ABSTRACT

EMPIRICAL AND THEORETICAL ANALYSIS OF FOREIGN EXCHANGE MARKETS
A CASE OF BELGIUM, GERMANY, AND THE NETHERLANDS

by
Ozan Akyureklier

The paper uses an efficiency specification model of the spot and forward foreign exchange markets and tests the random walk, the general efficiency, and the unbiasedness hypotheses by utilizing a regression estimation and many different specification and diagnostic tests for the series and the error terms.

The paper discusses the important aspects of efficiency, expectations, and risk in the foreign exchange market. First a brief presentation of the existing single-equation structural models of exchange-rate determination is given. An efficiency specification model of the spot and forward foreign exchange markets applied to test the random walk, the general efficiency, and the unbiasedness hypotheses. The model is examined by employing time series analysis to test for the absence of the long run equilibrium or cointegration relationships. The existence of either one would imply a direct violation of the Efficient Market Hypothesis in a speculative efficient market (Granger, 1986).

In this study we addressed the efficiency of Germany's, Holland's and Belgium's foreign exchange markets. The random walk hypothesis has been failed to be rejected. However, Belgium's spot rate follows a random walk but their variances are not constant. On the other hand, cointegration found to be present for all the countries tested in this research. The empirical results also showed that Belgium's market efficiency is questionable.

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EMPIRICAL AND THEORETICAL ANALYSIS OF FOREIGN EXCHANGE MARKETS A CASE OF BELGIUM, GERMANY, AND THE NETHERLANDS

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This thesis is dedicated to
my father Kadir, my mother Sirin, my brother Okan.

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CHAPTER I

INTRODUCTION

An efficient market is defined as one in which prices *fully reflect* all available information (Fama, 1970). The allocation of ownership of the economy capital stock, and resources in general, is a very difficult task that economists have not resolved yet. So far, we have just depended on the markets and the price mechanism that exists. Later in this chapter I will explain how market efficiency relates to the concepts of rational expectations and unbiasedness.

An understanding of market efficiency and an improvement of its disefficiency is important to government policy makers, central bankers, multinational financial managers and international investors. The greatest importance of the market behavior is to the government policy makers, so that they can design the appropriate macro-policy for achieving the goals of efficient resources allocation, steady growth, full employment, price stability, and improvement of the welfare of their citizens. Although market efficiency made its first appearance in the finance literature some two decades ago, the basic idea should be familiar. In a sense, market efficiency is simply a special case of a fundamental principle of economics, it is the application of the no free lunch' argument to the field of information, because in so far as the exist unexploited profit opportunities. My concern in this chapter is with the consequences of market efficiency for the relationship between spot and forward exchange rates.

The importance of efficiency of organized markets for delivery of future delivery of foreign currencies became a critical argument since the abandonment of the Bretton Woods arrangement in early 1970. Most tests of market efficiency are testing a joint hypothesis first on the structure determining equilibrium prices or expected returns and second, the hypothesis about the available information set and the ability of agents efficient actual prices or returns to conform to their expected values.

The results of Meese and Rogoff [1] [2] indicate that current economic models of spot exchange rate determination are generally unable to explain the movement in major exchange currency exchange rates. The preponderance of previous studies show that a very strong evidence exists against the hypothesis that the forward exchange rates, of any maturity are unbiased predictors of future spot rates. There are two major interpretations which reject the unbiased hypothesis. First is the so called *asymptotic distribution theory* where the sample moments of the data are poor reflections or their asymptotic counterparts. This may be because that the types of government policies and other exogenous processes that determine exchange rates make this problem particularly prominently apparent in those studies. A second interpretation relies on *Fama's decomposition argument* [3] where the forward premium is view as the sum of two unobservable components, the expected rate of deprecation and the normalized risk premium. By considering the algebra of least squares, Fama demonstrated that risk

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[1] Meese, R. and K. Rogoff: "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" Journal of International Economics, 14 (1983), 3-24

[2] Meese, R. and K. Rogoff: "The Out-Of-Sample Failure of Empirical Exchange Rate Models: Sampling Error or Misspecification?" in Exchange Rates and International Macroeconomics, ed. by J.A. Frenkel, Chicago: University of Chicago Press for National Bureau of Economic Research, 1983.

[3] Fama, E.: "Forward and Spot Exchange Rates," Journal of Monetary Economics, 14 (1984) 319-38

premiums are more variable than the expected rate of depreciation and that they tw covary negatively. The profitability of various trading strategies shows that there ar inefficiencies in the forward exchange markets. The work of Hodrick and Srivastava questions whether Bilson's[5] trading strategy produces expected profits that are too goo to be consistent with risk aversion. Similarly the profitability of the interesting filter rul studies of Dooley and Shalfer show that many currencies either were not efficient in thei use of price information or real interest differentials were large and variable during th sample period.

The notion of market efficiency is usually associated with the rationality of marke expectations. Our way to examine this issue is to determine whether market participant could systematically earn an excess profit. In the foreign exchange markets, the curren prices reflect all available information. The efficient market approach in conjunction wit rational expectations implies that economic agents' expectations about future values o exchange rate determinants are fully reflected in the forward rates. Under thes circumstances, the investor cannot earn an unusual profit by exploiting the availabl information.

Empirical tests conducted by Hansen and Hodrick (1980, 1983), Fama (1984), Domowitz and Hakkio (1985), show that the evidence supporting the unbiased forward rate hypothesis is quite weak.

Market efficiency implies a testable restriction that a=0 and b=1 in equation (1.1')as implied by the unbiased hypothesis. Hadsen and Hodrick (1988) called it "simple

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[4] Hodrick, R. J. and S. Srivastava: "An Investigation of Risk and Return in Forward Foreign Exchange," Journal of International Money and Finance, 3 (1984), 1-29

efficiency" whereas Bilsson (1981) call it "speculative efficiency" meaning that traders have rational, the supply of speculative funds is infinitely elastic at the forward price that equals the expected future price.

Edam and Diction (1988) observed that final price series were generally found to be nonstationary. As a result the standard *F*-test of the hypothesis a=0 and b=1 is no longer appropriate, rejecting market efficiency[6].

Regression estimation by Cornell and Edwards finds that the coefficient of the forward rate (for predicting the subsequent spot) does not differ significantly from one and the error term displays no serial correlation. Their evidence supports the unbiasedness hypothesis.

Kon S. Lai and Michael Lai after analyzing five major forward currency markets their results are not favorable to the joint hypothesis of market efficiency and no-risk premium[7]. The problems they encounter in testing forward or futures were that the series are not stationary and statistical procedures are no longer valid in providing a test for market efficiency.

Shen and Wang(1990) suggest a cointegration approach[8] developed by Engle and Granger(1987)that can test efficiency accounting for nonstationarity in price series. Least

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[5] Bilson, J. F. O.: “The Speculative Efficiency Hypothesis,” Journal of Business, 54 (1981), 435-452

[6]. Elam, E., and Dixon,B.L.(1988) "Examining the Validity of a Test of Futures Market Efficiency", *Journal of Futures Markets, 8:365-372.*

[7]. Kon S.Lai, Michael Lai, "A cointegration Test for Market Efficiency", *The Journal of Futures Markets,* 11:567-575

[8].According to cointegration the information carried on past an current observations of the rates could be employed *vis-à-vi* an error correction model to forecast future price movements in the market. This witnesses that the market is not efficient .

square residuals of the equilibrium regression equation were tested for stationarity. If the residuals are found to stationary, the null hypothesis of no equilibrium relationship between S_t and f_t^{t-1} is rejected. However no strong statistical evidence could be drawn with respect to the parameters a and b which are of main interest.

In this paper, we start from an equilibrium state in the foreign exchange markets and we try to study the dynamics of the stochastic coefficients of four models used to test the unbiased efficiency hypothesis. In addition, statistical and time series tests for the variables of the model as well as many diagnostic tests for the underlying assumptions and the adequacy of the validity of the model are performed.

Since the focus is on testing the market efficiency represented by various specifications, it is not the intention of this work to introduce a new technique to examine the related empirical issue. Rather it follows a conventional approach.

The paper is organized as follows. Chapter I gives a brief explanation of exchange rate determination and defines market efficiency. Chapter II discusses the empirical models pertinent to testing the efficient market hypothesis, an selection is made for the modes that are used in this research. The third chapter provides some basic statistics of the variables of the models that are used. The fourth chapter gives the empirical results and discusses the assumptions or problems encountered. The next chapter deals with the different specification and diagnostic testing of the model. The last chapter gives a summary, implication of test results and the concluding remarks.

CHAPTER II

EXCHANGE RATE DETERMINATION AND MARKET EFFICIENCY

2.1. Purchase Power Parity Theory and the Law of One Price

If the law of one price were true for all goods and services, the *purchasing power parity* (PPP) exchange rate could be found from any individual set of price. By comparing the price of identical products denominated in different currencies, one could determine the real" or PPP exchange rate that should exist if markets were efficient.

PPP is a prominent theory of international finance explaining how exchange rates react to changes in inflation rates of countries. One country's inflation rises relative to another, the demand for its currency declines as its exports decline (due to its higher prices). There are various forms of PPP. The *absolute* form, also called the law of one price, suggests that prices of similar products of two different countries should be equal when measured in a common currency. Realistically, the existence of transportation cost, tariffs, quotas may prevent the absolute form of PPP, where the *relative form* accounts for the possibility of such market imperfections. For PPP to hold the exchange rate should adjust to offset the differential in the inflation rates of the two countries. Assuming $P_h(1+I_h)$ is the price index of the home country after experiencing an inflation rate I_h and $P_f(1+I_f)$ is the price index of the foreign country that changes due to inflation I_f. If inflation occurs and the exchange rate of the foreign country changes, the foreign price index from the home consumer's perspective becomes

$$P_f(1+I_f)(1+e_f) \qquad (2.1.)$$

where e_f represents the percentage change in the value of the foreign currency in order to maintain parity in the new price index of the foreign country equal to the formula for the new price indexes of the two countries. Setting the two country indexes equal each other as follows

$$P_f(1+I_f)(1+e_f)= P_h(1+I_h) \qquad (2.1.a)$$

and then solving for e_f we obtain

$$(1+e_f)= P_h(1+I_h)/ P_f(1+I_f)$$

$$e_f = P_h(1+I_h)/ P_f(1+I_f)-1 \qquad (2.1.b)$$

In using purchase parity to assess future currency movements the new value of the spot exchange rate of a given country

$$S_{j,t+1}= S_j [1+(1+I_h)/ P_f(1+I_f)-1] = S_j [(1+I_h)/P_f(1+I_f)] \qquad (2.1.c)$$

and the approximate version is

$$S_{j,t+1}= S_j [1+(I_h-I_f)] \qquad (2.1.d)$$

Empirical evidence showed that PPP does not consistently holds true. The percentage change in exchange rates typically was much more than the inflation differential. The reason is that exchange rates are affected by other factors in addition to the inflation differential and also there are no substitutes for certain traded goods and services and that will impel consumers to continue buying high priced goods and services.

If interest rates rise in the US we will tend to hold few assets money domestic and foreign; securities domestic and foreign; If interests go up the demand for money will drop. Because money are defined to be non-interest baring, and we don't want to for-sake the higher interest that securities can provide, we will demand more bonds either domestic of foreign. As a result the less demand for dollars will devaluate the dollar. (because in addition we will demand more foreign bonds that we have to get by selling dollars for foreign currencies). If interest rates declines we have the opposite effect. The monetary model also builds a high degree of exchange rate volatility. A current change in the money supply can have a more than proportionate effect on the coexisting exchange rate if the market expects more money growth and currency depreciation in the future.

2.1.1. The International Fisher Effect (IFE)

The relationship between the percentage change in the spot rate over time and the differential between comparable interest rates in different national capital markets is known as the *international fisher effect.* Fisher-open, as it is often termed, states that the spot exchange rate should change in an equal amount but in the opposite direction to the difference in interest rates between two countries. More formally:

$$\frac{S1 - S2}{S2} * 100 = I\$ - I¥ \qquad (2.1.1)$$

where I¥ and I$ are the respective national interest rates, and S is the spot exchange rate using indirect quotes at the beginning of the period (S1) and the end of the period (S2). This is the approximation form that commonly used in industry. The precise formulation using indirect quotes on the U.S. dollar would be the following:

$$\frac{S1 - S2}{S2} = \frac{(I\$ - I¥)}{1 + I¥} \qquad (2.1.1.a)$$

Justification for the international Fisher effect is that investors must be rewarded or penalized to offset the expected change in exchange rates. For example, if a dollar-based investor buys a 10-year yen bond earning 4% interest, compared to 6% interest available on dollars, the investor must be expecting the yen to appreciate vis-a-vis the dollar by at least 2% per year during the 10 years. If not, the dollar-based investor would be better off remaining in dollars. If the yen appreciates 3% during the 10-year period, the dollar based investor would earn a bonus of 1% higher return. However, the international Fisher effect predicts that with unrestricted capital flows, an investor should be indifferent between investing in dollar or yen bonds, since investors worldwide would see the same bonus opportunity and compete it away.

If the ex ante purchase power parity incorporated into the fisher parity condition we can see that the expected change in exchange rates correspond to the interest rate differential.[1]

$$S^{ex}_{t+1} - S_j = (i_h - i_f) \qquad (2.1.1.b)$$

The rate of exchange is determined by the difference in the exchange rates. Assuming the interest rate differential between the U.S. and the Germany is 5% (r_t - r_t') this condition can be used to predict that the US currency will depreciate by 5%. The interest rate differential will exist only if the exchange rate is expected to change is such a way that the advantage of the higher interest rate is offset by the loss of the foreign exchange transactions.[2]

International Fisher Effect implies that while an investor in a low-interest country can convert his funds into the currency of the high interest country and get paid a higher rate, his gains will be offset by his expected loss of foreign exchange rate returns.

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[1] Roll, R. and B. Soinik "On Some Parity Conditions Frequently Encountered in International Economics," Journal of Macroeconomics, 1 (1979), 267-283.

[2] Rogalski, R.J. and J.D. Vinson "Emperical Properties of Foreign Exchange Rates," Journal of International Betties Studies, 9 (1978), 69-79.

Value at t+1 of an original investment earning interest at rate of i(interest of the home country) is equal to the value of and equal amount converted to a foreign currency at t, invested at the foreign interest rate i_f and converted back into domestic currency at $1+i_h$ that is[3]

$1+ i_h = [1/ S_t (1+i_f) E(S_{t+1})]$ (2.1.1.c)

subtracting 1 from both sides we get:

$[E(S_{t+1}) /S_t]-1 = [(1+i_f)/ 1+ i_h]-1$

$[E(S_{t+1}) - S_t]/ S_t = [(1+i_f)/1+ i_h]-1$

$E(\Delta\%S_t)= 1+ i_h$ (2.1.1.d)

We can derive IFE as follows; the actual return to investors who invest in foreign money market security depends not only on the interest rate i_f but also the percent change in the value of the foreign currency e_f denominated security. The effective(exchange rate adjusted) return of the foreign bank deposit is

$r = (1+i_f)(1+e_f)-1$

According to the IFE, the effective return on a home investment should be on average equal to the effective return on a foreign investment:

$r= i_h$

We can determine the degree by which the foreign currency must change in order to make investments in both countries generate similar returns. Taking the previous formula of what determines r, and set it equal to i_h.

$r= i_h$

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[3] Roll, R. and B. Soinik "On Some Parity Conditions Frequently Encountered in International Economics." Journal of Macroeconomics, 1 (1979), 267-283

$(1+i_f)(1+e_f)-1 = i_h$

solving for e_f we get

$e_f =[(1+i_h)/(1+e_f)] -1$ (2.1.1.e)

Whether IFE holds in reality depends on the particular time period examined.

Empirical tests lend some support to the relationship postulated by the international Fisher effect, although considerable short-run deviations occur. However, a more serious criticism has been posed by recent studies that suggest the existence of a foreign exchange risk premium for most major currencies. Thus the expected change in exchange rates might not consistently equal the difference in interest rates.

2.1.2. Interest Rate Parity (IRP)[4]

The theory of interest rate parity (IRP) provides the linkage between the foreign exchange markets and the international money markets: The difference in the national interest rates for securities of similar risk and maturity should be equal to, but opposite in sign to, the forward rate discount or premium for the foreign currency, except for transaction costs.[5] Unlike the International Fisher Effect, the theory is applicable only to securities with maturities of one year or less (money market instruments), since forward contracts are not routinely available for periods longer than one year.

Assume an investor has $1,000,000 and several alternative but comparable Swiss franc (SF) monetary investments. If the investor chooses to invest in a dollar money market instrument, the investor would earn the dollar rate of interest. This results in (1 +

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[4] Kouri, P. "International Investment and Interest Rate Linkages Under Flexible Exchange Rates," in The Political Economy of Monetary Reform, ed. bby R.Z. Aliber. London: Macmillan, 1977.

I$) at the end of the period, where I$ is the dollar rate of interest in decimal form. The investor may, however, choose to invest in a Swiss franc money market instrument of identical risk and maturity for the same period. This would require the investor to exchange the dollars for Swiss francs at the spot rate of exchange, invest the Swiss francs in a money market instrument, and at the end of the period convert the resulting proceeds back to dollars.[6]

2.2. Efficient Market Hypothesis

The selection of equilibrium process describing foreign exchange is certainly critical for a proper testing of market efficiency. If we assume that market equilibrium is expressed in terms of equilibrium expected returns then the excess market return on asset *j* is given by[7]

$$Z_{j,t+1} = r_{j,t+1}| - E(\_{j\,t+1}|I) = 0 \qquad (2.2.)$$

where $Z_{j,t+1}$ is one-period percentage return and (I) presents the information set, which is assumed to be fully reflected in the price at time *t*. When the return sequence $Z_{j,t}$ is a "fair game" with respect to the information sequence I_j the market is efficient. Conditional of a constant-equilibrium expected rate of return, random price movement suggests market efficiency

Following Fama's (1970) definition of an efficient market no particular market operation can earn an excess profit. Defining the excess market return for currency asset (*j*) at time *t*+1 as $P_{j,t+1} = R_{j,t+1} - E(Rj,_{t+1}|I_t)$where I_t is the information available reflected in

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[5] Aliber, Robert Z. "The Interest Rate Parity Theorem: A Reinterpretation" Journal of Political Economy (December 1973), pp. 1451-1459

[6] Lucas, R.E. Jr. "Interest rates and Currency Prices in a Two-Country World," Journal of Monetary economics, 10 (1982), 335-360.

the price of the price at time t. If the excess market return $[P_{j,t+1}]$ is a "fair game" with respect to the information set I_t we say that the market is efficient and the expected value of the excess return equals zero.

