign currencies prevented Lebanon from any crisis that may hit the economy.

The thesis tests for the unbiased forward rate hypothesis as an optimal predictor of the future spot rate. It also supports the fact that the Lebanese pound became a perfect substitute to foreign currencies during the peg period.

The study is conducted for the period January 31, 1991 to October 31. The study is divided into two sub-periods. The first sub-period is prior to December 1998, which is renowned as the dirty float period, whereas the second sub period is after December 1998, which is referred to as the adjustable peg period.

The empirical results show that the unbiasedness forward rate hypothesis fails to be rejected during the adjustable peg period, whereas it is rejected in the earlier period. The rejection is due to a bias in the prediction by the forward rate, serial correlation, heteroscedasticity, non-normality of the residuals and a probable presence of a constant

and significant risk premium. Moreover, the empirical results reveal that the Lebanese pound became a perfect substitute to foreign currencies during the adjustable peg period.

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I. Introduction

A. An Overview of the History of the Currency

The material for the subsequent section is taken from Eiteman, Stonehill and Moffett (2007):

Gold is identified as a medium of exchange and a store of value since the days of the pharaohs. Gold coins were used by the Greek and the Romans, who also passed on this tradition through the mercantile era to the nineteenth century. The great increase in trade during the late nineteenth century created a need for a more formalized system for settling international trade balances. For this reason, countries started to set a rate at which their currency units could be converted to a weight of gold. The previously stated formalized system came to be known as the classical gold standard, which worked adequately until the outbreak of World War I.

Under the classical gold standard, countries had to maintain adequate reserves of gold to back the value of their currencies. The system also limited the rate at which countries could expand their money supply. Any expansion in the money supply was linked to the rate at which official authorities could acquire additional gold.

During World War I and the early 1920s, currencies were allowed to fluctuate with respect to gold and each other. Moderate changes in exchange rates were caused due to the changes in supply and demand for a country's exports and imports.

From 1934 to the end of World War II, exchange rates were supposedly set by the value of the currency in terms of gold. However, during World War II and its chaotic aftermath, some of the currencies lost their convertibility with respect to other currencies.

The material for the subsequent section is taken from Brigham and Daves (2004):

Every country has a financial system and a financial authority. For example, in the United States, the Federal Reserve is the financial authority. Its task is to control inflation while promoting economic growth and raising the national standard of living. In addition, if countries want to trade with one another, they must have a system intended to facilitate payments between each one another.

During the period extended from the end of World War II till August 1971, the world economy was characterized by a fixed exchange rate system, which was administered by the International Monetary fund. This system linked the US dollar to gold, and other currencies were then pegged to the US dollar. Exchange rates between currencies relative to the US dollar were controlled within narrow limits but then adjusted periodically.

Since March 1973, major trading nations have operated under a floating exchange rate system. In this system of trade exchange, rates are allowed to seek out for their own levels without much governmental intervention. Nevertheless, to smooth out exchange rate fluctuations, the central bank of each country intervenes to some extent by buying and selling its currency.

B. An Overview of the History of the Lebanese Currency

The material for the subsequent section is taken from the website of the Central Bank of Lebanon:

In 1943, as a result of the political independence of Lebanon, a new era of monetary independence started in the country.

On January 25, 1944, the parity of the Lebanese pound was set at £1 = LBP 8.83 = FF 176.60. This rate, which was set by the French-English-Lebanese-Syrian Protocol, could not be modified without prior consultation with the Lebanese and the Syrian governments.

On February 8, 1944, as a result of the devaluation of the French franc against the sterling, the Lebanese pound was not devalued as in the past. The official rate of the Lebanese pound was preserved at LBP 8.83 against the sterling, and it was set at 22.65 with respect to the French franc.

Lebanon became a member of the International Monetary Fund and of the World Bank on April 22, 1947. It informed the IMF Managing Director that the Lebanese pound was pegged to the French franc by the agreement of 1937. This agreement allows Bank of Syria and Lebanon to issue the Lebanese pound.

On January 24, 1948, the Lebanese and the French governments signed a monetary agreement under which the official rate of the Lebanese pound became the rate declared to the IMF. This agreement also separated the Lebanese pound from the Syrian pound due to the severance of the customs union between both countries.

With the agreement of 1948, the coverage of the Lebanese currency in French franc came to an end. The Lebanese pound was covered up to fifty percent by gold and by foreign currencies convertible to gold.

On December 1961, in order to improve the value of the Lebanese pound and to encourage capital inflows to Lebanon, Bank of Syria and Lebanon continued to increase the gold coverage of the national currency till it reached 92.2%.

On August 1, 1963, after the establishment of the Banque du Liban, the central bank of Lebanon, it was given the privilege of issuing the national currency. The exchange rate of the Lebanese pound was set against the US dollar, whose rate was set at 0.888671 gram of pure gold.

In accordance with the coverage of the Lebanese pound, the assets of the central bank must be comprised of funds in gold and foreign currencies that are, at least, equal to 30% of the total value of the issued currency and sight deposits. The only condition for this coverage is that the ratio of coverage in gold and foreign currencies must not be inferior to 50% of the value of the issued currency.

On October 5, 1973, a new exchange rate was set for the Lebanese pound against the US dollar, valued at 42.2222 ounces of pure gold and on the basis of the average closing rates of foreign currencies at the corresponding dates.

At present, the Lebanese pound is covered with 9,222,000 ounces of gold and US dollar reserves due to the economic activity, which is mainly carried out in dollar with a very high dollarization rate of bank deposits. Also, it is worth noting that in the future a

partial pegging of the Lebanese pound to the Euro might be considered, depending on the development of economic and commercial activities of Lebanon.

The material for the subsequent section is taken from Azar (2007 & 2008a):

In December 1998, the Banque du Liban pegged the Lebanese pound to the US dollar. The effect of this pegging was an unprecedented stability in the Lebanese foreign exchange market.

Lebanon has witnessed a stable period after the adjustable peg, which also enhanced the effectiveness of fiscal policy on growth. Another reason for the economic stability in Lebanon after the peg was the absence of conflict between monetary and fiscal policy.

A banking crisis or any financial crisis in Lebanon is an unlikely event, since currency convertibility was never abandoned. Moreover, the Lebanese economy is characterized by an intensive dollarization and freedom of exchange.

C. The Purpose of the Thesis

The aim of this thesis is to test for the unbiased forward rate hypothesis as an optimal predictor of the future spot rate. It also aims at supporting the fact that the Lebanese pound became a perfect substitute to foreign currencies during the peg period.

D. The Methodology of the Thesis

The study is conducted for the period January 31, 1991 to October 31, 2010 by using monthly exchange rate data, which are taken from the website of Banque du Liban. The study is divided into two sub-periods. The first sub-period is prior to December 1998, which is renowned as the dirty float period, whereas the second sub period is after December 1998, which is referred to as the adjustable peg period. Testing will be carried out to find out whether the two periods are alike in what concerns forward market efficiency.

E. The Structure of the Thesis

The thesis is organized as follows: The second part is the survey of the literature, which discusses the empirical findings of different authors. The third part is the theory, which will be used in the empirical part. Part four is the empirical analysis, which discusses the empirical finding of the study conducted for the period January 31, 1991 to October 31, 2010. Part five concludes the thesis.

II. Literature Review

A. Empirical Study of Hansen and Hodrick (1980)

The exchange rates which are studied in Hansen and Hodrick's paper are the Canadian dollar, Deutschemark, French franc, British pound, Swiss franc, Japanese yen, and the Italian lira relative to the US dollar. The study is conducted for the period

October 9, 1973 to January 16, 1979, by obtaining weekly data for the spot and 3-month or 13-week forward exchange rates for the seven currencies mentioned previously.

The empirical estimation of the unbiased forward rate hypothesis conducted by Hansen and Hodrick (1980) consists of running the following econometric models:

$$S_{t+13}^i - f_t^i = a_i + b_{i1}(S_t^i - f_{t-13}^i) + b_{i2}(S_{t-1}^i - f_{t-14}^i) + u_t^i \quad (1)$$

$$S_{t+13}^i - f_t^i = a_i + \sum_{j=1}^5 b_{ij}(S_t^j - f_{t-13}^j) + u_t^i \quad (2)$$

Where in Equation 1 and Equation 2, S_t and F_t are the levels of the spot rate and the forward rate. In Equation 2, j is the currency variable. In Equation 1, Hansen and Hodrick (1980) test the joint hypothesis that a_i , b_{i1} and b_{i2} are equal to zero, whereas in Equation 2, they test the joint hypothesis that a_i and $\sum b_j$ are equal to zero.

Results from testing Equation 1 conducted on the seven currencies reveal that the Deutschemark relative to the US dollar has the most damaging evidence against the null hypothesis. Although the constant is insignificantly different from zero, the reason for the damaging evidence is that the two lagged forecast errors in Equation 1 have marginal significance levels less than 0.02. Moreover, in case of the Swiss franc and the Italian lira test results reveal individual coefficient estimates having marginal significance level smaller than 0.1. Further tests related to Equation 1 reveal that the remaining currencies, which are the Canadian dollar, French franc, British pound, and the Japanese yen do not provide strong evidence against the null hypothesis.

In case of Equation 2, the test is conducted on five currencies, which are the Canadian dollar, Deutschemark, French franc, British pound, and Swiss franc, having the

same null hypothesis as Equation 1. Results from testing Equation 2 reveal that at all significance levels greater than 0.06 the null hypothesis is rejected in case of the Canadian dollar, Deutschemark, and the Swiss franc.

The biased results are mainly due to the time interval in which the test was conducted, which incorporates the especially volatile period from October 1973 to February 1974 characterized by the Arab-Israeli War and the oil embargo.

B. Empirical Study of Sanderson (1984)

The exchange rates which are studied in Sanderson's paper are the Deutschemark, British pound, and the Canadian dollar relative to the US dollar. The study is conducted for the period February 1972 to April 1979, by employing monthly data and using three-month forward rate.

The empirical estimation of the unbiased forward rate hypothesis conducted by Sanderson (1984) consists of running the following econometric model:

$$S_t = \beta_0 + \beta_1 F_{t-n} + \varepsilon_t \quad (3)$$

Where S_t and F_t are the logs of the spot rate and the forward rate, and n is the lagged period. In Equation 3, Sanderson (1984) tests the joint hypothesis that $\beta_0 = 0$, $\beta_1 = 1$, $E(\varepsilon_i, \varepsilon_j) = 0$ for $i \neq j$ in order to prove that market efficiency and absence of risk premium prevail.

