A THRESHOLD MODEL FOR THE EXCHANGE RATE BEHAVIOR OF TURKEY

A Master's Thesis

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To My Wife

A THRESHOLD MODEL FOR THE EXCHANGE RATE BEHAVIOR OF TURKEY

The Institute of Economics and Social Sciences
of
Bilkent University

by

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In Partial Fulfillment of the Requirements for the Degree of
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I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

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ABSTRACT

A THRESHOLD MODEL FOR THE EXCHANGE RATE BEHAVIOR OF TURKEY

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This thesis analyzes the effects of global market conditions and interest rate policy decisions on $/T.L. exchange rate in a nonlinear framework. VIX (Chicago Boards Options Exchange Volatility Index) and unexpected interest rate change are used in the model. It is found that when the exchange rate risk is below a threshold level, exchange rate is sensitive to both unexpected interest rate change and VIX. On the other hand, when the exchange rate risk is high, it becomes insensitive to unexpected interest rate change and significantly more sensitive to VIX.

Keywords: VIX, unexpected interest rate change, nonlinear

ÖZET

TÜRKİYE'DEKİ DÖVİZ KURU DAVRANIŞLARI İÇİN BİR EŞİK DEĞER MODEL

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Bu çalışma, küresel market koşulları ile faiz politikası kararlarının $/T.L. döviz kuru üzerindeki etkilerini inceler. Modelde VIX ve beklenmedik faiz değişimi kullanılmıştır. Sonuç olarak, kur riskinin belli bir eşik değerin altında olduğu zamanlarda kurun hem beklenmedik faiz değişimlerine, hem de VIX'e duyarlı olduğu görülmüştür. Öte yandan, kur riskinin yüksek olduğu zamanlarda, kur beklenmedik faiz değişimlerine duyarsızlaşırken istatistiksel olarak anlamlı biçimde VIX'e daha duyarlı hale gelmiştir.

Anahtar Kelimeler: VIX, beklenmedik faiz değişimi, doğrusal olmayan

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Exchange rate dynamics is one of the most important issues in economics on which there has been a growing literature since there has not been found a satisfactory model so far. In particular, exchange rate movements in Turkey have always been important and open to debate, but why?

At first, Turkey has been implementing inflation targeting since 2006. Due to pass through effect exchange rate movements are so crucial for inflation targeting countries. Especially in Turkey, price levels are highly dependent on exchange rate since %70 of consumable goods is tradable. The importance of exchange rate in inflation targeting countries can also be seen in academic literature. Orr et al. (1998) discuss the role of the exchange rate in New Zealand's inflation targeting program. They state that in small open economies exchange rate changes can have important influence on prices so it plays a central role in monetary policy. Also Mishkin (2000) focuses on the importance of exchange rate in emerging countries that use inflation targeting. It is stated that in emerging countries since debt burdens are highly dollarized, exchange rate depreciations can increase debt burden and deteriorate balance sheets which leads to an increase in the probability of a crisis. Minella et al. (2003) analyze the inflation targeting program in Brazil and point out exchange rate volatility as one of the two main challenges that Central Bank faces in applying the program. Werner et al. (2002) study the relationship between inflation targeting and exchange rate in Brazil, Chile and Mexico and conclude that Central Bank intervenes foreign exchange markets because of pass through effect, financial crisis risk due to dollar-denominated debt and recession risks due to high-dollar liabilities. Additionally Domaç and Mendoza (2004) examine the case of Mexico and Turkey and find that rather than using pure-floating regimes, emerging countries should use foreign exchange interventions under the inflation targeting regime.

Also output dynamics are seriously affected by exchange rate. Exporters follow exchange rate movements closely since they are seriously affected from the exchange rate level and expect Central Bank to adjust interest rates according to the exchange rate level. While Tunçsiper and Öksüzler (2006) state that exchange rate risk is a significant obstacle for exporters, with a slightly different result Öztürk and Acaravcı (2006) say that exchange rate uncertainty has a negative impact on exports in the short run but does not affect the export level in the long run, however the reduction of exchange rate uncertainty will lead to a less volatile export level. Besides, in recent times we can see that export level is not much affected from exchange rate changes possibly due to the fact that the most significant factor in explaining export level is foreign demand. On the other hand, intermediate goods are mostly imported in Turkey and firms' production costs are highly dependent on exchange rate level. Thus, there is another channel that exchange rate changes affect output.

In this study, we will try to explain the exchange rate dynamics in Turkey in rather a financial framework and use VIX (Chicago Boards Options Exchange Volatility Index) and unexpected interest rate changes. A nonlinear threshold model and the estimation procedure of Hansen (2000) is employed. The threshold variable is the standard deviation of exchange rate which is used as a risk indicator for exchange rate market.

The rest of the study is organized as follows. Section 2 goes over the exchange rate theories and the nonlinear models commonly used in the literature. Section 3 describes what VIX is and explains the features of VIX since it is not a very familiar concept. In section 4, we will present the exchange rate dynamics in Turkey. Then the methodology used in this study is discussed in section 5. The data and the model are described in section 6. The results are discussed in section 7 and section 8 presents the concluding remarks and some policy suggestions.

CHAPTER II

LITERATURE REVIEW

2.1 Related exchange rate theories

Although, exchange rate models can be compared based on several criteria, the most prevailing one is out-of sample forecasting after Meese and Rogoff (1983). Meese and Rogoff find out that none of the models in the literature perform better than the naïve random walk model in out of sample forecasting. After this influential paper, most of the exchange rate models in the literature try to beat the random walk model in out of sample forecasting. The models below present the most familiar theories for exchange rate modeling.

2.1.1. Random Walk Model

Random walk model for an exchange rate is simply $S_{t+1} = S_t + u_t$ where S_t is exchange rate at time t and u_t is an error term.

2.1.2. Purchasing Power Parity

The Purchasing Power Parity is one of the most well accepted theories about the exchange rate movements. According to the purchasing power parity theory a certain amount of money should have the same purchasing power in different countries. For example, if one can buy a bread with 1$ in US, then one should be able to buy a bread in Turkey with $1 \times S_t$ TL where S_t is the domestic price of foreign currency. What this theorem is fundamentally based on is the idea that if price of bread is higher than $1 \times S_t$ TL in Turkey, then one can buy bread in US and sell it in Turkey. Likewise, if price of bread is lower than $1 \times S_t$ TL in Turkey, one can buy bread in Turkey and sell it in US so that s/he can realize profits. S/he carries on this trade as there is a gap between prices. Thus amount of quantity supplied and demanded change in both countries which provides equivalent prices and the purchasing power parity is verified. This theory is formally stated as:

$S_t = p_t / p_t^*$ where p_t is the price level in domestic country and p_t^* is the price level in foreign country. If the changes in exchange rate is considered; then it can be stated as:

$$\frac{S_t}{S_{t-1}} = \frac{p_t}{p_{t-1}} \div \frac{p_t^*}{p_{t-1}^*}$$

2.1.3. Uncovered Interest Rate Parity

Uncovered Interest Rate Parity is one of the main concepts while discussing the changes in exchange rates. Uncovered Interest Rate Parity states that the difference between two countries' interest rates should be due to the expected changes in two countries' currencies so that an investor should be indifferent between investing in one country or another. For instance, it is expected that the dollar/euro parity will remain the same in a year from now and investing in dollar makes a return of %2 while investing in euro makes a return of %3 for 1 year. If one has 1 dollar, s/he first exchanges it and buy euro in order to invest in euro. After 1 year s/he can sell euro in hand and get dollar back, which brings 3% return in dollar. Thus it can be stated that investing on dollar does not make any sense. This is formally stated as:

$$(1+i)=\frac{E[S_{t+1}]}{S_t}\times(1+i^*)$$

where i is the interest rate of domestic currency and i^* is the interest rate of foreign currency.