$E(P_{j,t+1})=0$ (2.2.a)

With respect to currency exchange rates we will say that the expectation derived from the one-period-ahead forecast of the S^{ex}_{t+1} actual value of the spot exchange rate S_{t+1} is not different. E is the expectations operator and I is the available information.

$E[S_{t+1} - S^{ex}_{t+1}|I]=0$ (2.2.b)

The study of the efficient market and the random walk hypothesis involves joint tests of equilibrium price determination and of efficiency. The equilibrium price determination is mainly based on the following international parity conditions:

a. Fisher Parity Condition[8]

$r_t - r_t^{*} = Dp^{ex}_t - Dp^{ex*}_t$ (2.2.c)

which states that the nominal interest rate differential will reflect the expected inflation differential between the two countries.

b. Purchase Parity theory states that the percentage change in nominal rates will equal the differential in inflation rates between the countries. Simply we express the relationship as follows:

$Ds^{ex}_t = Dp^{ex}_t - Dp^{ex*}_t$ [9] (2.2.d)

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[7] Loopesko, B.E. "Relationships among Exchange Rate, Intervention, and Interest Rates: An Empirical Investigation," Journal of International Money and Finance, 3 (1984), 257-278.

[8] Cummy, R. and M. Obstfeld "A Note on Exchange Rate Expectations and Nominal Interest Rate Differentials: A Test of Fisher Hypothesis." journal of Finance 36 (June) 1981: pp.697-704.

[9] Jeff Madura, 1992 International Financial management

Assuming P_h P_d is the price index of a foreign and domestic country respectively, and I_h I_f the inflation rate of both countries are unequal then the percentage change in the value of the foreign currency required to maintain parity in the new price indexes of the two countries is as follows:

c. The International Fisher Parity[10]

States that the expected change in exchange rates between two countries corresponds to the interest rate differential.

$$S^{cx*}_{t+1} - S_t = i_t - i_t^* \qquad (2.2.e)$$

where S_t i_t are the spot and nominal interest rate respectively.

Taking the mathematical expectation of the (2.2.e) where

$i_t = r_t + Dp^{cx}_t$ assuming also $Dp^{cx}_t - Dp^{cx*}_t = 0$ given that the real interest rates in two given countries are equal $r_t = r_t^*$ we get the following:

$$E(S_{t+1}|I_t) = i_t - i_t^* + s_t = r_t + Dp^{cx}_t - (r_t^* + Dp^{cx*}_t) + s_t =$$

$$E(S_{t+1}|I_t) = s_t \qquad (2.2.e')$$

Substituting (2.2.e') in (2.2.a) we get

$$E[S_{t+1} - s_t \,|I] = 0$$

Interest parity states that the interest rate differential between two countries will be matched by the forward premium of the exchange rate

$$f_t - S_t = i_t - i_t^* \qquad (2.2.f)$$

$$(1+e_f) = \frac{P_d\,(1+I_d)}{P_f(1+I_f)}$$

Since $P_f=P_d$ (because price indexes were initially assumed equal in both countries). The new value of the spot exchange rate of a five currency (called $S_{j,t+1}$) would be a function of the initial spot rate existed in equilibrium (S_j) and the inflation deferential

$$S_{j,t+1}) = S_j\ 1 + \frac{P_d\,(1+I_d)}{P_f(1+I_f)} - 1 = S_{j,t+1} = S_j\,[1+(I_d - I_f)]$$

[10] Roll, R. and B. Soinik "On Some Parity Conditions Frequently Encountered in International Economics," Journal of Macroeconomics, 1 (1979), 267-283.

2.2.1. Market Efficiency (Explanation Through Arbitrage)

We can show the relationship of the S^{ex} and forward F_t at time of present spot S_t by considering an arbitrage scenario. Assuming that there are no exchange controls, there are available funds for arbitrage operations, and no transaction cost.

Imagine an investor expect a 10% appreciation of the Yen. Lets say the yen appreciates Spot from $S_{t1}=110\ ^{\$/Y}$ to $S_{t2}=100\ ^{\$/Y}$ and the Forward rate at $F_{t1}=100\ ^{\$/Y}$ Arbitrage profits can be experienced by selling forward 12 months F_{12} yen for dollars. At expiration time he sells spot yen making a profit of 10% minus the premium paid for the forward dollars.

If the same view is shared with the rest of the market then the forward rate will be bit up until the premium is high enough to discourage any further speculation. The required forward risk premium (p_t) should be equal to the difference between the forward and the expected spot rate.

$$f_t^{t+1} - E_t(S_{t+1}) = p_t \qquad (2.2.1.)$$

The following equation represents an efficient market equilibrium between the forward and the expected spot. Where f_t^{t+1} is the forward price of the dollars at time t for delivery one period later $(t+1)$ and $E_t(S_{t+1})$ is the market's expectation of the future spot rate.

$$f_t^{t+1} = E_t(S_{t+1}) + p_t \qquad (2.2.1.a)$$

If we bring in to the setting the actual spot rate, S^a_{t+1}, then we get an expression which summarizes the efficient market hypothesis showing that the gap between the forward and the actual spot is equal to the sum of the two components, the random expectation error and a risk premium.

$$f_t^{t+1} - S^a_{t+1} = [E_t(S^a_{t+1}) - S^a_{t+1}] + p_t \qquad (2.2.1.b)$$

$$= u_{t+1} + p_t$$

u_{t+1} is a critical term representing the unexplained variation between the actual future spot rate S_{t+1} and the expected future spot rate $E_tS^a_{t+1}$. u_{t+1} should show no systematic pattern of variation over time, should have a mean value of zero, a zero autocorrelation function, and exhibit no cross correlation with other spot or forward rates.

The reason we want this unexplained error to remain unpredictable is because we want to exclude the possibility of the profitability of further exploited information.

Equation (2.2.1.b) implies that the following:

$$S_{t+1} = f_t^{t+1} - u_{t+1} - p_t \qquad (2.2.1.c)$$

if we shift this scenario back one period we get an expression for the current actual spot rate can be viewed as the sum of three components; the previous period forward rate, minus the risk premium, minus an unpredictable, expectational error.

$$S_t = f_{t-1}^{t} - u_{t+1} - p_{t-1} \qquad (2.2.1.c)$$

Note that if we were able to set of determine a certain structure of the risk premium then we would be able to test whether the spot rate and the forward rate are related in the way predicted by the efficient market hypothesis. Nevertheless, in a weakly efficient market, opportunities do remain for profit by exploiting information additional to the market price such inside information.

2.2.2. Weak Efficient Market Hypothesis

The weak efficient market hypothesis suggests that the historical price and volume data for assets contain no information that can be used to earn trading profits above the one could attained with a naive buy-hold investment strategy. Technical Analysis is well recorded but worthless folklore.

Evidence: Trading using the x percentage filter rule. The filter rules might enable an investor to earn significant profit, if some of the patterns used by technical analysis are reliable indicators. The 1 percent filter is the most profitable. However, after commissions are deducted it cannot win the naive strategy. Sweeney[11], developed a rule that was able to earn modest profits through long positions. But commissions made this rule not profitable.

Conclusion: Some patterns do exist that can be used for profitable trading strategy but are so weak and complex that the filter rule is unable to generate from every stock.

Studies of spot rate behavior focused on the short term patterns (1-90 days) that can let large profits after commissions from aggressive trading[12]. However, the serial correlation strategy failed to detect any significant patterns. The test of serial correlation furnish some support for the weakly efficient market hypothesis.

2.2.3. Semi-Strong Efficient Market Hypothesis

Markets are efficient for exchange rates to reflect all publicly available information. Only insiders who have access to valuable information could earn a profit greater than that

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[11] Richard J. Sweeney, "Some New Filter Rule Tests: Methods and results," Journal of Financial and Quantative Analysis, Sept. 1988, vol.23, no.3, pp. 285-300

[12] Wasserfallen, W. and H. Zimmerman "The Behavior of Intra-Daily Exchange Rates," Journal of Banking and finance, 9 (1985), 55-72

could earned by using a buy-hold strategy in a semi-efficient market[13]. Effects of federal discount rate showed a small but significant change (1/2%)[14]. Splits and dividends are public announced events that furnish a good vehicle with which to test the hypothesis.

Past researchers studied if dividend and splits had any influence on one period rate of return. Attention paid to the error term of returns around the time of split ($r = a + \beta_i(rm)+e_{it}$). If the error term is equal to zero at the time of split then the security's rate of return is equal to what the char line predicted.

Cumulative average error terms (e) month by month can show the influence that dividends or splits have on price. Dividends or splits are accompanied by and increase in cash dividends and this information discloses information about the internal workings of a company. showing that CEOs are confident that the earning power of the firm has increased to provide higher future dividends. Such firms showed a positive (e). If firm fails to rise its cash dividend earnings will fail to high as a result e would be negative.

Price changes occurring near the time of the dividends & splits can be implicit to their information content but in the long run the firm nor the investor's price (r_i)are changed by splits or dividends. The investor can earn $e>0$ by speculating on the announcement of dividends proceeding the public announcement. The studies show that security prices not only react immediately and rationally to news, they often are anticipated. Security prices seem to reflect publicly information.

Empirical results in the literature does not find a strong support of the semi-strong efficiency form. The difficulty may come either from a luck of a well specified model of

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[13] Rose, A.K. and j.G. Selody "Exchange Market Efficiency: A Semi-Strong Test Using Multiple Markets and Daily Data," Review of economics and Statistics, 66 (1984), 669-672.

the determination of exchange rates or from an insufficient precise procedure to decompose the anticipated parts in testing the model.

2.2.4. Strong Efficient Market Hypothesis

Strong market efficiency hypothesis suggests that all information public or not is fully reflected in securities' prices. Prices are always equal to its values. Prices adjust instantly to the arrival of new information. The past researchers have examined the profitability of inside traders to see if access to inside information allows statistically significant trading profits. Jaffe[15], analyzed the sum over six years to measure insides profits. He used the CAPM to determine if the error term, e, of the inside traders in their own companies' stock are positive or negative. He added selling and buying plurality and yield average residual for all insiders (after commissions).. Statistically speaking this rate of insiders trading profit is statistically greater than but practically the average investor is not getting richer by making investments based on their information because of the commissions paid.[16]

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[14] R.N. Waud "Public Interpretation of Discount Rate Changes: Evidence on the announcement Effect," Econometrica, 1971.

[15] J.F. Jaffe "Special Information And Insider Trading," Journal of Business, july 1974, 410-428. Another study of the profitablity insider trading is J.H.Lorie and V.Neiderhoffer, "Predictive and Statistical Properties of Insider Trading" Journal of Law and Economics, April 1968, 35-51.

[16] Sweeney, R.J. "Beating the Foreign Exchange Market,' Journal of Finance. 41 (1986), 163-182.

2.2.5. Against Efficient Market Hypothesis

Shiller compared the market prices of two stock market indexes (each for different period) with their present value for every year[17] v_t= PV at time t for t=71-79, T= terminal date f= period when dividends occur. Sum f=t+1 to T $df/(1+k)^{f-1} + p_T/(1+k)^{T-1}$

Theory of finance suggest that the true economic value of a security is equal to the PV of the dividends. However findings showed significant differences between PV of stock indexes and market prices.[18]

2.3. Unbiasedness

Unbiasedness is said to be obtained when the forward market is efficient and investors are risk neutral so that the forward rate is equal to the mathematical expectation of the future spot rate at the day the forward contract expires.

Under risk neutrality agents are willing to undertake risky transactions in return for a zero risk premium no risk premium is required to induce market agents to undertake risky transactions. This means that they are willing to speculate on the future spot rate up to the point where the reward is insignificant, and by doing so they are pushing the forward rate to the point where it is equal to the rational expected future spot rate S^{ex} reducing the risk premium p_{t-1} into zero. The following equation will hold true:

$$S_t = f_{t-1}^{1} - u_t \qquad (2.3.)$$

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[17] Shiller, R.J. "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" American Economic Review, 71 (1981), 421-436.

[18] LeRoy and M. Porter, "The present value relation: Test Based on Implied Varience Bounds," Econometrica, may 1981, vo.49, 555-574.

Similarly, we can express the actual rate of change of two periods by the one anticipated in advance, reflected by the previous period's premium or discount on the forward rate, plus or minus the random error.

$$S_t - S_{t-1} = (f_{t-1}^{1} - S_{t-1}) - u_t \qquad (2.3.a)$$

Each period's forward rate is an optimal forecast of the next period's actual spot rate, where any deviation form the actual spot is only explained by the unpredictable predictor u_t. Unbiasedness implies that the forward rate can not be improved as a forecast since there is little way of inside information in currency markets.[19] As a result there the actual future spot rate cannot be predicted any further by using any other forecast unless there is an inside information in currency markets.

The relationship between the spot and forward rates are shared by all the major currencies. Unbiasedness requires that the spot rate is on average equal to the one month forward rate that ruled at a lagged month. Looking at the background of efficiency studies reveled that when market sentiment changes that results in a change of direction on both spot and forward rate simultaneously. The predominant influences on the forward rate are exactly the same set of factors that determine the spot rate. That means that the spot rates may be more closely linked to contemporaneous rather than lagged forward rates.

The volatility of spot exchange rates has for the most part be unanticipated. Statistically, the forward premium has less volatility than the spot rate by one fifth. Moreover the correlation between them is statistically insignificant since the correlation

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[19] It is hard to imagine that day to day central bank information with respect to monetary policy gives a forecasting edge over the market.

coefficient is negative. It is not definitive answer that spot rates follow a pure random walk by the approximation is close enough for a forecast to be quite hard to beat. The forward premium IRA discount is better prediction than no change at all but the improvement is tiny.

All that is required for unbiasedness is that the forward rate be an unbiased predictor which means one that is not systematically wrong.

However, we have established that the u_t term in equation $S_t = f_t^{t-1} - u_t$ (2.3.), is both large and high volatile relatively to the lagged premium. What we have to determine is whether u_t is random or not. Latest studies seemed to support unbiasedness but most recent work shows that markets have become more inefficient in the last decade. This also contradicts to what one might reasonably have expected in view of the continued removal of controls on international capital movements, technology in money transfer, and consequent fall in the cost of transactions.

Efficiency implies an equation like

$$S_t = a + \beta f_t^{t-1} - u_t \tag{2.3.b}$$

if the risk premium is constant.

Nonetheless, at this point a consensus view seems to have emerged against unbiasedness (efficiency)and, by and large, against the constant risk premium version of efficiency. If the foreign exchange market is efficient, then it should be impossible to find a trading rule to 'beat the market'. The best strategy in that case would be buy-and-hold, since it involves the minimum of transaction cost.

We have two possible explanations of the failure of the efficiency hypothesis: either the market is efficient, but with a non-constant risk premium, or expectations are irrational, or both. The deviations from efficiency that have been uncovered seem difficult to square with any pattern of risk premium variation. Recent research using survey data appears to indicate that explanation may lie in irrational expectations.

2.3.1. Two Interpretations that Reject the Unbiasedness Hypothesis

Answering the questions such as: Is the forward rate an unbiased forecast of the future spot rate? are expectations rational? We notice that rational expectations on its own is not a testable hypothesis. Even if we had data on subjective expectations we would still need to specify a model determining exchange rates. The problem then would be to explain the divergence between the market expectations and the predictions of the model. This divergence would be attributable either to irrationality or to a misspecified model. A practical test of efficiency requires also some additional assumption made about the behavior of the risk premium in order to be consistent with the random error term.

Following there are two alternative interpretations that can justify a strong rejection of the proposition that the forward exchange rate is an unbiased predictor of the future spot rate.

First is the variance decomposition suggested by Fama[20]. Second is the profitability of various trading strategies. Note that these interpretations are not mutually exclusive because some combination of both could also be an explanation

This first position is followed by those who continue to support the unbiasedness hypothesis by arguing that either there is a statistical problem with the data that makes the application of asymptotic distribution theory inappropriate and the analysis to subject to severe small sample bias or it is argued that the unbiasedness hypothesis cannot be rejected until we have an alternative model of a time varying risk premium that is not rejected by the data.

Contingent to market efficiency and rational expectations Fama argues that the forward exchange rate is equal to the expected future spot rate plus a risk premium as demonstrated in derivation of (2.2.1.c).

$$f_t^{t+1} = E_t(S_{t+1}) + p_t \qquad (2.3.1.a)$$

where p_t is the logarithmic risk premium. Fama subtracts S_t from both sides in order to conduct a statistical inference which yields

$$f_t^{t+1} - S_t = E_t(S_{t+1} - S_t) + p_t \qquad (2.3.1.b)$$

where the left-hand side denotes the forward premium and the right-hand side indicates the expected rate of depreciation of the home country relative to the foreign plus a risk premium.

