# CAN RELATIVE YIELD CURVES PREDICT EXCHANGE RATE MOVEMENTS?
# EXAMPLE FROM TURKISH FINANCIAL MARKET

A THESIS SUBMITTED TO
GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF ECONOMICS

SEPTEMBER 2010

Approval of the Graduate School of Social Sciences

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# ABSTRACT

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September 2010, 114 pages

Exchange rate forecasting is hard issue for most of floating exchange rate economies. Studying exchange rate is very attractive matter since almost no model could beat random walk in short run yet. Relative yields and information in relative yield curves are contemporary topics in empirical literature and this study follows Chen and Tsang (2009) who model exchange rate changes with relative factors obtained from Nelson-Siegel (1987) yield curve model and find that relative factor model can forecast exchange rate change up to 2 years and perform better than random walk in short run. Analysis follows the methodology defined by Chen and Tsang (2009) and TL/USD, TL/EUR exchange rate changes are modeled by the relative factors namely relative level, relative slope and relative curvature. Basically, 162 weekly datasets from 09.01.2007 to 16.03.2010 are used and the relative factors for each week are estimated. Afterwards, regression analysis is made and results show that relative level and relative curvature factors are significant up to 4-6 weeks horizon but relative slope does not provide any valuable information for exchange rate prediction in Turkish financial market. Length of forecasting horizon of relative factor model is too short when compared to other exchange rate models. Since it is accepted that exchange rates follow random walk, we provided some tests to compare performance of the model. Similar to the literature, only short run performance of relative factor model is compared to random walk model and concluded that the relative factor model does not provide better forecasting performance in Turkish financial market.

Keywords: Term Structure of Interest Rates, Yield Curve, Relative Yield Curve, Nelson Siegel Model, Svensson Model, Exchange Rate Prediction

# ÖZ

GÖRELİ GETİRİ EĞRİLERİ DÖVİZ KURU HAREKETLERİNİ TAHMİN EDEBİLİR Mİ?
TÜRKİYE FİNANSAL PİYASALARINDAN ÖRNEK

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Eylül 2010, 114 sayfa

Dalgalı döviz kuru ekonomilerinde döviz kuru tahmini zor bir meseledir. Kısa dönemli döviz kuru tahmininde neredeyse hiç bir model rastsal yürüyüş modelinden daha iyi sonuç vermediğinden döviz kuru üzerine çalışma yapmak hala ilgi çekicidir. Göreli getiriler ve getiri eğrilerinin içerdiği makro ekonomik bilgiler literatürdeki güncel konulardan biridir ve bu çalışma döviz kurunu Nelson-Siegel (1987) modelinden elde ettiği faktörlerle modelleyen ve modelinin 2 yıla kadar döviz kuru tahmini yapabildiğini, hatta kısa dönemde rastsal yürüyüş modelinden daha iyi sonuç verdiğini iddia eden Chen ve Tsang (2009)'ı takip eder ve TL/USD ve TL/EUR döviz kurunu göreli seviye, eğim ve kavis faktörleri ile modeller. Çalışmada temel olarak, 09.01.2007'den 16.03.2010'e kadar olan 162 haftalık veri seti kullanılarak göreli faktörler tahmin edilmiştir. Göreli faktörler kullanılarak regresyon analizi yapılmış ve göreli seviye ve göreli kavis faktörlerinin döviz kuru tahmininde 4-6 hafta tahmin ufkunda anlamlı olmasına rağmen göreli eğim faktörün herhangi değerli bir bilgi sunmadığı bulunmuştur. Diğer tahmin modellerine göre göreli faktör modeli çok kısa ufukta tahmin yapabilmektedir. Genel olarak, döviz kurunun rastsal yürüyüş yaptığı kabul edildiğinden bu model de rastsal yürüyüş modeli ile karşılaştırılmıştır. Literatürdeki uygulamalara paralel olarak modelin kısa dönem performansı rastsal yürüyüş ile karşılaştırılmış ve göreli faktör modelinin Türk finansal piyasasında rastsal yürüyüş modelinden daha iyi sonuç vermediği sonucuna varılmıştır.

Anahtar Kelimeler: Faiz Oranlarının Vade Yapısı, Getiri Eğrisi, Göreli Getiri Eğrisi, Nelson Siegel Modeli, Svensson Modeli, Döviz Kuru Tahmini

*to my family…*

*past, present and future.*

ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my supervisor Assist.Prof.Dr Esma Gaygısız for her guidance, advice, criticism, encouragements and insight throughout the research.

I would also express my deepest gratitude to my family for their invaluable support, guidance and patience throughout my education life.

I would also thank to dear my friend and my colleague Esra Sarıarslan for her invaluable help, support and motivation.