2.1.4. Monetary model

Monetary models are developed in the early 1970's and the earliest types are flexible-price monetary model. Due to poor fit of flexible-price monetary models, the sticky-price monetary model was developed in late 1970's (Dornbush, 1976). The monetary model can be stated as:

$$S_t=\beta_0+\beta_1\times(m_t-m_t^*)+\beta_2\times(y_t-y_t^*)$$
$$+\beta_3\times(i_t-i_t^*)+\beta_4\times(\pi_t-\pi_t^*)+u_t$$

where m is log money, y is log real output, i is the interest rate, π is the inflation rate, u is the error term and the "*" denotes the foreign variables. (Cheung, 2005; Alquist, 2006). In the sticky price version of the model, the coefficients of m and π are positive. An increase in m means an increase in the supply of money which leads to a decrease in its price. So the exchange rate depreciates which means that S_t increases. Additionally, π has a negative coefficient due to purchasing power parity. On the other hand, the coefficients of y and i are positive. An increase in y

increases the demand for the money. So the exchange rate appreciates which means that S_t decreases. Additionally, *i* has a positive coefficient due to uncovered interest rate parity.

2.2. Nonlinear Models

Nonlinear models comprise a remarkable amount of the literature in both real and nominal exchange rate determination. Most of the literature on nonlinear models for real exchange rate determination put emphasis on the fact that the relationship between real exchange rate and fundamentals holds in the long run (Mark 1995). There is a mean reverting process and a nonlinear adjustment of real exchange rate to its equilibrium value. (Sarno, 2003)

Also; when nominal exchange rates are discussed; there is a considerable literature with nonlinear models. One strand in this literature is about fundamentals and focuses on the nonlinear dynamics in nominal exchange rates as a result of nonlinear dynamics in real exchange rates. (Taylor and Peel, 2000; Liew et. al., 2008; Brasili and Sitzia, 2003)

Another part of the literature focuses on autoregressive modeling. In this part, the models are usually divided into two parts, which are threshold models and conditional heteroskedasticity models. The exchange rate data generally shows conditional heteroskedasticity effects in the short run. (Pippenger and Goering, 1998; Boero and Marrocu, 2002; Iovino and Sitzia, 2008). Thus autoregressive conditional heteroskedasticity (ARCH) models are generally used in weekly horizons. (Diebold and Nerlove, 1989; Boero and Marrocu 2002) On the other hand, threshold models are used in various time horizons. The well-known types of threshold models are SETAR and STAR models, which enable us to model symmetric nonlinear behavior of exchange rates. (Liew et al., 2002) Unlike conditional heteroskedasticity models, threshold models can usually be traced back to economic theory. (Pippenger and Goering, 1998) The motivation of using threshold models can be target zones, Central Bank interventions or exchange rate management. Furthermore, in the recent literature, there are mixed type of models, which try to capture both threshold and conditional heteroskedasticity effects in the data. (Iovino and Sitzia 2008; Özdemir and Yiğit, 2009)[1]

Chappel et al. (1996) study the behavior of French Frank/Deutsche Mark exchange rate for 1990-1992 periods with daily data. Since the currencies were allowed to lie in prescribed bands in that period, they use SETAR model and find out that SETAR model is sufficient to explain the changes in data and gives superior forecast to random walk in some forecast horizons.

In a more comprehensive study, Pippenger and Goering (1998) study the behavior of 11 currencies in 1979-1991 periods with monthly data. They use SETAR models with a motivation that CB interventions to exchange rate will cause nonlinearity in data. They find that SETAR model fits the data best and make better in-sample forecasts in all currencies and out of sample forecasts in most currencies than random walk in terms of mean square prediction error.

As an example to a monetary model in nonlinear way, Taylor and Peel (2000) study quarterly data between 1973 and 1996 for dollar-sterling and dollar-mark exchange rates. They find that the nominal exchange rates has a monetary fundamental equilibrium and there is a nonlinear mean reverting process such that the speed of reversion increases as the deviation from the equilibrium gets larger. Additionally, they observe that the best model which fits this process is ESTAR.

[1] There are also Markov chain models used in various types.(Cheung and Erlandsson, 2004; Frömmel et al., 2004)

Since exchange rate models are generally compared according to their forecasting performance, it is important to gauge this. Clements and Smith (2001) attain such a result that the forecasting performance of nonlinear models, whether they are better than a random walk or not, depends on the forecast accuracy criteria.

Boero and Marrocu (2002) make a comparison of various nonlinear models for both weekly and monthly data. In weekly data, both SETAR and GARCH models give significant results whereas in monthly data SETAR components were significant but GARCH components became insignificant except for the yen.

CHAPTER III

VIX AND ITS FEATURES

3.1. VIX: An Indicator For Volatility

VIX is a volatility index which is introduced by CBOE (Chicago Board Options Exchange) in 1993. It expresses the implied 30 day volatility of S&P 500 Index. However, it has become a benchmark as an indicator of the expected 30 day volatility of the US stock market.

It is a volatility index and uses options' prices rather than stock's prices to reflect the expected volatility of the market. The generalized formula used in VIX calculation is: (CBOE, VIX calculation, 2009)

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2$$

where

σ	${}^{VIX}/_{100} \Rightarrow VIX = \sigma \times 100$
T	Time to expiration

F	Forward index level derived from index option prices
K_0	First strike below the forward index level
K_i	Strike price of the i^th out-of-the-money option; a call if $K_i > K_0$ and a put if $K_i < K_0$; both put and call if $K_i = K_0$
ΔK_i	Interval between strike prices − half the difference between the strike on either side of K_i: $$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$$ (Note: ΔK for the lowest strike price is simply the difference between the lowest strike and the next higher strike. Likewise, ΔK for the highest strike is the difference between the highest strike and the next lower strike.)
R	Risk-free interest rate expiration
$Q(K_i)$	The midpoint of the bid-ask spread for each option with strike K_i

VIX uses the options in the first and second S&P 500 contract months to evaluate the 30 day expected volatility. T is the remaining time to expire of contracts in terms of minutes. For each contract, search for the strike price which has the lowest difference between call and put options is done. Then,

F = Strike Price + e^{RT} × (Call Price – Put Price) is calculated. Next, K_0 is discovered. Then put options with strike prices less than K_0 and call options with strike prices more than K_0 which have a nonzero bid price are selected. These are the options that will be used in calculation. For each option, ΔK is the half of the difference between the previous and next options' strike prices. $Q(K_i)$ is simply the price of that option and calculated as stated above. For both contracts calculations are done in the same way. Then, we put weights to each contract according to time of expiration and calculate the VIX as below:

$$VIX = 100 \times \sqrt{\left\{T_1\sigma_1^2\left[\frac{N_{T2} - N_{30}}{N_{T2} - N_{T1}}\right] + T_2\sigma_2^2\left[\frac{N_{30} - N_{T1}}{N_{T2} - N_{T1}}\right]\right\} \times \frac{N_{365}}{N_{30}}}$$

where

N_{T1}= remaining minutes to expiration of near term options

N_{T2}= remaining minutes to expiration of next term options

N_{30}= minutes in 30 days

N_{365}= minutes in 365 days

As the volatility in the market rises, both the price of the options and the number of options those have nonzero bid prices increases which leads to an increase in VIX. Although VIX is introduced in the market in 1993, former VIX levels are computed by using the historical prices of the options back to 1986 in order to see the level of VIX in October 1987 Crash which enable us to make an accurate comparison between the risk levels in the market. In 2003, some of the criteria used in computing VIX are revised, since then VIX stands for the series after the revision while series before the revision is called VXO. Now, VXO is from 1986 to today and VIX is from 1990 to today.