Fama examined regressions of the actual rate of depreciation on the forward premium that have been used to test the unbiased hypothesis (2.2.1.d) in the light of specification of the forward premium. His analysis considers two complimentary regressions of the forward premium. He uses two complimentary regressions with non-overlapping data to determine the degree of variability of the components of the forward premium.

$$f_t^{t+1} - S_{t+1} = a_1+\beta_1-(f_t^{t+1} - S_t) + \varepsilon^1_{t+1} \qquad (2.3.1.c)$$

$$S_{t+1} - S_t = a_2+\beta_2-(f_t^{t+1} - S_t) + \varepsilon^2_{t+1}$$

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[20] R.J. Hodrick, "The Emperical Evidence on the Efficiency of Forward and Futures Foreign Exchange Markets" Fundemantels of Pure and Applied Economics 24, ch#-4.1

The stochastic regressor is the same in both equations and the sum of the depended variables is the stochastic repressor. The complimentary of the regressions implies that $a_1 = -a_2$, $\beta_1 = 1 - \beta_2$ and $\varepsilon^1_{t+1} = -\varepsilon^2_{t+1}$. The equations of 6a are viewed as linear predictors of the risk premium and the expected rate of depreciation of the currency. The ordinary least squares will isolate ε^1_{t+1} & ε^2_{t+1} as the components of $f_t^{t+1} - S_{t+1}$ and $S_{t+1} - S_t$ that are orthogonal to the forward premium. The limits of β_1 and β_2 are given by

$$\beta_1 = Cov(f_t^{t+1} - S_{t+1} ; f_t^{t+1} - S_t) / Var(f_t^{t+1} - S_t)$$

$$\beta_2 = Cov(S_{t+1} - S_t ; f_t^{t+1} - S_t) / Var(f_t^{t+1} - S_t) \qquad (2.3.1.d)$$

where *Cov* and *Var* denote unconditional covariance and variance respectively. The assumption of rational expectations implies that

$$S_{t+1} - S_t = E_t (S_{t+1} - S_t) + v_{t+1} \qquad (2.3.1.e)$$

where v_{t+1} is serially uncorellated white notice to all time *t* information. Combining the rational expectations assumption (2.3.1.e) with the decomposition of the forward premium (2.3.1.) we get

$$Cov(f_t^{t+1} - S_{t+1} ; f_t^{t+1} - S_t) = Cov [p_t ; E(S_{t+1} - S_t) + p_t] =$$

$$Cov [p_t ; E(S_{t+1} - S_t)] + Cov(p_t) \qquad (2.3.1.f)$$

$$Cov(S_{t+1} - S_t ; f_t^{t+1} - S_t) = Cov [E_t (S_{t+1} - S_t) ; E(S_{t+1} - S_t) + p_t] =$$

$$Cov [p_t ; E(S_{t+1} - S_t)] + Var [E(S_{t+1} - S_t)] \qquad (2.3.1.g)$$

$$Var (f_t^{t+1} - S_t) =$$

$$Var [E_t (S_{t+1} - S_t)] + Var (p_t) + 2\, Cov [E(S_{t+1} - S_t) ; p_t] \qquad (2.3.1.h)$$

Substituting (2.3.1.f), (2.3.1.g), (2.3.1.h) into (2.3.1.a) and solve for β_1 and β_2 we get

$$\beta_1 = \frac{Cov\left[p_t ; E_t\left(s_{t+1} - s_t\right)\right] + Var\left(p_t\right)}{Var\left[E_t\left(s_{t+1} - s_t\right)\right] + Var\left(p_t\right) + 2Cov\left[p_t ; E_t\left(s_{t+1} - s_t\right)\right]} \quad (2.3.1.i)$$

and,

$$\beta_2 = \frac{Cov\left[p_t ; E_t\left(s_{t+1} - s_t\right)\right] + Var\left[E_t\left(s_{t+1} - s_t\right)\right]}{Var\left[E_t\left(s_{t+1} - s_t\right)\right] + Var\left(p_t\right) + 2Cov\left[p_t ; E_t\left(s_{t+1} - s_t\right)\right]} \quad (2.3.1.j)$$

The coefficients β_1 and β_2 describe roughly the variability of the components of the forward premium. Fama states that if the risk premium and the expected rate of depreciation are uncorellated then β_1 would be equal to the proportion of the variance of the forward premium due to the variance of the risk premium.[21] Similarly β_2 would be equal to the proportion of the variance of the forward premium due to the expected rate of depreciation.

Since the denominator, Var [E_t (S_{t+1} - S_t)] +Var (p_t) + 2 Cov [E(S_{t+1} -S_t) ; p_t], should be always positive in order the fraction to have meaning, and the variance term premium associated with the expected rate of depreciation, E_t (S_{t+1} - S_t)] , must be positive. A negative finding of coefficient β_2 , ($\beta_2 < 0$)denotes that the covariance between the expected rate of depreciation and the risk premium ,Cov [p_t ; E(S_{t+1} -S_t)], must be negative and greater in absolute value than the variance of the expected rate of depreciation. Since the variance of the forward premium must be positive, Var [E(S_{t+1} - S_t)+ p_t]>0, then the following is true

$V(p_t) > Cov$ [E(S_{t+1} -S_t) ; p_t] ½> Var [E_t (S_{t+1} - S_t)]

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[21] Fama, E. "Forward and Spot Exchange Rates," Journal of Monetary Economics, 14 (1984), 319-338

Thus the variance of the risk premium is greater than the variance of the expected rate of depreciation.

The intuitive explanation of the negative covariation between $E_t(S_{t+1} - S_t)$ and p_t is what might be expected. The reason is that p_t will be the expected return from selling the foreign currency forward $E(S_{t+1} - S_t) + p_t$ while $(- p_t)$ is the expected dollar denominated return from buying foreign currency forward and selling forward currency in the spot market. Hence, $(- p_t)$ is expected to increase with expected inflation in the U.S., as a result the expected depreciation of the dollar relative with foreign currencies will increase.

CHAPTER III

EMPIRICAL MODELS

3.1. Wide Macroeconomic Models

There are two type of models that can determine exchange rate. Models where there is a specific equation for the exchange rate and models where the exchange rate implicitly determined by the balance-of-payments equation. From the mathematical point of view the two approaches are equivalent. Intuitively a theory of exchange rate determination is regarded as integrated of it does explain how the variables determine the exchange rates. It considers actually translated into supply and demand in the foreign exchange market which together with supplies and demands coming from other sources. When all these sources are present in the balance-of payment equation , this equation then becomes a market clearing condition and it is perfectly legitimate to use the balance-of payments to calculate the exchange rate once all the behavioral equations for all the items included in the balance have been specified.

On the other hand economists make a distinction between models of a single country where we consider a small open economy in which the rest of the world is considered exogenous and multicountry models where there is a common structure for national blocks.

3.1.1. Single Country Model

For the single country, nominal exchange rate models is determined according to Purchase

Power Parity (PPP). Exchange rates are determined according to the relative current-account balance and relative prices.

Under uncovered interest parity condition (UIP) nominal exchange rates are determined given the assumption of perfect substitutability between domestic and foreign denominated assets. When the possibility of a risk premium is introduced then UIP is modified by adding K imperfect capital mobility. UIP in real terms and rational expectations are involved in FRBSF [1] where the expected real exchange rate depends on the expected fiscal year budget.

As a result the current fiscal policy influences the exchange rate not only through interest rates but also through changes in expectations. This influence strongly depends on the degree of asset substitutability. If perfect substitutability exists then an expected fiscal expansion would lead to an increase of in the real value of the domestic currency and vise-versa.

Concluding this approach, the exchange-rate equations presented in the models considered are not much different from the specifications used in the single-equation models. The main difference is the fact that the variables which are taken as exogenous in the single equation model (output, interest rate, money supply, etc.) are endogenous in the economy-wide macroeconomic models.

3.1.2. A Multicountry Approach Model

Referring to the following models; (EPA) Economic Planning Agency, a Japanese model [2], OECD-INTERLINK[Holtham(1986)], MSG [the McKibbin-Sachs model: Sachs and

McKibbin(1985)], we can see that in these models there is no equation normalized on the exchange-rate variable, but exchange rates are determined so as to satisfy the balance of payments equation. Under this approach given the equations for the current-account balance and the assumptions on the behavior of the monetary authorities as regards the management of the international reserves, the determination of the exchange rate rests upon the specification of international capital movements. the Italian continuous time model[3] also follows the balance-of payments approach.

The forecasting performance of the structural models remains very poor and deteriorates as the forecasting horizon increases. One would expect a better performance of these models when there is more time for the fundamentals to make their influence felt, the result cast additional doubt on the validity of the structural models.

What Meese and Rogoff did was to examine the out-of-sample predictive performance of the structural models using a benchmark the simple random walk model[4], $e_t = e_{t-1} + u_t$, (where $\hat{e}_{t-1} = e_t$ denotes the predictive value), where e is the (log) of the exchange rate and is a zero-mean white noise process. Meese and Rogoff concluded that the structural exchange rate models have explanatory power, but predict badly because their explanatory variables are themselves difficult to predict which shows that explanation and prediction are not necessarily related. The basic problem in the debate on exchange rate determination is the question of the adjustment speeds in the various markets. Assuming that asset markets adjusts instantaneously or have adjustment speeds higher

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[1] Federal Reserve Bank of San Francisco model: Throop(1989)

[2] Amano(1986) and Kameko and Yasumara (1986)

[3] Gandolfo and Padoan (1987,1990)

than the goods markets, it is the asset flows in a country which have immediate effects on the exchange rate. If this is not true then the asset market approach is not a correct way of describing the process of exchange rate determination. With the continuous time approach, we can determine the adjustment speed accurately by using the balance-of payment equation in which all the relevant variables are present and come from adjustment equations with their specific estimated adjustments speeds.[5]

3.2. The Random Walk Model

This concept is based on the stock market literature and explains an apparent regularity in time series patterns of stock prices where changes of prices of stocks from one period to the next are purely random.

$$S_t = S^{t-1} + u_t \text{ or } \quad S_t - S^{t-1} = d(S_t) = u_t \qquad (3.2.1)$$

The time series is said to follow a trend if the change in the S_t from one period to the next is said to is equal to a slop factor, d, plus a purely random component u_t

$$S_t = S^{t-1} + u_t + d \qquad (3.2.2.)$$

The random walk model is perfectly harmonious with the RE, market efficiency and unbiasedness but it is neither a necessary nor a sufficient condition for market efficiency. If the expected equilibrium return varies considerably, market efficiency requires non-random walk price movements.

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[4] Meese, R. and K. Rogoff: "The Out-of-Sample Failure of Empirical Exchange Rate Models: Sampling Error or Misspecification?" in Exchange Rates and International Macroeconomics, ed. by J.A. Frenkel. Chicago: University of Chicago Press for National Bureau of economic Research, 1983.

[5] Exchange Rate Determination; Single-Equation of Economy-wide models. A case Against the Random Walk

If the spot follows a random walk slop then the expectation of the spot rate conditional to the information at time t-1 is;

$$E_{t-1} S_t = E_{t-1}S^{t-1} + E_{t-1}d + E_{t-1}u_t \qquad (3.2.3.)$$

Since the expected $E_{t-1}S^{t-1}$ is known at time t-1 and the constant drift factor *d* and because the expected value of the next period's random walk error, u_t is always zero, we conclude that the RE forecast of the next period's spot rate is simply the currently observed rate plus or minus the slop. The pure random walk model implies that agents with rational expectations forecast neither appreciation or depreciation over the next period.

Suppose the spot does not follow a random walk but a multiple linear function such as:

$$S_t = aS^{t-1} + bS_{t-2} + tZ_t + dZ_{t-1} \qquad (3.2.4.a)$$

where Z is another variable such relative money stock. Since past values of both s and Z are assumed known at *t*-1 the RE forecast of the next period's spot rate is:

$$E_{t-1} S_t = aS^{t-1} + bS_{t-2} + tE_{t-1} Z_t + dZ_{t-1} \qquad (3.2.4.b)$$

Both efficiency and unbiasedness are potentially consistent with the random walk process. On the other hand, random walk is not required by either rational expectation or efficiency. Considering the formal definition of forward market efficiency for a random walk we will have the forward rate ruling at *t* for delivery at *t*+1 will be equal to the spot rate in the market at *t* plus the risk premium. Under unbiasedness (with risk neutrality) the forward rate at any period would be simply that period's spot rate, so that the forward premium would be always zero[6].

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[6] Ibid , 1993, p.41

An intuitive explanation why the random walk model is not a necessary implication an efficient market is as follows; it might seem reasonable that any other process than a random walk leaves open the opportunity for profit. It is true that the expected return from holding the currency over a single period will only be zero if the spot rate follows a random walk. Essentially in all other cases the return will be predictably non-zero. In order to harmonize this with efficiency we go back to Fama's equation (3.2.4.b) but this time we represent an efficient market equilibrium using the forward rate because it is assumed that the forward rate reflects both the publicly available information summarized in the rational expectation where, $f^{t+1}_{t} = ES_{t} + p_{t}$

Where p_{t+1} is the market's attitude to risk.

$E[\, f^{t+1} - S_{t+1}\,] = p_{t+1}$ (3.2.4.c)

Assuming risk neutrality p_t in the above equation can be reduced to zero, getting the following:

$E[\, f^{t+1}_{t} - S_{t+1}\,] = 0$ [7] (3.2.4.d.)

Where (log of the) forward price of dollars at time (t)for delivery one period later at (t+1) As long as any predictable component in the spot rate depreciation is fully embodied in the forward rate, as it will be in an efficient market, the opportunity for profit is illusionary. Assuming that the spot rate generate from 3.2.4.a and expected spot from 3.2.4.b equations (not following a random walk) the profit made by a speculator paying the rationally expected spot rate at t-1 and selling on the spot in the next period can be found if we subtract 3.2.4.b from 3.2.4.a:

$S_t - E_{t-1} S_t = c(Z_t - E_{t-1} Z_t) + e_t$ (3.2.4.e)

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[7] Using Purchasing Power Theory we can obtain S

This Profit, $c(Z_t - E_{t-1} Z_t)$, is generated by a speculator paying the rationally expected spot rate at t-1 and selling on the spot in the next period. Although in any particular instance this profit is expected to be non-zero on the average it would be zero, if we take expectations conditional on t-1 and also considering that the error made in forecasting Z_t, will be random.

3.3. The Models Tested in this Research

The expectation derived from the one-period-ahead forecast of the S^{ex}_{t+1} actual value of the spot exchange rate S_{t+1} is not different. (E) is the expectations operator and (I) is the available information.

$$E[S_{t+1} - S^{ex}_{t+1} | I] = 0 \qquad (3.3.a)$$

The study of the efficient market and the random walk hypothesis involves joint tests of equilibrium price determination, and of efficiency. The equilibrium pricing determination is mainly based on the international parity conditions mention in chapter one.

The empirical models pertinent to testing the efficient market hypothesis are based on the efficient foreign exchange market hypothesis implying that the information predicting the future spot rate is fully summarized in the forward rate. Algebraically, the notion of the simple efficiency hypothesis is given by $E_t\,(S_{t-1}\,|I_1) = F_t$, were S_{t-1} is the is the natural logarithm of the spot rate at time $t+1$ expected at time t and F_t is the logarithm of the spot rate at time t.

A derivation of the general efficiency model is based on the following parities and assumptions;

First the interest rate differential between two countries is zero,(3.3.b).

Second, that purchase power parity holds true, (3.3.c), and

Third the Fisher effect, (3.3.d), is cogent.

$$r_t = r^*_t \tag{3.3.b}$$

$$r_t = rr_t + E(q_t) \tag{3.3.c}$$

$$\Delta s_t = \Delta p_t - \Delta p^*_t \tag{3.3.d}$$

Following by forwarding eq. (3.3.b) for one period and taking the mathematic expectation, adding and subtracting r_t and substituting the relationship into eqs. (3.3.b), (3.3.c), and (3.3.d), we receive[8]

$$s^e_{t+1} = E[s_{t+1}|\Pi_t] = p_t + \Delta p^e_t - (p^*_t + \Delta p^{*e}_t)$$

$$= p_t + \Delta p^e_t - (p^*_t + \Delta p^{*e}_t) + r_t - r^*_t$$

$$= p_t - p^*_t + r_t + \Delta p^e_t - (r^*_t + \Delta p^{*e}_t) \tag{3.3.e}$$

$$= s_t + i_t - i^*_t$$

$$= f_t$$

---

[8] Dr. John Malindretos, John Kallianiotis Foreign Exchange Market Efficiency, May 1995. Presented at the Eastern Economic Association Conference New York City March,1995. p.6

Substituting eq. (3.3.b), into (3.3.a), we derive;

$$E[s_{t+1} - f_t|\Pi_t] = 0 \qquad (3.3.f)$$

or

$$E[s_{t+1} - f_t|I_t] \cong 0 \qquad (3.3.g)$$

The development of the recent work focuses on the role of the risk premium, where the forward rate contains the components of expectations and the risk premium (general efficiency hypothesis). The notion of rational expectations with no risk premium is formally expressed and is usually called the "simple efficiency" hypothesis[9] (3.3.g). It has been argued that the forward rate may also contain a risk premium , RP_{t+1}, if the economic agents are assumed to be risk averse. This relationship can be specified algebraically as[10],

$$E[s_{t+1} - f_t|I_t] = -RP_{t+1}\ ^{11} \qquad (3.3.h)$$

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[9] This risk premium exists due to the unexpected part of the exchange rate $U(s_{t+1})$, because $S_{t+1} = E(s_{t+1}) + U(s_{t+1})$ that we call innovations, surprises or "news", which is the difference between actual and expected values of some macro-variables,

i.e., $RP_{t+1} = (i-i^*)_{t+1} - E(i-i^*)_{t+1}$, see Frenkel (1981).

[10] Ibid 93

[11] This risk premium exists due to the unexpected part of the exchange rate $U(s_{t+1})$, because $s_{t+1} = E(s_{t+1}) + U(s_{t+1})$ that we call innovations, surprises or "news", which is the difference between actual and expected values of some macro-variables,
i.e., $RP_{t+1} = (i-i^*)_{t+1} - E(i-i^*)_{t+1}$, see Frenkel (1981).

First, we are testing the following equations:

$S_t = a_0 + a_1 S_{t-1} + e_{1t}$ (1)

A Random Walk process of spot exchange rate can be tested by examining the joint hypothesis that $a_0 = 0$, $a_1 = 1$ and that the error term is serially uncorrelated

$S_t = b_0 + b_1 f_{t-1} + e_{2t}$ (2)

The unbiased hypothesis involves the joint hypothesis testing that $b_0 = 0$, $b_1 = 1$ and the error term displays no serial correlation. Failure to reject the null hypothesis implies that $f_{t\text{-he }1}$ reflects all the relevant information for predicting the one-period ahead future spot rate.

$S_t = g_0 + g_1 S_{t-1} + g_2 f_{t-1} + e_{2t}$ (3)

It is reasonable to model the exchange rate equation by using the information reflected in both the forward rate and the one period previous spot to determine the current spot rate. The actual spot rate can be seen as the weighted average of the one period previous spot and forward rates. The restriction $g_1 + g_2 = 1$.

It has been argued that the forward rate may also contain a risk premium , RP_{t+1}, if the economic agents are assumed to be risk averse. This relationship can be specified algebraically and tested by the following expression.

$S_t = d_0 + d_1 f_{t-1} + d_2 [(i-i^*)_t - E_{t-1} (i-i^*)_t] + e_{4t}$ (4)

The relationship between s_t and s_{t-1}, f_{t-1} and "Information" is linear; the s_t's, f_t's and "Information" are nonstochastic variables whose values are fixed, and $s^2_{st}\ ^1\ 0$, $s^2_{ft}\ ^1\ 0$, $s^2_{\text{"news"}}\ ^1\ 0$ and finite; and $E(e_t) = 0$, $E(e_t^2) = s^2$, and $E(e_t, e_{t-1}) = 0$ meaning that e_{1t}, e_{2t}, e_{3t} and $e_{4t} \sim N(0, s^2)$.

CHAPTER IV

COINTEGRATION

Recently, much attention has been given to possibility that two or more assets might share the same stochastic trend i.e., that the assets might be cointegrated. Cointegration is important because, as shown in Engle and Granger (1987) the presence of common stochastic trends further restricts the set of statistical models that can be used to test an implement financial theories. In particular, error correction models, which can be interpreted as models in which this period's price change depends on how far spot rates were out of long-run equilibrium last period, become necessary.

