# INTERNATIONAL FISHER EFFECT: A REEXAMINATION WITHIN THE CO-INTEGRATION AND DSUR FRAMEWORKS

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Business Administration.

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## ABSTRACT

INTERNATIONAL FISHER EFFECT:
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International Fisher Effect (IFE) is a theory in international finance which asserts that the spot exchange rate between countries should move in opposite direction with the interest rate differential between these countries. The aim of this thesis is to analyze whether differences in nominal interest rates between countries and the movement of spot exchange rates between their currencies tend to move together over the long run. The presence of IFE is tested among the G-5 countries and Turkey for the period from 1985:1 to 2007:12. The long run relationship is estimated with the Johansen co-integration method and supportive evidence is found for all country pairs. Individually modeled equations are further tested with the Dynamic SUR method. Those DSUR equations that include the Turkish currency provide supportive evidence for IFE that higher interest rates in favor of Turkey would cause depreciation of the Turkish Lira. The magnitude of the effect is found to be lower than expected which indicates that there might be other factors in economy, such as inflation rates, that affect the exchange rate movements.

Key Words: International Fisher Effect (IFE), Dynamic Seemingly Unrelated Regressions (DSUR), Co-integration , Uncovered Interest Rate Parity (UIP).

# ÖZ

ULUSLARARASI FISHER ETKISI:
EŞBÜTÜNLEME VE DİNAMİK GÖRÜNÜŞTE İLİŞKİSİZ REGRESYON YÖNTEMLERİ DAHİLİNDE YENİDEN İNCELEME

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Uluslararası Fisher Etkisi (UFE), ülkeler arasındaki geçerli kurun bu ülkeler arasındaki faiz oranı diferansiyeliyle zıt yönde hareket etmesi gerektiğini savunan bir uluslararası finans teorisidir. Bu tezin amacı, ülkeler arasındaki nominal faiz oranlarındaki farklılıkların ve bu ülkelerin para birimleri arasındaki geçerli kur hareketinin uzun dönemde birlikte hareket etme eğiliminde olup olmadığının analiz edilmesidir. UFE'nin varlığı 1985:1 - 2007:12 dönemleri arasında G-5 ülkelerinde ve Türkiye'de test edilmiştir. Johansen eşbütünleme yöntemi ile uzun dönem ilişki tahmin edilmiş ve tüm ülke çiftleri için destekleyici kanıt bulunmuştur. Buna ilave olarak, ayrı ayrı modellenmiş denklemler, Dinamik Görünüşte İlişkisiz Regresyon (DGİR) yöntemiyle test edilmiştir. Türk para birimini içeren DGİR denklemleri, Türkiye lehine yüksek faiz oranlarının Türk Lirası'nda değer kaybına yol açacağına yönelik, UFE'ni destekleyici, kanıt sunmuştur. Bu etkinin şiddeti beklendiğinden daha küçük olmuş ve bu da ekonomide kur hareketlerini etkileyen, enflasyon oranı gibi, başka faktörlerin de olabileceğini göstermiştir.

Anahtar Kelimeler: Uluslararası Fisher Etkisi, Dinamik Görünüşte İlişkisiz Regresyon, Eşbütünleme, Karşılanmamış Faiz Paritesi

To My Dear

Mother and Grandmother

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# CHAPTER 1

# INTRODUCTION

Investment is the commercial way of using money with an aim to obtain profit in return. A crucial point for investors is predicting the forthcoming returns of their investment. Investors usually have to compare different investments on the basis of their risks and return potential in order to make a choice from among different alternatives. When the decision is about an international investment opportunity, the comparison of investment returns becomes a lot more complicated. In addition to the risk and return comparisons, the investors also have to take into account the potential changes that they expect to occur in the exchange rate between the foreign currency and the domestic currency. In such a case, theories regarding the determination and interaction of interest and exchange rates come into the picture.

Many economic theories have been developed to analyze how macroeconomic variables like interest and exchange rates move through time when exterior interventions to financial markets are minimized. These theories simply reveal that the interactions between international markets should be analyzed carefully concerning the expected responses of such macroeconomic variables. One of these theories is derived from the well-known Fisher Effect, which asserts real interest rates across countries are equalized when nominal interest rate differences are driven by the discrepancies in inflation rates across countries. In other words, according to the Generalized Fisher Effect, high inflation countries should bear higher interest rates, if perfect integration of capital markets is achieved by financial markets. When the main question is the international equilibriums, in addition to interest rates and inflation rates, movements of exchange rates are also important. Many theories have been developed to explain the changes in exchange rates. The Purchasing Power Parity condition is one of these theories. The theory implies that the exchange rates will move to offset changes in inflation rate differentials. The rationale behind this parity theory is the equality of prices across countries.

Another international market equilibrium condition is the International Fisher Effect, which can be defined as a combination of the Generalized Fisher Effect and the Purchasing Power Parity. Briefly, the theory asserts that the higher interest rate country's currency is expected to depreciate until the real returns of investments are equalized across countries.

The aim of this thesis is to analyze the responses of exchange rates to the differences in interest rates across countries. In an open market, changes in exchange rates will affect the future value of current investments. Therefore, this analysis is important for investors, as they are concerned about future earnings while making decisions about investments today. Theoretically, in order to analyze the relationship between interest rates and exchange rates, parity conditions are developed in the international finance literature. In line with the theory, this thesis evaluates the relationship between exchange rates and interest rates of six selected countries, namely the G-5 countries and Turkey. The theory is evaluated with selected countries for the period starting from January, 1985 and ending with December, 2007. It is expected to find empirical results in favor of the International Fisher Effect so that the higher/lower interest rate country's currency is expected to depreciate/appreciate in order to equalize interest rates across countries. Since the financial data used are not stationary, the traditional regression models are not appropriate to test this relationship. Instead, the relationship between interest rate differentials and changes in exchange rates is analyzed within the co-integration framework. The Johansen co-integration method is applied to the data and at least one co-integration vector is found for each of the county pair, which is a result indicating that interest rate differentials and exchange rate movements drift together in the long-run.

Econometric analysis in this thesis aims to examine the effectiveness of international markets to respond to the capital flows and the relationship between macroeconomic variables of developed countries among themselves and their interaction with the Turkish financial markets. The main reason for selecting the G-5 countries is the integration of the capital markets in these countries. In general, the capital markets of developed countries are accepted to be integrated so that the basis for international parity conditions is established. In addition, governments in developed countries are less likely to intervene in financial markets. Currency restrictions and other governmental interventions affect the adjustment of exchange rates over time and inhibit capital integration. Therefore, testing for the existence of parity conditions has to be carried out in markets where such market imperfections are deemed to be at a minimum.

The following chapter reviews the literature and explains the underlying theories about the relationship between exchange rate adjustments and interest rate differentials.

In Chapter 3, the data used for the analyses and the research methodology used to test the relationship between exchange rate movements and interest rate differentials are described. In addition, the data periods and formation of sub-periods are explained.

In Chapter 4, the results and analyses are presented. EVIEWS outputs are rearranged in tables and results obtained from the tests are interpreted.

Finally, the main findings of the research and implications for further studies are summarized in Chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The main purpose of this thesis is to test whether the International Fisher Effect (IFE) holds among the six sample countries' interest and exchange rates. The IFE is one of the interest rate parity conditions. There are two versions of the theory which are defined as the covered and uncovered interest parity (UIP) conditions. The uncovered interest rate parity theory suggests that risk-neutral investors are indifferent between foreign and domestic assets, assuming transactions costs are ignored with perfect capital mobility and no intervention of monetary authorities. The covered interest rate parity claims that the difference between the forward and spot exchange rates will reflect the differences between the interest rates between two countries.

The main question of this thesis is to examine whether the interest rate differentials are unbiased predictors of future spot exchange rates or not. Since both theories analyze the relationship between interest rates and exchange rates, the IFE and UIP literature is reviewed together in section 2.4.

In order to explain the IFE hypothesis more precisely, two building block theories, namely the Fisher Effect (FE) and the Purchasing Power Parity (PPP) are first discussed in Sections 2.2 and 2.3, respectively.

### 2.2 The Fisher Hypothesis and Fisher's Findings

The Fisher hypothesis, which was first proposed by Irving Fisher**,** suggests that there is a positive correlation between nominal interest rates and expected inflation. This hypothesis also implies that the real interest rate is constant and independent of monetary measures. In a world of perfect foresight, the Fisher effect can be defined as a one-to-one relationship between nominal interest rates and expected inflation, leaving real interest rates independent of the inflation rate. The basic version of the equation that has been used to test the existence of the Fisher effect is as follows:

$$i_t = \alpha + \beta \pi_t^e \qquad \textbf{(1)}$$

In this equation, $i_t$ is the nominal interest rate, $\alpha$ is the real interest rate and $\pi_t^e$ is the expected inflation for the period $t$. By definition, $\beta$ is expected to be equal to 1 in order to conclude for a strong Fisher effect. If $\beta$ is positive but not equal to one, then there is evidence of the weaker form of the Fisher effect.

Fisher (1930) employed a distributed lag structure by using annual consumer price index (CPI) data between the years 1890 and 1927 in the US market and 1820 and 1924 in the UK market. He used the arithmetically declining weights method and 20 years of lags for price changes in the US and 28 years of lags for the UK. He tested Equation (1) and reached the following conclusion: (1930, p 451)

> When the effects of price changes upon interest rates are distributed over several years, we have found remarkably high coefficients of correlation, thus indicating that interest rates follow price changes closely in degree, though distantly in time.

Fisher's study provides strong evidence about the one-to-one positive relationship between nominal interest rates and expected inflation which leaves the real interest rates constant over time. This conclusion is known as the Fisher hypothesis/effect and has been debated for several years in the literature.

In his study, Fama (1975) questions the Fisher hypothesis by using rational expectations assumptions while pointing out the characteristics of an efficient market which uses all relevant information in setting prices. According to Fama, in an efficient market, if the inflation rate is to some extent predictable, there will be a relationship between nominal interest rate observed at a point of time and rate of inflation subsequently observed. In order to test his assertion, he tests the efficiency of the US Treasury bill (T-bill) market by using 1- to 6-month maturity T-bills and the CPI during the postwar period between January 1953 and July 1971. Results suggest the existence of a definite relationship between nominal interest rates and rate of inflation. During the sample period, the nominal interest rates summarize all the information about future inflation rates. This observation leads to the conclusion that the T-bill market seems to be efficient in the sense that short term interest rates are good predictors of inflation. Another major conclusion of the paper is that during this period, equilibrium expected real returns on T-bills are found to be constant. As a result of these findings, Fama concludes that the US T-bill market is efficient in setting 1- to 6-month nominal interest rates. In other words, the market correctly uses all information contained in the time series of past inflation rates to form expectations for future inflation rates.

The Fisher hypothesis has been studied for many different time periods and contradictory results are reached in different studies. The Fisher effect has been found to be strong in some countries, for instance in US, Canada and UK, during the postwar period until the late 1970s. However, the same consistent relationship between interest rates and expected inflation is not observed in other countries. Hence, several studies have attempted to examine the reason behind why Fisher effect holds for some countries while it does not for others.

Mishkin (1992) analyzes the reason for obtaining different results over different sample periods. He uses monthly data on inflation rates calculated from CPI series and 1- to 12-month US T-bill rates during the postwar period between February 1964 and December 1986. The analysis provides no evidence for a short run Fisher effect during the postwar period. However, the existence of a long run Fisher effect implies that when inflation exhibits trends, there will be a strong correlation between inflation and interest rates. Therefore, the Fisher effect appears to be strong during the periods when interest and inflation rates both exhibit trends and he concludes that the Fisher effect is due to the existence of a stochastic trend between interest rates and inflation. Mishkin also shows that between 1979 and 1982 period and during the pre-World War II period, no Fisher Effect is observed in the US data due to the nonexistence of this stochastic trend. Hence, the evidence in the Mishkin study suggests that the validity of the Fisher effect depends heavily on the period considered and that the Fisher effect is most apparent in periods when there is strong evidence for stochastic trends.

Other studies in the literature also suggest that country selection is another critical factor in the empirical testing of the Fisher effect. One of the recent multi-country Fisher effect studies is done by Berument and Jelassi (2002). In his study, Berument and Jelassi test the existence of a long run Fisher effect by taking into consideration the short-run dynamics of the interest rates for 12 developed and 14 developing countries. Treasury bill rates from these countries are used for the tests. Whenever T-bill rates are not available, the lending rate is used instead. The authors use monthly data in order to avoid the aggregation bias problem which can occur with annual data. The inflation rate is measured by the logarithmic first difference of the CPI. The strong form of the Fisher hypothesis is examined and it is concluded that the short-run responses of the nominal interest rate to expected inflation do not display a consistent pattern. For some developing countries, the short term adjustment of the nominal interest rate to expected inflation is more than proportional. In contrast, for developed countries, the short run adjustment of the nominal rate to expected inflation is always less than proportional. The empirical results suggest a point-for-point relationship between nominal interest rates and expected inflation for 16 out of 26 countries and the conclusion of the existence of the Fisher hypothesis holds more for developed countries than developing ones.

The Fisher effect is a hypothesis for domestic interest rates. An extended version of this hypothesis is the **Generalized Fisher Effect** (GFE) which considers the interactions between countries and states that real returns are equalized across countries through arbitrage. Within the context of the GFE, the nominal interest rate differential between two countries is equal to their anticipated inflation differential.

$$i_h - i_f = \pi_h^e - \pi_f^e \qquad \textbf{(2)}$$

In Equation (2), $i_h$ and $i_f$ are home and foreign nominal interest rates, respectively, and $\pi_h^e - \pi_f^e$ denotes the anticipated inflation differential between the two countries. The theory suggests that the higher inflation rate country should bear higher interest rates relative to the lower interest rate country so that, in the absence of government intervention, capital flows towards the higher expected return country until expected real returns are equalized. Capital market integration is an important condition for the GFE since there should not be any restrictions on capital mobility so that capital is can flow freely across borders.