Conducting the study by using monthly data caused a discrepancy between the forward contract maturity period and data frequency, which produced strong autocorrelation. Moreover, the study resulted in a downward bias of the standard errors for β_0 and β_1 , which, in its turn, favored the rejection of the null hypothesis. For this reason, the test was repeated, using quarterly data.

Although results from conducting the test using quarterly data showed a distinct enhancement in case of the Canadian dollar, in the case of the British pound and the Deutschemark, a number of the autocorrelation coefficient estimates were significant, which resulted in the rejection of the null hypothesis.

To test further for the unbiasedness hypothesis, Sanderson performs a similar test, using 30-day forward rates, which has the advantage of allocating a larger sample. Test results were very satisfactory, indicating that the coefficients of β_0 and β_1 were never significantly different from their hypothesized values. Moreover, the Box-Pierce Q-statistics did not indicate autocorrelation of the residuals, except for the Deutschemark.

The conclusion from the test results is that the Canadian dollar and the British pound are undoubtedly consistent with market efficiency, whereas there remains some doubt over the performance of the Deutschemark relative to the US dollar.

The probable reasons behind the inefficiency in the mark/dollar market are the existence of a risk premium which caused autocorrelation, or the inability of the market to use relevant information in forming its expectation of the future spot rate, or the absence of rational expectations.

C. Empirical Study of Chiang (1988)

The exchange rates which are studied in Chiang's paper are the Canadian dollar, French franc, Deutschemark, and the British pound relative to the US dollar. The study is conducted for the period January 1974 to August 1983 by using monthly exchange rate data. In addition, Chiang also uses 30-day forward rates in his study, to avoid potential autocorrelation involved in the data with overlapping periods.

The empirical estimation of the unbiased forward rate hypothesis conducted by Chiang (1988) consists of running the following econometric model:

$$S_t^j = \alpha + \beta F_{t-1}^j + \epsilon_t^j \quad (4)$$

Where S_t and F_t are the logs of the spot rate and the forward rate, α and β are the time invariant parameters, j is the exchange rate for country j and ϵ_t^j is the error term. The unbiased forward rate hypothesis consists of testing the joint null hypothesis that $\alpha = 0$, $\beta = 1$ and ϵ_t^j is white noise.

To test further for market efficiency, Chiang (1988) examines whether the lagged value of forward rate F_{t-2}^j still contains unexploited information. To proceed with the test, Chiang introduces the following logarithmic econometric model:

$$S_t^j = \alpha + \beta F_{t-1}^j + \gamma F_{t-2}^j + \epsilon_t^j \quad (5)$$

Where S_t and F_t are the logs of the spot rate and the forward rate, α is the constant, β is the slope, j is the exchange rate for country j and ϵ_t^j is the error term. The unbiased

forward rate hypothesis consists of testing the joint null hypothesis that $\alpha = 0$, $\beta = 1$ and ϵ_t^j is white noise.

Failure in rejecting the hypothesis that the forward rate is an unbiased predictor of the future spot rate implies that the coefficient of F_{t-2}^j is not significantly different from zero. This infers to testing the restriction $\gamma = 0$ by using a standard F-test or t-test.

With the exception of the constant term for the German mark, the results of the conducted tests show that at 5% level of significance neither the individual hypotheses that $\alpha = 0$ and $\beta = 1$ nor the joint hypothesis that $\alpha = 0$ and $\beta = 1$ can be rejected.

The Durbin-Watson statistics indicates lack of first order autocorrelation in each market.

Finally, at 5% significance level, all the coefficients on F_{t-2}^j in Equation 2 are not statistically significant, which means that F_{t-2}^j contains no significant increase in explanation S_t^j compared to Equation 1.

The test results indicate that the outcomes support the unbiased hypothesis of the forward foreign exchange markets.

D. Empirical Study of Copeland (1991)

The exchange rates which are studied in Copeland's paper are the Deutschemark, British pound, French franc, Swiss franc, and the Japanese yen relative to the US dollar.

The study is conducted for the period 1976 to 1990 by using daily exchange rate data and one-month forward rate contracts.

The empirical estimation of the unbiased forward rate hypothesis conducted by Copeland (1991) consists of running the following econometric model by cointegration analysis:

$$S_t = b_0 + b_1 F_{t-1} + u_t \quad (6)$$

Where S_t and F_t are the logs of the spot rate and the forward rate. In Equation, 6 Copeland (1991) tests the hypothesis that b_0 is zero and b_1 unity.

The study conducted by Copeland (1991) reveals the existence of highly significant but unstable lag patterns in the residuals of the cointegrating regressions, tested by the Box Pierce Q statistic, which was a long way above its critical value, often into the 0.1 percent tail of the distribution. Moreover, the autocorrelation coefficients were significantly different from zero for up to 30 lags and more. The study also shows the possibility of profit from forward market speculation.

The test results reveal that although the necessary cointegration condition is satisfied in Copeland's (1991) study, the sufficient conditions are certainly not. The necessary cointegration condition is satisfied due to the existence of at least one cointegrating vector, whereas the sufficient conditions are not satisfied because of autocorrelation and the probable presence of risk premium. This means that Copeland's (1991) study indicates that the forward rate is a biased predictor of the future spot rate.

E. Empirical Study of Corbae, Lim and Ouliaris (1992)

The exchange rates which are studied in Corbae, Lim and Ouliaris's paper are the Canadian dollar, Deutschemark, Swiss franc, French franc, Japanese yen, and the British pound relative to the US dollar. The study is conducted for the period January 2, 1976 to January 2, 1985 by using weekly data on exchange rates.

The empirical estimation of the unbiased forward rate hypothesis conducted by Corbae, Lim and Ouliaris (1992) consists of running the following econometric model:

$$S_{t+k}^i = \alpha_i + \gamma_i t + \beta_i f_{t,k}^i + \epsilon_{t+k}^i \quad (7)$$

Where S_t and F_t are the logs of the spot rate and the forward rate, i is the currency variable, and t is the time variable. Moreover, α_i should be equal to zero, β_i should be equal to one, γ_i should be equal to zero, and the test should indicate the absence of auto correlation.

Results from applying the Augmented Dickey-Fuller test reveal that at 5% significance level, the presence of a unit root in the spot and the forward rate cannot be rejected.

Test results reveal that at 10% and 5% significance level, the null hypothesis of cointegration cannot be rejected in case of all the countries found in the data set. In addition, at 5% significance level, the null hypothesis of forward rate unbiasedness is rejected in case of the Japanese yen and the Swiss franc.

Additional test results indicate that at 5% and 1% significance level, the Wald statistic rejects the null hypothesis that α_i should be equal to zero, β_i should be equal to

one and γ_i should be equal to zero for all the countries found in the data set. Moreover, the Wald statistic also rejects the zero risk premium hypothesis.

F. Empirical Study of Swanson (1998)

The exchange rates which are studied in Swanson's paper are the British pound, Canadian dollar, French franc, Deutschemark, and the Japanese yen relative to the US dollar. The study is conducted for the period January 1, 1986 to December 31, 1995 by using daily spot rates and 30-day forward exchange rates. Two sub-periods are noted with regards to each currency relative to the US dollar. The first-sub period is identified by the depreciation of the US dollar, whereas the second sub-period is recognized by the appreciation of the US dollar relative to the currencies mentioned in this study.

The empirical estimation of the unbiased forward rate hypothesis conducted by Swanson (1998) consists of running the following econometric models:

Forward Rate Model:

$$S_{t+1} = \alpha + \beta F_t + \alpha_{t+1} \quad (8)$$

Random Walk Model:

$$S_{t+1} = \alpha + \sigma S_t + \varepsilon_{t+1} \quad (9)$$

Where in Equations 8 and 9, S_t and F_t are the logs of the spot rate and the forward rate. Moreover, in Equations 8 and 9, market efficiency entails testing the joint hypothesis that $\alpha = 0$ and β and $\sigma = 1$.

The Augmented Dickey-Fuller unit root test is used to test for stationarity. Test results reveal that the spot and the forward rate of the British pound and the French franc, the spot rate of the Canadian dollar and the forward rate of the yen are stationary. Additional results reveal that the British pound, French franc, Canadian dollar, and the Japanese yen are not cointegrated with a cointegrating vector (1,-1). Moreover, only the Deutschemark is cointegrated with a cointegrating vector (1,-1).

Test results of Equation 8 reveal that the intercept is negative during the US dollar appreciation period, whereas it is positive during the depreciation period. Test results also show that the slope is negative in case of the Canadian dollar, Deutschemark, and the Japanese yen and is positive in case of the French franc and the British pound during the US dollar appreciation period. In addition, the slope is negative for all the currencies during the depreciation period.

Results from testing Equation 9 show that the outcomes of the intercept are similar to the ones of Equation 8. Test results also reveal that the slope is negative in case of the Deutschemark, the French franc, and the Japanese yen and is positive in case of the Canadian dollar and the British pound during the US dollar appreciation period. In addition, the slope is negative in case of the Deutschemark, the French franc, and the British pound and is positive in case of the Canadian dollar and the Japanese yen during the depreciation period.

Results from the rolling regression performed on the forward rate model and the random walk model indicate inconsistency in predicting future exchange rates. The main reason for obtaining such a result is the statistical significant differences, which were

originated between the means of the intercept and the slope coefficients during the US dollar depreciation and appreciation period.

G. Empirical Study of Choudhry (1999)

The exchange rates which are studied in Choudhry's paper are the Australian dollar, Canadian dollar, French franc, Deutschemark, Hong Kong dollar, Italian lira, Japanese yen, South African rand, and the British pound relative to the US dollar, except for the British pound, where it is dollars per pound sterling. The study is conducted for the period January 1985 to December 1996 by using one-month forward exchange rate.

The empirical estimation of the unbiased forward rate hypothesis conducted by Choudhry (1999) consists of running the following econometric models:

$$S_{t+k} = \alpha_0 + \alpha_1 f_t + \epsilon_{t+k} \quad (10)$$

$$S_{t+k} = \alpha_0 + \alpha_1 f_t + \alpha_2 f_{t-1} + \epsilon_{t+k} \quad (11)$$

$$S_{t+k} = \alpha_0 + \alpha_1 f_t + \alpha_3 S_t + \epsilon_{t+k} \quad (12)$$

Where in Equations 10, 11 and 12, S_t and F_t are the logs of the spot rate and the forward rate. In addition, Equation 10 is used to test for the unbiased rate hypothesis, whereas Equations 11 and 12 are used to test for semi-strong efficiency.