I would also thank to dear my friend and my colleague Zeynep Anaklı for her invaluable help and support.

I would also thank to TUBITAK for scholarship throughout this study.

Finally, I would like to thank to Ilhan BOZ, Cost Analysis and Financial Planning Manager at ASELSAN Inc., for his encouragement, support and patience throughout my study.

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| | |
|---|---|
| ADF | Augmented Dickey-Fuller |
| BMA | Bayesian Model Averaging |
| CBRT | Central Bank of the Republic of Turkey |
| DTM | Day To Maturity |
| ECB | European Central Bank |
| ENS | Extended Nelson Siegel |
| EU | European Union |
| EUR | Euro (Currency) |
| FRBNY | Federal Reserve Bank of New York |
| GDP | Gross Domestic Product |
| GNP | Gross National Product |
| ISE | Istanbul Stock Exchange |
| MAE | Mean Absolute Error |
| NS | Nelson-Siegel |
| O/N | Overnight |
| OLS | Ordinary Least Squares |

| | |
|---|---|
| PPP | Purchasing Power Parity |
| RW | Random Walk |
| RMSE | Root Mean Square Error |
| RFM | Relative Factor Model |
| SIC | Schwarz Information Criterion |
| SP | Sticky Price |
| STRIPS | Separate Trading of Registered Interest and Principal of Securities |
| TR | Turkey |
| US | United States |
| UIP | Uncovered Interest Parity |
| UK | United Kingdom |
| WMAE | Weighted Mean Absolute Error |
| YTM | Yield to Maturity |

# CHAPTER 1

# INTRODUCTION

Exchange rate is one of the most important tools in international business which enables international trade among the countries. After collapse of Breton Woods of fixed exchange rates system among major industrial countries, exchange rate prediction became one of the major concerns of the economists. However, forecasting exchange rate is a difficult task since exchange rate is a price and it is accepted that it is the fastest moving price in the economies.

The answer to the question why forecasting exchange rate is a hard issue is not difficult. In other words, nominal exchange rate is affected by lots of financial, monetary and real economic variables and a complete set of effective variables could not be defined yet. For instance, export, import and their difference and foreign direct investments are just some of real economic variables affecting the exchange rates, interest rates on Treasury bonds is one of the monetary variables and inflation rate and balance of payments are some of the effective financial variables in exchange rate forecasting. Economists have formed several theories and improved numerous models to explain exchange rate movements. Purchasing Power Parity model (PPP), Uncovered Interest Rate Parity (UIP), Sticky Price (SP) monetary model and Bayesian Model Averaging (BMA) method are some of these models. PPP model explains exchange rate movement with changes in price levels of the countries, UIP model states that exchange rates moves according to the expected returns of holding assets in two different currencies, SP model includes macro economic variables that capture the money demand and BMA model includes 16 economic and financial variables as determinants of the model. Moreover, typical time series analysis and some technical approaches are used to determine exchange rate change, but most of the models could not become successful especially in out of sample analysis in short run when compared to random walk.

Term structure of interest rates obtained from Treasury bond market or yield curves embodies plenty of valuable macro economic information inside and Chen and Tsang (2009) benefit this information hidden in cross country yield curves. They model exchange rate change with the relative yield curve factors. In other words, the term structure of interest rates embodies information about future economic activity such as GDP growth and inflation; the authors model the exchange rate change directly by the relative factors instead of macro economic variables themselves. Chen and Tsang found that relative factors became quite successful in exchange rate forecasting and they claim that relative factors model provide better performance over random walk model. This study follows Chen and Tsang (2009) and tries to identify the applicability of the relative factors model to Turkish financial market since each financial market has idiosyncratic behavior and one exchange rate model appropriate for some market may not be suitable for another.

To test whether the relative factors are also illustrative in TL/USD and TL/EUR exchange rate prediction, 162 weekly datasets from 09.01.2007 to 16.03.2010 are used and Turkish yield curve is estimated by Svensson's (1994) Extended Nelson Siegel (ENS) model as a first step. Then, United States and European Union yield curve parameters are obtained and yields for some determined maturities are calculated. Afterwards, relative yields (yield difference for the same maturity) are calculated. Using relative yields, relative yield curve is estimated by Nelson-Siegel model and yield curve factors, namely, relative level, relative slope and relative curvature factors are estimated. The explanatory power of relative factors is tested by regression analysis and found that relative level and relative curvature factors are significant up to 4-6 weeks exchange rate prediction horizon. However, the relative factors model couldn't beat random walk out of sample analysis for Turkish financial market.