In the literature, most empirical studies concerning the GFE have primarily focused on developed countries. Most of these studies find evidence that does not support the existence of a GFE. However, some studies are able to present supportive results when the GFE is analyzed over longer time periods. The study by Al-Khazali and Osamah (2004) test for the existence of the GFE by looking at the relationship between inflation and common stock returns in nine Asian countries: Australia, Hong Kong, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan, and Thailand. They use monthly short-term interest rates (Treasury bill rates or deposit rates) and monthly changes in the CPI as proxies for expected inflation in the individual countries between January 1980 and December 1994.

The econometric results of the study indicate that stock returns in general are negatively correlated with both expected and unexpected inflation and that common stocks provide a poor hedge against inflation. As a conclusion, the GFE is rejected for all countries in this study.

Not only the country choice but the method of estimation is also an important factor that affects empirical results. A study by Panopoulou (2005) questions the reason behind the fact that there is no consensus among economists about the true size of the Fisher effect. This study brings a different perspective to the literature and argues that the inconsistency of results lies on the choice of the estimation method. Panopoulou seeks to find an answer in terms of the best estimator choice by including commonly used estimators such as OLS (ordinary least square), FMLS (fully modified least square), JOH (Johansen's Maximum Likelihood), DOLS-type (dynamic least square) estimators and the ADL (autoregressive distributed lag) framework. Outcome of the research states that within the ADL framework, the Fisher hypothesis is not rejected. In contrast, when DOLS estimators are used, the rejection of the hypothesis is observed. Panopoulou concludes that the choice of the estimation method is a key factor for both approving and rejecting the Fisher hypothesis.

In summary, the evidence about the Fisher effect is inconclusive since some studies support and others oppose the hypothesis. The severity of inflation, financial and legal development level of the country, choice of econometric estimation methods and time period analyzed are factors that seem to affect the results obtained from various studies of the Fisher hypothesis.

### 2.3 The Theory of Purchasing Power Parity

Section 2.2 analyzed the relationship between interest rates and inflation expectations – the Fisher Hypothesis. Section 2.3 presents another building block theory of the International Fisher Effect. The Purchasing Power Parity (PPP) was first developed by the Swedish economist Gustav Cassel in 1920s to examine the relationship between the exchange rates of different countries. The PPP holds if and when exchange rates move to offset the inflation rate differentials between two countries. Throughout the literature PPP is defined on the basis of the "law of one price" which asserts that the exchange rate between two currencies should be equal to the ratio of the price level of identical goods and services in the two countries. According to the PPP, increase in the price level of a country will cause depreciation of its exchange rate relative to other countries, thereby keeping the relative price of identical goods the same across countries.

Assuming the foreign inflation rate is relatively smaller than the home country inflation rate, the PPP can be represented with the following equation:

$$\frac{s_{t+1}-s_t}{s_t} = \pi_{h,t} - \pi_{f,t} \tag{3}$$

In Equation (3), $s_{t+1}$ and $s_t$ are the spot exchange rates at time $t+1$ and $t$, respectively and $\pi_{h,t}$ denotes home country inflation rate and $\pi_{f,t}$ is the inflation rate of the foreign country at time $t$. This equation states that inflation differentials will be offset by changes in exchange rates.

Gailliot's 1970 study is one of the earlier studies and tests whether price changes can be the primary determinant of exchange rates. The author examines the relationship between the relative degrees of inflation in US versus some of its industrialized trading partners and the relative changes in exchange rates between these nations for two sub periods covering 1900-1904 and 1963-67. Gailliot explains that both of these time periods are characterized by relatively free movement of trade and capital and freely convertible currencies and, therefore, provide a proper environment for testing the PPP. The results of Gailliot's study provide strong supporting evidence for the PPP.

In a later study, Webster (1987) analyzes the PPP relation by using various industry data from the 1970s for US and UK. The evidence in this study does not support the PPP but indicate a high degree of sensitivity for the exchange rates in the face of inflation differentials. Although the results are not statistically significant, Webster concludes that the goods that have significant trading volume between countries are associated with more rapid price adjustments. For this reason, the author argues, the insignificant results should not be interpreted as an argument against the PPP.

In a more recent study, Taylor and Taylor (2004) analyze the PPP debate in a wider perspective and summarize finding from previous studies. The PPP predicts that internationally traded goods should have the same price anywhere in the world once the price is expressed in a common currency. Authors mention that the term "purchasing power parity" was introduced after the World War I, during a period of high inflation rates in industrialized countries. Many empirical studies have been conducted to analyze the relationship between price levels in different countries and special indexes were calculated and published in order to compare the prices of similar/identical goods in different countries. One of the most famous price indexes is the Big Mac index. According to the values of this index, when expressed in common currency prices, an identical hamburger sells at different prices in different countries. The usual explanation for this observation is the inclusion of non-tradable input prices like wages and property rental costs in hamburger prices in different countries. Since these inputs cannot be traded internationally, their prices are determined locally and this may cause deviation from the law of one price.

The studies that do not provide supporting evidence for the PPP typically highlight the importance of some of the irrational assumptions of the theory, such as zero transaction costs. In real world, the presence of transportation costs, taxes, tariffs and non-tariff barriers are likely to cause violations of the PPP. Besides, Taylor and Taylor point out that data selection is very important. Since the PPP is based on traded goods, it might be more reasonable to use the producer price index (PPI) rather than the consumer price index (CPI). The PPI tends to contain the prices of relatively more manufactured goods while the CPI might reflect the prices of relatively more non-tradable goods and this may make the PPI a better measure of price level changes within the context of PPP. Also, empirical evidence obtained from British and American data shows that price levels, expressed in common currency, tend to move together in the long run and the correlation between two national price levels is much greater with PPI compared to CPI.

Another recent study about the PPP is carried out by Jacobson et al. (2008). This study analyzes the period from 1974 to 1999 and the countries UK, Germany, France and Italy. The results indicate that the theoretical strong PPP relationship does not hold for all of the analyzed European countries. However, the authors are able to find evidence of co-integration between nominal exchange rates and prices. Although the strong form of the PPP is rejected, the overall panel estimated co-integrated vector supports the theory. Authors conclude that this result may be a reasonably accurate approximation of how nominal exchange rates and price levels evolve over time.

### 2.4 The International Fisher Effect Hypothesis

Throughout Sections 2.2 and 2.3, two key international finance relationships are analyzed. In this section, the literature about the International Fisher Effect and the parity conditions is reviewed together.

The **International Fisher Effect (IFE)** is a theory which should be considered as a combination of the Purchasing Power Parity (PPP) and the Fisher Effect (FE). The Fisher theory simply argues that real interest rates across countries will be equal due to the possibility of arbitrage opportunities between financial markets which generally occurs in the form of capital flows. Real interest rate equality implies that the country with the higher interest rate should also have a higher inflation rate which, in turn, makes the real value of the country's currency decrease over time.

It is important to note that two crucial assumptions are made for the IFE to hold. First, investors view foreign and domestic assets as perfect substitutes, and, therefore, no risk premium is postulated by investors. Second, capital markets are perfectly integrated with no regulatory and psychological barriers so that free flow of capital is achieved across countries.

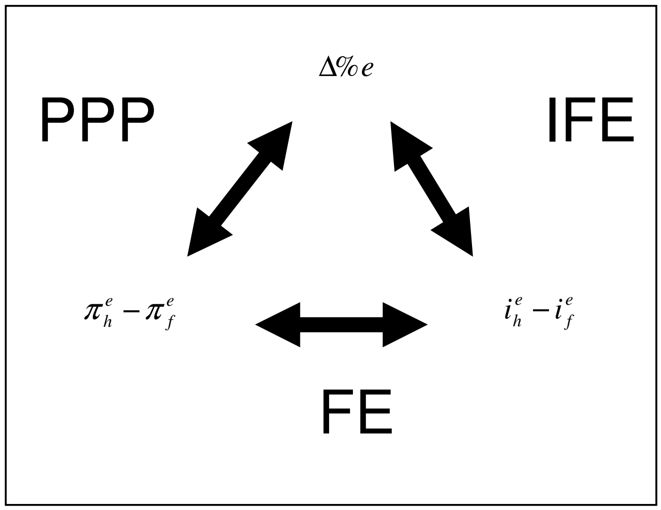


**Figure 2.4.1**

Figure 2.4.1 summarizes the relationship between the three theories. In the figure, $\Delta\% e$ denotes the change in spot exchange rate, $\pi_h^e - \pi_f^e$ is the difference in inflation expectations between the home and foreign country, and $i_h^e - i_f^e$ is the difference in nominal interest rates between the home and foreign country. Generalized Fisher Effect asserts that nominal interest rate differences are caused by differences in inflation expectations. Besides, if PPP holds, inflation differentials should be offset by exchange rate changes. In conclusion, the IFE hypothesis states that, if real interest rates are equal across countries, the interest rate differential between two countries is an unbiased predictor of the future changes in spot exchange rates. At this point, it should be noted that this does not mean that the interest rate differential is a precise estimator of exchange rates but that the estimation errors will be cancelled out over time. The theories are connected to each other such that, if the home country inflation rate is higher than the foreign country inflation rate, the home country nominal interest rate should be higher than the foreign country nominal interest rate. Under the assumptions of (1) two country assets being perfect substitutes for each other, and (2) no barriers to capital market integration, the capital flows to home country are observed to cover the advantages of higher interest rates which will result in a depreciation of the home currency relative to the foreign currency.

Parity conditions about interest rates are basic definitions which connect exchange rates to interest rates. The **Covered Interest Parity** postulates that the difference in the national interest rates and foreign rates for securities of similar risk and maturity should be equal to the forward discount or premium for a currency, but with an opposite sign. Instead of the forward rate, if the forecasted spot exchange rate is used, then the **Uncovered Interest Parity (UIP)** condition is satisfied, which asserts that exchange rate adjustments will be equal to the interest rate differentials, but in the opposite direction. The UIP condition is the same as the IFE hypothesis and simply states that the expected uncovered returns will be equalized in all markets.

If the domestic and foreign market returns are different from each other, then investors should be able to earn arbitrage returns. For example, let's suppose that at time t an investor decides to invest in the domestic market:

$$V(T, YTL, D) = V(t, YTL, D)(1 + i_d) \qquad \textbf{(4)}$$

In Equation (4), $V$ is the value of investment, $YTL$ denotes the domestic currency, location of investment is denoted by $D$ for domestic market and $i_d$ is the home country interest rate between at time $t$ and $T$. Therefore, $V(T, YTL; D)$ is the future value of the investment at time $T$ in the domestic market.

If the same investor decides to invest in the foreign market, s/he buys foreign currency at the spot exchange rate. Then, the value of the investment at time t becomes the following:

$$V(t,\$,F) = \frac{V(t,YTL,D)}{FX(t,YTL/\$)} \quad \textbf{(5)}$$

In Equation 5, $\$$ denotes the foreign currency, location of investment is denoted by $F$ for foreign market, $i_f$ is the foreign country interest rate between at time $t$ and $T$, and $FX(t,YTL/\$)$ is the spot exchange rate between home and foreign currency at time $t$.

The investor's return from the foreign market will be in foreign currency terms and will be equal to the foreign interest rate at the end of maturity $T$:

$$V(T,\$,F) = V(t,\$,F)(1+i_f) \quad \textbf{(6)}$$

In Equation (6), $i_f$ is the foreign interest rate at time $t$.

In order to compare domestic and foreign investment returns, the earnings at the end of the maturity have to be converted into the domestic currency by using the spot exchange rate at time $T$:

$$V(T,YTL,F) = [V(T,\$,F)]\,[FX(T,YTL/\$)] \quad \textbf{(7)}$$

In Equation (7), $FX(T,YTL/\$)$ is the spot exchange rate between home and foreign currency at time $T$.

The theory asserts that the Uncovered Interest Parity will hold if the returns from investing in the domestic market and the foreign markets are equal to each other at the end of maturity:

$$V(T, YTL, D) = V(T, YTL, F) \quad \textbf{(8)}$$

The equality in Equation (8) predicts that real returns across countries will be equalized. Exchange rate movements will cancel out the interest rate differentials. In other words, the currency of the high interest rate country will depreciate through time to equalize the expected uncovered returns in all markets.
As previously explained, the IFE is a combination of the Purchasing Power Parity and the Fisher Effect. This predicted adjustment of exchange rates to interest rate differentials has been questioned in various empirical studies from diverse perspectives.

In his empirical study, Throop (1994) mentions the importance of financial market integration for the IFE hypothesis and analyzes the real interest rate equality across five industrialized countries during the period of international integration of financial markets. The author observes that the integration of financial markets has increased dramatically starting from the 1970s after the collapse of the Bretton Woods system[1] and government imposed barriers to international flow of capital between industrialized countries were reduced and mostly eliminated by 1980s. This integration further caused a decrease in the ability of central banks to influence their own national macroeconomic parameters, such as the nominal interest rates.

Throop tests the relationship between the real interest rates of US, Canada, Germany, UK and Japan during the period between 1981 and 1994. He explains the well-known Mundell Fleming Model[2] (MFM), which is essentially an extension of the IS-LM model. The MFM asserts that under a flexible exchange rate system

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[1] Bretton Woods is an international economic agreement signed between 44 nations after World War II in 1944. Briefly, it was a system in which each country adopted a monetary policy of fixing the exchange rate of its currency in terms of the US dollar and gold. The fixed exchange rate system collapsed in early 1970s and a system of mostly floating exchange rates was adopted

[2] The Mundell-Fleming Model is also known as the Unhold Trinity, which simply asserts that only two out of (1) free capital flow (2) fixed exchange rate (3) independent monetary policy, can be attained at the same time. It is impossible to have all three at the same time.

with static exchange rate expectations and perfect capital mobility, nominal rates are expected to be equalized continuously. Throop indicates that after the 1980s barriers to capital flow were eliminated for the majority of industrialized countries and in such an environment only the currency risk was left for similar investments in different countries. Therefore, according to author, the expected change in the value of the currency is the source of the differences between the real rates of return on similar assets in different countries. Throop's results indicate no causal linkage between the US and foreign real rates during the period between 1981 and 1994. This evidence is interpreted by the author to imply that central banks have been able to influence their domestic interest rates quite independently from the influence of interest rates abroad.