Results from testing Equation 10 reveal that the null hypothesis of $\alpha_0 = 0$ and $\alpha_1 = 1$ is rejected for all the currencies except for the Canadian dollar and South African rand. This means that at 5% significance level or above the unbiased hypothesis is

rejected in case of all the currencies except for the Canadian dollar and the South African rand.

Results from testing Equation 11 show that cointegration is rejected in case of the Australian dollar, Canadian dollar, Italian lira, and the British pound, whereas it is confirmed in all the remaining five cases. The null hypothesis of the unbiased hypothesis is rejected for all the currencies except for the Canadian dollar and South African rand. But only South Africa provides evidence of a semi-strong efficient forward market, since the conducted test fails to find in the Canadian market cointegration between the exchange rates.

Results from testing Equation 12 reveal that α_3 is positive in all cases but significant in case of Australia, Canada, Hong Kong, Japan, and South Africa. α_1 is negative in case of Australia, Canada, Hong Kong, Japan, and South Africa, but it is significant only in case of Hong Kong. Moreover, the null unbiased hypothesis is only accepted in case of South Africa. This means that in this case only the South African market provides evidence supportive of the semi-strong efficient forward market.

Results from testing the three Equations reveal that only South Africa supports both the weak-form and the semi-strong efficiency, whereas Canada supports the weak-form efficiency. The biased results of the unbiased forward rate hypothesis are probably due to a risk premium or irrational expectation errors.

H. Empirical Study of Ho (2002)

In his paper, Ho (2002) collects data from 17 OECD countries which are Australia, Austria, Belgium, Canada, Denmark, France, Germany, Hong Kong, Italy, Japan, Netherlands, Norway, Singapore, Spain, Sweden, Switzerland, and United Kingdom. The study is conducted over two periods, the first being for the period 01/01/1990 to 23/09/1999 and the second being for the period 23/05/1998 to 24/12/1998.

The empirical estimation of the unbiased forward rate hypothesis conducted by Ho (2002) consists of running the following econometric model:

$$S_{t+n} = \alpha + \beta f_t + \varepsilon_{t+1} \quad (13)$$

Where S_t and F_t are the levels of the spot rate and the forward rate. Moreover, the forward rate unbiasedness hypothesis consists of testing the joint hypothesis that $\alpha = 0$ and $\beta = 1$.

In accordance with the study conducted over the period of 01/01/1990 to 23/09/1999 by using cointegration to test for forward rate unbiasedness hypothesis (FRUH) with the inclusion of 2035 observations, it is revealed that at 5% significance level 10 out of 17 countries reject the FRUH. These countries are Australia, Canada, Germany, Italy, Japan, Norway, Spain, Sweden, Switzerland, and UK.

Further analysis is conducted over the period of 23/05/1998 to 24/12/1998 by using a small sample of 153 observations. The study reveals that at 5% significance level 12 out of 17 countries reject the FRUH, which are Austria, Belgium, Canada, Denmark, France, Germany, Hong Kong, Japan, Netherlands, Singapore, Spain, and Sweden.

Being unsatisfied with the test results, Ho (2002) uses the LM statistic to test for panel cointegration. Test results reveal that the value of the LM statistic is around 0.95, which supports the cointegration between the spot rate and the one-month forward rate. In addition, the value of the t-statistic for the joint hypothesis ($\alpha = 0$ and $\beta = 1$) is around 0.4, which accepts the forward rate unbiasedness hypothesis at any possible significance level.

I. Empirical Study of Hodgson, Linton and Vorkink (2004)

The exchange rates which are studied in Hodgson, Linton and Vorkink's paper are the Japanese yen, British pound, and the Canadian dollar relative to the US dollar. To test for forward market unbiasedness, the authors use daily and weekly data of spot and future exchange rates. The daily data ranges from January 1998 to December 2001, whereas the weekly data ranges from January 1993 to December 2001.

Hodgson, Linton and Vorkink (2004) use the cointegrated model and the stationary model to conduct the forward market unbiasedness test. The two regression Equations related to the cointegrated model and the stationary model are the following:

Stationary Model:

$$S_{t+1} - S_t = \alpha + \beta(f_t - S_t) + u_{t+1} \quad (14)$$

Cointegrated Model:

$$S_{t+1} = \alpha + \beta f_t + u_{t+1} \quad (15)$$

Where S_t and F_t in Equation 14 are the logs of the spot rate and the forward rate, whereas S_t and F_t in Equation 15 are the levels of the spot rate and the forward rate. In addition, the forward rate unbiasedness hypothesis consists of testing the joint hypothesis that $\alpha = 0$ and $\beta = 1$.

Test results reveal that at 5% significance level the Augmented Dickey-Fuller (ADF) test rejects the presence of a unit root for all the series, when the spot and forward rates are converted to percentage changes for the stationary model. Moreover, the Box-Pierce test shows little evidence of serial correlation, with the exception in the weekly data for the British pound.

Comparing the results obtained by using the OLS method and the semiparametric adaptive estimator, it is revealed that the null hypothesis ($\alpha = 0$ and $\beta = 1$) is actually accepted for both estimators with daily data and is rejected with weekly data.

J. Empirical Study of McMillan (2005)

The exchange rates which are studied in McMillan's paper are the Canadian dollar, French franc, Deutschemark, Japanese yen, and the British pound relative to the US dollar. The study is conducted for the period January 1, 1986 to September 10, 1999 by using daily spot and one-month forward exchange rate quotations.

The empirical estimation of the unbiased forward rate hypothesis conducted by McMillan (2005) consists of running the following econometric model:

$$f_t = \alpha_0 + \alpha_1 S_t + \varepsilon_1 \quad (16)$$

Where S_t and F_t are the logs of the spot rate and the forward rate. The constant parameter (α_0) should be insignificantly different from zero, and the cointegrating parameter (α_1) should be equal to one. Moreover, the regression should indicate the absence of autocorrelation of the residuals.

The Augmented Dickey-Fuller unit root test supports the presence of a unit root in the log spot and log forward rates, which is a precondition for the existence of cointegration. In addition, to support the unbiasedness hypothesis, the spot and the forward rate should be cointegrated with a cointegrating vector (1,-1).

The test results reveal the presence of cointegration between the log spot and the log forward rates for all countries considered. Moreover, the estimated cointegrating parameters appear close to their hypothesized values supporting the hypothesis that the forward rate is an unbiased predictor of the future spot rate.

However, a likelihood ratio test that the parameter α_1 is equal to one reveals that the null hypothesis is rejected by a large margin for all series. This means that the forward rate provides a biased predictor of the future spot rate probably due to time-varying risk premium.

K. Empirical Study of Kenourgios, Samitas and Christodoulou (2006)

The exchange rates which are studied in Kenourgios, Samitas and Christodoulou's paper are the British pound, Japanese yen, and the Deutschemark

relative to the US dollar. The study is conducted for the period May 31, 1994 to July 31, 2004 by using spot rates and 3-, 6-, and 12-months forward exchange rate data.

The empirical estimation of the unbiased forward rate hypothesis conducted by Kenourgios, Samitas and Christodoulou (2006) consists of running the following econometric models:

$$S_t = \alpha + \beta F_{t-k} + \varepsilon_t \quad (17)$$

$$S_{t+k} - S_t = \alpha + \beta(F_t - S_t) + \varepsilon_t \quad (18)$$

Where S_t and F_t in Equations 17 and 18 are the logs of the spot rate and the forward rate and the hypothesis being tested is $\alpha = 0$ and $\beta = 1$. Moreover, $(F_t - S_t)$ in Equation 18 is the time varying forward discount.

Results from applying the Augmented Dickey-Fuller and Phillips Perron tests reveal that at 5% and 1% significance level, the presence of a unit root is not rejected in case of the British pound. On the other hand, the presence of a unit root is rejected in case of the Japanese yen and the Deutschemark.

Cointegration test results in the long run related to Equation 17 reveal that the British pound is the only currency which is cointegrated with a cointegrating vector (1,-1). Cointegration is found in the Japanese yen and the Deutschemark only when the first differences are taken into consideration.

Test results of Equation 18 in the short run support the presence of serial correlation. Moreover, at 5% significance level the forward rate unbiasedness hypothesis

is rejected in case of all the currencies tested in this study, since the coefficient α is not close to 0 and the estimated slope coefficient β is not close to 1.

As a result of investigating the exchange market efficiency in the long run and in the short run, Kenourgios, Samitas and Christodoulou (2006) conclude that market efficiency is verified in the long run due to the presence of cointegration, and is rejected in the short run due to the presence of serial correlation.

L. Empirical Study of Azar (2008a)

The exchange rates which are studied in Azar's paper are the Lebanese pound relative to the US dollar and relative to the Euro. The study is conducted from end January 1991 to end June 2003 by using monthly data. Two sub-periods are noted in this study. The first sub-period is before December 1998, which is identified as the dirty float period, whereas the second sub-period is after December 1998, which is recognized as the adjustable peg period.

The empirical estimation of the unbiased forward rate hypothesis conducted by Azar (2008a) consists of running the following econometric model:

$$S_{t+1} = \alpha + \beta f_t + \varepsilon_{t+1} \quad (19)$$

Where S_t and F_t are either the levels or the logs of the spot rate and the forward rate. The joint hypothesis tested is $\alpha = 0$ and $\beta = 1$ in order to prove that forward rate unbiasedness prevails.

With respect to the euro during the floating period, test results support the presence of first-order serial correlation. Moreover, the constant is significant, and the slope is significantly different from one, which results in the rejection of the forward rate unbiasedness hypothesis.

Azar (2008a) uses the $\sum_{i=0}^7 \varepsilon_{t+1-i}^2$ as a measure of risk premium to test for time-varying risk premium in the log-log version. Test results reveal the absence of a significant time-varying risk premium in the second-pass AR1 regression. Moreover, the risk premium in the OLS regression is significant. In case of the implied Coefficients of Relative Risk Aversion (CRRA) the values are between 2.0602 and 2.2718 respectively for the two regression specifications. This implies that they are of a reasonable magnitude.