In the following parts, Chapter 2 identifies basic bond concepts and theories of term structure of interest rates, Chapter 3 defines the yield curves and points out what type of yield curves exist in the bond market and mentions the uses of yield curves. Chapter 4 gives literature review and theoretical background. To some extent, yield curve models, the relationship between yield curves and macro economic variables, how the information in yield curves can be used to exchange rate prediction and which yield curve model fits best to Turkish financial market are mentioned. Chapter 5 constitutes the main body of the study and defines and models the relative yield curves and estimates relative yield curve factors. Afterwards, relative factors are regressed over exchange rate change and regression results are tested in terms of robustness and model results are compared with random walk. Finally, Chapter 6 concludes.

# CHAPTER 2

# BASIC BOND CONCEPTS AND THEORIES OF TERM STRUCTURE OF INTEREST RATES

## 2.1. Bonds and Bond Types

For a simple definition, a bond is a contract between a lender and a borrower by which the borrower promises to repay a loan with interest[1]. Bonds can be classified according to its type of issuer, priority, coupon rate and redemption features[2]

For instance, the financial securities issued by governments are called government treasury securities. (Bond; for 10 years +, Note for 1-10 years, T-Bill < 1 year). If the bonds are issued in international market then they are called international bonds such as Eurobonds. In addition the bonds can be issued by municipalities and private firms and they are called municipality bond and corporate bonds respectively. In general, government bonds are less risky when compared to other bonds.

The priority of the bond is a determiner of the probability that the issuer will pay you back your money and the bonds can be classified junior - subordinated or senior - unsubordinated according to their priorities.

Bond issuer can choose to issue bonds having variety of types of interests and coupon payments. Coupon payments are nothing more than interest payments that the bond holder receives for purchasing a bond. Most of the bonds pay coupons annually or semi annually. Coupon rate can change according to the issuer's interests

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[1]Technically a bond is a fixed-income security with a maturity of ten years or more. We use "bond" for all fixed income securities in this study.

[2] Investopedia, Advance Bond Concepts: http://www.investopedia.com/university/advancedbond/

and risk perceptions. The issuer may issue fixed coupon rate bonds, floating coupon rate bonds (may be tied up to some indices inflation rate etc.) or zero coupon bonds which is issued at deep discount and pay the full face value at maturity date.

Lastly, there are also callable bonds which give a bond issuer the right, but not the obligation, to redeem his issue of bonds before the bond's maturity. In this case, the issuer, however, must pay the bond holders a premium[3].

## 2.2. Bond Pricing

It is important to know the price of a bond since the price and the yield received from a bond is closely related to each other. Bonds can be priced at premium, discount, or at par. If the bond's price is higher than its par (face) value, it will sell at a premium because its interest rate is higher than current prevailing rates. If the bond's price is lower than its par value, the bond will sell at a discount because its interest rate is lower than current prevailing interest rates.

The price of a bond can be calculated by the sum of present values of all cash flows which are coupon payments and par value at maturity. In other words, all future cash values are discounted by a discount function to get the price of a bond. If we assume bond pays constant coupons and we know that the constant interest rate we will get and assume each payment is re-invested at some interest rate once it is received, bond price can be calculated by the following formula:

$$P = \frac{C}{(1+i)} + \frac{C}{(1+i)^2} + \ldots\ldots + \frac{C}{(1+i)^n} + \frac{M}{(1+i)^n}$$

Where $P$ is price of bond, $C$ is constant coupon rate, $i$ is interest rate and $M$ is the value paid at maturity or par (face) value.

[3] Investopedia, Advance Bond Concepts: http://www.investopedia.com/university/advancedbond/

## 2.3. Yield and Bond Price

Interest rate which equals present value of future cash flows to a bond price is the Yield to Maturity (YTM). In literature, when referred to yield, it is referred to YTM in general. YTM is the interest that the investor gets from his entire investment. In other words, it is the return from receiving the present values of coupon payments and par values with respect to the price that he paid. If price of a bond and cash flows are known then, the yield can be calculated as follows:

$$\text{Price of Bond} = \frac{\text{Cash Flow1}}{(1+yield)} + \frac{\text{Cash Flow2}}{(1+yield)^2} + \ldots.. + \frac{\text{Last Cash Flow}}{(1+yield)^n}$$

In general, as a bond's price increases, yield decreases, that is, there is an inverse relationship between bond price and bond yields and graphical representation for this relationship is given below.