In another study Juntilla (2001) extends the traditional Fisher equation through international direction by introducing foreign interest rates and exchange rates into the standard Fisher equation. He first tests the traditional Fisher hypothesis for Finland and the results do not support the existence of a Fisher effect for monthly Finnish data for the period between 1987 and 1996. Second, by taking the international dependencies into account, the author tests the dependencies between the Finnish interest rates and rates from its close trade partners, Germany and US. Results of the tests provide supportive evidence for a positive long run relationship between nominal interest rates and inflation in Finland, and, moreover, tests of the augmented version of the Fisher equation indicate that the Finnish money market is not independent of the markets of those countries with which Finland has a high trading volume.

Mishkin (1984) analyzes whether real rates are equal across countries. Data from US, Canada, UK, France, West Germany, Netherland and Switzerland are used for the period between 1967 and 1979. Mishkin tests for this equality by using the international parity conditions. UIP and PPP hypotheses are tested independently and jointly, where the joint testing of the parity conditions means testing for the equality of real rates. When individually tested, neither the PPP nor the UIP are rejected. However, when these hypotheses are tested jointly, the null hypotheses are rejected which indicates that the joint results are not supportive of real rate equality across countries. Therefore, the basic conclusion of Mishkin is the same as that of Throop's (1994). The equality of real rates is statistically rejected across countries, which leaves the possibility for central banks to control their interest rates independent from other countries. Mishkin's explanation for the rejection of equal real rates is that the underlying assumptions of the theory may not hold in the real world. For example, the marginal tax rates on interest payments might differ across countries. Also, assuming no transaction costs is unrealistic. According to Mishkin, real rates can differ across countries because risk premiums asked in the forward exchange market and securities denominated in different currencies are not perfect substitutes of each other.

The empirical results and their interpretation are often contradictory when the equality of real rates is analyzed across countries. Although Mishkin (1984) and Throop (1994) have rejected real rate equality, contradictory results are also present in the literature. For instance, Roll (1979) argues that in efficient capital markets, expected real interest rates should be equalized across borders with the assumption of perfect integration and the strict presence of the PPP. It is important to mention that in his hypothesis, Roll assumes homogeneous goods/assets which are perfect substitutes of each other and they are traded with no costs across countries with perfect capital mobility.

In a more recent study, Minford and Peel (2007) question the findings of Roll (1979). Overall, their empirical findings are not supportive of Roll's hypothesis of real rate equality. According to Minford and Peel, rejection of equality does not imply that the asset markets are inefficient but rather that the theoretical conditions that have to be met and the underlying assumptions should be evaluated.

Wu (1999) examines the relationship between the exchange rate and interest rate differentials for Japan and Germany against the US for the period between 1974 and 1996. In order to test for a long run relationship, Johansen's co-integration test is applied to data. Results are in favor of the existence of a long run relationship between real exchange rates and the expected real interest rate differentials. This study differs from other studies by including cumulated current accounts in the regression models. A long run relationship exists between exchange rates and Pinterest rate differentials when the cumulated current accounts are included in the regressions. The author also emphasizes the importance of the characteristics of the time period under analysis. According to Wu, contradictory results could be found under persistent component regimes, such as a fixed exchange rate system.

In a later study, Ito and Chinn (2007) examine the relationship between depreciation[3] and interest rate differentials for 21 developed and 36 emerging market economies. A set of rather inconclusive results are obtained from the analysis. The diversity of results is attributed to the differences in the level of financial development and the restrictions imposed upon capital mobility. Results are in line with the previous findings in the literature and imply that higher financial development and financial openness tend to reduce deviations from the UIP, while volatility of inflation tends to increase the deviations.

Another cross country analysis for the IFE is performed by Shalishali and Ho (2002) for eight industrialized countries: Canada, France, Germany, Japan, Netherlands, Sweden, Switzerland and UK Quarterly data are used covering the period between 1972 and 1996. According to the authors, governments of industrialized countries are less likely to intervene in the foreign exchange markets and therefore, the results for these countries are expected to be more statistically significant in favor of the IFE. The OLS regression results are in line with those of Ito's (2007) study and show that while the theory holds for some countries, it does not hold for others, but in most cases the theory holds except for a few instances. An interesting outcome of the study is the inconsistency of results such that theory holds when some countries were used as home country but rejected when the same

[3] Instead of changes in exchange rates, depreciation is used by author. Depreciation; is loss of value of country's currency with respect to other currencies, usually in floating exchange rate system.

countries are taken as the foreign country in the IFE equation. According to authors, these results suggest that there are some barriers to foreign trade which may affect exchange rate adjustments and these effects are in addition to the effects from interest and inflation rate differentials.

The period and countries that are used by Shalishali (2002) are reexamined by Chakrabarti (2006) in order to test the relationship between real exchange rates and real interest rates within a multivariate panel co-integration framework. The results obtained from panel tests fail to detect any evidence of co-integration between the two variables. These results indicate that although the same data are used, different estimation techniques may produce different results.

A different perspective is provided to the literature by Jaebeom's 2007 study. The author examines the relationship between real exchange rates and real interest rate differentials during the 1974-2003 period by using two kinds of data, prices of traded goods and non-traded goods, in five industrialized countries: Canada, Japan, Italy, UK and US. The Producer Price Index is used to calculate the rate of inflation and thus the real rate of interest. The author uses the dynamic SUR methodology for panel data in order to estimate the link between real exchange rates and real interest rate differentials. Empirical results support the link between real exchange rates and real interest rate differentials for traded goods but not for non traded goods. This finding implies that traded goods are more plausible indicators of expected parity conditions. The author mentions that the link is found for traded goods because the sample countries are close trade partners, and, therefore, they have relatively stable non-tariff barriers in order to trade with lower transaction costs.

Contrary to the majority of the studies that use monthly or quarterly data, Chaboud and Wright (2005) use high frequency data and analyze the UIP condition by using daily bilateral intraday exchange rates between the Japanese Yen, German Mark, Swiss Franc, Pound Sterling and the US Dollar and the corresponding overnight interest rates. The results are supportive of the uncovered interest parity within this high frequency data. . Interestingly, if the data frequency is extended for even a few hours, it is no longer possible to find evidence of the uncovered interest rate parity condition.

Most of the IFE studies are conducted on data from industrialized countries. It may be plausible to expect that this relationship may not hold in emerging countries with high levels of inflation. In these countries, it may take longer for the interest rates to adjust to unanticipated inflation. As a result of the uncertainty, high inflation countries tend to invest more in inflation forecasts, and, therefore, may have a greater incentive to incorporate inflationary expectations in required returns and this might cause the exchange rate adjustments to take longer. In addition, emerging economies might be affected more from developments in industrialized countries.

Within this context, Özmen and Gökcan (2004) test the validity of the PPP and the UIP by using Turkish and US data for the period between 1986 and 1999. Findings are consistent with some of the earlier studies which reject the pure parity conditions. The evidence in this study suggests that neither the PPP nor the UIP can be valid by itself for the Turkish data. According to the authors, disequilibrium in international commodity markets may affect international asset markets. In open economies, policy makers should consider the importance of the interaction of PPP and UIP while setting targets for the exchange rates.

In another study which uses the Turkish data, Saatçioğlu and Korap (2007) investigate the empirical validity of the uncovered interest rate parity. Econometrical results obtained from the Johansen co-integration tests are in favor of the UIP hypothesis in the long run for the Turkish economy. Positive interest rate differentials which are in favor of domestic interest rates cause nearly a one-to-one increase in the expected exchange rates. Just like Özmen and Gökcan (2004), Saatçioğlu and Korap mention that the policymakers should consider spot exchange rate movements while setting targets in open economies.

### 2.5 Conclusion

The International Fisher Effect (IFE) asserts that differences in nominal interest rates between two countries would determine the movement of the nominal exchange rate between their currencies.

As explained in Sections 2.2 and 2.3, the IFE should be considered as a combination of the two well-known international finance theories: the Fisher Hypothesis and the Purchasing Power Parity. The PPP suggests that there is a one-to-one relationship between the inflation differential of two countries and the percentage change in the spot exchange rate of their currencies over time. The IFE suggests that there is a relationship between the interest rate differential of two countries and the percentage change in the spot exchange rate over time. The IFE is based on nominal interest rate differentials which are, in return, influenced by expected inflation. Thus, the IFE is closely related to the PPP. Typically, the inflation expectation is higher in countries that have higher interest rates and this is expected to cause the depreciation of such a country's currency against the currencies of lower interest rate countries.

Throughout the literature, it is generally argued that evidence that supports the existence of the IFE can be found only if the underlying assumptions are met in the markets. The crucial assumptions of the IFE can be summarized as follows:

- Perfect mobility of capital without any regulation or restriction by government institutions, indicating that trade barriers are eliminated.
- Investors are risk neutral, therefore, no risk premium is asked by them.
- Zero transaction costs, with no psychological barriers and transportation costs, so that investors are indifferent between countries.

Time period under analysis is also important because the nature of the exchange rate regimes is crucial for the IFE hypothesis. For example, under a fixed or pegged float, exchange rates are not allowed to move freely. Rather, they are either set fixed or are allowed to fluctuate within a pre-announced band. Since exchange rates are not determined freely in the financial markets, adjustments necessary for the parity conditions to hold cannot occur.

The level of financial development in a country is another important factor which effects capital mobility. Since institutional development is complete in developed countries, it is less likely for the authorities of these countries to restrict mobility of capital. The literature also presents evidence that political risk and psychological factors play an important role in the determination of exchange rates. Moreover, it is widely argued that emerging markets are affected more from developments in industrialized countries.

The empirical evidence about the relationship between interest rate differentials and exchange rates is inconclusive since there are many studies that support or oppose the International Fisher Effect hypothesis. The reasons for these different results can be summarized as below:

1) The macro-economic characteristics of the period under analysis are important. Exchange rate targeting policies enforced by regulatory bodies vary through time. The external influences in the market are examples of violation of the assumptions mentioned above.
2) Financial development and capital market integration of countries under analysis are also important factors that affect the results of the empirical studies. Literature shows that close trading partners have more influence on each other's financial markets.
3) The type and frequency of data used and other variables (such as current accounts, inflation differentials etc.) that are included in regression analyses are also important factors.

4) The methodologies used and the path of the analyses vary among empirical studies. For example, some studies do not directly test the IFE equation but use the inverted Fisher equation to test the real interest rate equalities across countries. Although results of the equations are individually supportive of the hypotheses, when they are used together, the real rate equality assertion is not supported with the same data.

As summarized above, when the concern is the international interactions of markets, results obtained from empirical studies are highly diverse. The goal of this study is to examine the validity of the IFE hypothesis across the sample countries, namely the G-5 countries and Turkey. The next chapter explains the methodology, the data and the sample periods used for testing the International Fisher Effect.

# CHAPTER 3

# DATA AND RESEARCH METHODOLOGY

## 3.1 Introduction

In this chapter, data and methodology are presented. The objective of the methodology section is to explain the econometric method used to analyze the effects of interest rate changes on exchange rates. Before methodology, the data and time period used in the analysis are described. As explained in detail in Chapter 2, Section 2.4, the International Fisher Effect (IFE) is a theory which asserts that changes in spot exchange rates are related with interest rate differentials across countries. According to the IFE, higher interest rate countries' currencies are expected to depreciate against lower interest rate countries' currencies and this equalizes the investment returns across countries. The objective of this thesis is to test the existence of this relationship between the spot exchange rates and interest rates in the G-5 countries and Turkey.

The sampling period and data used for analyses are described in Section 3.2 while Section 3.3 presents the research methodology.

## 3.2 Data

### 3.2.1 Exchange Rate Data

The theoretical definition of an exchange rate is the price of one currency against another currency. The exchange rate data used in this study are taken from the databases of relevant country central banks on the last business day of each month. Prior to 1999, Deutsche Mark and French Franc are used for Germany and France, respectively. Since Germany and France are member states of the European Union (EU), the official currency of these two countries became Euro as of January 1, 1999. For this reason, starting in 1999, Euro is used as the currency for Germany and France. Data on the historical values of the exchange rate between French Franc and Japanese Yen could not be found; therefore, this exchange rate is excluded from the analysis.

### 3.2.2 Interest Rate Data

In the finance literature, Treasury bills are accepted as the risk free investment tools, and, therefore, it is assumed that Treasury bills in different countries are perfect substitutes of each other. All interest rates, except for the Turkish interest rate, are taken from the International Finance Statistics (IFS) database. For countries other than Turkey, interest rates used are the 90-day Treasury bill rates for the period between January, 1985 and December, 2007. For Turkey, the compound interest rates of Treasury bills that are traded on the İstanbul Stock Exchange (ISE) and that have a remaining maturity closest to 90 days are used. The Turkish treasury bill data, covering the period 1995:1 to 1999:12 are obtained from the ISE monthly bulletins. For the period 2000:1 to 2007:12, the compound interest rates are downloaded from the electronic database of the ISE. Since the interest rate data for Turkey goes back to only 1995, instead of 1985, in order to avoid two short sub periods, Turkey is included in the analyses starting in January, 1999.

As explained in Section 3.2.1, starting in January, 1999, Euro is used as the currency for Germany and France. For this reason, in addition to the individual interest rates of Germany and France, the 90-day LIBOR rate for Euro, which is published by the British Bankers' Association[4], is also used for the German and French interest rate as an alternative test.