With regard to the US dollar during the floating period, test results are similar to the results of the euro during the same period, indicating the presence of first-order serial correlation. The floating period of the US dollar is characterized by a constant which is significant and a by a slope which is significantly different from one, resulting in the rejection of the forward rate unbiasedness hypothesis.

During the peg period, test results of the Euro reveal the absence of serial correlation. In addition, the constant is insignificant, and the slope is statistically insignificantly different from 1, which means that the joint hypothesis of $\alpha = 0$ and $\beta = 1$ is not rejected.

In conclusion, the peg period is characterized by stability and efficiency due to the absence of serial correlation and time-varying risk premium, whereas the floating

period did not support the forward rate unbiasedness hypothesis due to the presence of serial correlation and forward market inefficiency.

M. Empirical Study of Aggarwal and Zong (2008)

The exchange rates which are studied in Aggarwal and Zong's paper are the Canadian dollar, British pound, Deutschemark, French franc, Italian lira, Dutch guilder, Swiss franc, Belgian franc and the Japanese yen relative to the US dollar. The study is conducted for the period 1981 to 1995 by using weekly spot and 90-day and 180-day forward exchange rate data.

The empirical estimation of the unbiased forward rate hypothesis conducted by Aggarwal and Zong (2008) consists of running the following econometric models:

$$FE_t = \alpha + \beta FR_t + \mu_t \quad (20)$$

$$FE_t = \alpha_0 + \alpha_1 PSCH_{t-1} + e_t \quad (21)$$

Where FE , FR , and $PSCH$ stand for forward error, forward revision, and prior spot rate change. Moreover, $FE_t = ({}_tF_{t+1} - S_{t+1})$, $FR_t = [({}_{t-1}F_{t+1}) - ({}_tF_{t+1})]$ and $PSCH_t = (S_{t-1} - S_{t-2})^2$.

The null hypothesis of rationality in Equation 20 consists of testing $\alpha = \beta = 0$. Positive α means optimism, and negative α means pessimism, whereas positive β means over-reaction, and negative β means under-reaction to new information.

Results from applying the Augmented Dickey-Fuller unit root test reveal that except for the 90-day level forward rate of the French franc, all level spot rates, level forward rates, and forward premiums have unit root in the level series.

Applying the cointegration tests for the spot and 90-day forward rate, and for the spot and 180-day forward rate for each currency, reveals the absence of cointegrating vector (1,-1) for about half the currencies mentioned in Aggarwal and Zong's study.

Test results of Equation 21 reveal that the coefficients of $PSCH_t$ for all currencies are statistically significantly positive, which means that the forward rates under-react to information in prior changes in the spot rate.

In accordance with Equation 20, test results reveal significant negative coefficients for the intercept and FR . These results may indicate non-rationality, pessimism, and under-reaction to new information, which cause the rejection of the null hypothesis of rationality.

N. Empirical Study of Azar (2008b)

The exchange rates which are studied in Azar's paper are the Lebanese pound relative to the US dollar and relative to the Euro. The study is conducted from end January 1991 to end June 2006 by using monthly data. Two sub-periods are noted in this study. The first sub-period is before December 1998, which is identified as the dirty float period, whereas the second sub period is after December 1998, which is recognized as the adjustable peg period.

The empirical estimation of the unbiased forward rate hypothesis conducted by Azar (2008b) consists of running the following econometric model:

$$S_{t+1} = \alpha + \beta F_t + \epsilon_{t+1} \quad (22)$$

Where S_t and F_t are the logs of the spot rate and the forward rate and the hypotheses being tested in relation to the econometric model are the following:

- H1: The residual ϵ is normally distributed
- H2: $\alpha = 0$
- H3: $\beta = 1$
- H4: $\alpha = 0$ and $\beta = 1$ jointly
- H5: The residual ϵ has zero mean and is not serially correlated

The Phillips and Perron unit root tests support the integration of Order 1 of the log spot and the log forward rate. This means that the spot and the forward rate follow a random walk, regardless of the sample period and the currency. The first differences of the spot and the forward rates are integrated of Order 0, which means that they are stationary in distribution. Therefore, they have a constant mean and a constant variance regardless of the sample period and the foreign currency.

With regards to the adjustable peg period, test results of the Euro support the presence of cointegration between the future spot rate and the current forward rate. This means that the residual ϵ is normally distributed with a zero mean and is not serially correlated. In addition, test results show that hypotheses H2, H3, and H4 fail to be

rejected due to the fact that the constant is not significant statistically and the slope is statistically insignificantly different from 1.

During the dirty float period, test results of the Euro reveal the absence of cointegration for the euro exchange rate. The residual ϵ is not normally distributed and is serially correlated. Moreover, test results reveal that hypotheses H2, H3, and H4 are rejected, since the constant is statistically significant and the slope is significantly different from 1. The statistical significance of the intercept indicates the presence of a constant foreign exchange risk premium.

With respect to the US dollar during the dirty float period, test results are similar to the results of the euro during the same period indicating the absence of cointegration. The dirty float period for the US dollar is characterized by non-normality and the presence of serial correlation. In this case also, the constant is statistically significant, and the slope is significantly different from 1; therefore, hypotheses H2, H3, and H4 are rejected. The rejection of hypothesis H2 is probably due to the presence of a time-variable foreign exchange risk premium.

In conclusion, all the results reveal that the unbiased forward rate hypothesis holds during the adjustable peg period, where investors are risk neutral or the domestic and foreign currencies are perfect substitutes.

O. Empirical Study of Thornton (2009)

The exchange rates which are studied in Thornton's paper are the Canadian dollar, British pound, Swiss franc, Japanese yen, Belgian franc, Italian lira, French franc, Dutch guilder, and the Deutschemark relative to the US dollar. The Canadian dollar, British pound, Swiss franc, and the Japanese yen are studied for the period December 1978 to January 2002, whereas the Belgian franc, Italian lira, French franc, Dutch guilder, and the Deutschemark are studied for the period December 1978 to December 1998.

The empirical estimation of the unbiased forward rate hypothesis conducted by Thornton (2009) consists of running the following econometric model:

$$S_{t+1} = \alpha + \beta f_t + v_{t+1} \quad (23)$$

Where S_t and F_t are the logs of the spot rate and the forward rate. The hypotheses being tested with regards to the econometric model are $\alpha = 0$ and $\beta = 1$. Moreover, the study is conducted by employing end-of-month foreign currency per US dollar spot and forward exchange rates data.

Test results reveal that at 5% percent significance level the unbiased forward rate hypothesis fails to be rejected in case of all the currencies except for the Italian lira and the French franc.

The high estimates of R^2 , the constant which is statistically insignificant and the slope which is statistically insignificantly different from 1 were the reasons for failing to reject the unbiased forward rate hypothesis.

III. The Theory

A. The Tested Hypotheses

The hypotheses which will be tested in the empirical part are the following:

- The residual ε is normally distributed
- $\alpha = 0$
- $\beta = 1$
- $\alpha = 0$ and $\beta = 1$ jointly
- The residual ε is not auto correlated

If market efficiency does not hold, the time-varying risk premium will be equal to $\log S_{t+1} - \log F_t$. Therefore, the risk premium of all currencies will be compared to the US dollar. Two tests will be undertaken: the first one with separate regressions and the second one with joint regressions. Moreover, a model for the risk premium is introduced and its significance is tested by separate and joint regressions.

The econometric models which will be used in the empirical part are the following:

- Model 1: $DIF_t = \ln(S_{t+1}) - \ln(F_t)$
- Model 2: $\ln(S_{t+1}) = \beta_0 + \beta_1 D_t + \beta_2 \ln(F_t) + \beta_3 D_t \ln(F_t) + \varepsilon_{t+1}$
- Model 3: $\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2$
- Model 4: $DIF_t = \gamma_0 + \gamma_1 DIF_t(USD) + v_t$
- Model 5: $DIF_t = \ln(S_{t+1}) - \ln(F_t) = \lambda_0 + \lambda_1 (d(\ln(USD_t)))^2 + \xi_t$

In Model 1 S is the spot foreign exchange rate in domestic units per foreign currency, F is the forward foreign exchange rate, and the symbol \ln is for the natural logarithm.

In Model 2 S is the spot foreign exchange rate in domestic units per foreign currency, F is the forward foreign exchange rate, the symbol \ln is for the natural logarithm, and the variable D is a dummy that takes the value 1 between January 1991 and November 1998, and the value zero otherwise.

In Model 3 α_1 and α_2 are the parameters of the model of the conditional volatility.

In Model 4 the aim is to prove that the risk premium of a foreign currency is proportionately related to the risk premium of the US dollar by testing the hypothesis that $\gamma_1 = 1$ or by testing the joint hypothesis that $\gamma_0 = 0$ and $\gamma_1 = 1$.

In Model 5 S is the spot rate at time $t + 1$, F is the forward rate at time t , λ_1 is a measure of relative risk aversion, and $(d(\ln(USD_t)))^2$ is the square of the percentage change in the US dollar at time t for the period January 1991 to November 1998.

B. The Significance Level

The significance level is the probability of rejecting the null hypothesis when it is true. It is also sometimes called the level of risk (Lind, Marchal and Wathen, 2005).

There is no one level of significance that is applied to all tests. A decision is made to use the 0.05 level, the 0.01 level, the 0.10 level, or any other level between 0 and 1. Traditionally, the 0.05 level is selected for consumer research projects, for quality assurance, and for financial data. The researcher must decide on the level of significance before a decision rule and collecting sample data (Lind, Marchal and Wathen, 2005).

Since the thesis is concerned with finance, therefore the 0.05 significance level is chosen to be implemented in the empirical part.

C. The Forward Rate

The forward rate is an exchange rate that is quoted today to be settled at some future date. A forward exchange agreement among currencies identifies the exchange rate at which a foreign currency will be bought forward or sold forward at a specific date in the future. A forward rate agreement typically occurs after 30, 60, 90, 180, 270, or 360 days from the day of the agreement (Eiteman, Stonehill and Moffett, 2007).

For any maturity date, the forward rate is calculated by adjusting the current spot exchange rate by the ratio of foreign currency interest rates of the same maturity for the two subject currencies (Eiteman, Stonehill and Moffett, 2007). A forward rate is calculated as follows:

$$F_{Days}^{LL/USD} = S_{Days}^{LL/USD} \times \frac{[1 + (i^{LL} \times \frac{Days}{360})]}{[1 + (i^{USD} \times \frac{Days}{360})]} \quad (24)$$

Where USD is the foreign currency and LL is the domestic currency (Eiteman, Stonehill and Moffett, 2007).