The theory behind the computations of cointegration analysis is not so straight forward. Therefore, it is necessary to start with a depiction of some elementary concepts of *stochastic process and time series analysis*. Stochastic processes is denoted as the set $\{X_t\}$ representing a family of real values random variables, $X_1, X_2, ..., X_t$ index by t, where t represents time. By analogy with the notation describing a single random variable, μ_t, $\sigma^2{}_t$, denotes the mean and variance of a stochastic process respectively, where $\sigma_{t,\ t+i}$, denotes the covariance between two variables such as X_t and X_{t+i}. which belong to the stochastic process.

A stochastic process is said to be stationary, if the joint and conditional probability distributions of the process are unchanged over time. Thus, a stochastic process $\{X_t\}$ is said to be stationary if :

$E(X_t) = \text{constant} = \mu_t$,

$\mathrm{Var}(X_t) = \text{constant} = \sigma^2{}_t$, and

$\mathrm{Cov}(X_t ,X_{t+j}) = \sigma_{t,\ t+i}$.

Variances and means of the process are constant over time, while the value of the covariance between two periods depends only on the gap between periods, and not the actual time at which the covariance is considered. If one or more of the conditions above are not fulfilled, the process is nonstationary. Assuming implicitly that a stochastic process and time series are the same, y_t will denote a time series and e_t will denote a series of identically distributed continuous random variables with zero means (white noise).

A random walk process $S_t = S_{t-1} + \varepsilon_t$ as well as the random walk with a drift, $S_t = \mu + S_{t-1} + \varepsilon_t$, is non stationary since the variance of this process is a linear function of time which is not constant. We have seen that the variance in a random walk process and the correlation between the neighboring values increases over time revealing a trend. Nonstationarity of time series has always regarded as a problem in econometric analysis where diagnostic test statistics become unreliable. Regressions subjected to stochastic or deterministic trends often give promising results supporting spurious relationships. Since almost all economic data series contain trends, it follows that these series have to be detrended. A convenient way of getting rid of a trend in a series is using first differences between successive observations. Hence, for a random walk we define the detrended variable $\Delta S_t = S_t - S_{t-1} = \varepsilon_t$, and ΔS_t is apparently stationary. However, if the error term ε_t , is autocorrelated with $\varepsilon_t = \rho\, \varepsilon_{-1} + \xi_t$, where ξ_t is a white noise variable, first differencing y_t guarantee us stationary provided that $|\rho|<1$. Otherwise, it is necessary to difference a series a series more than once in order to achieve stationarity. A stationary series which can be transformed to stationary series by differencing d times is said to be *integrated of order d*, $y_t \sim I(d)$. Hence, I(2) is the first differences of the first differences of y_t -to achieve stationary.

$$\Delta\Delta\, y_t = \Delta(y_t - y_{t-1}) = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2}) \qquad (4.a)$$

If y_t is stationary, then no differencing is necessary, that is $y_t \sim I(0)$

Before any sensible regression analysis can be performed, it is essential to identify the order of integration. An appropriate and simple method of testing the order of integration of y_t in equation,

$$\varepsilon_t = \rho y_{t-1} + \xi_t \qquad (4.b)$$

proposed by Dickey and Fuller (1979) (DF). DF is a test of the hypothesis that in (4.b) $\rho = 1$, the so-called *unit root test*. This test is based on the equivalent regression equation to (4.b),

$$\Delta y_t = \delta\, y_{t-1} + \varepsilon_t \qquad (4.c)$$

or $y_t = (1+\delta)\, y_{t-1} + \varepsilon_t$, where $\rho = (1+\delta)$. The DF test consists of testing the negativity of δ in the OLS regression. Rejection of the null hypothesis: $\delta = 0$ in favor of the alternative $\delta < 0$ implies that $\rho < 1$ and that y_t is integrated for order zero $y_t \sim I(0)$. To test the null hypothesis it is necessary to know the distribution of the statistic used for the test and the associated critical region for its evaluation. If the computed t statistic is smaller than the lower critical value for a particular critical observations (n), the null (unit root) hypothesis has to be rejected and the alternative of stationarity of y_t is accepted. If the calculated t statistic is greater than the upper critical value, then the null hypothesis cannot be rejected. There is an indecisive range between the lower and upper limits that one is unsure whether or not to reject the null hypothesis. If the null hypothesis cannot be rejected then y_t is integrated of order higher than zero or not integrated at all. Consequently, the next steps are to test whether the order of cointegration is one or greater than one.

The traditional solution of first differencing the data imposes too many unit roots in the system, invalidating standard inference procedures. These problems become particularly important in finance when testing for market efficiency, or when implementing many other financial models using multivariate time series analysis.[1] Over-differencing normally results in a very high positive (instead of negative) value of the DF test accompanied by a very high coefficient of determination for the fitted regression. A weakness of the original DF test is that it does not take account of possible autocorrelation in the error process. In such case the Augmented Dicker-Fuller test (ADF) is regarded as being the most efficient test from among the simple test for integration. The ADF uses lagged left-hand side variables to approximate the autocorrelation. The ADF equivalent of (c) is the following:

$$\Delta y_t = \delta \cdot y_{t-1} + \sum_{i=1}^{k} \delta \cdot \Delta y_{t-i} + \varepsilon_t \qquad (4.d)$$

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[1] Robin J. Brenner and Kenneth F. Kroner "Arbitrage Cointegration and Testing the Unbiasedness in the Financial Markets" Journal of Financial and Quantitative Analysis Vol 30, No 1, March 1985 , 29-36

where k is the number of lags for Δy_{t-1}. The testing procedure is the same as before with the examination of the t ratio for δ. Another quick way of testing whether a variable is integrated of order zero is to compute for the variable y_t the Durbin-Watson statistic, IDW;

$$IDW = \frac{\Sigma(y_t - y_{t-1})^2}{\Sigma(y_t - \overline{y}_t)^2}, \qquad (4.f)$$

where $\overline{y_t}$ stands for the arithmetic mean of y_t. If $\rho = 1$ in (4.b), the numerator in (4.f) is equal to $\Sigma \varepsilon_t^2$, where y_t represents the "fitted" value for a regression of y_t on y_{t-1} under the restriction that the coefficient of y_{t-1} is equal to one. In such a case the value of IDW should be equal to zero.

According to Engle and Granger time series x_t, y_t are said to be cointegrated of order d, b where $d>=b>=0$, written as:

$x_t, y_t \sim \mathrm{CI}(d,b)$,

if:

1. both series are integrated of order d,
2. there exist a linear combination of these variables such $\alpha_1 x_t + \alpha_2 y_t$, which is integrated of order d - b. The vector [α_1, α_2] is called *cointegrating vector.*

Suppose that S_{t-1}, f_{t-1}^t are cointegrated with order one I(1) and the long run relationship between them is $S_{t-1} = f_{t-1}^t$ then ; if both variables are CI(1,1) and their cointegrating vectors [b,-1] so that the deviations of S_{t-1} from its long run path S_t then a model of first differences incorporating an error correction mechanism can be developed;

$$\Delta S_t = \beta_1 \Delta f_{t-1}^t + \beta_2 \left(S_{t-1} - b \cdot f_{t-1}^t \right) + \varepsilon_t \qquad (4.g)$$

where ΔS_t and the regressors, Δf_{t-1}^t and $\left(S_{t-1} - b \cdot f_{t-1}^t \right)$ are I(0). The model incorporates both a long run solution and has an error correction mechanism (ECM) when β_2 is negative. ECM $= S_t - S_t^{ex} = \left(S_t - b \cdot S_t \right) = u_t$

where u_t reflects the error correction aspect of that equation. The following possibilities of integration and cointegration exist;[2]

1. if S_t ~ I(1) and $f_{t-1}^t \sim I(0)$, then $u_t \sim I(1)$, and the variables , S_t ~ are not cointegrated;
2. if S_t ~ I(1) and $f_{t-1}{}^t \sim I(1)$, then it might be that $u_t \sim I(0)$, and the variables f_{t-1}^t, S_t ~ cointegrated given that [b,-1] constitutes a cointegrated vector;
3. if S_t ~ I(0) and $f_{t-1}{}^t \sim I(0)$, then $u_t \sim I(0)$, and the variables f_{t-1}^t, S_t ~ are cointegrated;
4. if S_t ~ I(0) and $f_{t-1}{}^t \sim I(1)$, then $u_t \sim I(1)$, and the variables f_{t-1}^t, S_t ~ are not integrated;

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[2] Drymes, Phoebus J., Econometrics (1970): Statistical Foundations and Applications. Cointegration Analysis (Harper and Row) pp. 147

In a long run relationship between two variables both must be integrated of the same order if the error term is to be $I(0)$. Stationarity of the error term is especially important if one is going to examine models incorporating error correction mechanisms such as in equation (4.g). If the number of variables involved in the long run relation increases, the problem becomes much more complicated. Considering the model

$$S_t = \alpha_4 + \beta_1 f_{t-1}^{t} + \beta_2 S_{t-1} \beta_3 (i - i^*) + \varepsilon_t \qquad (4.h)$$

some one has to consider that it is possible for the variables to be integrated for different orders in order the error term u_t to be stationary. A common situation would be

$S_t \sim I(1), f_{t-1}^{t}(2)$, $S_{t-1} \sim I(2)$ and $(i - i^*) \sim I(2)$

Despite the different orders of integration , the error term could still be stationary provided $\beta_1 f_{t-1}^{t} + \beta_2 S_{t-1} + \beta_3 (i - i^*) \sim I(1)$ This lead to a major complication of the entire concept of cointegration in a long run relationship and in the stationarity of the error term. A general rule is that if the variables in a long run relationship rate of different order of integration and the order of the dependent variable is lower that the highest order of integration of the explanatory variables, there must be at least two explanatory variables integrated of this highest order if the necessary condition for stationarity of the error term is to be met.

The DF, and ADF is used to determine whether the linear combination of two or more variables for each of the four models is $I(0)$. Special attention is given to the t values and the critical values of the cointegrating test since both depend on the number of the unknown cointegrating coefficients.

An algorithm developed by Engle and Granger is as follows;[3]

Step-1

Test for the order of cointegration of the variables involved in the postulated long run relationships. For equation (2), where two variables appear S_t , f_{t-1}^{t}, both have to be of the same order of integration. For equation (3) where the number of explanatory variables is greater than two, the order of integration of the dependent variable cannot be higher than the order of integration of any of the explanatory variables. In addition, there must be either none of at least two explanatory variables integrated to an identical order higher that the order of integration of the dependent variable.

Step-2

The purpose of Step-2 is to decide whether the cointegrating vector is known, or has to be estimated. Sometimes the cointegrating vector may be known a *priori*. For example if it is believed that the long run spot rate appear S_t , is equal to the forward rate f_{t-1}^{t}. In that case the Cointegration vector would be [1,-1] given by [1,-β] or [1, -β$_1$,-β$_2$] respectively for equation (3) and (4). Coefficients of these vectors have to be estimated, usually by OLS. If the cointegrating vector is known a *priori* we test the order of integration and then we perform SF Cointegration test to determine the significance of *t* for δ in the OLS regression

$$\Delta u_t = \delta_1 \Delta u_{t-1} + \varepsilon_t \qquad (4.j)$$

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[3] Engle R.F., and C.W.J. Granger "Co-Integration and Error Correction: Representation, Estimation and Testing" Econometrica, 55 (1987), 251-276

where $u_t = S_t - f^{t}_{t-1}$. The critical values of the test are same as used for testing integration. AFD uses the t ratio for δ from the equation

$$\Delta u_t = \delta \cdot u_{t-1} + \sum_{i=1}^{k} \delta \cdot \Delta u_{t-i} + \varepsilon_t \qquad (4.k)$$

If the cointegrating vector is not known a *priori*, and this applies to equations (3) and (4) where we are dealing with long run relationships of the type

$$S_t = \beta_t x_{1t} + \beta_2 x_{2t} + \ldots + \beta_m x_{mt} + u_t , \qquad (4.l)$$

and the cointegrating vector $[1, -\beta_1, -\beta_2, \ldots, -\beta_m]$ is not known and has to be estimated.

Computationally speaking we use the same ADF equations (4.j) and (4.k) but this time we estimate the residuals from (4.l). The important difference between the two cases is the fact that in the second case coefficients in the cointegrating vector are estimated and the distribution of the t ratio depends on the number of coefficients estimated. In equation (3) where there are two explanatory variables, and the number of observations is 295, the approximate critical values for the cointegration test are for the 5% level of significance : -3.31(lower bound) and -.3.15 (upper bound). The null hypothesis of no cointegration is rejected if the t value for δ in equation (l) or (k) is bellow -3.31, and is not rejected if the value was above -3.15, and unsure whether to reject or not if the value lies between -3.31 and -3.15.

In the same fashion a 'rough and ready' method for testing cointegration is to use an analog of Durbin-Waston test for cointegration which tests estimated deviations form a long run path which, under the cointegration hypothesis, are stationary:

$$CIDW = \frac{\Sigma(u_t - u_{t-1})^2}{\Sigma(u_t - \bar{u}_t)^2}, \qquad (4.m)$$

where $\bar{u}_t$ is the arithmetic mean for the residuals u_t. The power of *CIDW* depends positively on the goodness of fit of the *OLS* of the long run relationship (4.1). A "rule of thumb"' proposed by Banerge *et. al.*(1986) asserts if *CIDW* computed for u_t on an equation (3) is smaller than the coefficient of determination (R^2) for this equation, the cointegration hypothesis is likely to be false; otherwise, when *CIDW*> R^2 cointegration may occur. If the Durbin-Watson statistic, computed for the residuals of a static model representing a long run relationship, is close to 2, there is no danger of lack of cointegration of the variables.

4.1.Modeling Cointegrated Series through Error Correction Models

When we dealing with cointegrated nonstationary variables we can estimate a model with an error correction mechanism. The fact the variables are cointegrated implies that there is some adjustment process which prevents the errors in the long run relationship becoming larger and larger. Engle and Granger (1987) have shown that any cointegration series have an error correction representation. The converse is also true where cointegration is a necessary condition for error correction models to hold[4].

Under the assumption that in equation (2)

$$S_t = \beta_1 f_{t-1}^t + \mathrm{u}_t \qquad (4.1.a)$$

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[4] Engle and Granger (1991, pp.7-8)

both S_t, f_{t-1}^t are $I(1)$ and the coefficient β is unknown, but for its *OLS* estimate of β, the DF/ADF tests indicate stationarity of the *OLS* residuals u_t which indicted that cointegration of S_t, f_{t-1}^t of order (1,1)with the cointegrating vector [1,-β] is accepted. Reasonably, the next step is to switch to a short run model with an error correction mechanism and direct estimate

$$\Delta S_t = \beta_1 \Delta f_{t-1}^t + \beta_2 \left(S_{t-1} - b \cdot f_{t-1}^t \right) + \varepsilon_t \qquad (4.1.b)$$

where β_2 is negative. Since stationarity of the residuals in (4.1.a) is not rejected we will estimate (4.1.b) replacing β by its previously computed OLS estimate β* . As a result of this substitution the condition of identical cointegration for the variables in (4.1.b)is met;

ΔS_t, Δf_{t-1}^t and $\left(S_{t-1} - b \cdot f_{t-1}^t \right), \varepsilon_t$ are all $I(0)$

However, a note should be made here that using Engel-Granger method, we should be aware of the fact that we do not prove that the relation (4.1.a) is really a long run one. This is an assumption and cannot be statistically verified. We have to have a strong belief in a long run equilibrium relationship between the variables that is supported by relevant economic theory.

Assuming that interest rates are stochastic and using widely accepted no-arbitrage arguments this section would test cointegration in the currency spot and forward market.

Because of the importance of the unbiased hypothesis in financial theory , many tests for it have been developed. In past literature researchers advocate that cointegration is likely to hold in currency markets and that optimal hedging and forecasting models are market specific. Since market efficiency implies that the price at each point in time should include all available information and, given past prices, no other information should improve prediction of forward price , then cointegration of two speculative markets of two different assets, spot and forward, implies efficiency. The cointegration approach is attractive in that it can properly account for the non-stationarity in price series. Following Engle and Granger (1987) we will test for an equilibrium relationship between S_t and f_{t-1}^{t}. The approach is estimating equations (2), (3) and (4) as the cointegrating or equilibrium regression, and check its least squares residual for stationarity using unit-root tests. If the residual is found to be stationary, the null hypothesis of no equilibrium relationship between S_t and f_{t-1}^{t} is rejected. Cointegration between these two variables implies that they never drift part. This is what market efficiency hypothesis implies that the forward and spot rate are lose together. If these two price series are not cointegrated, they will tend to deviate apart without bound, which is contrary to market efficiency hypothesis.

Recent developments in the cointegration analysis by Jonathan (1988,1990) provide a new technique for testing market efficiency. Jonathan devises a statistical procedure for testing cointegration using maximum Likelihood ratio method. This method tests the parameters of the equilibrium relationship between nonstationary variables. In the contrary to the Engle-Granger single equation procedure, Jonathan's procedure is based on the vector autoregressive model that allows for possible interactions on the determination of spot prices and forward prices.

A time series is integrated of order d, denoted I(d). The series can achieve stationarity only after differencing d times. A $I(0)$ series is thus, by definition, stationary;

whereas, an $I(1)$series contains a unit root and is nonstationary. The simplest example of an I(1) series is a random walk.[5]

When the spot price and, S_t, and the forward price , f^{t}_{t-1} are cointegrated, $I(1)$ then the following linear relationship would be also contains a unit root.

$$e_t = S_t - b_0 - b_1 f^{t}_{t-1}$$

Cointegration between S_t and, f^{t}_{t-1} is a necessary condition of market efficiency. The hypothesis of market efficiency suggests that f^{t}_{t-1} is an unbiased predictor of S_t on average. If S_t and, f^{t}_{t-1} are not cointegrated, the error term, e_t is nostationary and S_t and, f^{t}_{t-1} tend to deviate apart without bound. Hence, f^{t}_{t-1} has little predictive power about the movement of S_t which is inconsistent with market efficiency hypothesis. The cointegration is, however, only one of the necessary conditions for market efficiency. Market efficiency also requires that $b_0 = 0$ and $b_1 = 1$ in equation (2), otherwise, f^{t}_{t-1} is not an unbiased predictor of S_t, even when S_t and, f^{t}_{t-1} move loosely together over time.