### 3.2.3 The Sample Period

Monthly data are used for both exchange rates and interest rates. The interval of analysis covers the period from January, 1985 to December, 2007. The analyses are performed over three sub-periods: (1) January, 1985 to December, 2007 (2) January, 1985 to December, 1998 and (3) January, 1999 and December, 2007. The rationale behind the three sub-periods is as follows:

The first sub period data set includes three countries: USA, UK and Japan. The data of these three countries do not include any structural breaks, and, therefore, this period allows for testing the hypotheses in the study over the longest time period possible.

After January, 1999, due to the adaptation of Euro as the official currency by the EU countries, a structural break exists in the data. The first period is between January, 1985 and December, 1998 and this period is uses the German Mark and the French Franc. The second period is between January, 1999 and December, 2007 and this period is analyzed with Euro. In addition, the January, 1999 - December, 2007 period is analyzed with two different interest rates. First,

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[4] For detailed information please refer to website at **www.bba.org.uk**

individual interest rates of Germany and France are used. As an alternative test, the 90-day LIBOR for Euro is used instead of the German and French interest rates.

Throughout the thesis, the following abbreviations are used for countries and their corresponding currencies:

| **Country** | | **Currency** | |
|---|---|---|---|
| Turkey | TR | Turkish Lira | TL |
| Japan | JP | Japanese Yen | Yen |
| France | FR | French Franc | FF |
| United Kingdom | UK | Sterling | Sterling |
| Germany | GER | Deutsche Mark | DM |
| United States of America | USA | United States Dollar | USD |

**Figure 3.2.3.1**

| | TR (TL) | GER (DM) | FR (FF) | JP (YEN) | USA (USD) | UK (STERLING) | DM&FF (Euro) |
|---|---|---|---|---|---|---|---|
| TR- (TL) | - | - | - | x | x | x | x |
| GER-(DM) | | - | xx | xx | xx | xx | - |
| FR-(FF) | | | - | NA | xx | xx | - |
| JP-(YEN) | | | | - | xxx | xxx | x |
| USA-(USD) | | | | | - | xxx | x |
| UK-(STERLING) | | | | | | - | x |
| Euro (DM&FF) | | | | | | | - |

**Figure 3.2.3.2 – Analyzed County Pairs**

Figure 3.2.3.2 summarizes the country pairs analyzed for exchange rate and interest rate differentials. "NA" denotes the unavailability of data between Japan and France. Regression equations are estimated over the three sub periods:

**X:** January, 1999 - December, 2007;

**XX:** January, 1985 - December, 1998;

**XXX**: January, 1985 – December, 2007.

The interest rates and currencies that are used over the relevant sub periods are presented in Figure 3.2.3.3 below.

| Period | 1985-2007 | 1985-1998 | 1999-2007(A) | 1999-2007(B) |
|---|---|---|---|---|
| Interest Rates | USA<br>UK<br>Japan | USA<br>UK<br>Japan<br>Germany<br>France | USA<br>UK<br>Japan<br>Germany<br>France<br>Turkey | USA<br>UK<br>Japan<br>LIBOR (Euro)<br>Turkey |
| Currencies | USD<br>Sterling<br>Yen | USD<br>Sterling<br>Yen<br>Deutsche Mark<br>French Franc | USD<br>Sterling<br>Yen<br>Euro<br>Turkish Lira | USD<br>Sterling<br>Yen<br>Euro<br>Turkish Lira |

**Figure 3.2.3.3 Summary of Interest Rates and Currencies**

The following section presents the research methodology.

### 3.3 The Research Methodology

The main question asked throughout this thesis is whether the interest rate differentials between countries are unbiased predictors of future changes in exchange rates. The main findings of the literature review in Chapter 2 regarding the relationship between interest and exchange rates across countries can be summarized as follows:

1) Results from previous studies are inconclusive due to differences in the selection of time frame and type of data. For instance, narrow time frames may cause statistical problems, such as low power of tests and longer periods of data usually span different exchange rate regimes, which might cause biased outcomes.

2) Empirical studies which could not find supportive evidence for the IFE highlight the importance of assumptions of the theory. Most of the rejected results are attributed to the unrealistic assumptions of the hypothesis.
3) Purchasing Power Parity and Generalized Fisher Effect are two building block theories of the IFE. Therefore, deviations from these conditions may cause IFE not to hold.
4) The institutional and financial development level of the country is crucial such that emerging economies tend to follow the developments in industrialized countries.

Based on the finding presented and methodologies used in the previous studies, the following steps make up the econometric framework for testing the IFE in this thesis:

3.3.1 Unit Root Test

3.3.2 Cointegration Test and Error Correction Model

3.3.3 Panel Unit Root Test

3.3.4 Panel Cointregration Test

### 3.3.1 Unit Root Tests

Before the interest and exchange rates can be tested for the existence of a long-term relationship, the time series properties of these variables need to be examined. It is necessary to understand whether the stochastic process generating the time series can be assumed to be constant over time. The unit root test is applied to the variables in order to determine whether the time series data collected have stationary I(0) or non-stationary I(1) characteristics. Econometrically, a stationary process is a random process which has a constant mean, a constant variance and other statistical properties that do not vary with time. Parallel to this definition, a process whose statistical properties do change through time is defined as a non-stationary process. If exchange rates $(e_t)$ and interest rate differentials $(i_h - i_f)_t$ are proven to be non-stationary, it would be difficult to represent the relationship between the past and futures values of these variables within a simple algebraic model. If two such random variables are regressed on one another, the results can be misleading in that conventional significance tests may tend to indicate a relationship with a high $R^2$ and a low Durbin-Watson statistic even though no true relationship exists between the variables[5]. Such cases create the so-called spurious regressions in which two independent and unrelated time series are found to be related.

In this thesis, two types of unit root tests are applied. The Dickey-Fuller test, developed by D. A. Dickey and W. A. Fuller in the 1970s, is the most common test used to determine whether a unit root is present in an autoregressive model. First, the Augmented Dickey Fuller (ADF) statistic, which is developed by E. Said and A. Dickey (1984), is used to test the unit root characteristics of interest rate differentials and exchange rates. Second, the Kwiatowski, Phillips, Schmidt, and, Shin (KPSS) test is performed for the same purpose.

#### 3.3.1.1 Augmented Dickey-Fuller (ADF) Test

Unit Root test distributions are affected by the inclusion of deterministic terms such as dummy variables, constant terms or time trends. Therefore, according to the nature of variables that are being tested, different test regressions should be used. For non-trending economic and financial series, a regression model with a constant term and without a trend would be appropriate. In this setting, the interest rate differentials and exchange rates can be modeled in the following manner in order to test whether these two series have a unit root, and, thus, are non-stationary:

[5] A low value for the Durbin-Watson statistic means that there is a positive correlation between tested variables.

$$(i_h - i_f)_t = \alpha + \delta_1 (i_h - i_f)_{t-1} + u_t \quad \textbf{(1)}$$

In Equation (1), $(i_h - i_f)_t$ is the interest rate differential between home and foreign country at time t, $\alpha$ is the constant term, $\delta_1$ is the coefficient that represents the relationship between the current and one-period lagged values of the interest rate differential, and $u_t$ is the error term.

$$e_t = \alpha + \delta_1 e_{t-1} + u_t \quad \textbf{(2)}$$

In Equation (2), $e_t$ is the exchange rate between home and foreign country at time t, $\alpha$ is the constant term, $\delta_1$ is the coefficient that represents the relationship between the current and one-period lagged values of the exchange rate, and $u_t$ is the error term.

In the following discussions, for notational parsimony, the interest rate differential and the exchange rate variables are both replaced with $y_t$ and the unit root testing steps are explained using the shorter notation:

$$y_t = \alpha + \delta_1 y_{t-1} + u_t \quad \textbf{(3)}$$

In Equation (3), $u_t$ is the white-noise error term with a zero mean and a constant variance: WN $(0, \sigma^2)$. In order to test the relationship between time t and t-1, $y_{t-1}$ is subtracted from both sides of Equation (3):

$$\Delta y_t = \alpha + \delta_1^* y_{t-1} + u_t \quad \textbf{(4)}$$

In Equation (4), $\Delta y_t = y_t - y_{t-1}$ and $\delta_1^* = \delta_1 - 1$. The existence of a unit root is tested with the following null hypothesis: $H_0 : \delta_1^* = 0$

If the absolute value of the calculated ADF statistic is smaller than the critical value at the specified significance level, then the test statistic fails to reject the null hypothesis. Failing to reject the null means that the time series has the characteristics of a non-stationary series which is integrated of order 1 [I(1)]. This result also indicates that the time series tested has a unit root.

The ADF unit root test is carried out for interest rate differentials as modeled in Equation (1). The log-difference command is used in E-Views™ for exchange rates to test the presence of unit root for changes in exchange rates. The mathematical logic of the log-difference is presented in Equations (5) and (6).

$$d\log(e) = \log(e_t) - \log(e_{t-1}) \quad \textbf{(5)}$$

$$\log(e_t) - \log(e_{t-1}) = \log\left(\frac{e_t}{e_{t-1}}\right) \approx \frac{(e_t - e_{t-1})}{e_{t-1}} \quad \textbf{(6)}$$

In Equation (6), $\frac{(e_t - e_{t-1})}{e_{t-1}}$ indicates the percent changes in spot exchange rates.

### 3.3.1.2 Kwiatowski Phillips Schmidt Shin (KPSS) Test

The KPSS Test, which is proposed by Kwiatkowski et al. (1992), is an alternative analysis to test the presence of unit root in time series. The test differs from other unit root tests in a way that the analyzed series, $y_t$, is assumed to be stationary, I(0), under the null hypothesis. $H_o = y_t \sim I(0)$

For this reason, in order to confirm unit root by the KPSS test, the calculated statistics should be higher than the critical value. Therefore, contrary to the ADF test, the null hypothesis should be rejected to conclude for the presence of unit root in $y_t \sim$ I(1).

The next section describes the co-integration tests of the variables related with the International Fisher Relationship.

### 3.3.2 Co-integration Tests

If unit root test results indicate that the interest rate differentials and exchange rates are non-stationary, then both variables are said to follow random walks. In such a case, regressing one random walk against another may generate spurious results. Alternatively, these variables could be differenced once and the differenced variables can be re-tested for the existence of a unit root. Even though differencing usually solves the problem of non-stationarity, it may cause a loss of information since the long-run relationship hypothesized between the variables should hold for the level values of the variables. In order to avoid such an information loss, one solution is to create linear combinations of the variables under study and test to see if these linear combinations are stationary. If there exists a stationary linear combination of two random variables, then these variables are co-integrated. The parameter that describes the linear relationship between the variables is called the co-integrating parameter and can be estimated by running an OLS regression of one variable on the other. The residual of this regression model can further be used to test whether the two variables are indeed co-integrated.

The co-integration relationship in this context can be described as a model in which a non-stationary dependent variable and a non-stationary independent variable drift together over time such that the residuals of the regression equation are stationary over time. It is important to mention that the non-parametric cointegration tests are applied solely to series which are proven to be I(1) in unit root tests.

The International Fisher Effect can be tested by linking the interest rate differential between two countries to the change in the exchange rates in the following linear model:

$$\frac{e_{t+1} - e_t}{e_t} = \alpha + \beta \left( \frac{i_h - i_f}{1 + i_f} \right)_t + \varepsilon_t \qquad \textbf{(7)}$$

In Equation (7), $e_t$ denotes the exchange rate at time t, $i_h$ and $i_f$ are the home and foreign country interest rates respectively, $\varepsilon_t$ is the error term and, $\alpha$ is the constant. If $\beta$=0 cannot be rejected, then the change in the exchange rate equals the value of the constant parameter $\alpha$. In other words, Equation (7) can be defined as the basic model to test whether the interest rate differentials are unbiased predictors of changes in exchange rates where this prediction is tested by examining the $\beta$ coefficient.

If the foreign country interest rate is sufficiently small, Equation (7) can be re-written as follows:

$$\Delta e_t^{t+1} = \alpha + \beta (i_h - i_f)_t + \varepsilon_t \qquad \textbf{(8)}$$

In Equation (8), $\Delta e_{t+1}^{t}$ denotes the change in the spot exchange rate between time t and t-1 and the other variables are defined as before. Equation **(8)** is estimated within the Johansen cointegration framework in order to test for cointegration between the exchange rates and interest rate differentials.

Econometrically, cointegration defines the correlation between non-stationary variables by testing for the existence of a unit root in the residuals $\hat{\varepsilon}_t$ of Equation (8). In order to test for a unit root in the residuals, the residuals are modeled similar to Equation (3). The rejection of the null hypothesis of a unit root in the residuals shows that $\Delta e_{t+1}^{t}$ and $(i_h - i_f)_t$ are cointegrated.

If the residuals of Equation (6) are stationary and the interest and exchange rate differentials are cointegrated, then the International Fisher Effect predicts that $\beta$ in

Equation (8) should be equal to 1. Thus, if the null hypothesis of $\beta=1$ cannot be rejected, then there is evidence in the time series which supports the unbiasedness hypothesis of IFE which argues that interest rate differentials are unbiased predictors of changes in the future exchange rates.

After testing for cointegration between countries on a pair-by-pair basis, the same set of countries are also examined for the existence of cointegration on a panel basis. For this purpose, first, the panel of country series needs to be tested for the existence of a unit root. The following section explains this methodology.

### 3.3.3 Panel Unit Root Tests

In Sections 3.3.1 and 3.3.2, country pairs are modeled individually and regression equations are tested separately for the unbiasedness hypothesis. In this section, the unit root hypothesis explained in Section 3.3.1 is tested by using panel data.