The forward premium or discount is the percentage difference between the spot and the forward exchange rate. The end result is stated in annual percentage terms. When the foreign currency price of the home currency is used, the formula for the forward premium or discount becomes the following (Eiteman, Stonehill and Moffett, 2007):

$$f^{LL} = \frac{\text{Spot} - \text{Forward}}{\text{Forward}} \times \frac{360}{\text{Days}} \times 100 \quad (25)$$

A positive sign in Equation 25 indicates that the foreign currency is selling at a forward premium over the domestic currency, whereas a negative sign indicates that the foreign currency is selling at a forward discount relative to the domestic currency (Eiteman, Stonehill and Moffett, 2007).

D. The Central Limit Theorem

The Central Limit Theorem states that, for large random samples, the shape of the sampling distribution of the sample mean is close to a normal probability distribution. The approximation is more accurate for large samples than for small samples. This is one of the most useful conclusions in statistics (Lind, Marchal and Wathen, 2005).

Because of the Central Limit Theorem the average of the regression residuals is approximately normally distributed.

E. Uncovered Interest Parity

The concept of interest parity recognizes that portfolio investors should earn the same return on security investments in all countries after adjusting for risk. Therefore, when an investor invests in a country other than the home country, the effect of two forces arise, which are returns on the investment itself and changes in exchange rate. It is identified that the investor's overall return will be higher than the investment's stated return if the currency in which the investment is denominated appreciates relative to the home currency. On the other hand, the overall return of the investor will be lower if the foreign currency received declines in value (Brigham and Daves, 2004).

Investors borrow in countries and currencies denoted by having relative low interest rates and convert the proceeds into a currency that offers much higher interest rate. Some investors leave their foreign currency positions uncovered because they choose not to sell the higher yielding currency proceeds forward and accept the currency risk of exchanging the higher yield currency into the lower yielding currency at the end of the period (Eiteman, Stonehill and Moffett, 2007).

Assuming that investors are risk neutral, the uncovered interest parity emphasizes that the expected returns from investing in the domestic currency is equal to the foreign values of investing abroad (Kenourgios, Samitas and Christodoulou, 2006). The expression for the uncovered interest parity is the following:

$$\log[E_t S_{t+1}(1 + I_t^*)] = \log[S_t(1 + I_t)] \quad (26)$$

Where I_t is the domestic interest rate; I_t^* is the foreign interest rate; S_t is the nominal spot exchange rate at time t , and $E_t S_{t+T}$ is the expectation of the spot nominal exchange rate (Kenourgios, Samitas and Christodoulou, 2006).

The logarithmic expression of Equation 26 indicates that the interest rate differential is equal to the difference between the expected value of the spot exchange rate formulated at time $t + 1$ and the spot exchange rate formulated at time t (Kenourgios, Samitas and Christodoulou, 2006). Therefore the expression becomes the following:

$$I_t - I_t^* = \log E_t(S_{t+1}) - \log(S_t) \quad (27)$$

If in Equation 27, inequality occurs, then investors will have the ability to make arbitrage profits (Kenourgios, Samitas and Christodoulou, 2006). For example, if the expression is the following:

$$I_t - I_t^* < \frac{E_t S_{t+1} - S_t}{S_t} \quad (28)$$

Then, in order to make arbitrage profits, investors would borrow an amount of the domestic currency, convert the proceeds into a foreign currency, and invest in the country of the foreign currency which offers a higher interest rate. This transaction will lead to the appreciation of the currency of the foreign country against the domestic currency. It will also lead to an upward movement of the interest rate of the domestic currency and a downward movement of the interest rate of the foreign currency (Kenourgios, Samitas and Christodoulou, 2006).

Another type of inequality resulting in Equation 27, which will also enable investors to make arbitrage profits is the following:

$$I_t - I_t^* > \frac{E_t S_{t+1} - S_t}{S_t} \quad (29)$$

In this case, in order to make arbitrage profits, an investor has to borrow an amount of the currency of the foreign country, convert the proceeds into the domestic currency, and invest in the domestic country which offers a higher interest rate. This transaction will be identified by the appreciation of the currency of the domestic country against the currency of the foreign country. It will result by an upward movement of the interest rate of the foreign currency and a downward movement of the interest rate of the domestic currency (Kenourgios, Samitas and Christodoulou, 2006).

In Equations 28 and 29, the interest rates will continue to fluctuate until the interest differential will be equalized with the spot exchange rate differential ($E_t S_{t+1} - S_t$) (Kenourgios, Samitas and Christodoulou, 2006).

F. Testing for Uncovered Interest Parity

The uncovered interest parity assumption is difficult to test, since market expectations of future exchange rates are not directly observable. Consequently, uncovered interest parity has generally been linked with the assumption that exchange market participants form rational expectations. Hence, the future realizations of the exchange rate will be equated to the value expected at time t plus an error term that is

serially uncorrelated with the information known at time t (Isard, 2006). Together, the two assumptions are expressed in the following way:

$$S_{t+1} = f_t + u_{t+1} \quad (30)$$

And hence

$$\log(S_{t+1}) - \log(S_t) = I_t - I_t^* + u_{t+1} \quad (31)$$

Where S_t and F_t in Equation 30 are the logs of the spot rate and the forward rate, and u in Equations 30 and 31 is the prediction error (Isard, 2006).

In order to assess the uncovered interest parity assumption empirically, economists estimate the values of α and β by testing the following econometric models:

$$S_{t+1} = \alpha + \beta f_t + u_{t+1} \quad (32)$$

And

$$\frac{S_{t+1} - S_t}{S_t} = \alpha + \beta(I_t - I_t^*) + u_{t+1} \quad (33)$$

Where the assumption is that the error terms are serially uncorrelated and have a zero mean (Isard, 2006).

Empirical assessments of uncovered interest parity as a predictor of the future spot exchange rate have realized two issues, which are the size of the prediction errors and the question of whether the predictions are systematically biased (Isard, 2006).

With respect to the size of the prediction errors, it has become generally recognized that interest differentials explain only a small percentage of successive changes in

exchange rates. This finding entails that pragmatic changes in exchange rates are primarily the result of unexpected information or “news” about economic developments, policies, or other relevant factors (Isard, 2006).

In case of the question of whether the predictions are systematically biased, the forward rate unbiasedness hypothesis can be assessed by testing whether $\alpha = 0$ and $\beta = 1$ in Equations 32 and 33. Studies based on Equation 32 strongly support the test that the slope coefficient is equal to unity, whereas studies based on Equation 33 soundly reject the test that $\beta = 1$ at least for prediction horizons of a year or less (Isard, 2006).

Although the unbiased hypothesis is rejected at prediction horizons of up to one year, the evidence is much more favorable to unbiasedness at prediction horizons of five to twenty years. Particularly, the slope coefficients in Equation 32 become insignificantly different from unity when data for industrial countries are pooled, and when annual exchange rates change and interest differentials are averaged over non-overlapping five- to twenty-year periods (Isard, 2006).

G. Weak-Form Market Efficiency

Market efficiency, which is one of the most important concepts in finance, deals with informational efficiency that measures how quickly and accurately the market reacts to new information (Strong, 2007). An efficient market is the market in which prices at any time fully reflect all available information (Fama, 1970). According to Grossman and Stiglitz (1980), the requirement of obtaining market efficiency is that the cost of information and trading profits must always be equal to each other.

The weak-form market efficiency according to Strong (2007) states that future prices can't be accurately predicted by analyzing prices from the past. If weak-form market efficiency prevails, it is impossible for investors to make continuously superior profits by studying past returns. This means that prices will follow a random walk (Brealey, Myers and Allen, 2008).

H. Random Walk Model

In accordance with market efficiency, the statement which states that prices at any time fully reflect all available information was assumed to imply that successive price changes are independent. Moreover, successive price changes were usually assumed to be identically distributed. The two hypotheses stated previously form the random walk model (Fama, 1970). To be more precise, the model is stated in the following way:

$$f(r_{j,t+1}|\phi_t) = f(r_{j,t+1}) \quad (34)$$

Where f is the density function of the conditional and marginal probability distribution, $r_{j,t+1}$ is the one-period percentage return, j is the currency, and ϕ_t symbolizes a set of information assumed to be fully reflected in the price at time t (Fama, 1970).

The statistical meaning for independence is that the probability distribution for the price change during time period t and the sequence of price changes during previous time periods are independent. This means that knowledge of the sequence of price changes leading up to time period t does not help in estimating the probability distribution for the price change during time period $t + 1$ (Fama, 1965).

Concerning the distribution, the hypothesis says that the price changes conform to some probability distribution. In relation to the random walk model, the form or shape of the distribution does not need to be specified. Consequently, any distribution is consistent with the theory as long as it properly distinguishes the procedure causing the price changes (Fama, 1965).

Therefore, the random walk model only prevails when the knowledge of the past behavior of the series of price changes cannot be used by investors or market participants to increase expected gains (Fama, 1965).

IV. Empirical Analysis

A. The Data

The study is conducted for the period January 31, 1991 to October 31, 2010 by using monthly exchange rate data. The domestic interest rates and the price in Lebanese pounds of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar are taken from the web page of Banque du Liban, which is the central bank of Lebanon. The interest rates are taken from Economagic and Econstats.

The study is divided into two sub-periods. The first sub-period is prior to December 1998, which is renowned as the dirty float period, whereas the second sub-period is after December 1998, which is referred to as the adjustable peg period.

The study comprises of eleven samples, which are the following:

- Two samples of the Canadian dollar before and during the peg

- Two samples of the Swiss franc before and during the peg
- Two samples of the Euro before and during the peg
- Two samples of the British pound before and during the peg
- Two samples of the Japanese yen before and during the peg
- One sample of the pre-peg US dollar model

B. Unit Root Tests

Table 1 shows the results of testing for a unit root using the KPSS (1992) method. Even at 10% significance level, test results do not support the presence of a unit root, and the null hypothesis of stationarity fails to be rejected in case of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998. Hence, the weak form market efficiency is not satisfied. Reasons for inefficiency may be the following:

- Compensation for the risk of speculation
- Compensation for research costs
- Presence of transaction costs
- Mathematical feasibility but economical infeasibility
- Presence of liquidity constraints on speculation
- Presence of abnormal profits ex post but not ex ante
- Presence of mean reversion in the long run
- Post-crisis political uncertainty
- Post-crisis macroeconomic uncertainty

- Just inefficiency

These inefficiency reasons are for the period before November 1998. In this period, the random walk model did not hold, which means that exchange rates were predictable.