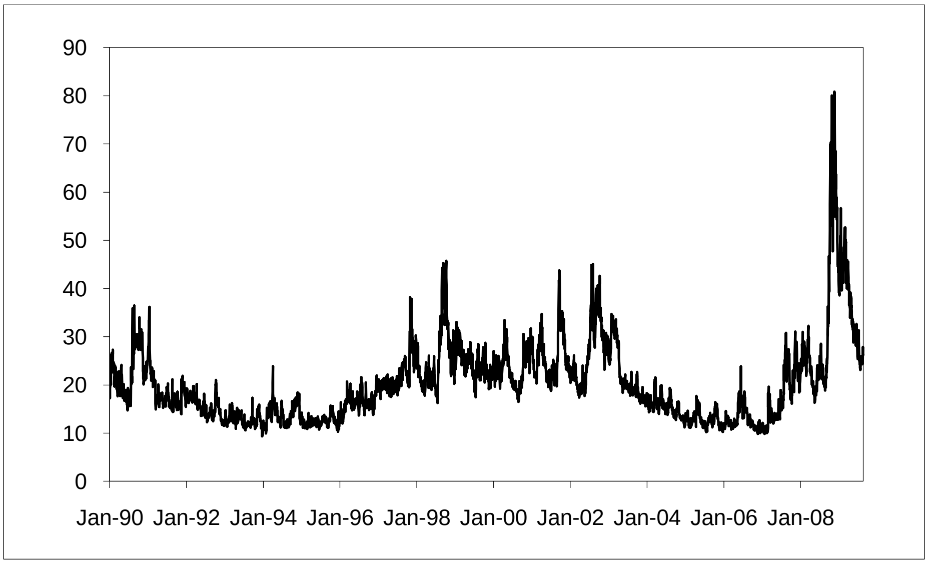

Figure 3.1.1: VIX History

Periods that VIX has higher values are explained below:

August 1990: Invasion of Kuwait by Iraq

January 1991: Attack on Iraq by the United Nations forces

October 1997: Asian crisis

October 1998: Russian Crisis

September 2001: 11 September terrorists attacks

July 2002: Geopolitical tensions and the WorldCom accounting scandal

June 2006: Multi-market sell-off

October 2008: The last global crisis

VIX is called as "investor fear gauge" (Whaley, 2000) and mostly used by hedgers to diversify their portfolios. Moreover, there is an academic literature that using VIX makes a better performance in portfolios which we will examine in the next section.

VIX is an annualized standard deviation and can be read as the following. If VIX is equal to y, then the probability of S&P 500 index to move out of the region $\frac{y \times z_{1-p}}{\sqrt{12}}$ percent is$2 \times p$. For instance, if VIX is equal to 50 then S&P 500 index is expected to move up or down in the range of $\frac{50\times1.96}{\sqrt{12}}$ percent with 95% probability in the following 30 days since $z_{0.975} = 1.96$. Now, we will see the features of VIX in the next chapter.

3.2. Features of VIX

VIX has been increasingly popular and it is closely watched by investors. It is an explanatory variable to understand the behavior of exchange rates or sovereign spreads and also an efficient tool to reduce risk in hedge fund portfolios. In this section, we will summarize these features of VIX.

3.2.1. Spreads

Garcia-Herrero and Ortiz (2005) study the relationship between Latin American sovereign spreads and global risk aversion for which the VIX is accepted as a proxy. They find out that the sovereign spreads are significantly correlated with global risk aversion. In a paper in which the VIX is directly used, Remolona et al. (2007) study the effect of sovereign risk on sovereign spreads. Three variables are evaluated as a proxy for sovereign risk and in all models VIX is included as a control variable. In all three models it is remarked that VIX significantly affects the sovereign spreads. By factor-analysis technique, Ciarlone et al. (2009) study the emerging markets' spreads and try to decompose them to a common factor and country specific factors. It detects that a single common factor is determinant on the spreads and it is VIX. In addition to this, Özatay et al. (2009) point out that EMBI spreads are mostly affected by external factors one of which is VIX.

3.2.2 Hedging

Soon after VIX is introduced by CBOE, Fleming et al. (1995) showed that VIX and stock market returns are inversely related**.** In recent literature**,** Dash and Moran (2005) show the negative correlation between VIX and hedge fund portfolios and suggest a VIX allocation of up to %10 to make an efficient portfolio, which optimizes the risk and the return. On the other hand, Psychoios and Skiadopoulos (2006) express that, in general volatility options are not better hedging instruments than plain vanilla options to hedge standard type of options but this does not curtail the importance of volatility options because it is proved that they are useful in hedging exotic options. However, Black (2006) states that a small VIX allocation substantially increases the Sharpe ratios of portfolios and this may be more effective than any other methods studied in the literature. Furthermore, it is useful to use VIX to eliminate the skewness and kurtosis problems of the portfolios since VIX increases extraordinarily in very risky market conditions, which may increase the skewness and kurtosis of the portfolios. Also Daigler and Rossi (2006) study the correlation between VIX and S&P 500 Index. As expected, they find out that there is a negative correlation between VIX and S&P 500 Index and VIX is an efficient tool to reduce risk of S&P 500 portfolio. More notably, they state that using previous year's optimal allocation of VIX gives almost optimal results for this year's portfolio. Also in the graph below, we can see the correlation between VIX and S&P 500 Index. Generally, there are changes in VIX and S&P 500 Index in opposite sites.

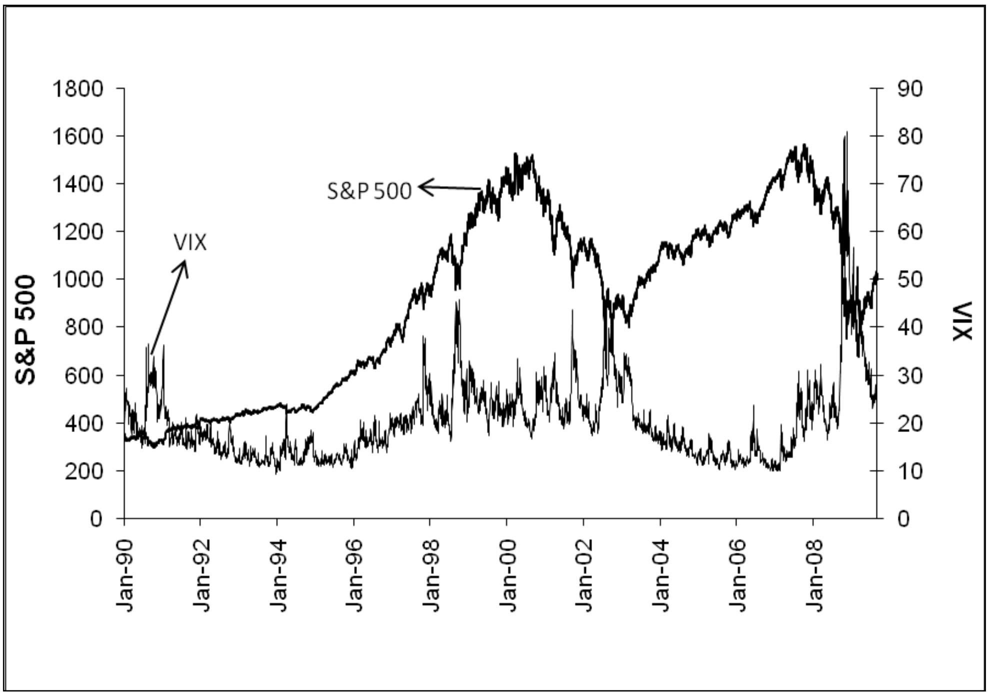

Figure 3.2.2.1: VIX vs. S&P 500 Index

3.2.3. Exchange Rate Markets

Lustig et al. (2009) study currency portfolios for 37 currencies. They find a slope factor in exchange rates and show that it is global risk factor. They come up with a conclusion that when there is high volatility, developed countries' currencies offer insurance for currency portfolios because they appreciate during high volatility periods. Moreover in this paper, the volatility measure is constructed by authors. If this result is evaluated by taking into consideration that VIX is a global volatility index, it can be stated that when VIX is high, developed countries' currencies tend to appreciate since they are seen as safe haven.