It is widely agreed in the literature that panel-based unit root tests have higher power than individual unit root tests. The presence of cross-sections generates multiple series out of a single series and the unit root procedure is applied to panel data. Panel estimation brings additional information by evaluating cross-sectional dependencies between individually constructed regressions.
In order to search for a cointegration relationship in the entire panel of countries, first the panel needs to be tested for the existence of a unit root. Panel unit root testing is carried out by estimating the following equation within the SUR (Seemingly Unrelated Regressions) framework:

$$\Delta y_{it} = \gamma_i + \alpha_i \, y_{it-1} + \lambda_i T + \sum_{k=1}^{p} \delta_{ij} \Delta y_{it-k} + \xi_{it} \qquad \textbf{(9)}$$

In Equation (9), the p values are determined from the univariate ADF test results for each variable in the equation. Also, $i = 1, 2, ......, N$ where N is the number of cross sectional equations and $t = 1, 2, ......, T$ where T is the number of time series observations. The null hypothesis for the presence of a panel unit root is $H_0 : \alpha_i = 0$. If the absolute value of the calculated ADF statistic is smaller than the critical value at the specified significance level, then the test statistic fails to reject the null hypothesis. In addition to the calculated test statistics, p-values can also be used to interpret the results of the tests. Failing to reject the null confirms the presence of a panel unit root.

Once the panel unit root tests are completed, if supportive unit root results are found in panel data, the next step is to examine the cointegration relationship within the panel of countries. Alternatively, if the panel unit root is not confirmed, further panel cointegration testing is not performed.

The following section describes the procedure for estimating the IFE equations for different countries as a system in order to test whether additional information is available across equations.

### 3.3.4 The DSUR Estimation

In this section, individually modeled regressions are estimated as a system within the DSUR (Dynamic Seemingly Unrelated Regression) framework in order to examine the cross sectional dependence between the selected countries. The parametric DSUR estimator, proposed by Mark et al. (2005), is an econometric method to test for multivariate cointegration across countries and it tests for long-run cross sectional dependence in equilibrium errors. DSUR is applicable for panels where the number of cross sectional equations $(N)$ is substantially smaller than the number of time series observations $(T)$.

Cross sectional panel data analysis incorporates additional information into the estimations by evaluating cross sectional dependencies between individually constructed regressions. One requirement of this analysis is strict exogeneity which means that the error term in each equation at a given point in time must be uncorrelated with the independent variable (the interest rate differentials) from all equations in the system. This may not be a very realistic assumption in this study since unexpected macroeconomic shocks in one country may affect the other countries considered within the system and this means that the forecasted error in each of the equations will be correlated with the interest rate differentials in the other equations.

The SUR technique was first proposed by A. Zellner (1962) as a method for analyzing a system of equations simultaneously while allowing the examination of error correlations between equations. In other words, this model is designed to simultaneously test for the correlation relationship between the error terms within a system of independent equations.

In this thesis, the unbiasedness hypothesis is tested within the DSUR framework based on Mark et al.'s (2005) methodology. In the first step, the exchange rate change over time is modeled as a function of the interest rate differential between the country pairs:

$$\Delta e^{t}_{i,t+n} = \alpha_i + \beta_i \left(i_h - i_f\right)_{i,t} + \varepsilon_{i,t+n} \qquad \textbf{(10)}$$

In Equation (10), $\Delta e^{t}_{i,t+n}$ is the change in the spot exchange rate for country pair i between time t and t+n, $(i_h - i_f)_{i,t}$ is the interest rate differential for country pair i at time t, and the other variables are defined as before. For notational simplicity, the dependent and independent variables of Equation (10) are replaced by $y_{it}$ and $x^{*}_{it}$ respectively and each equation $i = 1,......,N$ has a triangular representation as follows:

$$y_{it} = \underline{x_{it}^*} \underline{\beta_i} + u_{it} \quad \textbf{(11)}$$

$$\underline{\Delta x_{it}^*} = \underline{\varepsilon_{it}} \quad \textbf{(12)}$$

In Equation (11), $y_{it}$ is the change in the spot exchange rate for country pair i between time t and t+n and $x_{it}^*$ is the interest rate differential for country pair i at time t. Underlined symbols in the equations stand for vector representations. The DSUR framework assumes that $u_{it}$ is correlated with $p_{ij}^+$ and $p_{ij}^-$ of $\Delta x_{it}^*$ where $p_{ij}^+$ denotes the lead and $p_{ij}^-$ denotes the lag values of $\Delta x_{it}^*$. Leads and lags of independent variable are included in the right-hand side of each equation in the system. Equation (12) represents the assumptions that error terms are correlated.

In the next step of estimation, a new cross-sectional variable, $z_{it}^*$, is created which is a vector of all lead and lag values of the variable $\Delta x_{it}^*$ for each country pair:

$$z_{it}^* = \left(\Delta x_{i,t+p}^*, \ldots\ldots\ldots, \Delta x_{i,t-p}^*\right) \quad \textbf{(13)}$$

In this setting, if there are N cross-sectional equations in the system, then the variable $z_t^*$ is a vector of N equations constructed across time where t goes from 1 to T:

$$z_t^* = \left(z_{1t}^*, \ldots\ldots\ldots, z_{N.t}^*\right) \quad \textbf{(14)}$$

Since the DSUR system tries to detect and take into account the dependence of the error term on the interest rate differential variable from each of the country pair equations, the error term is projected on the variable $z_t^*$ and is thus modeled as a function of $z_t^*$ in the following manner:

$$\varepsilon_{it} = \phi_i \underline{z_t^*} + \eta_{it} \quad \textbf{(15)}$$

Equation (15) is substituted into Equation (11) as follows:

$$y_{it} = \underline{\beta_i} \underline{x_{it}^*} + \phi_i \underline{z_t^*} + \eta_{it} \quad \textbf{(16)}$$

In Equation (16) $\phi_i$ is the vector of unknown projection coefficients and $\eta_{it}$ denotes the projection error, which is orthogonal to all leads and lags of $\Delta x_{it}^*$.

Furthermore, Equation (16) can be stacked together in a vector system as follows:

$$Y_t = \begin{bmatrix} X_t \\ Z_t \end{bmatrix}^* \begin{bmatrix} \beta \\ \phi \end{bmatrix} + \eta_t \quad \textbf{(17)}$$

Following Mark et al., the moving averages of the error terms are then incorporated into the system by creating the variable $\underline{w_t^*} = \left(\eta_t, \varepsilon_{1t}, \ldots.., \varepsilon_{Nt}\right)$ as follows:

$$w_t = \begin{bmatrix} \psi_{11}(L) & 0 & \ldots & 0 \\ 0 & .. & .. & . \\ .. & \ldots & \ldots & \ldots \\ 0 & \ldots & .. & \psi_{NN}(L) \end{bmatrix} .. \begin{bmatrix} \upsilon_t \\ .. \\ .. \\ \upsilon_N \end{bmatrix} \quad \textbf{(18)}$$

In Equation (18), $\psi$ is the matrix polynomial in the lag operator $L$, which obeys the functional limit theorem with the long run covariance matrix $\underline{\Omega}$ with the following matrix representation:

$$\Omega = \begin{bmatrix} \Omega_{\eta\eta} & 0 \\ 0 & \Omega_{\varepsilon\varepsilon} \end{bmatrix} \quad \textbf{(19)}$$

Finally, the DSUR estimator with a known covariance matrix $\Omega_{\eta\eta}$ can be formulated as follows:

$$\begin{bmatrix} \beta_{dsur} \\ \phi_{dsur} \end{bmatrix} = \left( \sum_{t=1}^{T} \begin{bmatrix} X_t \\ Z_t \end{bmatrix} \Omega_{\eta\eta}^{-1} \begin{bmatrix} X_t & Z_t \end{bmatrix} \right)^{-1} \cdot \left( \begin{bmatrix} X_t \\ Z_t \end{bmatrix} \Omega_{\eta\eta}^{-1} Y_t \right) \qquad \textbf{(20)}$$

In Equation (20), all variables are defined as before. The null hypothesis to test for detecting panel cointegration requires an equality of the $\beta$ coefficients across equations:

$$Ho : \beta_1 = ........= \beta_N$$

In their study, Mark et al. compare the performances of DSUR, SSE, System DOLS and DOLS estimators in an environment where the cointegrating vector exhibits heterogeneity across equations. They are able to show that DSUR exhibits moderate to strong efficiency advantages compared to the other estimators. The relative efficiency of DSUR is proven to increase for larger values of N (number of cross-sectional equations) and T (number of time periods).

The advantage of the DSUR methodology over DOLS is also mentioned in a recent study by J. Kim (2007). In this study, real exchange rates and real interest rate differentials are examined within the DSUR framework. DSUR provides more precise estimates compared to DOLS by incorporating the long run cross sectional correlation in the equilibrium errors. DOLS method only includes leads and lags of the first difference regressors from the own equation but not from cross equations. The DSUR method corrects the endogeneity in equation i by incorporating leads and lags of not only the first difference of the regressors of equation i but also regressors of all other equations in the system.

Mark et al. state that Equations (11) and (12) exhibit an endogeneity problem in the regression estimates. In order to control for the endogeneity among the variables, Mark et al. suggest that both lead and lag values of the independent variable should be included in the regressions. However, there is no standard method for the choice of the number of leads and lags ( $p_{ij}^{+}$ and $p_{ij}^{-}$). Mark et al. state that generally an ad hoc rule is used to determine the proper $p_{ij}^{+}$ and $p_{ij}^{-}$ in empirical studies. According to this rule, $p$ is set based on the number of time series observations such that $p = 1$ for $T = 50$; $p = 2$ for $T = 100$; $p = 3$ for $T = 300$. The same rule is adopted in this thesis and three leads and three lags are used for the DSUR estimations.

### 3.4 Summary

The methodologies described in this chapter all have the purpose of examining the effect of interest rate differences on the behavior of exchange rates. The sample consists of six countries: Turkey and the G-5 countries of United States, United Kingdom, Japan, France and Germany.

For interest rate data, Treasury bill interest rates are collected since it is assumed that Treasury bills are risk free investment vehicles and investors view Treasury bills of different countries as perfect substitutes of each other.

In this chapter, a four-step methodology is constructed to test whether the interest rate differentials are unbiased predictors of the future changes in exchange rates. These four steps and their purposes can be summarized as follows:

1) ADF and KPSS unit root tests are applied to exchange rate and interest rate differentials to determine whether the data exhibit non-stationarity.
2) Johansen cointegration test is applied to those series that are shown to be non-stationary. Cointegration tests are performed to test whether residuals

of linearly combined exchange rates and interest rate differentials are stationary over time. Stationary residuals are an indication of the existence of a long run relationship between exchange and interest rate differentials.

3) Individually modeled regressions are tested together to analyze cross-sectional dependencies. Panel data for exchange and interest rate differentials are examined for the existence of a panel unit root. If evidence of a panel unit root is found, then a panel cointegration test is performed in order to utilize the additional information that is assumed to be contained in the panel data.
4) As a last step, individually modeled regressions are estimated as a system by applying the Dynamic SUR method proposed by Mark et al. (2005). Three leads and three lags of the independent variable are used in each equation within the system. ,

The four-step procedure described above is applied to monthly interest and exchange rate value over three sub periods: (1) January, 1985 to December, 2007 for USA, Japan and UK; (2) January, 1985 December, 1998 for Germany, France, USA, Japan and UK; and, (3) January, 1999 to December, 2007 for Germany, France, USA, Japan, UK and Turkey.

The next chapter presents the results of the analysis.

# CHAPTER 4

# RESULTS AND ANALYSIS

## 4.1 Introduction

In this chapter, output obtained from E-Views™ for the different stages of the analysis is examined and the following subsections are presented in line with these steps: Results of unit root tests for interest rate differentials and exchange rate changes and the results of cointegration tests are presented in Sections 4.2 and 4.3, respectively. Section 4.4 presents the results obtained from panel unit root tests. Finally, in Section 4.5, DSUR results are presented and analyzed.

## 4.2 Unit Root Test Results

Unit root tests results are important since the presence of a unit root is necessary in order to continue with the cointegration tests. The following tables present the results of unit root tests of exchange rate and interest rate differentials. Tables are organized in accordance with the sample periods.