Consequently, a test for market efficiency involves formal testing of restrictions on cointegrating parameters namely $b_0 = 0$ and $b_1 = 1$ which can be conducted using standard asymptotic chi-square tests under the Jonansen approach. The test for market efficiency

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[5]. Edam and Dixon (1988) and Shen and Wang (1990) discuss the problem in testing market efficiency when the spot price follows a random walk. Usual F-tests are not valid as the series has a unit root $I(1)$.

thus consists of two parts. The stationary series S_t and, f_{t-1}^{t} are first examined for cointegration.

Unit root tests are important in examining stationarity of a time series. Non stationary regressors invalidate menu standard results and require special treatment. In cointegration analysis, an important question is whether the disturbance term is the cointegrating vector has a unit root. Each unit root requires to be first differentiated.

In order to make our series stationary we took the first difference of the Foreign Exchange Market data. We use the cointegration test results to show why we reject unbiasedness and why shocks are persistent in the foreign exchange markets, and why forward forecast errors are serially correlated.

CHAPTER V

BASIC STATISTICS OF THE MODELS

5.1 Simple Testing of the Model and Basic Statistics

The data include monthly figures for the spot and forward rate of US dollar ($) with respect to German mark (DM), Belgian franc (B.F.), Dutch guilder (Fl), also, Treasury bill rates (3-months) or other interest rates. All the data come from Main Economic Indicators, OECD and cover the period from March 1973 to June 1994.

First, we started testing the random walk hypothesis by calculating the mean value, the variance, and the coefficient of variation of the error term (e_t). The results appear in Table-1. As we see, the E(e_t) is small and the variance is small but it is not constant over time. Then, the General Efficiency hypothesis was tested and in Table-2 the results are presented. The results show that the random walk is not outperformed from the other foreign exchange equations. We use one step ahead spot to determine the magnitude of the variance and the error term. Table-3 shows the correlation matrix for the exchange rates. In Table-4, some basic statistics are provided.[1] These are: mean values, standard deviations, maximum, minimum, skewness, kurtosis, correlation, normality test statistics, autocorrelation and partial autocorrelation, cross correlation, and finally unit roots (stationary) tests.

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[1] See, Theodossiou and Lee (1993), Koutmos, Negakis, and Theodossiou (1993), and Theodossiou (1994) for a detailed discussion of all these statistics and for other formal time series tests

To predict the S_t we must use F_t (best predictor because sRP_t is small). Then, the forward rate cannot predict very well the future spot rate (no efficiency). A negative RP means that the forward rate contains a risk premium (i.e. Germany, and Holland). A positive RP means that the forward rate does not contain a risk premium and the investors are accepting a lower exchange rate for the safety of the forward market (they pay for the certainty of the forward market, they prefer forward market to spot market) (i.e. Belgium) (spot market contains a risk and investors require a risk premium). The smallest risk premium in the forward market appears in Belgium's RP. The foreign exchange market is not very efficient. The most efficient (RP) is Netherlands (1-month forward) and least efficient (large RP) is Belgium (3-month forward). The most stable market (sRP) is Belgium (current spot market, sRP_t) and least stable market (largest sRP_t) are the EC member countries (all the same s) (sRP_{t+2}).

Table-1 Testing the Random Walk Hypothesis: st-st-1 = et; E(e2t)=s2

Country	E(ε_t)	E(ε_t^2)	σ^2(constant)
Germany	**0.0022594**	**0.0350565**	**0.001228958**
Belgium	**0.0007741**	**0.034895**	**0.001217661**
Holland	**0.001953**	**0.0348101**	**0.001211743**
	MIN	**CV**	
Germany	**-0.12117437**	**15.51584491**	
Belgium	**-0.1210755**	**45.07815528**	
Holland	**-0.1220074**	**17.82391193**	

Table-2 Testing the "General Efficiency" Hypothesis

Country	RPt	σ_{RPt}	RPt+1	σ_{RPt+1}	RPt+3	σ_{RPt+3}
Germany	**-0.00479**	**7.9E-05**	**-0.00258**	**0.000988**	**0.001957**	**0.000675**
Belgium	**0.000289**	**4.98E-05**	**0.0039**	**0.000903**	**0.00597**	**0.003982**
Netherlands	**-0.0049**	**9.01E-05**	**-0.0002**	**0.001099**	**0.002974**	**0.003967**

Table-3 Correlation Matrix for Spot and Forward Exchange Rates

	s_B	f_B	s_N	f_N^a	s_G	f_G
s_B	1.000					
f_B	0.999	1.000				
s_N	0.833	0.828	1.000			
f_N^a	0.856	0.858	0.999	1.000		
s_G	0.755	0.750	0.989	0.984	1.000	
f_G	0.759	0.755	0.988	0.983	0.999	1.000

Note: a = Netherlands' sample is from 1973.01 to 1994.06
S = spot exchange rate, f= forward exchange rate,
B= Belgium, N= Netherlands, G= Germany

Table-4 Basic Statistics of Spot and Forward Exchange Rates

Belgium

		Sb	D(Sb)	Fb	D(Fb)
Mean		0.9620373	0.0007741	0.9587851	0.0007127
St. Dev.		0.1961029	0.034895	0.1962403	0.0344486
Maximum		1.302967	0.1171684	1.302315	0.1171579
Minimum		0.4001845	-0.1210755	0.3973658	-0.1227583
Skewness		-0.840534	-0.238714	-0.824123	-0.218719
Kurtosis		3.2271855	4.0083	3.215536	3.936059
J-B St.		30.69444	13.22589	29.47379	11.34281
B-P Q-St.		2357.2	13.03	2356.74	13.84
L-B Q-St.		2432.52	13.52	2431.96	14.34
D-F t-St.		1.886	3.504	1.891	3.518

Holland

		Sn	D(Sn)	Fn	D(Fn)
Mean		3.771451	0.001953	3.7318228	0.0024873
St. Dev.		0.1909164	0.0348101	0.174648	0.0354273
Maximum		4.142499	0.1173382	4.775671	0.122035
Minimum		2.278653	-0.1220074	3.284664	-0.1493299
Skewness		-0.293862	-0.152274	-0.1739	-0.162953
Kurtosis		2.205521	3.886795	2.311792	4.833448
J-B St.		10.41724	9.34105	5.301809	30.77624
B-P Q-St.		2253.37	10.57	1655.7	8.56
L-B Q-St.		2324.82	10.96	1716.26	8.9
D-F t-St.		2.151	3.674	1.869	3.264

Note: D= The first difference operator

Table-4 (Continued)

Germany

		Sg	D(Sg)	Fg	D(Fg)
Mean		3.8666751	0.0022594	3.8714976	0.0021766
St. Dev.		0.2023665	0.0350565	0.1982744	0.0348803
Maximum		4.262116	0.1185412	4.246779	0.1146996
Minimum		3.404525	-0.1217437	3.412797	-0.1235337
Skewness		-0.104898	-0.092324	-0.142585	-0.086527
Kurtosis		1.838201	3.995281	1.81164	4.006272
J-B St.		14.86711	10.8872	15.9309	11.07688
B-P Q-St.		2296.76	10.71	2280.59	10.64
L-B Q-St.		2370.1	11.1	2353.24	11.04
D-F t-St.		2.249	3.742	2.272	3.705

Note: D= The first difference operator

CHAPTER VI

THE EMPIRICAL RESULTS

Regression theory has proven to be a most useful statistical technique in economic analysis. This usefulness stems from the value of regression in estimating the relationships among variables, thus providing economists with a tool for empirical verification of relationships postulated by various economic theories. However there are some problems and restrictions with the regression model that were discovered by economists when they attempted to apply it to economic problems. These limitations are important to analysts because they indicate why the results of regression studies should be viewed with caution.

Autocorrelation is a problem frequently encounter by financial analysts when their input to the regression model is a set of time series. The term "autoregression" refers to a problem in the "predictions" of thex_i input y's using the x_i variables. The problem arises because a prediction error in the regression model. If a low prediction in one quarter tends to be followed by a low prediction in the next quarter or an error on the high side tends to be followed by another high error, this relationship illustrates the problem of autocorrelation, which is that successive errors are correlated to each other. In this situation, ordinary regression is not strictly appropriate because it underestimates the amount of error in the regression equation estimates. Usually, autocorrelation is an indication that an important predicting variable has been left out of the study. The most straightforward solution to the problem therefore is to locate the missing variables. An alternative is to use a more complex, econometric estimation technique instead of standard regression.

Multicollinearity is another problem frequently encountered by analysts. When a number of the variables included in the study are very highly correlated to each other, it is difficult for the regression model tell them apart and determine the separate effect that each has on the variable being predicted. As a result, the standard error of the regression coefficient ($\hat{\sigma}_b$), which measures the reliability of these coefficients, may become very large and, in turn, make the coefficients of the variables in question fail their t test for significance. The problem can be avoided by eliminating one of the highly correlated variables from the study, or in some cases by adding more observations as input to the regression. If the $\hat{\sigma}_b$ are satisfactory, multicollinearity is not a problem, that is, the correlation of variables is not in itself damaging unless unsatisfactory values of $\hat{\sigma}_b$ result.

Heteroscedasticity occurs when the prediction errors resulting from the use of the model do not have the same variance (the same degree of reliability). Errors in variables pose a severe problem for analysts. The variables input to the regression are not known exactly, but only with some measurement error. Standard least squares regression does not allow specially for this type of error and may produce misleading results.

Other problems that have been explored include errors correlated with predicting variables that are themselves random variables not known with certainty (which causes the amount of error in the regression study to be underestimated).

Empirical investigation using regression theory still requires a great deal of ingenuity and "feel". Perhaps the most important single point made by the statistical researchers is their emphasis upon the *t* test of the regression coefficients instead of R-square. The *t* test determines whether a coefficient (and its variable) is reliable enough to use in the equation. To pass the *t* test, the regression coefficient must have an acceptably small standard error ($\hat{\sigma}_b$). In other words, we must be fairly certain that we have estimated the influence of the variable with a reasonable degree of accuracy. Reasonably good coefficient mean a reasonably good equation. Only after the ($\hat{\sigma}_b$) are considered acceptable do we evaluate R-square to discover the percentage improvement in prediction power. After all, if the estimated values for the regression coefficients are not reliable, it doesn't matter how well the unreliable equation "explained" the input data, because it cannot be expected to predict the future data.

We computed the regression estimates for equations (1), (2), (3) and (4) by using an Ordinary Least Squares (OLS). As instruments, we use a constant, time, time squared, and lagged values of the spot and forward rates. The expected interest rate differential is computed from a regression of the interest differential on a constant, two lagged values of the interest differential, two lagged spot exchange rates, and time. We found that equations using raw data are appropriate to a world in which shifts come and last for just one period. Equations using first differences of economic data are appropriate to a world in which shifts come and last and last forever. Another reason is that the presence of lagged differences into a model provides a short of hook on which the serial correlation can be hanging, instead of being pushed onto the disturbances. Furthermore, this device is illegitimate if we really know what the correct model for the problem. In addition this technique deals with unobservable expectations about the future on the part of economic decision-making units.

The F-Statistic for the goodness of fit of all linear equations was computed as follows

$R^2 \Big/ \left[\left(1 - R^2\right)/293\right]$, at the 1 percent significance level , the critical level of F is 7.88.

Therefore, we have no hesitation in rejecting the null hypothesis that R^2 could have arisen by chance. All countries display a high F-statistic to reject the null hypothesis at 1 and 5 percent level of confidence.

Following the standard error of the regression for all equations is bellow .04 which shows that the coefficient estimates are quite accurate since their probability density function is quite narrow. However, that does not tell us whether the regression estimates come from the middle of the function. The higher the variance of the disturbance term, the higher the standard errors of the coefficients in the regression equation, reflecting that the coefficient are inaccurate.

Next, the Residuals sum of square is another measurement which proves the accuracy of the tested models. No country under investigations has higher RSS than 0.337. In OLS we wish to fit the regression in such a way so that as to make these as small as possible $\min \sum e^2 = \sum \left(S_t - \overline{S_t}\right)^2$ (6.a)

The value of the likelihood function is evaluated at the estimate values of the coefficient [1]

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[1] Robert E. Hall, Jack Jonston, David M. Lilien, 1990, California,. Ch#15-5

$$ML = -\frac{T}{2} - \frac{T}{2}\log(2\pi) - \frac{T}{2}\log\left(\frac{SSR}{T}\right)$$

(6.b)

where T is the number of observations, and SSR is the sum of squared residuals. LM ratio test examines the statistic 2(LLU-LLR), where LLU and LLR are the log likelihood of the restricted and unrestricted versions, respectively, have a x^2 distribution in large samples with s degrees of freedom where s is the number of restrictions imposed, under the restricted version is correct.

6.1. Autocorrelation

The consequences of autocorrelation are somewhat similar to those of heteroscedasticity. The regression coefficient remain unbiased but they become inefficient and their standard errors are estimated wrongly. Autocorrelation normally become visible only in time series. The disturbance term picks up the influence of those variables affecting the dependent variable that have not been included in the regression equation. If it is reasonable to assume that time t values are only influenced by the previous period ($t-1$) and no further back, the Durbin-Watson statistic may be requested in the definition of the regression model.[2] Autocorrelation is on the whole more likely the shorter the interval between observations. One important point to note is that autocorrelation is on the whole more likely to be a problem the shorter the interval between observations. The well know Durbin-Watson test statistic d is defied as a variant of the following:

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[2] Durbin J. and G.S. Watson (1950) "Testing for Serial Correlation in Least Squares Regression" 1, Biometrica 37 (3-4), 409-428.

$$d = \sum_{t=2}^{T} (e_t - e_{t-1})^2 \Big/ \sum_{t=1}^{T} e_t^2 \qquad (6.1.a)$$

If there is no autocorrelation present, p is 0, so d should be close to 2. If there is positive autocorrelation, d should tend to be less than 2; If there is negative autocorrelation it should tend to be greater than 2.

The critical value of d, at any given significant level depends on the number of explanatory variables in the regression equation and the number of observations in the sample. Unfortunately, it also depends on the particular values taken by the explanatory variables. Thus, it is not possible to construct a table giving the exact critical values for all possible samples as it happens with t test and F test, but it is possible to calculate upper and lower limits for the critical value of d. (d_U, d_L).

If the exact value of d_{crit}, is known then a comparison can be made with the value of the regression with it. If $d \geq d_{crit}$, the null hypothesis of autocorrelation is failed to be rejected. If $d \leq d_{crit}$, the null hypothesis is rejected and the conclusions is that there is evidence of positive autocorrelation. All countries exhibit a d close to 2 which indicates there is no significant serial correlation. For the countries tested in this paper, there is no autocorrelation founded.

The results from the estimations of those four equations are shown in Tables 5,6,7 and 8. The overall results are robust and we have good statistics, too.

6.1.1. Detection of First-Order Autocorrelation: The Durbin-Watson Test

The so-called first-order autoregressive scheme has received most attention in the literature because it is intuitively plausible and there is usually insufficient evidence to make it worthwhile considering more complicated models.

When the disturbance term of our models are correlated the coefficient estimates of ordinary least squares become inefficient. However they may be still unbiased. The first order autoregressive correction of AR(1) correction. provides a method to obtain efficient estimates when the disturbance term display fires order serial correlation, that is

$u_t = e_t + u_{t-1}$

The AR(1) computes the residuals from the regression, and then finds the best prediction of the residual from its past value. Then it computes a new dependent variable by subtracting the predicted residual from the original dependent variable.

$S^N_t = S_t - S_{pred}$

where S^N_t is the new time series of spot rates and S_t is the original series. Then it runs a second regression of the new depended variable S_t based on the original independent f_{t-1}.

Following a new series of predicted residual a third regression is computed using the new series of spot rates. New values for the values are calculated by applying least squares to the linearized equation. This process continues until the coefficients convergence or the maximum number of iterations is reached. AR(1) procedure incorporates the residual from the past observation into the regression model of the current observation.

Note that there are two different kinds of residuals associated with AR(1) estimation. One kind is the unconditional residual, computed just as is LS; the Spot rate minus the forward rate multiplied by its regression coefficient. The other kind of residual is the one-period-ahead forecast error, which is the error made when the spot rate is forecast by applying the coefficients to the forward rate and then adding the prediction of the residual from its own past value.

Because of serial correlation, these residuals will tend to be smaller where forecast is improved by taking advantage of the predictive power of the lagged residuals. The improvement in the standard error is due to the extra predictive power of the lagged residual. However this improvement applies when forecast is made based on the already known forecast error from the immediately preceding period. A unique statistic measure for AR(1) which is the serial coefficient of the unconditional residuals. The AR(1) lies between (+1) and (-1) for extreme positive and negative serial correlation. When AR(1) is zero then serial correlation is absent. If the first-order specification is correct, the residuals would be then serially uncorrellated white noise.

6.2. Nonpredictive Tests

The most important tests concerned with specification are the Ramsey Test as a general test of specification error and two Chow procedures examining the stability of a relationship over different time periods or over different subsamples of cross-section data. Moreover, recursive least squares shows the evolution of an estimated relationship as the sample is extended one observation at a time.

6.2.1 Wald Test

The Wald Test tests hypotheses involving restrictions on the coefficients of the explanatory variables. The restrictions may be linear or nonlinear, and two or more restrictions may be tested jointly. Output from Test(W) depends on the linearity of the restriction. For linear restrictions the output is an F-statistic and a x^2-statistic with associated probability-values. When linear restrictions are tested on a linear equation estimated with the LS command the F-statistic may be started as

$$F = \frac{(e_*'e_* - e'e)/q}{e'e/(n-k)}$$

where

$e_*'e_*$ = residual sum of squares when the restrictions are imposed in the sample estimation

e = residual sum of squares when the equation is estimated without the imposition of any restrictions

q = number of restrictions in the null hypothesis

n = number of sample points

k = number of coefficients in the unrestricted relation.

If the restrictions are valid there should be little difference in the fits obtained for the unrestricted and restricted regressions. Thus the calculated F-statistic is likely to be small, the probability-value large, and the restrictions not rejected. The distribution of the computed F-value only follows this exact, finite sample distribution when the disturbance terms in the relation are independently and normally distributed with zero mean and constant variance and the regressors are completely independent of the disturbances. In any case too much weight should never be placed on small differences between test statistics and critical values. Such outcomes should be treated as inconclusive. Attention should be paid to strong rejections, and not marginal results.

We added a second period lag in every equation and ask whether the set makes a significant contribution to the explanation of the dependent variable. We test the hypothesis that the coefficient on the lag is zero. The output gives an F-statistic and a likelihood ratio (LR) statistic, with associated probabilities. The F-statistic is interpreted in exactly the same way as in Wald Test , being based on the difference between residual sums of squares in the restricted and unrestricted regressions. In this case the restricted regression is the equation without the lag; it is also referred to as the default equation.