Cairns et al. (2007) also study the relationship between VIX and exchange rate. In the first part, they analyze this relationship in August 1998, September 2001, June-July 2002 and May 2006. The chosen periods are the high volatility periods in which VIX has higher values. They examine the correlation between the currency changes and the yields of these currencies for the chosen high volatility periods. It is obtained that relatively high yielding currencies tend to depreciate in times of raised volatility while low yielding currencies appreciated since they are considered as safe havens. In the second part of their study, they make a regression analysis for 34 currencies, some of their forward rates and some composite rates with weekly data in 2000-2006 samples. They find the coefficients of how much a currency changes with respect to a one point change in VIX. In accordance with the first part of the study, they find that low yielding currencies take a negative value, i.e. currency appreciates as VIX increases while higher yielding currencies take a positive value, i.e. currency depreciates as VIX increases. A very attention-grabbing result for our study is that the Turkish Lira has the biggest coefficient among all the other rates. That is to say Turkish Lira has the highest sensitivity among all 42 rates. It has a coefficient of 0,285 which means that it appreciates 0,285 percent when VIX increases one point.

Kalra (2008) uses GARCH models to make a similar analysis for five East Asian countries during 2001-2007 periods and attains such a result that a five percent increase in global volatility leads to a depreciation up to 0,5 percent in selected countries' currencies.

In particular, for Turkey the high correlation between VIX and exchange rate expressed by Cairns et al. (2007) can also be seen in the following graph.

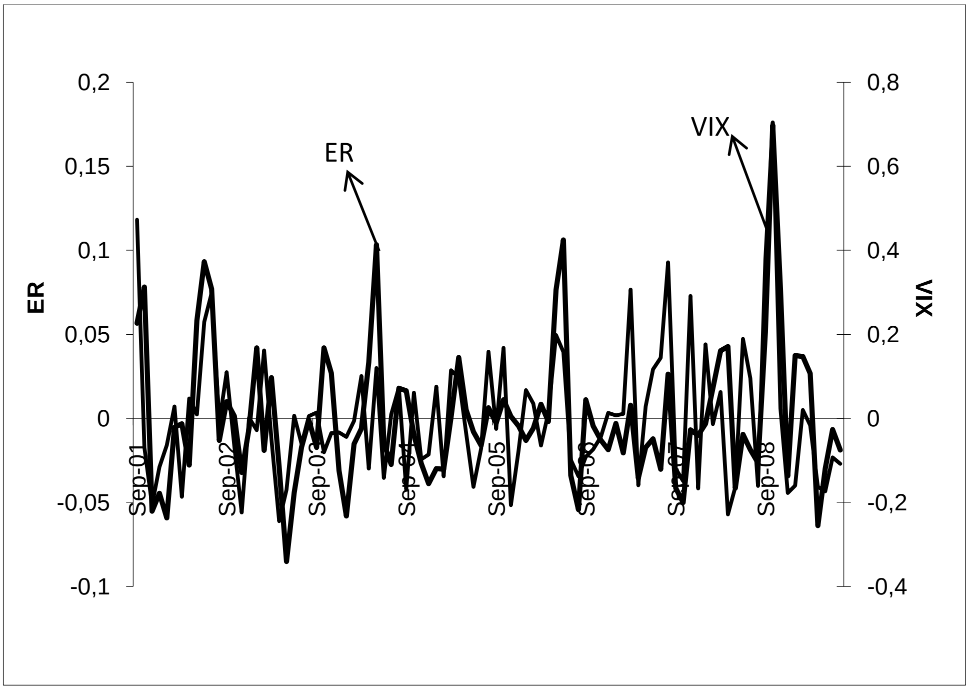

Figure 3.2.3.1: Changes in VIX and Exchange Rate

CHAPTER IV

EXCHANGE RATE DYNAMICS IN TURKEY

When examining the exchange rate movements in Turkey, it can be seen that there is a remarkable difference between pre-2001 and post-2001 periods. Moreover, there are some studies analyzing that the dynamics of the exchange rate changes after 2001. (Karaca, 2005; Şengönül and Aytemiz, 2007) Thus, we look at the literature studying the exchange rate dynamics in the post crisis period.

Ardıç and Selçuk (2006) use daily data for 13 March 2001 - 30 October 2003 period and show that EMBI+ is a significant factor to explain exchange rate movements. On the other hand, the response of exchange rate to a positive change in overnight interest rate is negative after 1 day. However in the following days, positive and negative impacts realize and die out after eight days. The overall impact is zero. That is to say, the changes in overnight interest rates do not affect the exchange rate.

On the other hand, Karaca (2005) works with monthly data for January 1990 and July 2005 period. The analyses are done for both the whole sample and after

March 2001 period and different results are found. For post March 2001 period, it is found that there is a significant but weak positive relationship between exchange rate and interbank overnight rate while a significant relationship does not exist for the whole sample. In other words, for post March 2001 period, the exchange rate depreciates as overnight rates increase which is contrary to common belief.

In another paper, in which different results are obtained for different periods, Şengönül and Aytemiz (2007) try to explain exchange rate movements by using exchange rate risk premium and the difference between 3 month government bonds' interest rates in United States and Turkey. They find that both variables are significant in January 1990 and December 2000 while only risk premium is significant and interest rate difference is insignificant for September 2001 and April 2006 period.

Additionally, Gül et al. (2007) make Granger causality tests between exchange rate and interest rate with monthly data for November 2000 and June 2006 period. They find that exchange rate Granger cause interest rate but interest rate do not Granger cause exchange rate which mean that exchange rates affect interest rates but the converse is not valid.

In this study, the effect of interest rate on exchange rate is analyzed in a different framework. At first, there is a nonlinear model so if the effect of interest rate is changing at different times, we can detect it with this model. Additionally, we use unexpected interest rate change which gives us an opportunity to distinguish the effect of a surprise policy action

CHAPTER V

METHODOLOGY

A threshold model as a special case of nonlinear models is used in this paper and there are 3 parts of the method used:

1) Estimating the threshold variable and regression coefficients

2) Testing whether there is nonlinearity in the data

3) Constructing the confidence intervals for estimated variables

Among these 3 parts, first one has a somewhat straightforward procedure but the others are more complex. For these parts we use the methodology developed by Hansen (2000).

5.1. Estimating threshold variable and coefficients

Let y, x and q be dependent, independent and threshold variables respectively. Then, y and q are $n \Delta 1$ vectors and x is an $n \Delta m$ vector where n is the sample size and m is the number of independent variables. The model can be stated simply as:

$y = \beta_1 \times x$ if $q \leq q^*$

$y = \beta_2 \times x$ if $q > q^*$

where β is the regression coefficient and q^* is the threshold level.

We should estimate the parameters of β and q* here. Since there are two parameters to be estimated, a logical way to use is sequential conditional least squares estimation.