**Table 4.2.1 - Unit Root Test Statistics for the 1985-2007 Period**

| | Calculated Test Statistics | | | |
|---|---|---|---|---|
| | Exchange Rate Differentials | | Interest Rate Differentials | |
| | ADF Test (3) | KPSS Test (3) | ADF Test (3) | KPSS Test (3) |
| **Country Pair:** | | | | |
| **Japan-USA** | -7.8388[‡] | 0.3761 | -1.8866 | 1.4116 |
| **UK-Japan** | -7.6641[‡] | 0.2171[†] | -2.6441 | 0.9768 |
| **USA-UK** | -8.2694[‡] | 0.1360[†] | -2.2225 | 3.0587 |
| **Critical Values:** | | | | |
| **1%** | -3.9922 | 0.739 | -3.9921 | 0.739 |
| **5%** | -3.4264 | 0.463 | -3.4264 | 0.463 |
| **10%** | -3.1364 | 0.347 | -3.1364 | 0.347 |

**Table 4.2.2- Unit Root Test Statistics for the 1985-1998 Period**

| | Calculated Test Statistics | | | |
|---|---|---|---|---|
| | Exchange Rate Differentials | | Interest Rate Differentials | |
| | ADF Test (3) | KPSS Test (3) | ADF Test (3) | KPSS Test (3) |
| **Country Pair:** | | | | |
| **France-Germany** | -6.8828[‡] | 0.4182 | -3.4574 | 3.4223 |
| **France-USA** | -6.2940[‡] | 0.3575 | -1.3605 | 1.1784 |
| **Germany-USA** | -6.4851[‡] | 0.4608 | -0.8899 | 0.9922 |
| **Japan-Germany** | -5.4960[‡] | 0.0448[†] | -2.2735 | 3.2195 |
| **UK-France** | -5.6597[‡] | 0.1050[†] | -1.5514 | 0.5376 |
| **UK-Germany** | -5.7370[‡] | 0.1690[†] | -0.9748 | 2.3190 |
| **Critical Values:** | | | | |
| **1%** | -4.0153 | 0.739 | -4.0149 | 0.739 |
| **5%** | -3.4376 | 0.463 | 3.4374 | 0.463 |
| **10%** | -3.1430 | 0.347 | 3.1429 | 0.347 |

**Table 4.2.3(A) - Unit Root Test Statistics for the 1999-2007 Period**

| | Calculated Test Statistics | |
|---|---|---|
| | Exchange Rate Differentials | |
| | ADF Test (3) | KPSS Test (3) |
| **Currency:** | | |
| **Euro-Turkey** | -5.4834‡ | 0.5407 |
| **Euro-USA** | -5.7050‡ | 0.3969 |
| **Euro-UK** | -6.1231‡ | 0.2210† |
| **Euro-Japan** | -5.5369‡ | 0.3862 |
| **Turkey-Japan** | -5.8154‡ | 0.7939 |
| **Turkey-UK** | -5.1146‡ | 0.6825 |
| **Turkey-USA** | -4.9407‡ | 0.9071 |
| **Critical Values:** | | |
| **1%** | -4.0495 | 0.739 |
| **5%** | -3.4540 | 0.463 |
| **10%** | -3.1526 | 0.347 |
| | **Interest Rate Differentials** | |
| | **ADF Test (3)** | **KPSS Test (3)** |
| **Country pair:** | | |
| **Turkey-France** | -3.1715 | 1.9146 |
| **Turkey-Germany** | -3.1636 | 1.9085 |
| **USA-France** | -1.8814 | 0.5221 |
| **USA-Germany** | -1.5757 | 0.5159 |
| **UK-France** | -1.8823 | 0.4966 |
| **UK-Germany** | -2.0746 | 0.4196 |
| **Japan-Germany** | -1.7856 | 0.8297 |
| **Japan-France** | NA | NA |
| **Turkey-Japan** | -3.1118 | 1.9201 |
| **Turkey-UK** | -3.1263 | 1.9096 |
| **Turkey-USA** | -3.1416 | 1.9038 |
| **Critical Values:** | | |
| **1%** | -4.0486 | 0.739 |
| **5%** | -3.4536 | 0.463 |
| **10%** | -3.1524 | 0.347 |

**Table 4.2.3(B) - Unit Root Test Statistics for the 1999-2007 Period**

| | Calculated Test Statistics | | | |
|---|---|---|---|---|
| | Exchange Rate Differentials | | Interest Rate Differentials | |
| | ADF Test (3) | KPSS Test (3) | ADF Test (3) | KPSS Test (3) |
| **Country Pair:** | | | | |
| **Euro (LIBOR)-Turkey** | -5.4834‡ | 0.5408 | -3.1733 | 1.9153 |
| **Euro (LIBOR)-USA** | -5.7050‡ | 0.3969 | -1.7909 | 0.4845 |
| **Euro (LIBOR)-UK** | -6.1231‡ | 0.2210† | -1.7864 | 0.4179 |
| **Euro (LIBOR)-JP** | -5.5370‡ | 0.3863 | -1.9137 | 0.7373 |
| **Turkey-UK** | -5.1147‡ | 0.6826 | -3.1264 | 1.9096 |
| **Turkey-USA** | -4.9408‡ | 0.9072 | -3.1416 | 1.9038 |
| **Turkey-JP** | -5.8155‡ | 0.7940 | -3.1118 | 1.9201 |
| **Critical Values:** | | | | |
| **1%** | -4.0495 | 0.739 | -4.0486 | 0.739 |
| **5%** | -3.4540 | 0.463 | -3.4536 | 0.463 |
| **10%** | -3.1526 | 0.347 | -3.1524 | 0.347 |

ADF Test (p) and KPSS Test (p) denote the number of lags. The ADF is calculated with trend and intercept. The MacKinnon (1996) critical values for ADF and asymptotic critical values of KPSS at 10%, 5% and 1% significance levels are provided in the bottom three rows of the tables. NA notes that the Japan-France exchange rate could not be found Superscript ‡ denotes rejection of the null hypothesis at all significance levels for the ADF Test and † denotes failure to reject null hypothesis for the KPSS Test.

Tables 4.2.1, 4.2.2 and 4.2.3 report the test results for the presence of a unit root for the three sub periods. For the 1999-2007 period, Table 4.2.3(A) presents the results obtained with the German and French interest rates while Table 4.2.3(B) presents the results with the 3-month Euro LIBOR. Numbers presented in tables are the calculated test statistics and critical values are provided at the bottom of each table. As explained detail in the methodology chapter, two test statistics are presented for each time series: the ADF statistics which tests the unit root null and the KPSS statistics which tests the null of trend stationary. As a result of this difference in the way the null hypotheses are formed in each test, the ADF null hypothesis should be failed to be rejected and the KPSS null should be rejected in order to verify the presence of a unit root in the series.

In the tables, the calculated test statistics for interest rate differentials are smaller than the critical values for the ADF tests, and, therefore, the results verify the unit root for interest rate differentials for all country pairs in all sub-periods. Similarly, the calculated test statistics are greater than the critical values for the KPSS tests, and, therefore, these results also confirm the existence of a unit root.

Unit root test results for exchange rate differentials are more diverse than those for interest rate differentials. ADF and KPSS tests results are inconsistent with each other in that ADF calculated test statistics are larger than the critical values for ADF tests. Therefore, unit root of exchange rate differentials cannot be verified with ADF test in all periods.

When the KPSS test results are analyzed, it is seen that calculated test statistics for exchange rates of Euro-UK during the 1999-2007 period, Japan-Germany, UK-France, UK-Germany exchange rates during the 1985-1998 period, and the UK-Japan and USA-UK exchange rates during the 1985-2007 period are smaller than the critical values. These results indicate that the null hypothesis of stationarity cannot be rejected for these currencies, which further implies the rejection of a unit root in these particular exchange rate series. Since both the ADF and KPSS tests fail to verify unit root in the exchange rate differentials for these currencies these country pairs are not tested further in the cointegration framework. Figure 4.2.1 presents those country pairs that are tested for cointegration in each of the sub periods. The next section presents the cointegration results.

<table>
<tr><th>1985-2007</th><th>1985-1998</th><th>1999-2007 (A)</th><th>1999-2007 (B)</th></tr>
<tr><td>USA-Japan</td><td>France-Germany</td><td>Turkey-Japan</td><td>Turkey-Japan</td></tr>
<tr><td></td><td>Germany-USA</td><td>Turkey-USA</td><td>Turkey-USA</td></tr>
<tr><td></td><td>France-USA</td><td>Turkey-UK</td><td>Turkey-UK</td></tr>
<tr><td></td><td></td><td>France-Turkey</td><td rowspan="2">LIBOR-Turkey</td></tr>
<tr><td></td><td></td><td>Germany-Turkey</td></tr>
<tr><td></td><td></td><td>Germany-Japan</td><td>LIBOR-Japan</td></tr>
<tr><td></td><td></td><td>France-USA</td><td rowspan="2">LIBOR-USA</td></tr>
<tr><td></td><td></td><td>Germany-USA</td></tr>
</table>

**Figure 4.2.1 – Co-integration Country Pairs**

### 4.3 Johansen Co-integration Results

**Table 4.3.1- Pairwise Co-integration Results 1985-2007**

| Analyzed Pair | Number of Cointegrating Vectors | Trace Statistic | Max-Eigen Statistic |
|---|---|---|---|
| Japan-USA | None * | 59.5785 | 56.1439 |
| | At most 1 | 3.4346 | 3.4346 |

**Table 4.3.2- Pairwise Co-integration Results 1985-1998**

| Analyzed Pair | Number of Cointegrating Vectors | Trace Statistic | Max-Eigen Statistic |
|---|---|---|---|
| France-Germany | None * | 39.7843 | 37.5437 |
| | At most 1 | 2.2406 | 2.2406 |
| France-USA | None * | 26.5337 | 25.2389 |
| | At most 1 | 1.2948 | 1.2948 |
| Germany-USA | None * | 26.533 | 25.2389 |
| | At most 1 | 1.2948 | 1.2948 |

**Table 4.3.3(A)- Pairwise Co-integration Results 1999-2007**

| Analyzed Pair | Number of Cointegrating Vectors | Trace Statistic | Max-Eigen Statistic |
|---|---|---|---|
| Turkey-France | None * | 376.959 | 318.651 |
| | At most 1** | 58.307 | 58.307 |
| Turkey-Germany | None * | 376.992 | 318.836 |
| | At most 1** | 58.155 | 58.155 |
| France-USA | None * | 391.398 | 340.325 |
| | At most 1** | 51.072 | 51.072 |

**Table 4.3.3(A)- Pairwise Co-integration Results 1999-2007 (continued)**

| Analyzed Pair | Number of Cointegrating Vectors | Trace Statistic | Max-Eigen Statistic |
|---|---|---|---|
| Germany-USA | None * | 373.149 | 339.312 |
| | At most 1 | 33.837 | 33.837 |
| Japan-Germany | None * | 258.249 | 233.868 |
| | At most 1 | 24.381 | 24.381 |
| Turkey-Japan | None * | 362.994 | 306.262 |
| | At most 1** | 56.731 | 56.731 |
| Turkey-UK | None * | 344.407 | 287.459 |
| | At most 1** | 56.947 | 56.947 |
| Turkey-USA | None * | 299.335 | 24.228 |
| | At most 1** | 57.055 | 57.055 |

**Table 4.3.3(B)- Pairwise Co-integration Results 1999-2007**

| Analyzed Pair | Number of Cointegrating Vectors | Trace Statistic | Max-Eigen Statistic |
|---|---|---|---|
| Euro(LIBOR)-Turkey | None * | 37.6679 | 31.8669 |
| | At most 1** | 5.8010 | 5.8010 |
| Euro(LIBOR)-USA | None * | 37.5547 | 34.2996 |
| | At most 1 | 3.2552 | 3.2552 |
| Euro(LIBOR)-Japan | None * | 21.2937 | 18.6229 |
| | At most 1 | 2.6709 | 2.6709 |
| Turkey-Japan | None * | 36.2994 | 30.6263 |
| | At most 1** | 5.6731 | 5.6731 |
| Turkey-UK | None * | 34.4407 | 28.7460 |
| | At most 1** | 5.6947 | 5.6947 |
| Turkey-USA | None * | 29.9335 | 24.2280 |
| | At most 1** | 5.7055 | 5.7055 |
| Critical Values | None | 15.4947 | 14.2646 |
| 5% | At most 1 | 3.8414 | 3.8414 |

Both Trace and Max-Eigen Statistics are presented to test the null hypotheses of "no cointegrating vectors (Ho: r = 0)" and "at most one cointegrating vector (Ho: r =1)." Critical values at 5% significance level are provided at the bottom of table 4.3.3(B) which are consistently the same for all periods. * denotes rejection of the null hypothesis of r =0 at the 0.05 significance level. ** denotes rejection of r =1 at 0.05 significance level.

Tables 4.3.1, 4.3.2, 4.3.3(A) and 4.3.3(B) report the summary of Johansen cointegration test results. Trace and Max-Eigen statistics for the null hypotheses of no cointegration (r = 0) are greater than the critical values for all of the country pairs in all sub periods. Therefore, the null hypothesis of no cointegration is strongly rejected. These results confirm the presence of at least one cointegrating vector for the analyzed country pairs. The evidence is summarized in Figure 4.3.1.

| | **One Cointegrating Vector** | **Two Cointegrating Vectors** |
|---|---|---|
| **Period: 1985-2007** | | |
| Japan-USA | **X** | |
| **Period: 1985-1998** | | |
| France-Germany | **X** | |
| France-USA | **X** | |
| Germany-USA | **X** | |
| **Period (A): 1999-2007** | | |
| Turkey-France | | **X** |
| Turkey-Germany | | **X** |
| France-USA | | **X** |
| Germany-USA | **X** | |
| Japan-Germany | **X** | |
| Turkey-Japan | | **X** |
| Turkey-UK | | **X** |
| Turkey-USA | | **X** |
| **Period (B): 1999-2007** | | |
| EURO-Turkey | | **X** |
| EURO-USA | **X** | |
| EURO-Japan | **X** | |
| Turkey-Japan | | **X** |
| Turkey-UK | | **X** |
| Turkey-USA | | **X** |

**Figure 4.3.1- Summary of Co-integration Test Results**

For all of the analyzed country pairs, at least one co-integrating vector is found. Presence of at least one co-integrating vector indicates that the residuals of linearly combined exchange rate and interest rate differentials are stationary over time. These results support the IFE theory which asserts that exchange rate movements and interest rate differentials drift together in long run.

The following section presents the panel unit root test results.

### 4.4 Panel Unit Root Results

**Table 4.4.1- Panel Unit Root Results 1985-2007** [6]

| | Exchange Rate Differentials | Interest Rate Differentials |
|---|---|---|
| **Method:** | | |
| **Levin, Lin & Chu (LLC)** | -9.5587 (0.0000) | 0.4201 (0.6628)* |
| **Breitung t-stat** | -3.3879 (0.0000) | -1.6649 (0.0480) |
| **Im, Pesaran and Shin (IPS)** | -12.6329 (0.0000) | 0.2040 (0.4192)* |
| **ADF - Fisher Chi-square** | 138.7770 (0.0000) | 5.0105 (0.5425)* |
| **PP - Fisher Chi-square** | 401.0370 (0.0000) | 6.2579 (0.3949)* |

**Table 4.4.2- Panel Unit Root Results 1985-1998** [7]

| | Exchange Rate Differentials | Interest Rate Differentials |
|---|---|---|
| **Method:** | | |
| **Levin, Lin & Chu (LLC)** | -10.4372 (0.0000) | 0.9660 (0.8330)* |
| **Breitung t-stat** | -4.7366 (0.0000) | -0.6021 (0.2735)* |
| **Im, Pesaran and Shin (IPS)** | -12.1905 (0.0000) | 1.2601 (0.8962)* |
| **ADF - Fisher Chi-square** | 152.449 (0.0000) | 8.6282 (0.7343)* |
| **PP - Fisher Chi-square** | 482.761 (0.0000) | 9.0989 (0.6945)* |

[6] Three cross sections are tested within the panel framework for both exchange and interest rate differentials: Japan-USA, UK-Japan and USA-UK.