Mathematical feasibility but economical infeasibility means that exchange rates are predictable by past exchange rates. This implies that the model does not follow a random walk. However, market participants cannot take advantage of this predictability in real life supposedly because of transaction costs.

Presence of abnormal profits ex post but not ex ante means that by hind sight or ex post there are abnormal profits. However, by ex ante or before the fact abnormal profits do not exist.

Presence of mean reversion in the long run means that foreign exchange rates revert to a certain value in the long run.

At 1% significance level, test results support the presence of unit root, and the null hypothesis of stationarity is rejected in case of the Canadian dollar, Swiss franc, and the Euro for the period December 1998 to October 2010. In addition, at 1% and 5% significance level test results support the presence of unit root, and the null hypothesis of stationarity is rejected in case of the British pound and the Japanese yen for the period extended between December 1998 and October 2010. Therefore, the weak form market efficiency is satisfied for the period mentioned in the previous statement.

C. Time-Varying Risk Premium and Forecast Error

Table 2 presents the statistics on the variable DIF for each currency and each sample period. This variable is a measure of both the time-varying risk premium and the forecast error. It also indicates the presence of autocorrelation by applying the Ljung-Box Q-statistic for the two periods. For each currency, the variable DIF is calculated as follows:

$$DIF_t = \ln (S_{t+1}) - \ln (F_t) \quad (35)$$

Where S is the spot foreign exchange rate in domestic units per foreign currency, F is the forward foreign exchange rate, and the symbol \ln is for the natural logarithm.

Test results for the period January 1991 to November 1998 reveal that for the lag periods 6, 12 and 18, the probability of the Q-statistic is less than 5% significance level for all the currencies, which supports the presence of time-varying risk premium and the presence of autocorrelation.

Test results for the period December 1998 to October 2010 reveal that for the lag periods 6, 12 and 18, the probability of the Q-statistic is greater than 5% significance level in case of the Canadian dollar, Swiss franc, Euro, and the Japanese yen, which supports the absence of time-varying risk premium and the absence of autocorrelation. However, in case of the British pound, test results reveal that for the lag periods 6, 12 and 18, the p-value of the Q-statistic is less than 5% significance level, supporting the presence of autocorrelation for the period December 1998 to October 2010.

In conclusion, Table 2 supports the presence of time-varying risk premium and the presence of autocorrelation in case of all the currencies for the period January 1991 to November 1998. On the other hand, Table 2 supports the absence of time-varying risk premium and the absence of autocorrelation in case the Canadian dollar, Swiss franc, Euro, and the Japanese yen for the period December 1998 to October 2010. The only exception is the British pound, supporting the presence of time-varying risk premium and the presence of autocorrelation for the period December 1998 to October 2010.

D. Forward Market Efficiency

Table 3 tests for forward market efficiency. The empirical estimation consists of running the following econometric models:

$$\ln(S_{t+1}) = \beta_0 + \beta_1 D_t + \beta_2 \ln(F_t) + \beta_3 D_t \ln(F_t) + \varepsilon_{t+1} \quad (36)$$

$$\varepsilon_t \sim (0, \sigma_t^2) \quad (37)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 \quad (38)$$

Where in Equation 36, S is the spot foreign exchange rate in domestic units per foreign currency, F is the forward foreign exchange rate, the symbol \ln is for the natural logarithm, and the variable D is a dummy that takes the value 1 between January 1991 and November 1998, and the value zero otherwise.

The period extended between January 1991 and November 1998, where the dummy variable D takes the value of 1, is designated by an intercept = $\beta_0 + \beta_1$ and a

slope = $\beta_2 + \beta_3$. In the period mentioned previously, β_1 and β_3 should be significantly different from zero if the two periods are different. On the other hand, the period extended between December 1998 and August, or September or October 2010, depending on the sample period of each currency, where the dummy variable D takes the value of 0, is designated by an intercept = $\beta_0 = 0$ and a slope = $\beta_2 = 1$ if forward market efficiency holds.

The AR(1) and the MA(1) are the autoregressive variable adjustments for serial correlation. They are calculated only in the case of the Canadian dollar and the US dollar due to the presence of autocorrelation.

Table 3 also calculates the values of α_1 and α_2 , which are the parameters of the model of the conditional volatility. If $\alpha_2 < 1$ and $\alpha_1 + \alpha_2 < 1$, this indicates that the variance of the residuals is stationary. Results of α_2 indicate that the variance of all the residuals are stationary, since all the values are less than 1. In addition, results of $\alpha_1 + \alpha_2$ also indicate that the variance of the residuals of all the currencies are stationary, since all the values are less than 1.

The hypothesis that $\beta_1 = \beta_3 = 0$ tests if the second period is the same as the first period. If forward market efficiency holds for the post-1998 period, it also holds for the pre-1998 period. On the other hand, the hypothesis that $\beta_0 = 0$ and $\beta_2 = 1$ tests for forward market efficiency for the post-1998 period.

Test results for the period January 1991 to November 1998 reveal that at 5% significance level, the hypothesis $\beta_1 = \beta_3 = 0$ fails to be rejected in case of the British pound and the Japanese yen. On the other hand, the hypothesis is rejected in case of the

Canadian dollar, Swiss franc, Euro, and the US dollar. Therefore, if $\beta_1 = \beta_3 = 0$ is rejected, it means that the period before December 1998 supports inefficiency.

Test results for the period December 1998 to October 2010 reveal that at 5% significance level, the hypothesis $\beta_0 = 0$ and $\beta_2 = 1$ fails to be rejected in case of the Canadian dollar, Swiss franc, Euro, and the British pound. On the other hand, the hypothesis is rejected in case of the Japanese yen. Therefore, if $\beta_0 = 0$ and $\beta_2 = 1$ fails to be rejected, it means that the period after December 1998 supports forward market efficiency.

At 5% significance level, the Q-statistic indicates the absence of serial correlation in case of the Canadian dollar, Swiss franc, Euro, and the British pound. On the other hand, in case of the Japanese yen and the US dollar, the Q-statistic supports the presence of serial correlation. In addition, the Q^2 -statistic, which is a test on the conditional volatility, indicates the presence of heteroscedasticity in case of the British pound and the US dollar.

The hypothesis of normal distribution fails to be rejected at 5% significance level in case of the Swiss franc and the Euro. On the other hand, this hypothesis is rejected in case of the Canadian dollar, British pound, Japanese yen, and the US dollar.

The robust standard errors are a correction of the standard errors for autocorrelation and conditional heteroscedasticity. The use of robust standard errors is done for the British pound, Japanese yen, and the US dollar. On the other hand, the robust standard errors are not used in case of the Canadian dollar, Swiss franc and the Euro, which do not show residual autocorrelation and heteroscedasticity.

In conclusion, for the period January 1991 to November 1998, forward market efficiency holds in case of the British pound and the Japanese yen. For the same period, forward market efficiency does not hold in case of the Canadian dollar, Swiss franc, Euro, and the US dollar. On the other hand, for the period December 1998 to October 2010, forward market efficiency holds in case of the Canadian dollar, Swiss franc, Euro, and the British pound. For the same period, forward market efficiency does not hold in case of the Japanese yen.

E. Time-Varying Risk Premium With Respect to the US Dollar

Table 4 estimates the time-varying risk premium of the Canadian dollar, Swiss franc, Euro, Japanese yen, and the British pound relative to the time-varying risk premium of the US dollar for the period January 1991 to November 1998. Therefore, the independent variable in this test is the US dollar risk premium, and the dependent variables are the risk premium of the five currencies mentioned. The empirical estimation consists of running the following econometric model:

$$DIF_t = \gamma_0 + \gamma_1 DIF_t(USD) + v_t \quad (39)$$

The aim of Equation 39 is to prove that the risk premium of a foreign currency is proportionately related to the risk premium of the US dollar by testing the hypothesis that $\gamma_1 = 1$ or by testing the joint hypothesis that $\gamma_0 = 0$ and $\gamma_1 = 1$.

The hypothesis that $\gamma_1 = 1$ fails to be rejected in case of the Canadian dollar, Japanese yen, and the British pound. On the other hand, the hypothesis is rejected in case of the Swiss franc and the Euro. However, in the latter case, the value of γ_1 is close to +1.

Additional test results related to Table 4 reveal that the joint hypothesis $\gamma_0 = 0$ and $\gamma_1 = 1$ fails to be rejected in case of the Canadian dollar, Japanese yen, and the British pound, whereas it is rejected in case of the Swiss franc and the Euro.

At 5% significance level, all the P-values of the Q-statistic indicate the absence of autocorrelation. In addition, the Q^2 -statistic indicates the presence of conditional heteroscedasticity for the British pound only.

The hypothesis of normal distribution fails to be rejected at 5% significance level in case of the Canadian dollar, Swiss franc, and the Euro. On the other hand, this hypothesis is rejected in case of the Japanese yen and the British pound.

In conclusion, Table 4 supports the hypothesis that the time-varying risk premium of the Canadian dollar, Japanese yen, and the British pound is unit proportional to the time-varying risk premium of the US dollar for the period January 1991 to November 1998. On the other hand, Table 4 supports the hypothesis that the time-varying risk premium of the Swiss franc and the Euro is not unit proportional to the time-varying risk premium of the US dollar for the same period. However, the value of the slope is close to +1 being between 1.17156 and 1.19816.

F. Pooled and Joint Time-Varying Risk Premium

Table 5 estimates the pooled time-varying risk premium of the Canadian dollar, Swiss franc, Euro, Japanese yen, and the British pound for the period January 1991 to November 1998 by using the Seemingly Unrelated Regression (SUR), the Full Information Maximum Likelihood (FIML), and the Panel Regression methods.

The aim of Table 5 is similar to the aim of Table 4, which is to prove that the risk premium of all currencies is proportional to the risk premium of the US dollar by testing the hypothesis that $\gamma_1 = 1$ or by testing the joint hypothesis that $\gamma_0 = 0$ and $\gamma_1 = 1$.

The hypothesis that $\gamma_1 = 1$ fails to be rejected in all the cases by using the Seemingly Unrelated Regression and Full Information Maximum Likelihood methods. On the other hand, the hypothesis is rejected in case of the Panel Regression method.