Let q* be given. We can split the sample according to q*. Then we can use ordinary least squares estimation technique to estimate the coefficients of two samples conditional on q*. In this estimation, parameter values are conditional on the threshold level since the samples are divided according to threshold level. We can formulize it as:

$\beta_1 (q^*) = (\Sigma x_1(q^*) x_1(q^*)')^{-1} (\Sigma x_1(q^*) y_1)$ and

$\beta_2 (q^*) = (\Sigma x_2(q^*) x_2(q^*)')^{-1} (\Sigma x_2(q^*) y_2)$.

Then, the residuals are:

$$\hat{e}_t(q^*) = y_t - x_t(q^*)'\hat{\beta}(q^*)$$

And the residual variance is:

$$\hat{\sigma}_n^2(q^*) = \frac{1}{n}\sum_{t=1}^{n} \hat{e}_t(q^*)^2$$

Since the coefficients are conditional on q*, the errors and the residual variance is conditional on q*, too. The least squares estimation of q* is the value which the residual variance is minimized and it is:

$$\hat{q}^* = \underset{q^* \epsilon q}{\operatorname{argmin}}\, \hat{\sigma}_n^2(q^*)$$

The set of values that q* can take is simply the values of threshold variable so we can find the result after n regressions. We take all variables in the threshold variable set as q* and split the sample. Then, least squares estimation is done and residual variances are calculated. After n regressions, the value which minimizes the residual variance is taken as the threshold level.

5.2. Testing Nonlinearity and Constructing Confidence Intervals

The classical method used to test whether there is nonlinearity in the model is the standard F-statistics. It is computed as:

$$F_n = n(\frac{\tilde{\sigma}_n^2 - \hat{\sigma}_n^2}{\hat{\sigma}_n^2})$$

where

$$\tilde{\sigma}_n^2 = \frac{1}{n}\sum_{t=1}^{n}(y_t - x_t^{'}\tilde{\alpha})^2$$

is the residual variance of the linear model and

$$\tilde{\alpha} = \left(\sum_{t=1}^{n} x_t x_t^{'}\right)^{-1}\left(\sum_{t=1}^{n} x_t y_t\right)$$

as standard.

Since Fn is a monotonic function of $\hat{\sigma}_n^2$, the argmin function used in calculating q* maximizes the F_n function. That is to say,

$$F_n = \sup_{q^* \epsilon\ q} F_n(q^*)$$

Hansen (2001) states that since q* is not identified under the null hypothesis of linearity, the asymptotic distribution of F_n is not chi-square. It is proved that the asymptotic distribution of F_n can be approximated by a bootstrap procedure. After approximating the distribution of F_n, linearity test is made easily and the confidence intervals are constructed accordingly to approximated distribution.

Since the coefficients of estimation are dependent on threshold level, the confidence intervals are constructed according to confidence interval of threshold variable, too.

CHAPTER VI

THE DATA AND THE MODEL

The data is composed of four variables. The dependent variable is log difference of monthly average $/TL exchange rate.

The independent variables are log difference of monthly average VIX level and unexpected Central Bank overnight interest rate changes. Although VIX is nonstationary, the log difference of the raw data is stationary and the test results are given in Appendix. Unexpected interest rate changes are calculated as the difference between the Central Bank overnight interest rates at the end of the month and the expected interest rate for the end of the month which is stated in Survey of Expectations Descriptive Statistics made by Central Bank of Turkey. The survey is made twice a month. One is at the beginning of the month and the other one is at the middle of the month. In both surveys, the respondents are asked about their expectation of money market overnight annual simple interest rate by the end of the current month. For recent years, the Monetary Policy Committee meetings are generally made before the deadline for respondents in the second survey of month. So the question may not make any sense for some respondents. Accordingly, the results of the first survey of the month are used in this study.

The motivation of using unexpected interest rate change as an explanatory variable for exchange rate dynamics can be traced back to literature. Kuttner (2001) states that in analyzing the reaction of market to a policy action, it is required to make a distinction between expected and unexpected changes and extracts information about expectations of Fed funds target rates from Fed funds future rates.

Subsequently, Kuttner and Bernanke (2005) apply the same technique to distinguish Federal funds target rate changes as expected and unexpected. Then they analyze the stock market's reactions to target rate changes and observe that while the return to raw target rate change is insignificant, unexpected target rate change is highly significant in explaining the stock market's return.

Additionally, Andersson et al. (2006) examine term structure of interest rates in Sweden and study the effects of unexpected changes in a domestic or foreign variable on interest rates. They find out that unexpected repo rate changes are the dominant factor in short end of the yield curve while speeches are more influential for the longer end.

The threshold variable is the standard deviation of exchange rate which is calculated for each month by using daily data. The risk in exchange rate market is used as a threshold variable for the nonlinear effect of interest rate differentials on exchange rate in the study of Brazili and Sitzia (2003). They analyze the effects of interest rate differentials on exchange rate in five Eastern European countries for 1993 and 2000 period. They find that the interest rate differential is insignificant for the whole period. Then, they use the exchange rate market risk, which is formulated as the average of exchange rate changes in previous two months, as threshold variable. They find that if the changes in exchange rate in previous two months is small, the interest rate differential is significant to explain the exchange rate movements.

On the other hand, standard deviation of exchange rate is a reasonable candidate to be used as a proxy for exchange rate risk and different formulations of exchange rate volatility is used as a risk indicator for exchange rate in Turkey in the literature. (Tunçsiper and Öksüzler, 2006; Öztürk and Acaravcı, 2006)

Our model is:

$$\Delta s_t = \beta_1 + \beta_2 \times \Delta vix_t + \beta_3 \times \Delta i_{t-1} \; if \; std(S_{t-1}) \leq \delta^*$$

$$\Delta s_t = \gamma_1 + \gamma_2 \times \Delta vix_t + \gamma_3 \times \Delta i_{t-1} \; if \; std(S_{t-1}) > \delta^*$$

where

Δs_t = difference of natural logarithm of monthly average exchange rate

Δvix_t = difference of natural logarithm of monthly average VIX

Δi_{t-1} = unexpected interest rate change at the end of the previous month

$std(S_{t-1})$ = standard deviation of exchange rate in the previous month

δ^* = threshold level

Motivation behind this formulation is that the high volatility of exchange rate can be perceived as a risk signal for investors and the behavior of investors should change accordingly.

The contribution of this study to the literature is that the effects of VIX and unexpected interest rate changes on exchange rate are discussed first time for Turkey. Another important contribution is to see the relationship between VIX and an exchange rate in a nonlinear model.

CHAPTER VII

RESULTS

The nonlinearity test results yield that the bootstrap p-value for testing nonlinearity is 0.000000. This shows us that there are very strong nonlinear effects between dependent variable and independent variables.

The threshold value for standard deviation of exchange rate is 0.021674 with a confidence interval between 0.015118 and 0.024498. The whole sample contains 95 variables and sub samples are divided as the first one contains 59 variables and the second one contains 36 variables. Henceforth, we will call these subsamples as regime 1 and regime 2 respectively. The graphical representations of F test for nonlinearity and the confidence interval for threshold variable are given below:

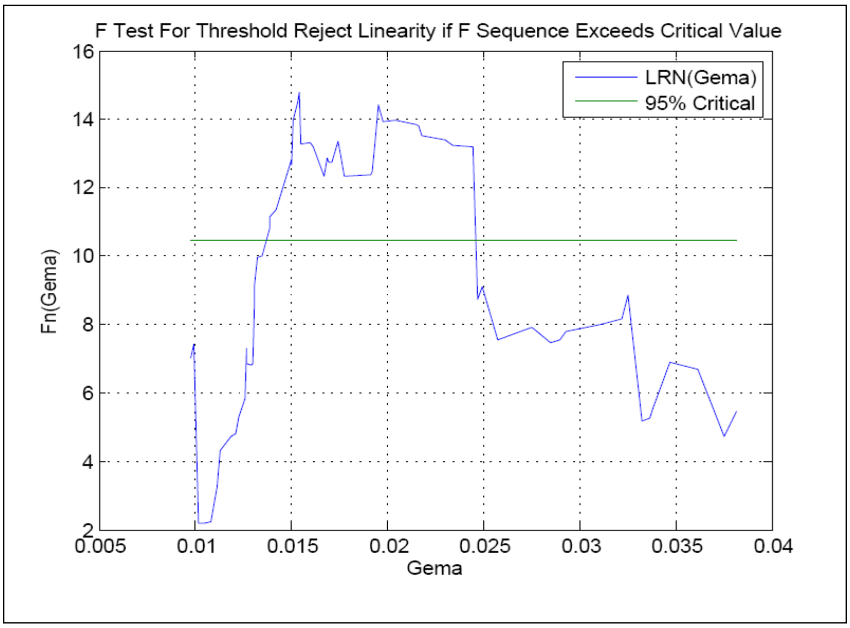

Figure 7.1: F test for linearity

In the graph above, we see that F sequence exceeds critical value for a large set of variables and this means that linearity is rejected.[1]

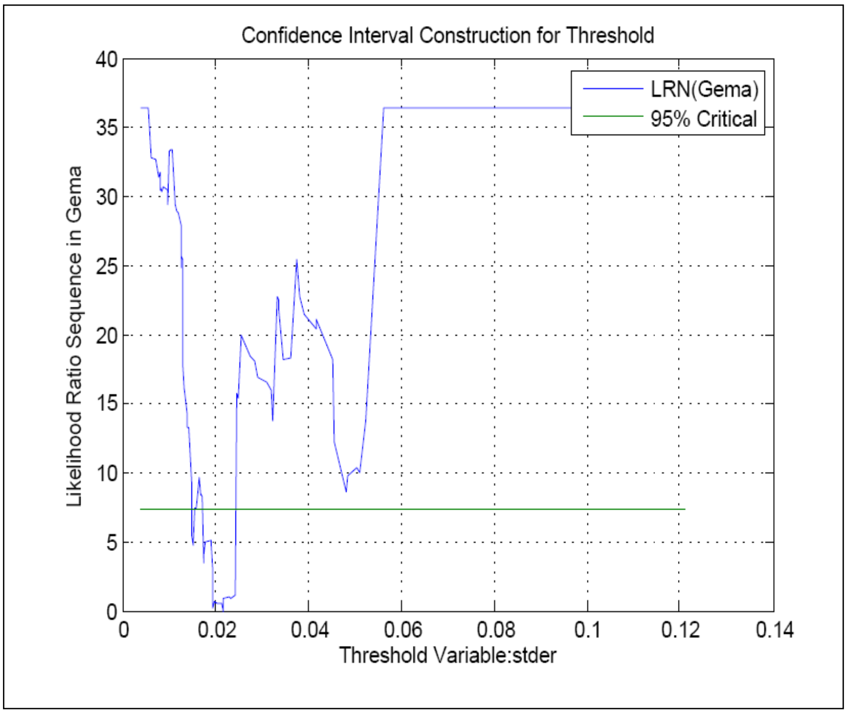

Figure 7.2: Confidence Interval Construction for Threshold

[1] Gema and stder stands for the thredhold variable in the model.

In Figure 7.2, the likelihood ratio for confidence interval of threshold variable is drawn.

Before analyzing the subsamples, we will first look at the results of whole sample and whole sample results are given below:

Table 7.1: The whole sample results

Variable	Estimate	St Error	t statistics
Constant	0.000141	0.00355	0.03971831
$\Delta \boldsymbol{vix_t}$	0.145386	0.028145	5.16560668
$\Delta \boldsymbol{i_{t-1}}$	-0.002794	0.004977	-0.561382359

The only significant variable is Δvix_t. On the other hand, Δi_{t-1} is insignificant although it has a negative coefficient as expected. The R^2 is 0.323.

The regime 1 results are given below:

Table 7.2: Results of regime 1

Variable	Estimate	St Error	%95 confidence region
Constant	-0.008218	0.002763	[-0.015589 -0.002324]
$\Delta \boldsymbol{vix_t}$	0.074253	0.021323	[0.023997 0.119641]
$\Delta \boldsymbol{i_{t-1}}$	-0.017497	0.004937	[-0.03383 -0.004232]

The confidence intervals are constructed by Hansen’s procedure. Δvix_t has a positive coefficient and it is statistically significant. On the other hand, Δi_{t-1} has a significant negative value which is the outstanding result of the estimation and contrary to the results analyzed in section 6. The R^2 is 0.314.

The regime 2 results are given in table 7.3:

Table 7.3: The results of regime 2

Variable	Estimate	St Error	%95 confidence region
Constant	0.015456	0.006648	[0.000641 0.029495]
$\Delta \boldsymbol{vix_t}$	0.214433	0.027651	[0.157703 0.274692]
$\Delta \boldsymbol{i_{t-1}}$	0.005478	0.006608	[-0.009976 0.018444]

When we look at the confidence intervals, we see that Δvix_t has a significantly higher coefficient in regime 2 since every point in confidence interval in regime 2 is higher than any point in confidence interval in regime1. On the other hand Δi_{t-1} has an insignificant coefficient contrary to results of regime1. R^2 for regime 2 is 0.544 and joint R^2 of the threshold model is 0.503. Hence we can say that our model can explain the exchange rate movements better in regime 2.

When we consider all these, we can come through the following results:

1) When the exchange rate volatility is below a threshold level, the exchange rate is sensitive to interest rate policies and has a negative correlation with unexpected interest rate policy changes. It is relatively less affected by global markets.

2) When market risk is high, exchange rate heavily depends on changes in VIX and becomes insensitive to interest rate policy changes. In other words, in risky conditions exchange rate market becomes much sensitive to global factors rather than country specific ones.

The graphs for the standard deviation of exchange rate and the periods of regime 2 are given below. The bold areas in Figure7.4 are the periods of regime2.

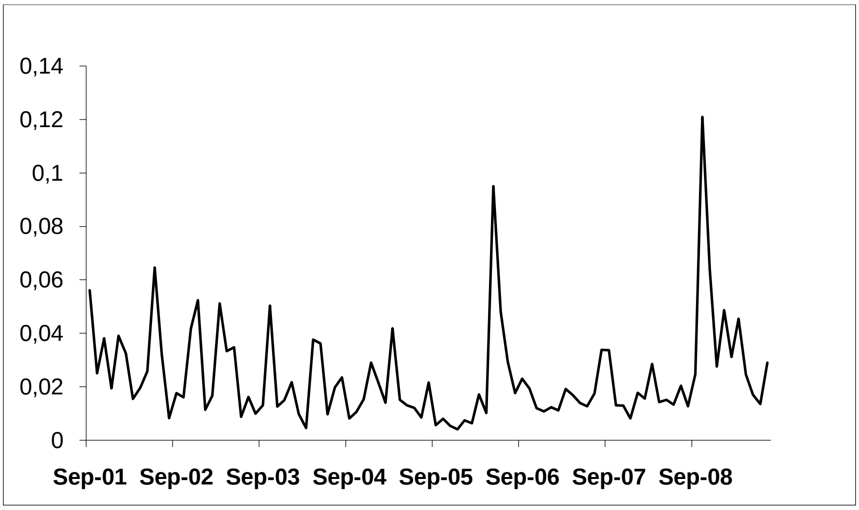

Figure 7.3: Standard Deviation of Exchange Rate

Figure 7.4: Regimes 1 and 2

Now, we will analyze the exchange rate dynamics for the periods in which regime 2 lasts 3 months or longer in a more detailed manner. In Figures A.1 to A.5, the daily data for exchange rate and VIX are given. In that part, we see that exchange rate is closely related with VIX as we found in estimation. More notably, 4 out of 5 periods coincide with the periods which we analyzed in Part 3 and explained the reasons of high VIX values in those periods. Hence, we can come through the result that the long volatile periods in exchange rate are mostly caused by global factors. In fact, the only exception, April-June 2003 period, is the period in which VIX falls from the plato that it rised in July 2002 so we can consider the volatility in this period as a result of changes in VIX also.