[7] Six cross sections are tested within the panel framework for both exchange rate and interest rate differentials: France-Germany, France-USA, Germany-USA, Japan-Germany, UK-France and UK-Germany.

**Table 4.4.3(A)-Panel Unit Root Results 1999-2007**[8]

| Method: | Exchange Rate Differentials | Interest Rate Differentials |
|---|---|---|
| **Levin, Lin & Chu (LLC)** | -13.3976 (0.0000) | -1.2095 (0.1132)* |
| **Breitung t-stat** | -5.6382 (0.0000) | -1.6948 (0.0451) |
| **Im, Pesaran and Shin (IPS)** | -11.2895 (0.0000) | -1.3339 (0.0911)* |
| **ADF - Fisher Chi-square** | 136.617 (0.0000) | 26.8465 (0.1396)* |
| **PP - Fisher Chi-square** | 336.536 (0.0000) | 124.466 (0.0000) |

**Table 4.4.3(B)-Panel Unit Root Results 1999-2007**[9]

| Method: | Exchange Rate Differentials | Interest Rate Differentials |
|---|---|---|
| **Levin, Lin & Chu (LLC)** | -13.3976 (0.0000) | -0.9845 (0.1624)* |
| **Breitung t-stat** | -5.6382 (0.0000) | -1.3727 (0.0849)* |
| **Im, Pesaran and Shin (IPS)** | -11.2895 (0.0000) | -1.4046 (0.0801)* |
| **ADF - Fisher Chi-square** | 136.617 (0.0000) | 20.4789 (0.1158)* |
| **PP - Fisher Chi-square** | 336.536 (0.0000) | 97.5005 (0.0000) |

Statistics are estimated with both intercept and trend. Numbers in parentheses are the calculated p-values. The null hypothesis for the LLC and Breitung tests is a unit root with a common unit root process. The null hypothesis for the IPS, ADF and PP tests is a unit root with individual unit root process. The specified number of lags is determined in the same manner as the univariate ADF tests. The probabilities for the Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. * denotes that the null of panel unit root is failed to be rejected at the 5% significance level.

[8] For exchange rate differentials, seven cross sections are tested within the panel framework: Euro-USD, Yen-Euro; TL-Euro, Sterling-Euro, TL-Japan, TL-Sterling, TL-USD. For interest rate differentials, ten cross sections are tested within the panel framework: France-USA, Germany-USA, Japan-Germany, Turkey-France, Turkey-Germany, UK-France, UK-Germany, Turkey-Japan, Turkey-UK and Turkey-USA.

[9] Seven cross sections are tested within the panel framework for exchange rate differentials: Euro-USD, Yen-Euro, TL-Euro, Sterling-Euro, TL-Yen, TL-Sterling, TL-USD. Also, seven cross sections are tested within the panel framework for the interest rate differentials: LIBOR-USA, LIBOR-Japan, LIBOR-Turkey, LIBOR- UK, Turkey-Japan, Turkey-UK and Turkey-USA.

Tables 4.4.1, 4.4.2, 4.4.3(A) and 4.4.3(B) report the estimation results for panel unit root with five different estimation methods. According to the calculated p-values, the null of panel unit root is rejected for exchange rate differentials at the 5% significance level. Panel data do not support the existence of a unit root in the cross section of exchange rate differentials. For interest rate differentials, test results with an asterisk support the presence of panel unit root at the 5% significance level. Calculated p-values, which are greater than 0.05, provide evidence that there is cross-sectional independence for interest rate differentials between all the country pairs in the sample.

Since the panel unit root cannot be confirmed for exchange rate differentials, it is not possible to continue the analysis of panel cointegration. Therefore, the next step in the analysis is estimating the IFE relationship within the DSUR framework. Section 4.5 presents these results.

### 4.5 DSUR Results

In this section, results obtained from the system estimation of panel data are presented. Country pairs which are presented in Figure 4.5.1 are analyzed within the panel framework by using the Dynamic Seemingly Unrelated Regressions (DSUR) method.

| **Table:** | **4.5.1** | **4.5.2** | **4.5.3(A)** | **4.5.3(B)** |
|---|---|---|---|---|
| **Period:** | **1985-2007** | **1985-1998** | **1999-2007** | **1999-2007** |
| **Equations in Panel System** | JP-USA<br>UK-JP<br>USA-UK | FR-GER<br>FR-USA<br>GER-USA<br>JP-GER<br>UK-FR<br>UK-GER | FR-USA<br>GER-USA<br>FR-TR<br>GER-TR<br>JP-GER<br>GER-UK<br>FR-UK<br>TR-JP<br>TR-UK<br>TR-USA | EURO-USA<br>EURO-JP<br>EURO-TR<br>EURO-UK<br>TR-JP<br>TR-UK<br>TR-USA |

**Figure 4.5.1- Country Pairs of DSUR Analysis**

Tables 4.5.1, 4.5.2, 4.5.3(A) and 4.5.3(B) present the results for β coefficient estimates and the corresponding p-values. As previously explained in the methodology chapter, three leads and lags are included in each of the equations in the system for all three sub periods under analysis.

**Table - 4.5.1 – DSUR Results for 1985-2007**

| **1985-2007** | | | | | |
|---|---|---|---|---|---|
| **β Coefficient** | **Estimated Coefficient** | **P-value** | **β Coefficient** | **Estimated Coefficient** | **P-value** |
| **Constant**** | **(0.006356)** | **0.0220** | Constant | (0.008080) | 0.0847 |
| JPUS | 0.004978 | 0.3555 | UKJP | 0.006282 | 0.2134 |
| JPUS (1) | 0.000796 | 0.8820 | UKJP (1) | (0.000110) | 0.9825 |
| JPUS(-1) | 0.004804 | 0.3717 | UKJP(-1) | 0.004198 | 0.4045 |
| JPUS (2) | (0.001330) | 0.8019 | UKJP (2) | (0.001110) | 0.8240 |
| JPUS(-2) | (0.008127) | 0.1275 | UKJP(-2) | (0.008460) | 0.0883 |
| JPUS (3) | 0.000600 | 0.8712 | UKJP (3) | 0.000943 | 0.7847 |
| JPUS(-3) | (0.000353) | 0.9244 | UKJP(-3) | (0.000360) | 0.9174 |
| | | | | | |
| Constant | (0.001410) | 0.5898 | | | |
| USUK | 0.004737 | 0.3470 | | | |
| USUK (1) | 0.000537 | 0.9148 | | | |
| USUK(-1) | 0.006407 | 0.2023 | | | |
| USUK (2) | (0.002080) | 0.6745 | | | |
| **USUK(-2)**** | **(0.010080)** | **0.0427** | | | |
| USUK (3) | 0.001376 | 0.6875 | | | |
| USUK(-3) | 0.000387 | 0.9105 | | | |

**Table - 4.5.2 - DSUR Results for 1985-1998**

| 1985-1998 | | | | | |
|---|---|---|---|---|---|
| **β Coefficient** | **Estimated Coefficient** | **P-value** | **B Coefficient** | **Estimated Coefficient** | **P-value** |
| Constant | 0.000088 | 0.9058 | Constant | (0.003362) | 0.1984 |
| **FFGE**** | **0.003365** | **0.0393** | FFUS | 0.005845 | 0.1078 |
| **FFGE (1)**** | **(0.003839)** | **0.0189** | FFUS (1) | (0.003343) | 0.3583 |
| FFGE(-1) | (0.000492) | 0.7629 | FFUS(-1) | (0.002514) | 0.4871 |
| FFGE (2) | 0.000916 | 0.5707 | FFUS (2) | 0.000131 | 0.9708 |
| FFGE(-2) | 0.002944 | 0.0675 | FFUS(-2) | 0.002746 | 0.4405 |
| FFGE (3) | (0.000479) | 0.6452 | FFUS (3) | (0.000201) | 0.9295 |
| **FFGE(-3)**** | **(0.002706)** | **0.0090** | FFUS(-3) | (0.002725) | 0.2302 |
| | | | | | |
| Constant | 0.002396 | 0.4385 | Constant | (0.001384) | 0.4611 |
| JPGE | 0.001482 | 0.8716 | UKFF | 0.003168 | 0.1464 |
| JPGE (1) | 0.008096 | 0.3765 | UKFF (1) | (0.002055) | 0.3467 |
| JPGE(-1) | (0.005268) | 0.5642 | UKFF(-1) | 0.000055 | 0.9796 |
| JPGE (2) | 0.009545 | 0.2971 | UKFF (2) | (0.001064) | 0.6235 |
| JPGE(-2) | (0.005222) | 0.5691 | UKFF(-2) | 0.001562 | 0.4652 |
| JPGE (3) | (0.007985) | 0.2109 | UKFF (3) | 0.000690 | 0.6210 |
| JPGE(-3) | 0.000589 | 0.9262 | UKFF(-3) | (0.002250) | 0.1047 |
| | | | | | |
| Constant | (0.003700) | 0.1360 | Constant | (0.001410) | 0.5380 |
| GEUS | 0.005396 | 0.2443 | UKGE | 0.003390 | 0.1797 |
| GEUS (1) | (0.004060) | 0.3801 | UKGE (1) | (0.002720) | 0.2848 |
| GEUS(-1) | (0.000970) | 0.8350 | UKGE(-1) | 0.000269 | 0.9149 |
| GEUS (2) | 0.002004 | 0.6643 | UKGE (2) | (0.000910) | 0.7176 |
| GEUS(-2) | 0.001505 | 0.7430 | UKGE(-2) | 0.001579 | 0.5224 |
| GEUS (3) | (0.001380) | 0.6555 | UKGE (3) | 0.000640 | 0.7049 |
| GEUS(-3) | (0.002700) | 0.3739 | UKGE(-3) | (0.002350) | 0.1525 |

**Table - 4.5.3(A) - DSUR Results for 1999-2007**

| 1999-2007(A) | | | | | |
|---|---|---|---|---|---|
| **β Coefficient** | **Estimated Coefficient** | **P-value** | **β Coefficient** | **Estimated Coefficient** | **P-value** |
| Constant | (0.002797) | 0.2527 | Constant | (0.002964) | 0.2198 |
| FFUS | (0.004487) | 0.4800 | GEUS | (0.007689) | 0.1167 |
| FFUS (1) | (0.002272) | 0.7078 | GEUS (1) | (0.001712) | 0.7278 |
| FFUS(-1) | 0.003272 | 0.6050 | GEUS(-1) | 0.006666 | 0.1729 |
| FFUS (2) | 0.002889 | 0.6194 | GEUS (2) | 0.003213 | 0.4945 |
| FFUS(-2) | (0.001320) | 0.8381 | GEUS(-2) | (0.000021) | 0.9965 |
| FFUS (3) | (0.000104) | 0.9811 | GEUS (3) | (0.000232) | 0.9494 |
| FFUS(-3) | 0.002379 | 0.6205 | GEUS(-3) | 0.000397 | 0.9165 |
| | | | | | |
| Constant | 0.003217 | 0.6160 | Constant | 0.004564 | 0.4373 |
| JPGE | (0.003075) | 0.7509 | **TRFF**** | **(0.000688)** | **0.0000** |
| JPGE (1) | 0.003767 | 0.6999 | TRFF (1) | (0.000018) | 0.9088 |
| JPGE(-1) | (0.002375) | 0.8091 | TRFF(-1) | 0.000114 | 0.4875 |
| JPGE (2) | 0.012985 | 0.1732 | TRFF (2) | 0.000144 | 0.3678 |
| JPGE(-2) | (0.004877) | 0.6213 | TRFF(-2) | 0.000015 | 0.9226 |
| JPGE (3) | (0.008828) | 0.2133 | TRFF (3) | 0.000083 | 0.5481 |
| JPGE(-3) | 0.002659 | 0.7239 | TRFF(-3) | 0.000117 | 0.3997 |
| | | | | | |
| Constant | 0.004582 | 0.4351 | Constant | (0.000024) | 0.9970 |
| **TRGE**** | **(0.000688)** | **0.0000** | **TRJP**** | **(0.000764)** | **0.0000** |
| TRGE (1) | (0.000019) | 0.9077 | TRJP (1) | 0.000030 | 0.8622 |
| TRGE(-1) | 0.000115 | 0.4846 | TRJP(-1) | 0.000164 | 0.3450 |
| TRGE (2) | 0.000145 | 0.3656 | TRJP (2) | 0.000136 | 0.4204 |
| TRGE(-2) | 0.000015 | 0.9223 | TRJP(-2) | 0.000145 | 0.3973 |
| TRGE (3) | 0.000083 | 0.5491 | TRJP (3) | 0.000104 | 0.4843 |
| TRGE(-3) | 0.000117 | 0.3987 | TRJP(-3) | (0.000075) | 0.6083 |
| | | | | | |
| Constant | 0.004504 | 0.4537 | Constant | 0.000050 | 0.9929 |
| **TRUK**** | **(0.000634)** | **0.0003** | **TRUS**** | **(0.000687)** | **0.0001** |
| TRUK (1) | (0.000077) | 0.6472 | TRUS (1) | (0.000014) | 0.9297 |
| TRUK(-1) | 0.000060 | 0.7230 | TRUS(-1) | 0.000106 | 0.5257 |
| TRUK (2) | 0.000154 | 0.3551 | TRUS (2) | 0.000115 | 0.4803 |
| TRUK(-2) | 0.000141 | 0.4031 | TRUS(-2) | 0.000078 | 0.6345 |
| TRUK (3) | 0.000112 | 0.4387 | TRUS (3) | 0.000106 | 0.4594 |
| TRUK(-3) | 0.000013 | 0.9245 | TRUS(-3) | 0.000018 | 0.8945 |