Test results reveal that the joint hypothesis $\gamma_0 = 0$ and $\gamma_1 = 1$ fails to be rejected in all the cases by using the Seemingly Unrelated Regression and Full Information Maximum Likelihood methods. On the other hand, the joint hypothesis is rejected by using the Panel Regression method.

In conclusion, Table 5 supports the hypothesis that the time-varying risk premium of all the currencies is unit proportional to the time-varying risk premium of the US dollar for the period January 1991 to November 1998, when the Seemingly Unrelated Regression and Full Information Maximum Likelihood methods are used. On the other hand, Table 5 supports the hypothesis that the time-varying risk premia of all the currencies are not unit proportional to the time-varying risk premium of the US dollar for

the period January 1991 to November 1998, when the Panel Regression method is used. However, the value of the slope is close to +1 being 1.1152.

G. A Model for a Time-Varying Risk Premium

The empirical estimation of Table 6 consists of running the following econometric model:

$$DIF_t = \ln(S_{t+1}) - \ln(F_t) = \lambda_0 + \lambda_1(d(\ln(USD_t)))^2 + \xi_t \quad (40)$$

Where S is the spot rate at time $t + 1$, F is the forward rate at time t , λ_1 is a measure of relative risk aversion, and $(d(\ln(USD_t)))^2$ is the square of the percentage change in the US dollar at time t for the period January 1991 to November 1998.

The hypothesis that λ_1 is zero is rejected in case of the Swiss franc, Euro, British pound, Japanese yen, and the US dollar, but not in the case of the Canadian dollar. This means that the model of time-varying risk premium is supported. λ_1 is estimated to be between 1.655 and 2.182, which are estimates of the Coefficients of Relative Risk Aversion (CRRA).

The P-values of the F-test in case of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar are less than 5% significance level. This implies that the risk premium is modeled in a significant way.

At 5% significance level, the P-value of the Q-statistic indicates the absence of serial correlation of the residuals in case of the Swiss franc and the Japanese yen. On the

other hand, serial correlation of the residuals is present in case of the Canadian dollar, Euro, British pound, and the US dollar. In addition, the Q^2 -statistic indicates the presence of conditional heteroscedasticity in case of the Canadian dollar, Swiss franc, Euro, British pound and the US dollar. Conditional heteroscedasticity is absent in case of the Japanese yen.

Table 6 also indicates that at 5% significance level, the hypothesis of normal distribution is rejected for all the currencies.

Additional test results of Table 6 reveal that the robust standard errors are used in all the cases except for the Japanese yen, since the Q-statistic and Q^2 -statistic of the Japanese yen are greater than the 5% significance level.

In conclusion, Table 6 supports the model of time varying-risk premium in case of the Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998. On the other hand, Table 6 does not support the model of time-varying risk premium in case of the Canadian dollar for the same period.

H. Pooled and Joint Estimation of a Model for a Time-Varying Risk Premium

Table 7 is a joint estimation of the time-varying risk premium of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998 by using the Seemingly Unrelated Regression (SUR), the Full Information Maximum Likelihood (FIML), and the Panel Regression methods.

Using the Seemingly Unrelated Regression (SUR), the Full Information Maximum Likelihood (FIML) and the Panel Regression methods, test results of Table 7 reveal that the hypothesis that λ_1 is zero is rejected in all the cases. This means that the model of time-varying risk premium is supported.

The parameter λ_1 is estimated to be between 1.81323 and 1.98856, which is equal to the Coefficient of Relative Risk Aversion (CRRA). In case of Azar (2008a) at 10% significance level, the risk premium in the OLS regression is significant. In case of the implied Coefficients of Relative Risk Aversion (CRRA), the values are between 2.0602 and 2.2718 respectively for the two regression specifications. This implies that they are of a reasonable magnitude when compared to the estimations of λ_1 .

In conclusion, Table 7 supports the model of time-varying risk premium of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998 by using the Seemingly Unrelated Regression (SUR), the Full Information Maximum Likelihood (FIML), and the Panel Regression methods.

V. Conclusion

A. Research Findings

The empirical results in Part IV show that the unbiasedness forward rate hypothesis fails to be rejected during the adjustable peg period, whereas it is rejected in the earlier period. The rejection is due to a bias in the prediction by the forward rate,

serial correlation, heteroscedasticity, non-normality of the residuals and a probable presence of a constant and significant risk premium. Moreover, the empirical results in Part IV reveal that the Lebanese pound became a perfect substitute to foreign currencies during the adjustable peg period.

Table 1 does not support the presence of a unit root, and fails to reject the null hypothesis of stationarity in case of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998. Hence, the weak form market efficiency is not satisfied. On the other hand, Table 1 supports the presence of a unit root, and rejects the null hypothesis of stationarity in case of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period December 1998 to October 2010. Therefore, the weak form market efficiency is satisfied for the period mentioned in the previous statement.

Table 2 supports the presence of time-varying risk premium and the presence of autocorrelation in case of all the currencies for the period January 1991 to November 1998. On the other hand, Table 2 supports the absence of time-varying risk premium and the absence of autocorrelation in case the Canadian dollar, Swiss franc, Euro, and the Japanese yen for the period December 1998 to October 2010. The only exception is the British pound, supporting the presence of time-varying risk premium and the presence of autocorrelation for the period December 1998 to October 2010.

Table 3 states that for the period January 1991 to November 1998, forward market efficiency holds in case of the British pound and the Japanese yen. For the same period, forward market efficiency does not hold in case of the Canadian dollar, Swiss franc,

Euro, and the US dollar. On the other hand, for the period December 1998 to October 2010, forward market efficiency holds in case of the Canadian dollar, Swiss franc, Euro, and the British pound. For the same period, forward market efficiency does not hold in case of the Japanese yen.

Table 4 supports the hypothesis that the time-varying risk premium of the Canadian dollar, Japanese yen, and the British pound is unit proportional to the time-varying risk premium of the US dollar for the period January 1991 to November 1998. On the other hand, Table 4 supports the hypothesis that the time-varying risk premium of the Swiss franc and the Euro is not unit proportional to the time-varying risk premium of the US dollar for the same period. However, the value of the slope is close to +1 being between 1.17156 and 1.19816.

Table 5 supports the hypothesis that the time-varying risk premium of all the currencies is unit proportional to the time-varying risk premium of the US dollar for the period January 1991 to November 1998, when the Seemingly Unrelated Regression and Full Information Maximum Likelihood methods are used. On the other hand, Table 5 supports the hypothesis that the time-varying risk premium of all the currencies are not unit proportional to the time-varying risk premium of the US dollar for the period January 1991 to November 1998, when the Panel Regression method is used. However, the value of the slope is close to +1 being 1.1152.

Table 6 supports the model of time varying risk premium in case of the Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991

to November 1998. On the other hand, Table 6 does not support the model of time-varying risk premium in case of the Canadian dollar for the same period.

Table 7 supports the model of time varying risk premium of the Canadian dollar, Swiss franc, Euro, British pound, Japanese yen, and the US dollar for the period January 1991 to November 1998 by using the Seemingly Unrelated Regression (SUR), the Full Information Maximum Likelihood (FIML), and the Panel Regression methods.

B. The Limitations of the Thesis

The thesis considered the Lebanese market only. It would be interesting to know if the same models apply to foreign currencies.

The thesis is limited only to six currencies, which are the Canadian dollar, Swiss franc, Euro, Japanese yen, British pound, and the US dollar.

The sample period in which the study is conducted is limited to the time frame extended between January 1991 and October 2010.

The sample size is rather small compared to the sample sizes in similar research in other countries. Usually financial data have very large samples. This means that the relations may not be robust.

A disturbing fact in the estimations is that the hypothesis of normality of the regression residuals is often rejected. It is known that hypothesis testing requires normality. This non-normality may have biased the standard errors and significance levels of the estimated coefficients, although one can invoke the Central Limit Theorem.

This theorem states that the sampling distribution of the average is approximately normally distributed as the sample size gets bigger. If by average is meant the averages of the regression residuals then normality would not be such a problem.

As in all econometric studies, the estimated relations describe the past. Will these relations remain stable in the future? And can we use these relations to predict what will happen?

The study computed the forward rate from the spot rate adjusted by domestic and foreign interest rates. This was done because there are no published data on market forward rates. Do these computed forward rates match the market forward rates that are quoted by banks but not made public?

C. Recommendations

After November 1998, the adjustable peg of the Lebanese pound to the US dollar played a major role in maintaining financial and price stability in the country. It also helped in the expansion of the economy and in massive capital inflows to the Lebanese market. Moreover, the high stock of assets in foreign currencies prevented Lebanon from any crisis that may hit the economy.

The research findings of the thesis show that after November 1998 the Lebanese pound became a perfect substitute for foreign currencies, which helped in stabilizing the Lebanese foreign exchange market.

It is recommended to keep the adjustable peg of the Lebanese pound to the US dollar in order to maintain this unprecedented stability in the Lebanese economy and the Lebanese foreign exchange market.

It is also recommended that a partial pegging of the Lebanese pound to the Euro be considered, which will also play a role in enhancing the financial and economic stability in Lebanon.

	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
CAD	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%
CNY	1% - 3%	2% - 10%	2% - 10%	2% - 10%	2% - 10%	2% - 10%
EUR	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%
GBP	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%
JPY	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%
USD	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%	1% - 3%

Notes: 1. Interest rate for the spot foreign exchange market in Lebanon, which is based on the Central Bank's monetary policy. The interest rate is for the national legislation. The interest rate is around 10% for the CAD, CNY, and JPY currencies. The interest rate is around 2% for the EUR. The interest rate is around 1% for the USD.

VI. Tables

Table 1: Unit root or stationarity tests (KPSS, 1992) with a constant but without a trend. The null hypothesis is stationarity. The marginal significance levels are reported.

January 1991 to October 2010	January 1991 to November 1998	December 1998 to October 2010
---------------------------------	----------------------------------	----------------------------------

currency	$\ln(S)$	$\ln(F)$	$\ln(S)$	$\ln(F)$	$\ln(S)$	$\ln(F)$
CAD	1%-5%	1%-5%	> 10%	> 10%	< 1%	< 1%
CHF	1%-5%	5%-10%	> 10%	> 10%	< 1%	< 1%
EURO	> 10%	> 10%	> 10%	> 10%	< 1%	< 1%
GBP	> 10%	> 10%	> 10%	> 10%	1%-5%	1%-5%
JPY	> 10%	> 10%	> 10%	> 10%	< 1%	1%-5%
USD			> 10%	> 10%		

Notes: S stands for the spot foreign exchange rate in domestic units per foreign currency. F stands for the forward foreign exchange rate. The symbol \ln is for the natural logarithm. The sample ends in August 2010 for the CAD, CHF, and JPY currencies. The sample ends in September 2010 for the Euro. The sample ends in October 2010 for the GBP.