If we look at the whole sample of exchange rate data in figure 7.5, we see that except May 2004 period, all serious changes are caused by VIX, also. The serious exchange rate change in May 2004 is a result of political instability and expectations of increase in FED target rate.

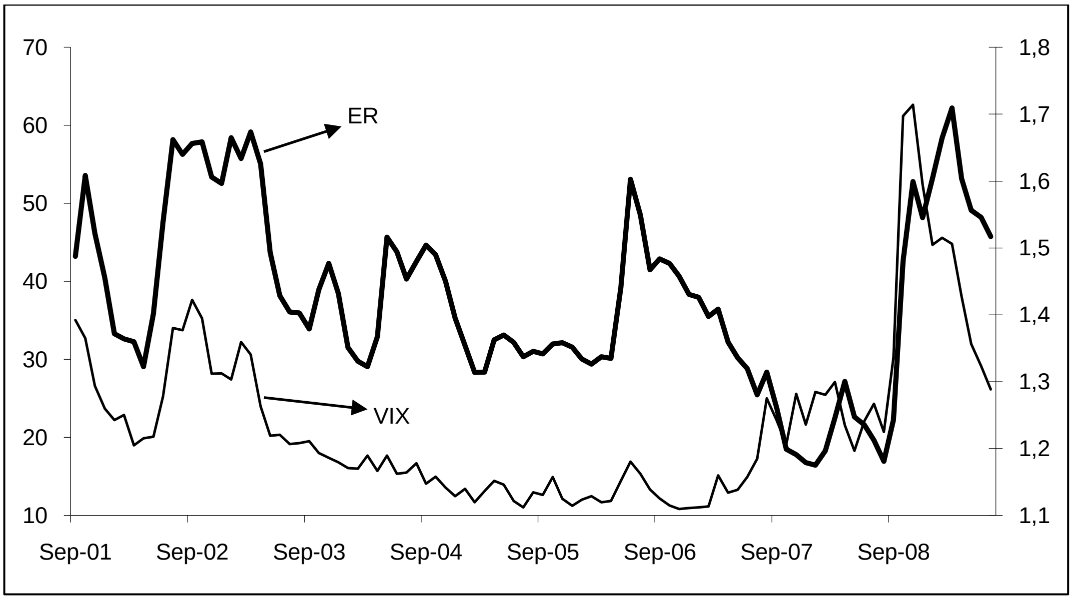

Figure 7.5: Exchange Rate vs. VIX

CHAPTER VIII

CONCLUSION

Exchange rate dynamics is still an attractive field in economics. It is influential on both price and output level which are the fundamentals of an economy in a country. Due to these factors, there are various exchange rate models studied in the literature and the nonlinear models are very popular in the recent literature.

In this study, we analyze the exchange rate dynamics in a threshold model where the threshold effect is stemming from the risk in the exchange rate market. We compute the risk of exchange rate market as the standard deviation of exchange rate in the previous month. We use VIX and unexpected interest rate change as explanatory variables for the exchange rate change.

We found that if the market risk is high, exchange rate excessively depends on the VIX and it is insensitive to unexpected interest rate changes. On the other hand, if the market risk is lower than a threshold level, unexpected interest rate change becomes a significant variable to explain the exchange rate change and the effect of VIX decreases although it is still significant. Additionally, the exchange rate change becomes more predictable during risky periods and the power of the model decreases if the market risk is below the threshold level. Furthermore, we can conclude that the longer periods that the exchange rate has heightened volatility is a result of global conditions. Thus, we can say that global conditions emerge as a variable to explain exchange rate volatility.

According to these results, a very important question that whether the Central Bank interest rate decisions affect the exchange rate or not is answered. If the exchange rate risk is below a threshold level, the Central Bank interest rate decision affects the exchange rate level. On the other hand, if the risk is higher than the threshold level, the Central Bank decision does not affect the exchange rate. It is mostly determined by the global conditions, in particular the global risk, for which we use VIX as an indicator.

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APPENDIX

Table A.1: Unit root test results for VIX

Null Hypothesis: VIX has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.13051	0.2334
Test critical values:	1% level	-3.50224	
	5% level	-2.89288	
	10% level	-2.58355	

Table A.2: Unit root test results for difference of natural logarithm of VIX

Null Hypothesis: VIX has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.22439	0.0000
Test critical values:	1% level	-2.5898	
	5% level	-1.94429	
	10% level	-1.61449	