The unrestricted equation is the new, expanded equation, also referred to as the test equation. The LR statistic is based on the ratio of the restricted maximized likelihoo to the unrestricted maximized likelihood, and under general conditions it has a asymptotic x^2 distribution with degrees of freedom equal to the number of added variables The LR statistic will be approximately proportional to the F-statistic, the factor o proportionality being the number of added variables.[3]

6.2.2. Serial Correlation Large Range Multiplier (LM) Test

We tested for autocorrelated disturbances. We also specified an order of three and twelv of the process thought to be determining the disturbances, so that the default equation i augmented by three and twelve lags of the residuals from those equations. Output fro the command consists of an F-statistic and a x^2-statistic, each with the relevant probabilit

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[3] Robert E. Hall, Jack Jonston, David M. Lilien, 1990, California,. Ch#15-5

value. The x^2-statistic is the Breusch-Godfrey, Lagrange multiplier test statistic and is nR^2, where n is the sample size and R^2 (R-squared) is the square of the multiple correlation coefficient from the test regression[4]. The exact distribution of the F-statistic is not know but nR^2 is asymptotically x^2(p) under quite general conditions.

6.2.3. Autocorrelations and Q-statistics

We also computed the autocorrelations and partial autocorrelations of the residuals up to twelve lags. And we got Box-Pierce and Ljung-Box Q statistics for testing for serial correlation. [5]

The conditions set by Gaus-Markov state that ;

1. The disturbance terms u_i in the n observations come all from probability distributions that have 0 mean $E(u_i)=0$
2. Population variance is constant for all observations pop.$Var(u_i)$ = Constant for all observations
3. pop. $Cov(u_i u_j)= 0,$ *if*
4. The explanatory variable is nonstochastic.

The term Heteroscedasticity refers to any case in which the variance of the probability distribution of the disturbance term is different for different observations.

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[4] Johnston Econometric Methods, third edition, pp. 319-321.

[5] Christopher Dougherty Introduction to Econometrics, 1992 Oxford University Press

There are two reasons why we are concerned about heteroscedasticity. One is that the presence of heteroscedasticity minimizes, in a probabilistic sense, precision of the unbiased estimators of the OLS estimators.[6] If there is no heteroscedasticity, the usual regression coefficients have the lowest variances, of all the unbiased estimators that are linear functions of the observations of *y*. If heteroscedasticity is present the OLS estimators become inefficient. A condition of heteroskedasticity exists when there is an appreciable trend in the plot of residuals versus predicted values . This can mean that the standard errors of the b's and hence their tests of significance will be incorrect. A pronounced funneling of values of the standard errors vs. the predicted reveals hateroscedasticity. One way to deal with this problem is to transform logarithmically the depended variable.[7]

In time series heteroscedastisity arises when both the depended and independent variables are growing over time and also the variance of the error term is growing over time . We will assume three different assumptions about the relationship between the variance of the disturbance term and the magnitude of the explanatory variables: Speark rank correlation test, the Goldfeld-Quandt test, and the Glejser test.

Heteroscedasticity is likely to be a problem when the values of the variables is the regression equation vary substantially in different observations. If the true relationship is given by $S_t = b_0 + b_1 f_{t-1} + e_{2t}$ (2) , and it may well be the case that the variations in the omitted variables and the measurement errors that are jointly responsible for the error

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[6] Hsiesh D. "A Heteroskedasticity-Consistent Covariance Estimator for Time Series Regressions," Journal of Econometrics, 22 (1983), 281-290

[7] Glejser H. "A new test for heteroskedasticity" Journal of the American Statistical Association 64 (325), 316-323, (1969)

term.[8] If S_t and f_{t-1} are growing over time, then it may well happen that the variance of the disturbance term e_2 is also growing over time[9].

This particular specification of heteroscedasticity was motivated by the observation that in working with macroeconomic series the size of residuals appeared to be the size of recent residuals. Thus the test is based on the regression of squared residuals on lagged squared residuals $e_t = b_0 + e_{t-1} \ldots e_{t-n}$

The ARCH test repeats the number of lags used and gives an F-statistic and an nR^2 statistic (n is the number of observations), each with the relevant probability value. Each statistic provides a test of the hypothesis that the coefficient of the lagged square residuals are all zero. Where the nR^2 statistic has an asymptotic x^2 distribution with degrees of freedom equal to the squared residuals.

6.3. Stability Tests

Stability tests of a regression model are the tests designed to evaluate whether the performance of a model in a post sample period is compatible with its performance in the sample period used to fit it. There are two principles on which stability tests can be organized. One approach is to focus on the predictive performance of the model; the other is to evaluate whether there is any evidence of shifts in the parameters in the prediction period.

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[8] Bollersiev, T. "Generalized autoregressive Conditional Heteroskedasticity," Journal of Econometrics (1987)

[9] The TEST (E) tests for Auto Regressive Conditional Heteroskedasticity. Econometrica, 50, 987-1008

6.3.1. F Test of Coefficient Stability

We performed the F test of a two structural break, one is 80.03, the next group is 79.05, 85.02. In this test, we evaluate whether the coefficients in the sample period and prediction period appear to be significantly different. To perform the test, we run the regression for the sample and prediction periods separately, and then for the two periods combined, and see whether sample period/prediction period division results in a significant improvement in fit compared with that obtained with the combined regression.

6.3.2. Ramsey Test

In the postulated model $S_t = b_0 + b_1 f_{t-1} + e_{2t}$ we have assumed that the disturbance term to have the multivariate normal distribution $N(0,s^2 I)$serially correlated, heteroskedastic or non-normal disturbances all violate the assumption that the disturbances are normally distributed. Specification errors include some or all of the following:

I. Omitted variables

II. Incorrect functional form of the variables that are required to be transformed to logs, powers or reciprocals.

III. Correlation between the random variables and the disturbance term or simultaneous equations, combination of lagged depended variables and serially correlated disturbances.

Ramsey (1969)[10], showed that any or all of these specification errors produce a non zero mean vector for e. Thus the null and alternative hypothesis are

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[10] "Test for Specification Errors on Classical Linear Least Squares Regression Analysis", Journal of the Royal Statistical Society Series B,31, 350-3781

H_o: $e \sim N(0,s^2I)$

H_1: $e \sim N(0,s^2I)$ $\quad m'0$

The test of H_o: is based on an augmented regression. The augmented model is $S_t = Zb_0 + b_1 f_{t-1} + e_{2t}$ (ii)where the specification error is then $a=0$. The question is what variables should enter the matrix Z. In the case of omitted variables there those variables constitute the Z matrix and the test of $a=0$ is simply the TEST (A). A TEST A enables you to add a set of variables to an existing equation an ask whether the set makes a significant contribution to the explanation of the dependent variable. For example by adding to the initial regression (16) a one month lag of the forward rate series it tests that the coefficients are zero and gives an output that reminds which variables have been added calculating an F- statistic and a likelihood ratio (LR) statistic with associated probabilities.

The F-statistic is based on the difference between residual sums of squares in the restricted equation and the unrestricted. In this case the restricted regression is the equations without lags and the unrestricted regression is the new, expanded equation. The LR statistic is based on the ratio of the restricted maximized likelihood to the unrestricted maximized likelihood, and under general conditions it has an asymptotic x^2 distribution with degrees of freedom equal to the number of added variables. The LR statistic will be approximately proportional to the F-statistic, the factor of proportionality being the number of added variables. In the case of incorrect functional form the omitted portion of the regression may well be some function of the regression included in x. For example, if a linear relationship

$S_t = b_0 + b_1 f_{t-1} + e_{2\,t}$ is specified instead of the true relation

$S_t = g_0 + g_1 S_{t-1} + g_2 f_{t-1} + e_{2\,t}$ or

$S_t = d_0 + d_1 f_{t-1} + d_2 [(i-i^*)_t - E_{t-1}(i-i^*)_t] + e_{4\,t}$

the augmented models have $Z_1 = S_{t-1}$ and $Z_2 = [(i-i^*)_t - E_{t-1}(i-i^*)_t]$ respectively. Ramsey's suggestion is to include in Z, powers of the predicted values of the dependent variable- the actual future spot rate (which is a linear combination of powers and cross-product terms of the explanatory variables. Specifically Ramsey suggests that that Z is the vector of predicted y values from the LS regression of y on x.

6.3.3 Chow Test

This is an important step in our investigation to split the time series into two or more subsamples and run separate regressions for each subsumable. Specifically the series of n data are split into n_1 to be used for estimation and the remaining $n_2 = n - n_1$ for testing. Using all available sample observations for estimation promotes a search for the formulation that best fits that specific dataset. We will denote the sum of the squares of the residuals of the separate regressions for the periods 1970.01 - 1982.01 & 1982.02-1994.06 U_A and U_B respectively. We will denote $U^P{}_A$ and $U^P{}_B$ of squares in then pool regression for the observations belonging to the two subsamples. Since the subsample regressions must fit their observations at least as will as, if not better than, the pooled regression, $U_A \quad U^P{}_A$ and $U_B \quad U^P{}_B$.

Hence $(U_A + U_B) \quad U^P$, where U^P is the total sum of squares of the residuals in the pooled regression, is equal to the sum of $U^P{}_A$ and $U^P{}_B$ Equality between U^P and $(U_A + U_B)$ will occur only when the regression coefficients for the pooled and subsample regression coincide. In general there would be an improvement $(U^P - U_A - U_B)$ when the time series is split up. There is a price to pay, in that (k+1) extra degrees of freedom are used up since instead of $(k+1)$ parameters for one combined regression we now have to estimate $(2k+2)$ in all (k being the number of explanatory variables, one being the constant term). After breaking up the sample, we are still left with $U_A + U_B$ (unexplained) sum of squares of the residuals, and we have $(n-2k-2)$ degrees of freedom remaining.

We use F- statistic in order to determine whether the improvement in the fit when we brake up the sample is significant.

$$\frac{\text{Improvement in fit / Degrees of freedom used up}}{\text{Unexplained / Degrees of freedom}} = \frac{(u_P - u_A - u_B)/(k+1)}{(u_P + u_B)/(n-2k-2)}$$

Test F is the forecast version of the Chow test. The equation estimated with the n_1 observations used to predict the values of the dependent variable in the remaining n_2 series. A vector of discrepancies between predicted and actual values is expected. If the discrepancies between predicted and actual values are small little doubt is cast on the estimated equation. Large discrepancies would cast suspicion on the estimated equation.

There are no hard and fast rules for determining the relative zones of n_1 and n_2. One obvious point would be the switch from fixed to flexible exchange rates. The purpose of the partitioning the data is to test whether the coefficient vector may be regarded as constant over the subsets. The equation under review is fitted separately to each subsample. Summing the residual sum of squares for each subsample gives the unrestricted residual sum of squares. The equation is then fitted to the complete set of sample observations, which yields the restricted residual sum of squares.

Table-5 Regression Estimates of equation (1)

		Germany	Holland	U.K.
Coefficients estimates				
a0		0.0640488	0.0642512	0.1149928
	SD	0.0420453	0.043162	0.060057
	T-stat	1.5233299	1.4886071	1.9147296
	2-tail stat	0.1289	0.1378	0.0567
a1		0.9840156	0.9834773	0.9774478
	SD	0.010862	0.0114328	0.0115832
	T-stat	90.592674	86.022063	84.38472
	2-tail stat	0	0	0
OLS				
R-square		0.970095	0.96694	0.965689
Adjusted R^2		0.969976	0.96681	0.965554
S.E. of Regression		0.034976	0.034736	0.03357
Log Likelihood		494.2107	495.9714	504.6735
Durbin-Watson Stat		1.892461	1.92957	1.771308
Sum of Square resid		0.309507	0.305262	0.285122
F-statistics		8207.033	7399.795	7120.781

Table-6 Regression Estimates of equation (2)

		Germany	Holland	U.K.
Coefficients estimates				
b0		-0.0138662	0.0258424	0.006517
	Std.E.	0.0448884	0.0535143	0.0639406
	T-stat	-0.3089035	0.4829062	0.1019232
	2-tail stat	0.7576	0.6297	0.9189
b1(forward)		1.0029151	0.992509	0.99812
	Std.E.	0.115826	0.0143244	0.0123294
	T-stat	86.587897	69.288098	80.954632
	2-tail stat	0	0	0
OLS				
R-square		0.967357	0.957709	0.96283
Adjusted R^2		0.967228	0.957509	0.962684
S.E. of Regression		0.036542	0.036511	0.034941
Log Likelihood		483.0416	405.7195	494.4697
Durbin-Watson Stat		1.778755	1.824158	1.65007
Sum of Square resid		0.337843	0.282614	0.308879
F-statistics		7497.464	4800.84	6553.652

Table-7 Regression Estimates of equation (3)

		Germany	**Holland**	**U.K.**
Coefficients estimates				
g0		0.0975422	0.0635932	0.1060223
	SD	0.0482813	0.0498624	0.0652345
	T-stat	2.0202889	1.2753471	1.6252485
	2-tail stat	0.0444	0.2036	0.1054
g1		1.3650342	1.4408309	0.9073729
	SD	0.2718176	0.2367745	0.1973782
	T-stat	5.0218763	6.0852459	4.5971287
	2-tail stat	0	0	0
g2		-0.3891955	-0.4566007	0.0717872
	SD	0.27743	0.2385029	0.2018516
	T-stat	-1.4028602	-1.914445	0.3556436
	2-tail stat	0.1619	0.0569	0.7224
OLS				
R-square		0.970326	0.964023	0.965706
Adjusted R^2		0.970091	0.963682	0.965434
S.E. of Regression		0.03491	0.033756	0.033628
Log Likelihood		495.2025	423.0206	504.7375
Durbin-Watson Stat		1.892134	2.066297	1.771489
Sum of Square resid		0.201857	0.240421	0.284979
F-statistics		0.307108	2826.896	3548.161

Table-8 Regression Estimates of equation (4)

		Germany	**Holland**	**U.K.**
Coefficients estimates				
d0		-0.0160122	0.0233793	0.0185081
	SD	0.0444751	0.0527442	0.0649477
	T-stat	-0.360026	0.4432578	0.2849688
	2-tail stat	0.7191	0.658	0.7759
d1		1.0034555	0.9931634	0.9957625
	SD	0.0114693	0.0141114	0.0125299
	T-stat	87.490566	70.380225	79.47087
	2-tail stat	0	0	0
d2		-0.0094046	-0.0045204	-0.0006611
	SD	0.0027577	0.0013927	0.0024559
	T-stat	-3.4103325	-3.245744	-0.2692067
	2-tail stat	0.0008	0.0014	0.788
OLS				
R-square		0.968413	0.959572	0.961923
Adjusted R^2		0.96816	0.959185	0.961618
S.E. of Regression		0.035871	0.035757	0.035034
Log Likelihood		484.46	406.8715	490.4298
Durbin-Watson Stat		1.726164	1.840297	1.655919
Sum of Square resid		0.321676	0.267215	0.306848
F-statistics		3832.281	2480.356	3157.822

Table-9.1 Specification and Diagnostic Test of Eq. (1) (Belgium)

BELGIUM			
Coefficient Tests			Probability
Wald Test	F-Statistic	0.94242	0.391
(a0=0, a1=1)	Chi-Square	1.88487	0.3897
Add Variable	F-Statistic	0.64345	0.4232
(St-2)	Likelihood Ratio	0.65031	0.42
Residuals Test			
Serial Correlation(12)	F-Statistic	1.19288	0.2887
	Obs*R-Squared	14.2969	0.2822
Serial Correlation(3)	F-Statistic	1.14892	0.3299
Cov(e1, et-1)=0	Obs*R-Squared	3.46789	0.325
Auto & Partial	Box-Pierce Q-Stat	14.22	0.2871
Autocorrelations	Ljung-Box Q-Stat	14.74	0.2558
(12 Mos.)	SE of Correlation's	0.063	
Normality of et	Mean	-7.42E-13	
	SD	0.0347743	
	Max	0.1197088	
	Min	-0.1188781	
	Skewness	-0.222947	
	Jarque-Bera Stat.	10.17053	
	Kurtosis	3.870864	
			0.006187
Heteroskedasticity	F-Statistic	0.89089	0.557
ARCH Test (12)	Obs*R-Squared	10.7932	0.5467
Heteroscedasticity	F-Statistic	2.90498	0.0566
White Reg. & Squares	Obs*R-Squared	5.74664	0.0565
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	1.64753	0.2005
(Fitted terms = 1)	Likelihood Ratio	1.66595	0.1968

Table 9.1 (Continued) Specification and Diagnostic Test of Eq. (1) (Belgium)

Chow Test			
Break-Point	F-Statistic	4.91283	0.0008
(79.05, 85.02)	Likelihood Ratio	19.3702	0.0007
(80.03)	F-Statistic	1.16443	0.3138
	Likelihood Ratio	2.35506	0.308
Chow Forecast Test	F-Statistic	0.85645	0.6846
(92.01)	Likelihood Ratio	27.8075	0.5806
Cusum Tests		-instability in the parameters of the equation	

Table-9.2 Specification and Diagnostic Test of Eq. (1) (Germany)

		GERMANY	
Coefficient Tests			Probability
Wald Test	F-Statistic	1.61483	0.201
(a0=0, a1=1)	Chi-Square	3.22966	0.1989
Add Variable	F-Statistic	0.71485	0.3986
(St-2)	Likelihood Ratio	0.72237	0.3954
Residuals Test			
Serial Correlation(12)	F-Statistic	0.92709	0.5204
	Obs*R-Squared	11.2524	0.5074
Serial Correlation(3)	F-Statistic	0.73517	0.5319
Cov(e1, et-1)=0	Obs*R-Squared	2.23004	0.5261
Auto & Partial	Box-Pierce Q-Stat	11.31	0.5026
Autocorrelations	Ljung-Box Q-Stat	11.72	0.468
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	1.23E-10	
	SD	0.0349739	
	Max	0.1119727	
	Min	-0.1188405	
	Skewness	-0.074365	
	Jarque-Bera Stat.	6.53049	
	Kurtosis	3.771319	
			0.038188
Heteroskedasticity	F-Statistic	0.69423	0.7564
ARCH Test (12)	Obs*R-Squared	8.4947	0.7454
Heteroscedasticity	F-Statistic	1.59144	0.2057
White Reg. & Squares	Obs*R-Squared	3.1806	0.2039
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.51636	0.4731
(Fitted terms = 1)	Likelihood Ratio	0.52098	0.4704

Table-9.2 (Continued) Specification and Diagnostic Test of Eq. (1) (Germany)