**Table- 4.5.3(A) - DSUR Results for 1999-2007 (continued)**

| 1999-2007(A) | | | | | |
|---|---|---|---|---|---|
| β Coefficient | Estimated Coefficient | P-value | β Coefficient | Estimated Coefficient | P-value |
| Constant | (0.001482) | 0.5660 | Constant | (0.000928) | 0.7650 |
| UKFF | 0.008175 | 0.1362 | UKGE | 0.003324 | 0.3567 |
| UKFF (1) | (0.004027) | 0.4701 | UKGE (1) | (0.000326) | 0.9266 |
| UKFF(-1) | (0.008637) | 0.1041 | UKGE(-1) | (0.003540) | 0.3238 |
| UKFF (2) | (0.001314) | 0.8031 | UKGE (2) | 0.000355 | 0.9174 |
| UKFF(-2) | (0.002498) | 0.6515 | UKGE(-2) | (0.002073) | 0.5831 |
| UKFF (3) | 0.002740 | 0.4976 | UKGE (3) | (0.000054) | 0.9845 |
| UKFF(-3) | 0.006137 | 0.1478 | UKGE(-3) | 0.002576 | 0.3991 |

**Table- 4.5.3(B) - DSUR Results for 1999-2007**

| 1999-2007 (B) | | | | | |
|---|---|---|---|---|---|
| β Coefficient | Estimated Coefficient | P-value | β Coefficient | Estimated Coefficient | P-value |
| Constant | (0.002564) | 0.2942 | Constant | (0.002718) | 0.7153 |
| EUUS | (0.005054) | 0.5326 | JPEU | 0.012173 | 0.5708 |
| EUUS(-1) | 0.005348 | 0.5262 | JPEU(-1) | (0.024561) | 0.2486 |
| EUUS (1) | (0.005694) | 0.4564 | JPEU (1) | 0.005155 | 0.8064 |
| EUUS(-2) | (0.001109) | 0.9018 | JPEU(-2) | 0.018780 | 0.3605 |
| EUUS (2) | 0.003378 | 0.6362 | JPEU (2) | (0.028275) | 0.1544 |
| EUUS(-3) | 0.000981 | 0.8809 | JPEU(-3) | (0.000180) | 0.9886 |
| EUUS (3) | 0.002478 | 0.6238 | JPEU (3) | 0.018608 | 0.1178 |
| | | | | | |
| Constant | (0.009372) | 0.2092 | Constant | (0.013185) | 0.1004 |
| **TREU**** | **(0.001372)** | **0.0000** | **TRJP**** | **(0.001420)** | **0.0000** |
| TREU(-1) | 0.000057 | 0.7971 | TRJP(-1) | 0.000118 | 0.6035 |
| TREU (1) | (0.000122) | 0.5843 | TRJP (1) | (0.000065) | 0.7729 |
| TREU(-2) | (0.000014) | 0.9504 | TRJP(-2) | 0.000126 | 0.5719 |
| TREU (2) | 0.000180 | 0.4167 | TRJP (2) | 0.000186 | 0.4076 |
| **TREU(-3)**** | **0.000402** | **0.0436** | TRJP(-3) | 0.000185 | 0.3611 |
| TREU (3) | 0.000296 | 0.1459 | TRJP (3) | 0.000312 | 0.1324 |

**Table - 4.5.3(B) - DSUR Results for 1999-2007(continued)**

| 1999-2007 (B) | | | | | |
|---|---|---|---|---|---|
| **β Coefficient** | **Estimated Coefficient** | **P-value** | **β Coefficient** | **Estimated Coefficient** | **P-value** |
| Constant | (0.008447) | 0.2604 | Constant | (0.012369) | 0.0847 |
| **TRUK**** | **(0.001317)** | **0.0000** | **TRUS**** | **(0.001329)** | **0.0000** |
| TRUK(-1) | 0.000003 | 0.9879 | TRUS(-1) | 0.000043 | 0.8445 |
| TRUK (1) | (0.000163) | 0.4787 | TRUS (1) | (0.000105) | 0.6312 |
| TRUK(-2) | 0.000118 | 0.6046 | TRUS(-2) | 0.000058 | 0.7904 |
| TRUK (2) | 0.000165 | 0.4698 | TRUS (2) | 0.000141 | 0.5170 |
| TRUK(-3) | 0.000298 | 0.1474 | TRUS(-3) | 0.000301 | 0.1248 |
| TRUK (3) | 0.000337 | 0.1091 | TRUS (3) | 0.000308 | 0.1241 |
| | | | | | |
| Constant | (0.002499) | 0.3935 | | | |
| UKEU | 0.019169 | 0.0521 | | | |
| UKEU(-1) | (0.013783) | 0.1601 | | | |
| UKEU (1) | (0.012112) | 0.2323 | | | |
| UKEU(-2) | (0.003089) | 0.7639 | | | |
| UKEU (2) | (0.005040) | 0.6032 | | | |
| UKEU(-3) | 0.007329 | 0.2850 | | | |
| UKEU (3) | 0.008817 | 0.1828 | | | |

The negative numbers in the variable names denote lags while positive numbers denote leads for the interest rate differentials. Bold results with double asterisks denote significance at the 5% level.

According to the IFE, the interest rate differentials between two countries should be compensated by changes in the exchange rate between the currencies of these countries. Mathematically, the exchange rate changes should be equal in amount but carry the opposite sign as the difference in the interest rates. When results from Tables 4.5.1, 4.5.2, 4.5.3(A) and 4.5.3(B) are analyzed, it is seen that none of the p-values of the estimated coefficients support this mathematical relationship, except for the bold results with double asterisks.

Results for the periods 1985-2007 and 1985-1998 are presented in Tables 4.5.1 and 4.5.2, respectively. Bold estimates should support the presence of an International

Fisher Effect. However, for these two periods, the significant results are sporadic, rather than consistent, and, therefore, cannot be interpreted as supportive evidence of the IFE.

For the period 1985-1998, calculated p-values support the existence of a relationship between exchange rate and interest rate differentials only for the France-Germany pair. The results provide evidence of significance in the one-period lead and the three-period lag of the interest rate differentials. However, when the sign and the magnitude of the significant coefficients are analyzed, it is seen that the effects of these lead/lag values cancel each other out almost perfectly. This outcome supports the previous literature which asserts that close trade partners have influence on each other's financial markets. Also, the results indicate that an over- or under-reaction of the exchange rate change to the interest rate differential is corrected in the market in about four months' time. Still, the exact predictions of the IFE are not observed even in the case of France and Germany. At this point, it is important to remember that European Union member countries adopted a system called the European Exchange Rate Mechanism[10] (ERM) in the early 1980s in order to achieve monetary stability in Europe by reducing exchange rate volatility. This might be one of the reasons behind the rejection of the IFE since the theory is expected to hold for market-determined interest and exchange rates with the assumption of no government intervention.

As previously explained in the methodology chapter, Germany and France adopted Euro as their common currency in 1999. For this reason, the period 1999-2007 is analyzed with two different interest rates. Table 4.5.3(A) presents the results obtained by using the German and French 90-day T-bill interest rates individually. Out of the ten country pairs that are analyzed, significant results are only found

[10] European Exchange Rate Mechanism was a system of pegged exchange rates which allowed individual country currencies to fluctuate in value against other currencies in the system within pre-determined bands. Before the introduction of Euro in 1999, each country's currency was tied to a basket exchange rate ECU (European Unit of Account) which was determined as a weighted average of participating currencies.

with the Turkish data. The tests are repeated by using the Euro LIBOR instead of the individual German and French interest rates and the results, presented in Table 4.5.3(B) are the same. In both cases, positive interest rate differentials in favor of Turkey indicate depreciation of the Turkish lira against the corresponding foreign currency. Direction of the effect supports the IFE; however, the magnitude of the effect is found to be smaller than expected. For the 1999-2007 period, significant results are found only between the Turkish lira and other currencies. It is important to note that while interpreting the results, the macroeconomic characteristics of the period should also be evaluated. For instance, at the end of 1999, as part of the stand-by agreement signed with the IMF, Turkey adopted an exchange rate stabilization program[11]. Although the system collapsed in 2001 and exchange rates were allowed to float free, the monetary authority intervention while the program was in effect might have caused the significant results obtained for the Turkish currency.

[11] The stabilization program was based on a crawling peg exchange rate regime in which the exchange rates were allowed to fluctuate within a pre-determined band. This is a system where the central bank intervenes in the market to keep the rates within the previously announced band.

# CHAPTER 5

# CONCLUSION

The purpose of this study is to analyze the relationship between interest rates and exchange rates. This relationship is rather important because there are lots of international investment opportunities available in financial markets and the return on these investments is the main concern of investors. The International Fisher Effect is a theory that states nominal interest rate differentials (hence, the differential between the returns that can be earned on investments of an equal risk) between countries are related to and are unbiased predictors of future spot exchange rates. If the theory holds, the advantage that arises from interest rate differentials should be cancelled out by exchange rate adjustments. Throughout this thesis, the tendency of adjustments of exchange rate movements to offset the differences in interest rates across selected countries is questioned.

The empirical analyses of the study consist of four main parts. In the first part, time series characteristics of the exchange rate differentials and interest rate differentials are tested with traditional unit root tests. In the second part, variables which are found to be non-stationary as a result of the unit root tests are tested for cointegration within the Johansen framework. The empirical results of this study indicate the presence of at least one cointegration vector for all of the individually modeled equations in all periods. These results imply that exchange rates and interest rates drift together in the long run.[12] In the third part of the study, the

[12] The presence of one or more cointegration vectors does not necessarily mean that interest rate differentials are precise estimators of changes in the exchange rates. However, the presence of cointegration means that when the two series are linearly modeled, estimation errors will cancel out in time.

variables of interest are tested again within the panel framework for the existence of a unit root. Evidence is found for the existence of a panel unit root in the interest rate data. However, none of the test results support the existence of a panel unit root in exchange rates. Failure to find evidence of panel unit root in exchange rates prevents further panel cointegration analysis. Finally, in part four, the individual country IFE equations are estimated as a system within the DSUR framework, an econometric method recently proposed by Mark et al. (2005). Results obtained from the DSUR analysis can be summarized as follows;

- Supportive results are found for the 1999-2007 period for equations which include Turkey. The calculated p-values indicate that, at the 5% significance level, changes in exchange rates can be explained by interest rate differentials. Direction of the effect is found as expected and implies that positive interest rate differentials in favor of Turkey cause depreciation of the Turkish currency against the other currencies in the sample.
- For the period 1985-1998, supportive results are found only between France and Germany. The results provide evidence of significance in the one-period lead and the three-period lag of the interest rate differentials. However, when the sign and the magnitude of the significant coefficients are analyzed, it is seen that the effects of these lead/lag values cancel each other out almost perfectly. This outcome supports the previous literature which asserts that close trade partners have influence on each other's financial markets. Also, the results indicate that an over- or under-reaction of the exchange rate change to the interest rate differential is corrected in the market in about four months' time.

The IFE predicts a one-to-one relationship between exchange rate changes and interest rate differentials. For the above mentioned country pairs, supportive results are found within the DSUR framework. However, a crucial point should be emphasized in that supportive estimation results could not be found for the magnitude of the effect. This means that the exchange rate movements are influenced by other factors in addition to the nominal interest rate differentials.

Another reason for not finding significant results can be attributed to money markets which are not fully internationalized. The theory assumes perfect capital mobility; however, this assumption is not realistic since there are restrictions in world markets that prevent free mobility of capital across borders. Investment decisions of investors are effected by factors such as political risk, currency risk, transaction costs, taxes and psychological barriers. Furthermore, monetary authorities might intervene in financial markets by using monetary tools to achieve their targets. Also, the length of the sample sub periods (the longest being 18 years) may not be sufficient to detect a truly long-term relationship between exchange rate changes and interest rate differentials. This might be another limitation of the current study.

It is interesting to note some implications for further study. In this thesis, interest rate and exchange rate differentials of the G-5 countries and Turkey are analyzed for the period from 1985:1 to 2007:12. In the literature survey, it is observed that when the data set is changed, different results are possible to be obtained. Therefore, further analyses can be performed with alternative country pairs. Additionally, the time period under analysis can be expanded. The longer the time period, the more information is likely to be included in the analysis, and, therefore, new results can be expected. While determining the sample period, attention should be paid to changing exchange rate regimes. Floating or fixed exchange rate regimes which are adopted by monetary authorities would affect the outcome of the empirical tests.

Also, new analyses can be performed by changing the type and frequency of the data. In this thesis, monthly data are used for exchange rates as recorded by central banks and the 90-day T-bill rates are used for interest rates for the G-5 countries and for Turkey, compound interest rates of T-bills traded in the secondary market are used. Alternatively, deposit rates or LIBOR can be used instead of the T-bill rates.

As explained in detail in Chapter 2, the IFE hypothesis is closely related with the theories of Fisher Effect and the Purchasing Power Parity. The building block theories should also be considered and the failure of IFE across the G-5 countries can further be evaluated within this context.

In this thesis, the effect of interest rate differentials on changes in exchange rates is analyzed. However, additional factors, such as accumulated current accounts or log of consumer price indexes of selected countries could be included in the analysis. Not only interest rate differentials but also these other factors may affect the movement of exchange rates. These factors can be evaluated with modified equations in future research.

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