Table 2: Statistics on the variable DIF for each currency and each sample period. This variable is a measure of both the time-varying risk premium and the forecast error. The variable DIF is calculated as follows for each currency:

$$DIF_t = \ln(S_{t+1}) - \ln(F_t)$$

Sample period				
1/1991 to 11/1998			Post 11/1998	
Currency for the DIF variable	mean	Q-statistic	mean	Q-statistic
CAD	-0.007759 (1.4013)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001	-0.002183 (0.9799)	k=6: 0.174 k=12: 0.475 k=18: 0.354
CHF	-0.007128 (0.9615)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001	-0.004139 (1.5612)	k=6: 0.907 k=12: 0.431 k=18: 0.376
EURO	-0.005650 (0.8082)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001	-0.003962 (-1.4822)	k=6: 0.734 k=12: 0.792 k=18: 0.684
GBP	-0.005235 (0.7335)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001	-0.004251 (0.8963)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001
JPY	-0.006630 (1.0087)	k=6: 0.001 k=12: 0.012 k=18: 0.046	-0.004680 (1.9217)	k=6: 0.193 k=12: 0.067 k=18: 0.247
USD	-0.005705 (1.0561)	k=6: < 0.001 k=12: < 0.001 k=18: < 0.001	-	-

Notes: S stands for the spot foreign exchange rate in domestic units per foreign currency. F stands for the forward foreign exchange rate. The symbol \ln is for the natural logarithm. Absolute t-statistics are in parenthesis. The t-test is a test on the mean of the variable DIF for each currency. The Q(k) is the Ljung-Box (1978) Q-statistic for lag order k on each DIF variable and each sample period. See notes under Table 1 for the end of the sample periods.

Table 3: Forward market efficiency. The model is:

$$\ln(S_{t+1}) = \beta_0 + \beta_1 D_t + \beta_2 \ln(F_t) + \beta_3 D_t \ln(F_t) + \varepsilon_{t+1}$$

$$\varepsilon_t \text{ is IID } (0, \sigma_t^2)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2$$

	CAD	CHF	EURO	GBP	JPY	USD
Sample period	1/1991-8/2010	1/1991-8/2010	1/1991-9/2010	1/1991-10/2010	1/1991-8/2010	1/1991-11/1998
Sample size	234	235	236	237	235	94
β_0	0.09987 (0.7990)	-0.02463 (0.2138)	-0.06378 (0.6093)	0.92130 (1.6754)	0.05056 (0.6801)	0.52818 (1.3478)
β_1	0.63762 (3.1626)	0.30820 (2.0455)	0.49802 (3.2862)	0.26087 (0.3602)	0.12132 (1.1539)	-
β_2	0.98557 (56.3030)	1.00315 (61.5585)	1.00825 (72.3585)	0.88184 (12.5789)	0.97849 (34.1322)	0.92698 (17.3536)
β_3	-0.09135 (3.2128)	-0.04510 (2.1102)	-0.06709 (3.3195)	-0.03316 (0.3583)	-0.04726 (1.1930)	-
AR(1)	0.14879 (2.7924)	-	-	-	-	-
MA(1)	-	-	-	-	-	0.30085 (2.7420)
α_0	3.89E-05 (6.3042)	0.000221 (2.3589)	0.000180 (2.4986)	0.000171 (0.9464)	0.000162 (2.4438)	-2.19E-07 (4.7386)
α_1	-	0.30415 (2.8355)	0.30478 (3.1885)	-	0.18511 (2.6509)	-
α_2	0.93458 (98.8469)	0.55014 (4.3302)	0.56027 (4.9558)	0.92530 (20.1535)	0.70278 (11.9007)	0.92347 (229.9059)
$\beta_0 = 0$ $\beta_2 = 1$	0.3219	0.6336	0.6453	0.1158	0.0339	< 0.0001
$\beta_1 = \beta_3 = 0$	0.0017	0.0094	0.0022	0.913	0.3693	-
\bar{R}^2	0.9505	0.9393	0.9384	0.8400	0.9497	0.9537
Q(12)	0.107	0.768	0.457	0.450	0.008	0.001
Q ² (12)	0.329	0.864	0.374	0.000	0.860	< 0.001
normality test	< 0.0001	0.1472	0.1841	< 0.0001	< 0.0001	< 0.0001
Robust standard errors	No	No	No	Yes	Yes	Yes

Notes: Absolute t-statistics are in parenthesis. S stands for the spot foreign exchange rate in domestic units per foreign currency. F stands for the forward foreign exchange rate. The symbol \ln is for the natural logarithm. The variable D is a dummy that takes the value 1 between 1/1991 and 11/1998, and zero otherwise. The actual p-values are recorded for the two hypothesis tests for each currency. The Q(12) is the Ljung-Box (1978) Q-statistic of lag order 12 on the standardized residuals. The Q²(12) is the Ljung-Box (1978) Q-statistic of lag order 12 on the squares of the standardized residuals. The actual p-values are reported for the Q(12) and Q²(12) statistics. The normality test is the Jarque-Bera (1980) test. Bollerslev-Wooldridge (1992) robust standard errors are computed where appropriate.

Table 4: Estimation of the following model:

$$DIF_t = \gamma_0 + \gamma_1 DIF_t(USD) + v_t$$

	DIF for CAD	DIF for CHF	DIF for EURO	DIF for JPY	DIF for GBP
γ_0	-0.00211 (1.4560)	-0.00029 (0.0798)	0.00103 (0.3445)	-0.00086 (0.2088)	0.00164 (0.5739)
γ_1	0.99004 (35.7995)	1.19816 (17.1781)	1.17156 (20.4510)	1.01147 (18.0700)	1.20477 (11.2890)
P-value of the F-test	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001
$\gamma_1 = 1$	0.7195	0.0055	0.0035	0.8382	0.0550
$\gamma_0 = 0, \gamma_1 = 1$	0.3394	0.0164	0.0113	0.9612	0.1260
P-value of the Q(12)	0.514	0.482	0.931	0.776	0.857
P-value of the Q ² (12)	0.518	0.111	0.111	0.964	< 0.001
P-value of the Jarque-Bera (1980) normality test	0.445	0.525	0.759	< 0.00001	0.000032

Notes: Absolute t-statistics are in parenthesis. The actual p-values for the hypotheses tests are provided. The Q(12) is the Ljung-Box (1978) Q-statistic for lag order 12 on the residuals. The Q²(12) is the Ljung-Box (1978) Q-statistic for lag order 12 on the squares of the residuals. The sample size is 94 for each currency, i.e. from 1/1991 to 11/1998.

Table 5: Joint estimation of the model in Table 4 by Seemingly Unrelated Regression (SUR, column 2), by Full Information Maximum Likelihood (FIML, column 3), and by Panel Regression (column 4). The sample includes the CAD, CHF, EURO, GBP and the JPY.

	System estimation: SUR	System estimation: FIML	Panel regression
γ_0	-0.001378 (1.0333)	-0.001545 (1.0254)	-0.00012 (0.0853)
γ_1	1.03474 (40.6517)	1.02070 (25.0777)	1.11520 (42.4219)
$\gamma_1 = 1$	0.1723	0.6110	< 0.0001
$\gamma_0 = 0, \gamma_1 = 1$	0.1944	0.4208	0.0001
Panel regression \bar{R}^2			0.79318
P-value of the panel regression F- test			< 0.000001

Notes: Absolute t-statistics are in parenthesis. The sample size is 94 for each currency, i.e. from 1/1991 to 11/1998. The total sample size is 94 x 5 or 470 observations. See notes under Table 4.

Table 6: Estimation of the following model for each currency:

$$DIF_t = \ln(S_{t+1}) - \ln(F_t) = \lambda_0 + \lambda_1(d(\ln(USD_t)))^2 + \xi_t$$

	DIF for CAD	DIF for CHF	DIF for EURO	DIF for GBP	DIF for JPY	DIF for USD
λ_0	-0.01197 (2.4980)	-0.01223 (1.7510)	-0.01044 (1.5718)	-0.01016 (1.5193)	-0.01211 (1.8768)	-0.01034 (2.1557)
λ_1	1.65540 (1.7378)	2.17267 (2.2132)	2.01841 (2.1664)	2.03152 (1.9838)	2.18186 (3.5895)	1.87147 (2.1907)
P-value of the F-test	0.001977	0.002319	0.002743	0.00322	0.000536	0.000284
P-value of the Q(12)	0.001	0.054	0.008	0.001	0.174	< 0.001
P-value of the Q ² (12)	< 0.001	0.010	0.003	0.004	0.088	< 0.001
P-value of the Jarque-Bera (1980) normality test	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Robust standard errors	Yes	Yes	Yes	Yes	No	Yes

Notes: Absolute t-statistics are in parenthesis. The Q(12) is the Ljung-Box (1978) Q-statistic for lag order 12 on the residuals. The Q²(12) is the Ljung-Box (1978) Q-statistic for lag order 12 on the squares of the residuals. The sample size is 93 for each currency, i.e. from 1/1991 to 11/1998. Newey-West (1987) robust standard errors are computed where appropriate.

Table 7: Joint estimation of the model in Table 6 by Seemingly Unrelated Regression (SUR, column 2), by Full Information Maximum Likelihood (FIML, column 3), and by Panel Regression (column 4). The sample includes the CAD, CHF, EURO, GBP, JPY, and the USD.

	System estimation: SUR	System estimation: FIML	Panel regression
λ_0	-0.01019 (0.6487)	-0.01019 (0.6487)	-0.01121 (4.2630)
λ_1	1.81980 (4.0372)	1.81323 (3.9208)	1.98856 (8.0291)
Panel regression \bar{R}^2			0.10229
P-value of the panel regression F- test			< 0.000001

Notes: Absolute t-statistics are in parenthesis. The sample size is 93 for each currency, i.e. from 1/1991 to 11/1998. The total sample size is 93 x 6 or 558 observations.

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