Chow Test			
Break-Point	F-Statistic	4.20015	0.0026
(79.05, 85.02)	Likelihood Ratio	16.6493	0.0023
(80.03)	F-Statistic	0.33544	0.7153
	Likelihood Ratio	0.68071	0.7115
Chow Forecast Test	F-Statistic	0.86531	0.6717
(92.01)	Likelihood Ratio	28.0893	0.5657
Cusum Tests		-some instability in the parameter of the equation	

Table-9.3 Specification and Diagnostic Test of Eq. (1) (Netherlands)

NETHERLANDS			
Coefficient Tests			Probability
Wald Test	F-Statistic	1.447377	0.2371
(a0=0, a1=1)	Chi-Square	2.89473	0.2352
Add Variable	F-Statistic	0.29878	0.5851
(St-2)	Likelihood Ratio	0.30215	0.5825
Residuals Test			
Serial Correlation(12)	F-Statistic	0.95491	0.4929
	Obs*R-Squared	11.5747	0.4804
Serial Correlation(3)	F-Statistic	1.04659	0.3725
Cov(e1, et-1)=0	Obs*R-Squared	3.16296	0.3672
Auto & Partial	Box-Pierce Q-Stat	11.39	0.4957
Autocorrelations	Ljung-Box Q-Stat	11.81	0.461
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	-6.23E-12	
	SD	0.0347258	
	Max	0.1168458	
	Min	-0.1189973	
	Skewness	-0.13265	
	Jarque-Bera Stat.	5.700586	
	Kurtosis	3.684291	
			0.057827
Heteroskedasticity	F-Statistic	0.93906	0.5086
ARCH Test (12)	Obs*R-Squared	11.3499	0.4992
Heteroscedasticity	F-Statistic	2.64893	0.0727
White Reg. & Squares	Obs*R-Squared	5.25036	0.0724
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.97152	0.3252
(Fitted terms = 1)	Likelihood Ratio	0.98111	0.3219

Table-9.3 (Continued) Specification and Diagnostic Test of Eq. (1) (Netherlands)

Chow Test			
Break-Point	F-Statistic	4.66404	0.0012
(79.05, 85.02)	Likelihood Ratio	18.4229	0.001
(80.03)	F-Statistic	0.54618	0.5798
	Likelihood Ratio	1.10742	0.5748
Chow Forecast Test	F-Statistic	0.8685	0.6671
(92.01)	Likelihood Ratio	28.1873	0.5605
Cusum Tests		-some instability in the parameters of the equation	

Table-10.1 Specification and Diagnostic Test of Eq. (2) (Belgium)

		BELGIUM	
Coefficient Tests			Probability
Wald Test	F-Statistic	2.62998	0.0741
(b0=0, b1=1)	Chi-Square	5.25996	0.0721
Add Variable	F-Statistic	0.91926	0.3386
(St-2)	Likelihood Ratio	0.92854	0.3352
Residuals Test			
Serial Correlation(12)	F-Statistic	1.4238	0.1555
	Obs*R-Squared	16.8805	0.1541
Serial Correlation(3)	F-Statistic	2.77735	0.0418
Cov(e1, et-1)=0	Obs*R-Squared	8.22416	0.0416
Auto & Partial	Box-Pierce Q-Stat	17.39	0.1355
Autocorrelations	Ljung-Box Q-Stat	17.9	0.1188
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	9.05E-12	
	SD	0.0360444	
	Max	0.117452	
	Min	-0.1157646	
	Skewness	-0.227172	
	Jarque-Bera Stat.	5.05272	
	Kurtosis	3.520571	
			0.07995
Heteroskedasticity	F-Statistic	0.77956	0.6713
ARCH Test (12)	Obs*R-Squared	9.49777	0.6599
Heteroscedasticity	F-Statistic	2.62807	0.0742
White Reg. & Squares	Obs*R-Squared	5.20987	0.0739
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	3.00303	0.0843
(Fitted terms = 1)	Likelihood Ratio	3.04503	0.081

Table-10.1 (Continued) Specification and Diagnostic Test of Eq. (2) (Belgium)

Chow Test			
Break-Point	F-Statistic	5.26747	0.0004
(79.05, 85.02)	Likelihood Ratio	20.7118	0.0004
(80.03)	F-Statistic	1.40919	0.2463
	Likelihood Ratio	2.84746	0.2408
Chow Forecast Test	F-Statistic	0.84908	0.6952
(92.01)	Likelihood Ratio	27.5899	0.5922
Cusum Tests		-some instability in the parameters of the equation	

Table-10.2 Specification and Diagnostic Test of Eq. (2) (Germany))

		GERMANY	
Coefficient Tests			Probability
Wald Test	F-Statistic	0.66884	0.5132
(b0=0, b1=1)	Chi-Square	1.33768	0.5123
Add Variable	F-Statistic	0.51212	0.4749
(St-2)	Likelihood Ratio	0.51769	0.4718
Residuals Test			
Serial Correlation(12)	F-Statistic	1.70188	0.067
	Obs*R-Squared	19.9189	0.0686
Serial Correlation(3)	F-Statistic	2.45636	0.0636
Cov(e1, et-1)=0	Obs*R-Squared	7.30097	0.0629
Auto & Partial	Box-Pierce Q-Stat	23.84	0.0214
Autocorrelations	Ljung-Box Q-Stat	24.68	0.0164
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	-6.85E-11	
	SD	0.0365269	
	Max	0.1070413	
	Min	-0.1191905	
	Skewness	-0.157028	
	Jarque-Bera Stat.	4.739492	
	Kurtosis	3.590927	
			0.0935
Heteroskedasticity	F-Statistic	0.46526	0.9333
ARCH Test (12)	Obs*R-Squared	5.7596	0.9277
Heteroscedasticity	F-Statistic	2.3134	0.101
White Reg. & Squares	Obs*R-Squared	4.59736	0.1004
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic		
(Fitted terms = 1)	Likelihood Ratio		

Table-10.2 (Continued) Specification and Diagnostic Test of Eq. (2) (Germany)

Chow Test			
Break-Point	F-Statistic	7.83347	0
(79.05, 85.02)	Likelihood Ratio	30.2207	0
(80.03)	F-Statistic	2.53971	0.0809
	Likelihood Ratio	5.10897	0.0777
Chow Forecast Test	F-Statistic	0.9676	0.5195
(92.01)	Likelihood Ratio	31.2135	0.405
Cusum Tests		some instability in the parameter of the equation	

Table-10.3 Specification and Diagnostic Test of Eq. (2) (Netherlands)

NETHERLANDS (range: 1973.03 / 1991.01)			
Coefficient Tests			Probability
Wald Test	F-Statistic	0.49506	0.6102
(b0=0, b1=1)	Chi-Square	0.99011	0.6095
Add Variable	F-Statistic	0.05605	0.8131
(St-2)	Likelihood Ratio	0.05682	0.8116
Residuals Test			
Serial Correlation(12)	F-Statistic	1.61561	0.0895
	Obs*R-Squared	18.9091	0.0907
Serial Correlation(3)	F-Statistic	3.42476	0.0181
Cov(e1, et-1)=0	Obs*R-Squared	10.026	0.0183
Auto & Partial	Box-Pierce Q-Stat	23.33	0.025
Autocorrelations	Ljung-Box Q-Stat	24.18	0.0192
(12 Mos.)	SE of Correlations	0.069	
Normality of et	Mean	1.28E-11	
	SD	0.036464	
	Max	0.120594	
	Min	-0.107709	
	Skewness	0.026923	
	Jarque-Bera Stat.	1.73898	
	Kurtosis	3.439366	
			0.41917
Heteroskedasticity	F-Statistic	1.00656	0.4445
ARCH Test (12)	Obs*R-Squared	12.1343	0.435
Heteroscedasticity	F-Statistic	0.89543	0.41
White Reg. & Squares	Obs*R-Squared	1.80109	0.4063
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.07985	0.7778
(Fitted terms = 1)	Likelihood Ratio	0.08062	0.7765

Table-10.3 (Continued) Specification and Diagnostic Test of Eq. (2) (Netherlands)

Chow Test			
Break-Point	F-Statistic	6.84416	0
(79.05, 85.02)	Likelihood Ratio	26.4569	0
(80.03)	F-Statistic	2.46242	0.0877
	Likelihood Ratio	4.96087	0.0837
Chow Forecast Test	F-Statistic	1.00179	0.4461
(92.01)	Likelihood Ratio	11.4241	0.4084
		(90.03)	
Cusum Tests		-some instability in the parameters of the equation	

Table-11.1 Specification and Diagnostic Test of Eq. (3) (Belgium)

		BELGIUM	
Coefficient Tests			Probability
Wald Test	F-Statistic	0.89041	0.4118
(g0=0, g1+g2=1)	Chi-Square	1.78083	0.4105
Add Variable	F-Statistic	0.37297	0.5419
(St-2)	Likelihood Ratio	0.37869	0.5383
Residuals Test			
Serial Correlation(12)	F-Statistic	1.26808	0.2383
	Obs*R-Squared	15.204	0.2305
Serial Correlation(3)	F-Statistic	1.06858	0.363
Cov(e1, et-1)=0	Obs*R-Squared	3.24138	0.3559
Auto & Partial	Box-Pierce Q-Stat	15.09	0.2367
Autocorrelations	Ljung-Box Q-Stat	15.67	0.2069
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	-4.84E-11	
	SD	0.0347565	
	Max	0.1205769	
	Min	-0.1198368	
	Skewness	-0.216646	
	Jarque-Bera Stat.	11.27597	
	Kurtosis	3.936859	
			0.00356
Heteroskedasticity	F-Statistic	0.9562	0.4918
ARCH Test (12)	Obs*R-Squared	11.5471	0.4827
Heteroscedasticity	F-Statistic	1.39591	0.2359
White Reg. & Squares	Obs*R-Squared	5.57085	0.2336
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	1.36805	0.00136
(Fitted terms = 1)	Likelihood Ratio	1.38319	0.00227

Table-11.1 (Continued) Specification and Diagnostic Test of Eq. (3) (Belgium)

Chow Test			
Break-Point	F-Statistic	3.46789	0.0026
(79.05, 85.02)	Likelihood Ratio	20.7044	0.0021
(80.03)	F-Statistic	2.17819	0.0911
	Likelihood Ratio	6.60601	0.0856
Chow Forecast Test	F-Statistic	0.84206	0.7052
(92.01)	Likelihood Ratio	27.4912	0.5974
Cusum Tests		-some instability in the parameters of the equation	

Table-11.2 Specification and Diagnostic Test of Eq. (3) (Germany)

GERMANY			
Coefficient Tests			
Wald Test			Probability
(g0=0, g1+g2=1)	F-Statistic	2.60409	0.076
Add Variable	Chi-Square	5.20817	0.074
(St-2)	F-Statistic	0.62552	0.4298
	Likelihood Ratio	0.63472	0.4256
Residuals Test			
Serial Correlation(12)			
	F-Statistic	0.91851	0.529
Serial Correlation(3)	Obs*R-Squared	11.1974	0.5121
Cov(e1, et-1)=0	F-Statistic	0.73615	0.5313
	Obs*R-Squared	2.2419	0.5237
Auto & Partial			
Autocorrelations	Box-Pierce Q-Stat	11.12	0.5187
(12 Mos.)	Ljung-Box Q-Stat	11.53	0.4844
	SE of Correlations	0.063	
Normality of et			
	Mean	-6.58E-11	
	SD	0.0348401	
	Max	0.1136553	
	Min	-0.1203715	
	Skewness	-0.0363	
	Jarque-Bera Stat.	7.918008	
	Kurtosis	3.861909	
Heteroskedasticity			0.01908
ARCH Test (12)	F-Statistic	0.76427	0.6869
	Obs*R-Squared	9.31867	0.6755
Heteroscedasticity			
White Reg. & Squares	F-Statistic	1.92856	0.1062
	Obs*R-Squared	7.63268	0.106
Specification &			
Stability Tests			
Ramsey RESET Test			
(Fitted terms = 1)	F-Statistic		
	Likelihood Ratio		

Table-11.2 (Continued) Specification and Diagnostic Test of Eq. (3) (Germany)

Chow Test			
Break-Point			
(79.05, 85.02)	F-Statistic	3.05117	0.0068
(80.03)	Likelihood Ratio	18.3039	0.0055
	F-Statistic	1.86823	0.1355
	Likelihood Ratio	5.67639	0.1285
Chow Forecast Test			
(92.01)	F-Statistic	0.93683	0.5653
	Likelihood Ratio	30.4067	0.445
Cusum Tests			
		-some instability in the parameter of the equation	

Table-11.3 Specification and Diagnostic Test of Eq. (3) (Netherlands)

NETHERLANDS (range: 1973.03 / 1991.01)			
Coefficient Tests			Probability
Wald Test	F-Statistic	2.29488	0.1033
(g0=0, g1+g2=1)	Chi-Square	4.58977	0.1008
Add Variable	F-Statistic	0.11849	0.731
(St-2)	Likelihood Ratio	0.12071	0.7283
Residuals Test			
Serial Correlation(12)	F-Statistic	1.30554	0.2176
	Obs*R-Squared	15.6176	0.2094
Serial Correlation(3)	F-Statistic	1.68111	0.1722
Cov(e1, et-1)=0	Obs*R-Squared	5.0661	0.167
Auto & Partial	Box-Pierce Q-Stat	14.74	0.2557
Autocorrelations	Ljung-Box Q-Stat	15.41	0.2199
(12 Mos.)	SE of Correlations	0.069	
Normality of et	Mean	-1.96E-11	
	SD	0.033674	
	Max	0.114534	
	Min	-0.106089	
	Skewness	0.037518	
	Jarque-Bera Stat.	3.818102	
	Kurtosis	3.651597	
			0.14822
Heteroskedasticity	F-Statistic	2.07089	0.0207
ARCH Test (12)	Obs*R-Squared	23.4671	0.024
Heteroscedasticity	F-Statistic	0.73688	0.5678
White Reg. & Squares	Obs*R-Squared	2.9762	0.5618
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.0069	0.9339
(Fitted terms = 1)	Likelihood Ratio	0.00701	0.9333

Table-11.3 (Continued) Specification and Diagnostic Test of Eq. (3) (Netherlands)

Chow Test			
Break-Point	F-Statistic	2.73224	0.0142
(79.05, 85.02)	Likelihood Ratio	16.4637	0.0115
(80.03)	F-Statistic	1.07294	0.3704
	Likelihood Ratio	217.719	0
Chow Forecast Test	F-Statistic	0.19209	0.9979
(92.01)	Likelihood Ratio	2.24977	0.9974
		(90.03)	
Cusum Tests		-some instability in the parameters of the equation	

Table-12.1 Specification and Diagnostic Test of Eq. (4) (Belgium)

		BELGIUM	
Coefficient Tests			Probability
Wald Test	F-Statistic		
(d0=0, d1+d2=1)	Chi-Square	5.58624	0.0612
Add Variable	F-Statistic	1.2847	0.2581
(St-2)	Likelihood Ratio	1.30196	0.2539
Residuals Test			
Serial Correlation(12)	F-Statistic	1.50625	0.1224
	Obs*R-Squared	17.8579	0.1201
Serial Correlation(3)	F-Statistic	1.74974	0.1574
Cov(e1, et-1)=0	Obs*R-Squared	5.26484	0.1534
Auto & Partial	Box-Pierce Q-Stat	17.42	0.1344
Autocorrelations	Ljung-Box Q-Stat	18.08	0.1133
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	-2.04E-11	
	SD	0.0344073	
	Max	0.0926972	
	Min	-0.1136786	
	Skewness	-0.232027	
	Jarque-Bera Stat.	2.659166	
	Kurtosis	3.19211	
			0.26459
Heteroskedasticity	F-Statistic	0.57937	0.8578
ARCH Test (12)	Obs*R-Squared	7.13135	0.8488
Heteroscedasticity	F-Statistic	0.77921	0.5396
White Reg. & Squares	Obs*R-Squared	3.1402	0.5346
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	1.39289	0.239
(Fitted terms = 1)	Likelihood Ratio	1.41352	0.2345

Table-12.1 (Continued) Specification and Diagnostic Test of Eq. (4) (Belgium)

Chow Test			
Break-Point	F-Statistic	3.61842	0.0019
(79.05, 85.02)	Likelihood Ratio	21.5655	0.0015
(80.03)	F-Statistic	0.71213	0.5456
	Likelihood Ratio	2.17888	0.5361
Chow Forecast Test	F-Statistic	0.89233	0.6319
(92.01)	Likelihood Ratio	29.0516	0.5149
Cusum Tests		-some instability in the parameters of the equation	

Table-12.2 Specification and Diagnostic Test of Eq. (4) (Germany)

		GERMANY	
Coefficient Tests			Probability
Wald Test	F-Statistic		
(d0=0, d1+d2=1)	Chi-Square	1.45072	0.4841
Add Variable	F-Statistic	0.63299	0.427
(St-2)	Likelihood Ratio	0.64231	0.4229
Residuals Test			
Serial Correlation(12)	F-Statistic	1.83577	0.0434
	Obs*R-Squared	21.4337	0.0444
Serial Correlation(3)	F-Statistic	2.24508	0.0836
Cov(e1, et-1)=0	Obs*R-Squared	6.71571	0.0815
Auto & Partial	Box-Pierce Q-Stat	23.39	0.0246
Autocorrelations	Ljung-Box Q-Stat	24.25	0.0188
(12 Mos.)	SE of Correlations	0.063	
Normality of et	Mean	6.08E-11	
	SD	0.035728	
	Max	0.1126567	
	Min	-0.1381236	
	Skewness	-0.1065	
	Jarque-Bera Stat.	10.571	
	Kurtosis	3.978475	
			0.00507
Heteroskedasticity	F-Statistic	0.38735	0.9672
ARCH Test (12)	Obs*R-Squared	4.81505	0.9639
Heteroscedasticity	F-Statistic	3.9432	0.004
White Reg. & Squares	Obs*R-Squared	15.1286	0.0044
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.2188	0.6404
(Fitted terms = 1)	Likelihood Ratio	0.22149	0.6379

Table-12.2 (Continued) Specification and Diagnostic Test of Eq. (4) (Germany)

Chow Test			
Break-Point	F-Statistic	5.47142	0
(79.05, 85.02)	Likelihood Ratio	31.9362	0
(80.03)	F-Statistic	1.50248	0.2145
	Likelihood Ratio	4.57532	0.2057
Chow Forecast Test	F-Statistic	1.01714	0.4477
(92.01)	Likelihood Ratio	32.8617	0.3286
Cusum Tests		-some instability in the parameter of the equation	