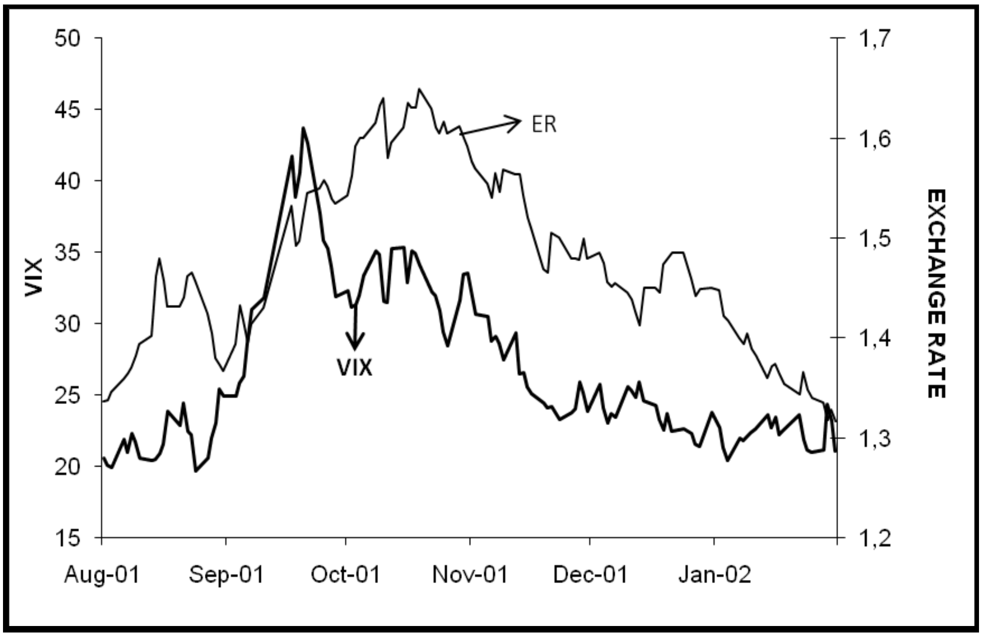

Figure A.1: September-December 2001 Period

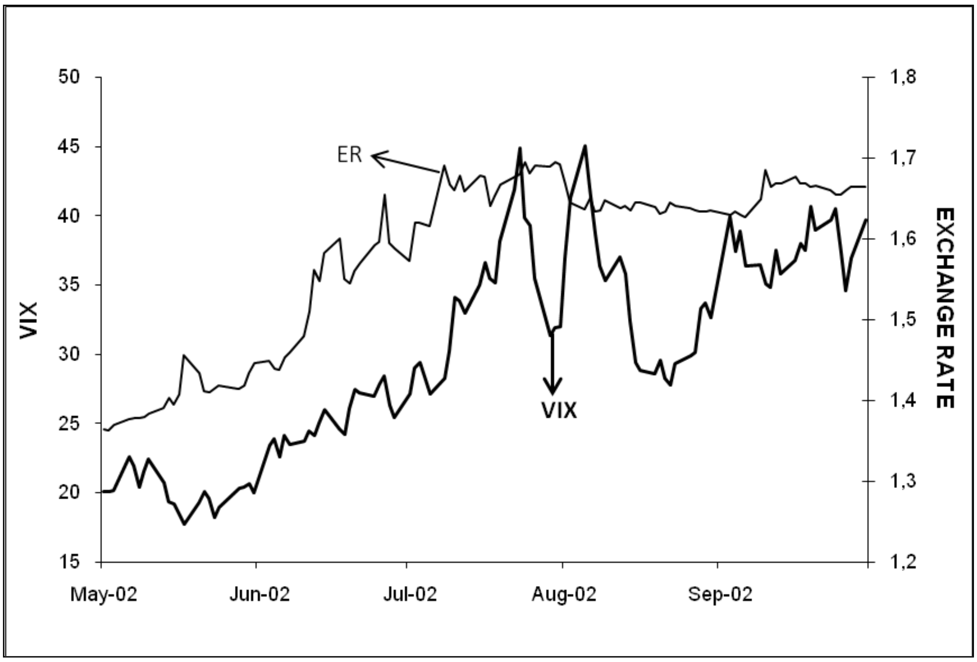

Figure A.2: June-August 2002

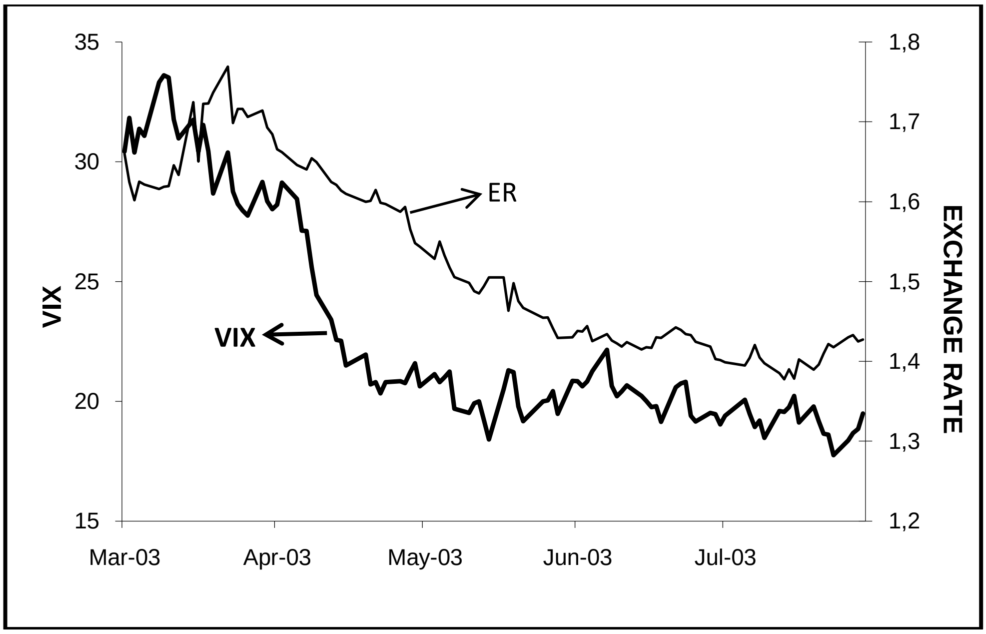

Figure A.3: April-June 2003

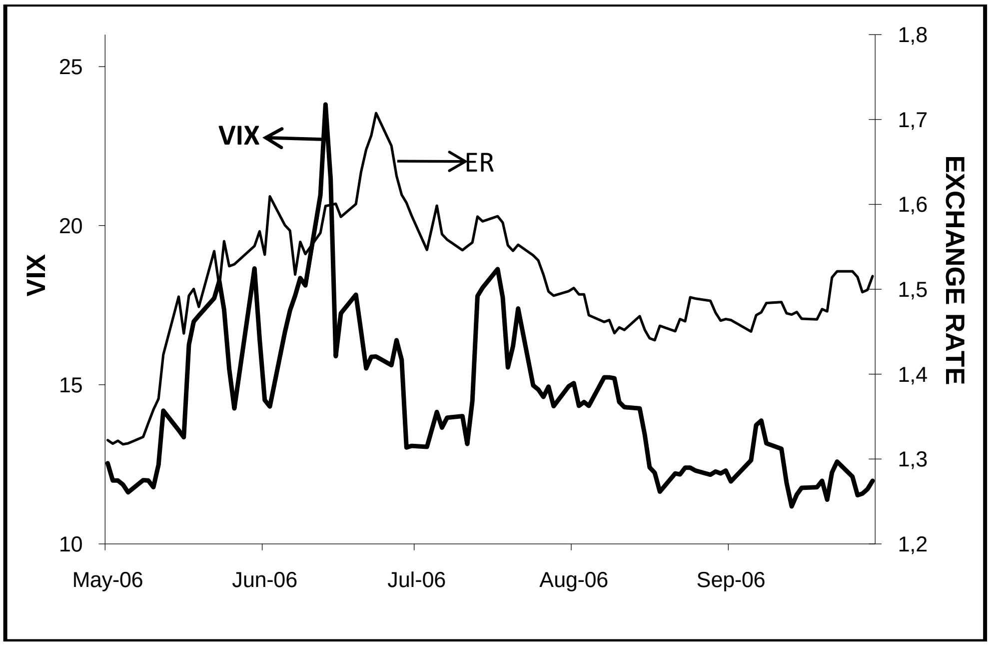

Figure A.4: June-August 2006

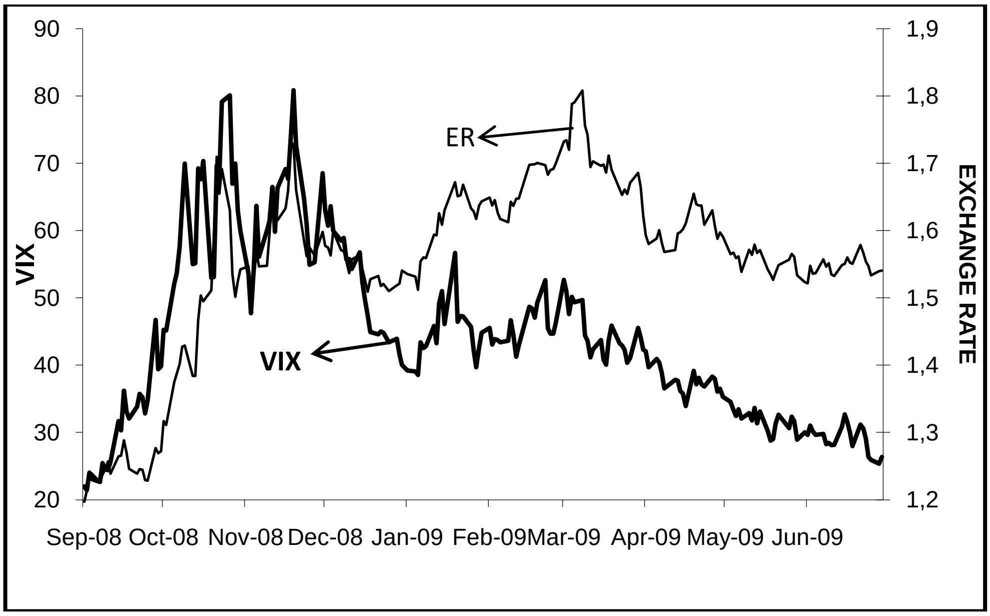

Figure A.5: October 2008-May 2009