Table-12.3 Specification and Diagnostic Test of Eq. (4) (Netherlands)

NETHERLANDS (range: 1973.03 / 1991.01)			
Coefficient Tests			Probability
Wald Test	F-Statistic		
(d0=0, d1+d2=1)	Chi-Square	0.99843	0.607
Add Variable	F-Statistic	0.02623	0.8715
(St-2)	Likelihood Ratio	0.0267	0.8702
Residuals Test			
Serial Correlation(12)	F-Statistic	1.45821	0.1428
	Obs*R-Squared	17.2947	0.1388
Serial Correlation(3)	F-Statistic	2.94086	0.0342
Cov(e1, et-1)=0	Obs*R-Squared	8.70667	0.0335
Auto & Partial	Box-Pierce Q-Stat	19.43	0.0787
Autocorrelations	Ljung-Box Q-Stat	20.15	0.0644
(12 Mos.)	SE of Correlations	0.069	
Normality of et	Mean	-2.88E-11	
	SD	0.035587	
	Max	0.119114	
	Min	-0.106952	
	Skewness	0.146234	
	Jarque-Bera Stat.	4.169859	
	Kurtosis	3.621709	
			0.12432
Heteroskedasticity	F-Statistic	0.71663	0.7341
ARCH Test (12)	Obs*R-Squared	8.793	0.7205
Heteroscedasticity	F-Statistic	1.12815	0.3443
White Reg. & Squares	Obs*R-Squared	4.523	0.3398
Specification &			
Stability Tests			
Ramsey RESET Test	F-Statistic	0.028	0.8673
(Fitted terms = 1)	Likelihood Ratio	0.02838	0.8662

Table-12.3 (Continued) Specification and Diagnostic Test of Eq. (4) (Netherlands)

Chow Test			
Break-Point	F-Statistic	4.28112	0.0004
(79.05, 85.02)	Likelihood Ratio	25.2592	0.0003
(80.03)	F-Statistic	1.2442	0.2948
	Likelihood Ratio	3.80694	0.2831
Chow Forecast Test	F-Statistic	1.04245	0.4105
(92.01)	Likelihood Ratio	11.9353	0.3685
		(90.03)	
Cusum Tests		-some instability in the parameters of the equation	

6.3.4. Cointegration Test

Finally we test for cointegration between spot and forward prices. In order to perform the ADF test we took the first difference of the exchange rate series to achieve the stationarity. The results appear in Table-13. ADF unit root test is applied to the residuals from the cointegrating regression. The movement of the spot and forward exchange rates over the time is presented in Figure-1, Figure-2, and Figure-3. We note that the observations presented on x-axis of the graphs are the monthly exchange rates over the sample periods. This procedure is known as the Engle-Granger Cointegration (EG) test.[11] Under the hypothesis that the series are not cointegrated, and that there exists a unit root in the residuals, the expected value of the t-statistic is zero. For a stationary disturbance, the t-statistic will be negative and, as in ADF procedure the hypothesis of a unit root is rejected if the t-statistic lies to the left of the relevant MacKinnon critical value. In our case we reject the hypothesis that spot rate and one period lagged forward rate are not cointegrated. We concluded that foreign currency spot and future prices are cointegrated with cointegration vector of (1.-1).

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[11] "Cointegration and Error Correction: representation, estimation and testing", Econometrica, vol. 55, pp.251-276

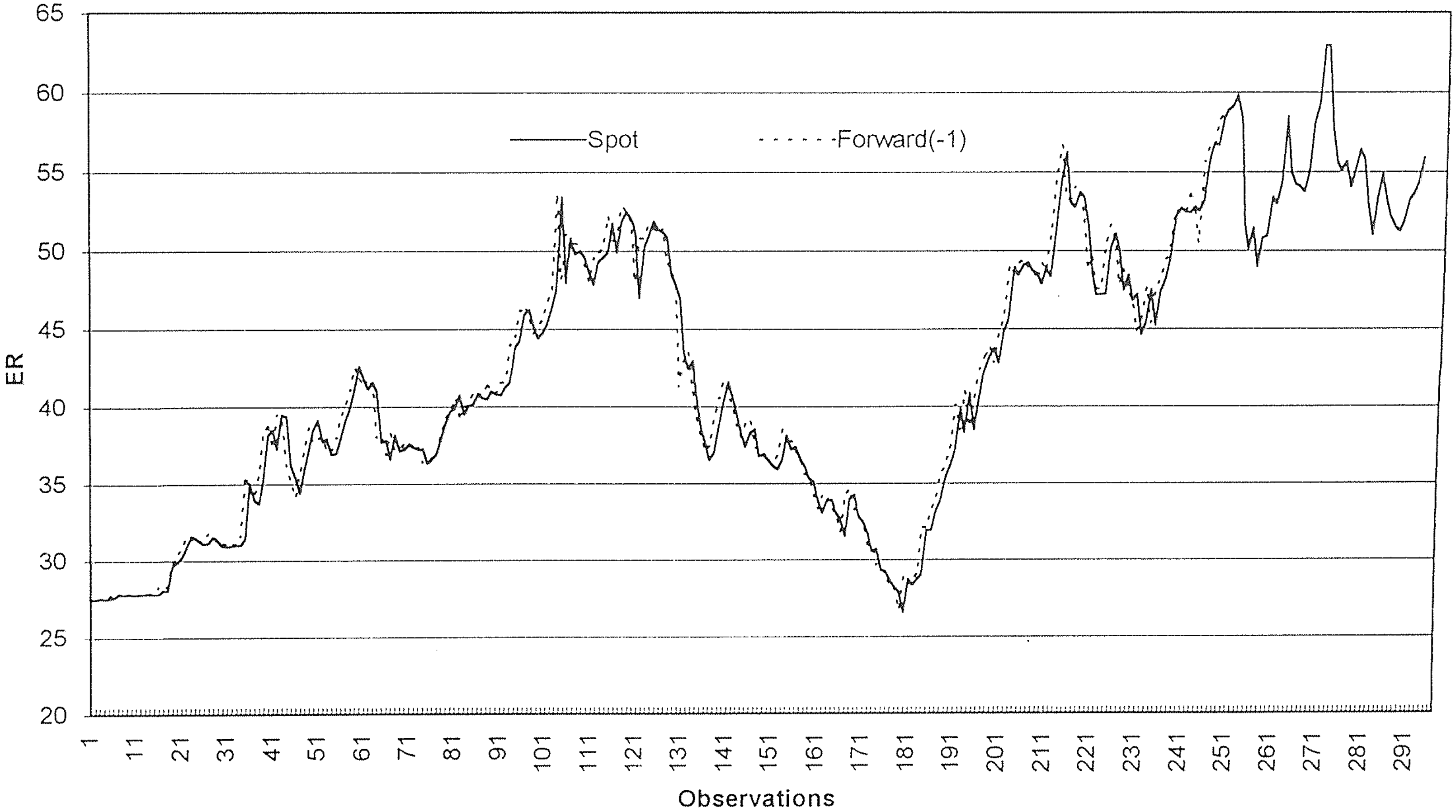


Figure-3 The Netherlands' Spot and One-Period-Lagged Forward Rate Movement

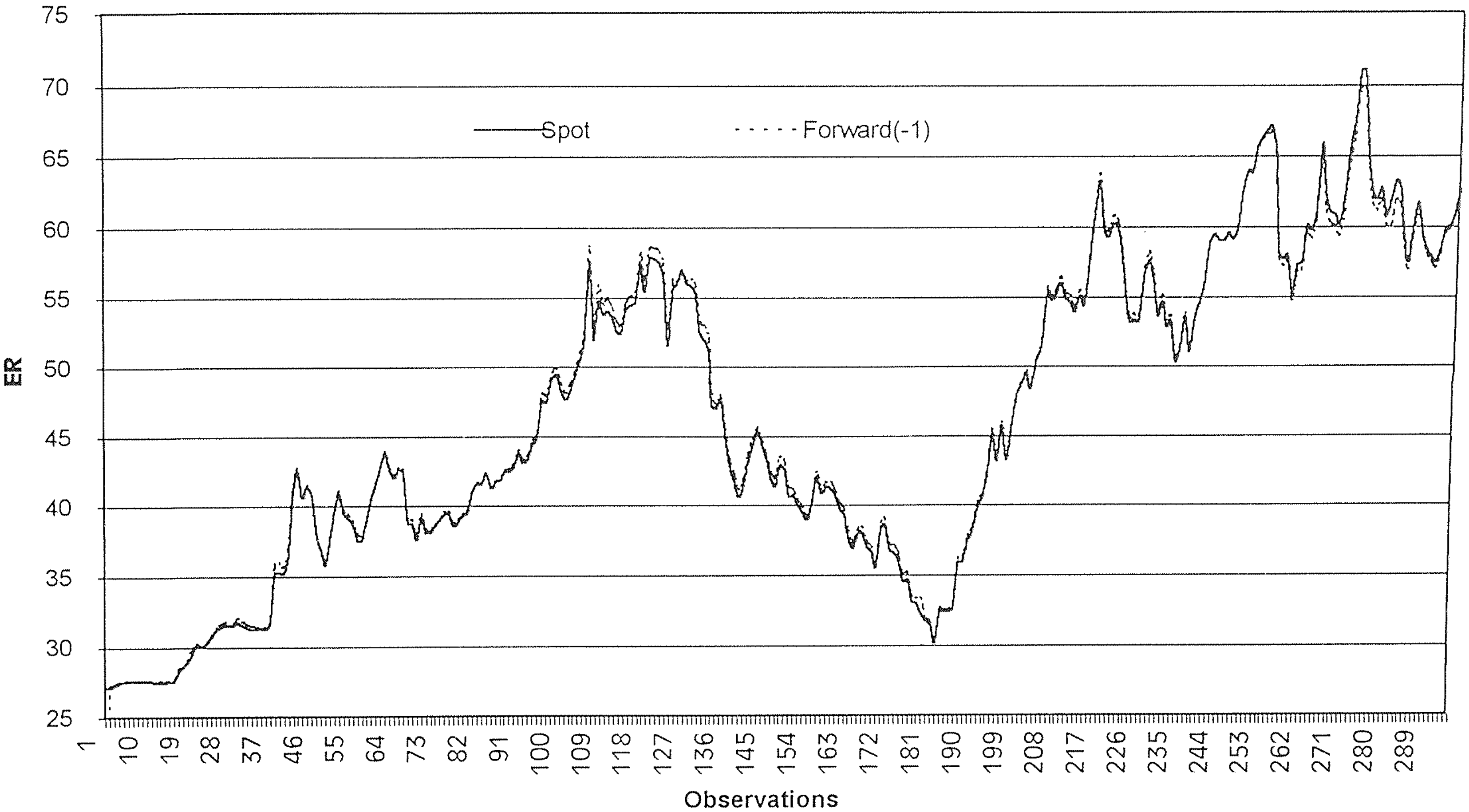


Figure-2 Germany's Spot and One-Period-Lagged Forward Rate Movement

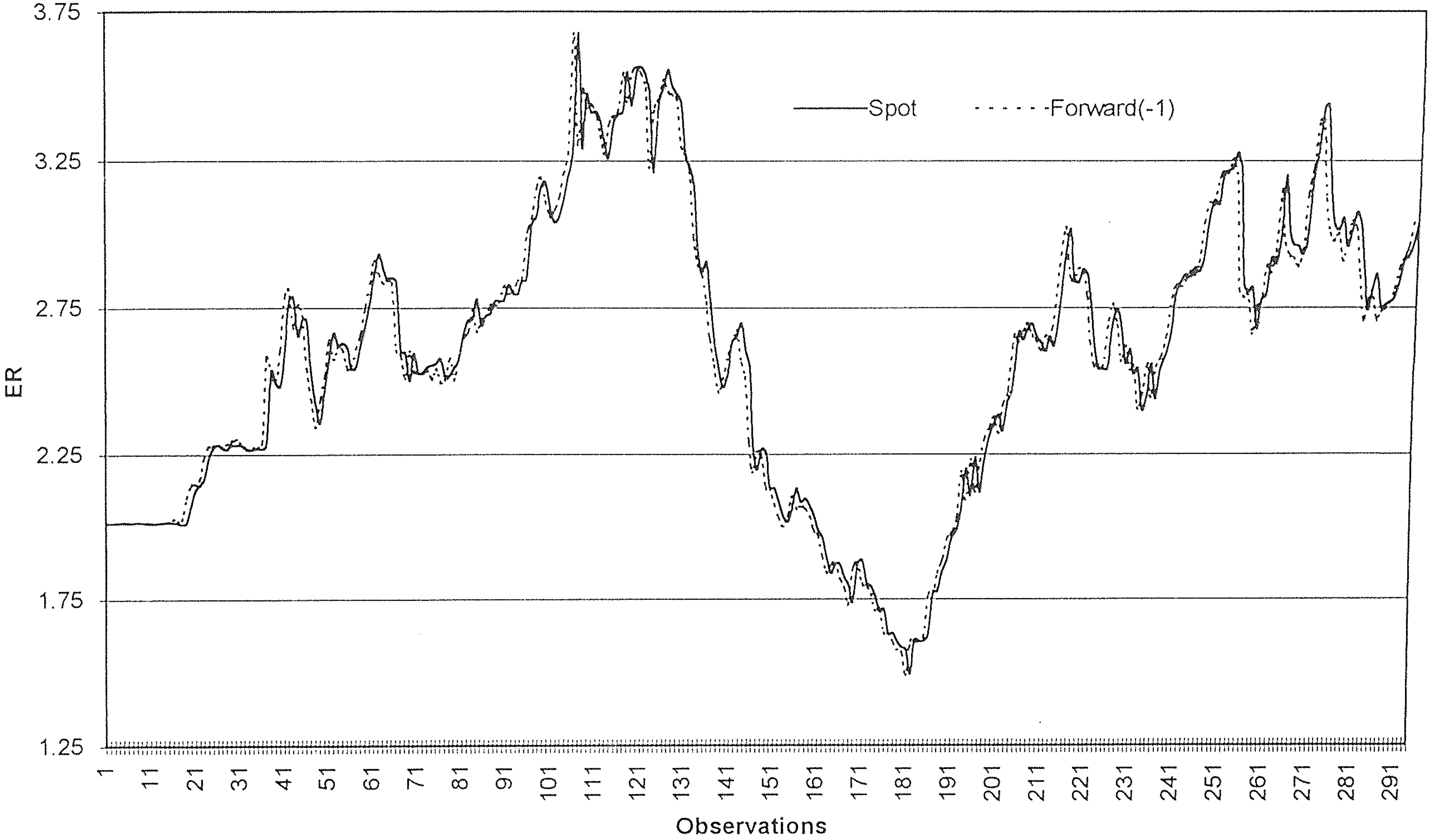
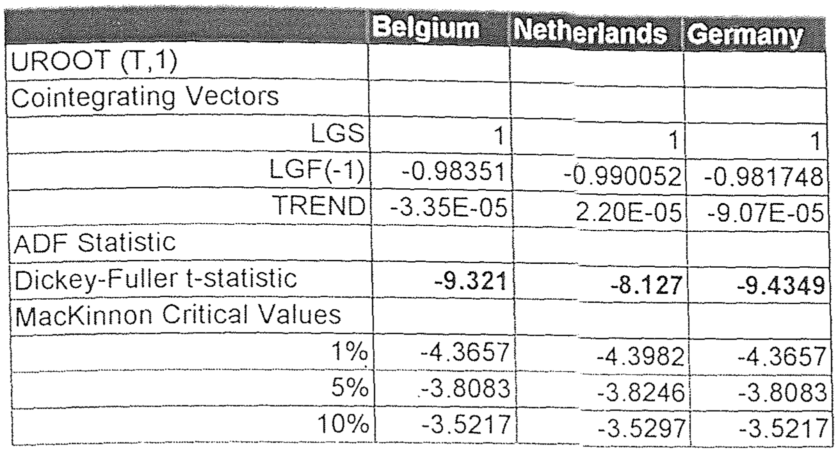


Figure-1 Belgium's Spot and One-Period-Lagged Forward Rate Movement

Table-13 Cointegration Tests



	Belgium	Netherlands	Germany
UROOT (T,1)			
Cointegrating Vectors			
LGS	1	1	1
LGF(-1)	-0.98351	-0.990052	-0.981748
TREND	-3.35E-05	2.20E-05	-9.07E-05
ADF Statistic			
Dickey-Fuller t-statistic	**-9.321**	**-8.127**	**-9.4349**
MacKinnon Critical Values			
1%	-4.3657	-4.3982	-4.3657
5%	-3.8083	-3.8246	-3.8083
10%	-3.5217	-3.5297	-3.5217

CHAPTER VII

SUMMARY AND CONCLUDING REMARKS

In this efficiency specification model of spot and forward exchange markets, we argued that the forward rate fully reflects the limited available information (due to the lack of complete and correct global knowledge) about the exchange rate expectations and the forward rate, thus it is usually viewed by the market as an unbiased predictor of the future spot rate. The conventional test of the unbiasedness hypothesis that we used was a regression estimation by fitting the current spot on the one-period lagged spot rate, on the one-period lagged forward rate, on the one-period lagged spot and forward rate, and on the one-period lagged forward rate and the "news" (the difference between actual and expected Interest differential). These tests involve the joint hypothesis that the constant terms do not differ from zero, that the coefficients on the one-period lagged spot and forward rates do not significantly differ from one, that the coefficient of the "news" is not different than zero, and the error terms pass some statistical tests (serial correlation, normality, ARCH, etc.).

We cannot reject the unbiased hypothesis for Belgium, the Netherlands, and Germany. The results imply that we can use the forward rate as a proxy for the prediction of the spot rate next period. There is some instability in the parameters of almost all the equations of the model, but from a forecasting point of view, this is consistent with the least cost approach to the economic agents, although it may not yield the minimum forecast error due to interventions, incomplete and partial knowledge (incorrect information), and simplicity in modeling. The overall results show that Netherlands', and Germany's foreign exchange market is pretty efficient. Belgium's market efficiency is questionable. Also, Belgium's spot rate follows a random walk but their variances are not constant. The results appear in Tables 9, 10, 11, and 12 in the previous chapter.

On the other hand, it is important not to forget that the world is rapidly changing and becoming more integrated. A global marketplace in assets and commodities is emerging as technological change has decreased the cost of communication around the world. The work presented here suggests that simple models may not work well, but we have only begun to develop the first models based on rational maximizing agents.

We conclude that most of the existing tests for the unbiased hypothesis should be expected to result in rejection. These theoretical results, combined with the vast empirical literature that supports it should cause us to question the common assumption of the unbiased hypothesis in financial models.

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