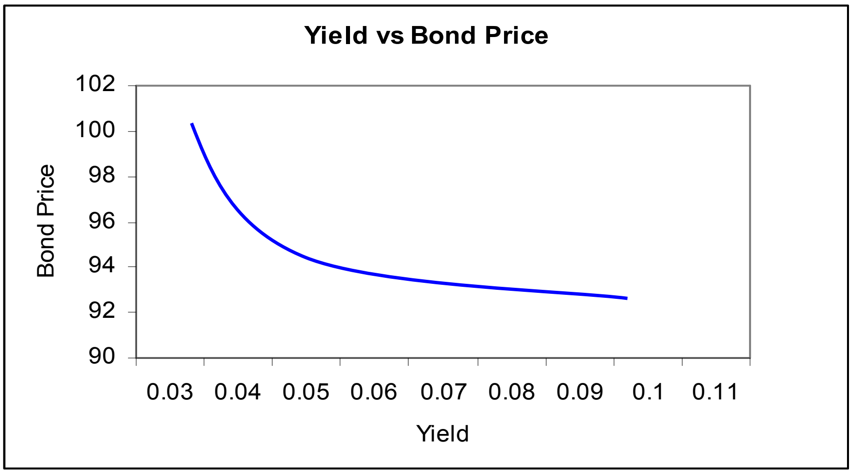


**Figure 2.1 The Relationship between Yield and Bond Price**

## 2.4. Term Structure of Interest Rates

The term structure of interest rates, also known as the yield curve, is a very useful bond evaluation method. The term structure of interest rates refers to the relationship between bonds of different maturities in general. When interest rates of bonds are plotted against their maturities, this is called the yield curve. Economists and investors believe that the shape of the yield curve reflects the market's future expectation for interest rates and the conditions for macro economy and monetary policy[4]

In addition, constructed by graphing the yield to maturities and corresponding maturity dates of similar fixed-income securities, the yield curve is a measure of the market's expectations of future interest rates given the current market conditions.

The term structure of interest rates and yield curves are used interchangeably in literature. The yield curves reflect the market expectations and may take the shape of normal, flat, inverted, humped and S shaped curves. Each shape includes different information for market and the details will be mentioned in the next chapter.

## 2.5. Theories of Term Structure of Interest Rates

Generally, yield curves are concave curves. That is, they slope rapidly upward at short maturities and continue to slope upward but more gradually as maturities lengthen. Why term structure behaves like this is an attractive question and there are three explanations or theories for the term structure outlined in Luenberger (1998, 81-83).

Expectation theory states that spot rates are determined by expectation of what rates will be in the future. For an increasing yield curve, it can be argued that the market is

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[4] The Financial Pipeline is a website dedicated to financial education and understanding: http://www.finpipe.com/index.html

expecting the interest rates to increase in the future mostly because of inflation rate will increase and overnight interest rates will be increased accordingly. On the other hand, expectation hypothesis implies that forward rate is exactly equal to market expectation of what one-year spot rate will be next year.

Another explanation for the term structure claims that investors usually prefer short term investments rather then longer term investments since they prefer keeping their securities liquid rather than tied up. Thus, they demand greater yield for longer maturity investments. This is called liquidity preference theory.

Market segmentation theory states that a market for fixed income securities is segmented by maturity dates. That is, the group of investors demanding long term securities and the group of investors demanding short term are independent and this view in fact, suggests that all points on the yield curve are mutually independent and each point is determined by the forces of supply and demand in its own market.

# CHAPTER 3

# YIELD CURVES

## 3.1. Yield Curves

The graphical representation of relationship between return (yield) of same type of financial instruments and its day to maturity is called yield curve. In other words, all the differences in terms of types, credit risks and liquidity are removed from bonds and just the path of interest rates according to maturity date is represented in yield curves. Yield curves can be grouped into two in terms of coupons they include; namely coupon bearing yield curves and zero coupon yield curve.

A coupon bearing yield curve is obtained from an observable market bonds at various time to maturity with the bonds having the same coupon rate. Most of government securities having long maturity date usually have coupons (bond pays some determined part of bond periodically under name of a coupon, i.e. 5% coupon bond pays back 5% of bond per 6 months if it pays semi annually coupon.) Interest can be obtained both from coupons and the money that paid at maturity date. In addition, bond itself and the coupons sometimes are traded separately. This is called STRIPS (Separate Trading of Registered Interest and Principal of Securities) in finance literature.

A zero coupon bond yield curve is the yield curve between zero coupon bond yield and maturity dates. Zero coupon yields are the difference between the purchasing price and face value of bonds since the bond does not pay any coupon until maturity date.

There are also nominal yield curves, spot yield curves and forward yield curves. Nominal yield curves take place in primary bond market and it is the graph of yields of bonds which are transacted at nominal prices. Spot yield curve is another definition of zero coupon yield curve. Forward yield curve is the curve representing the connection between the forward rate and its corresponding maturity where the forward rate is the interest rate implied by the zero coupon rates for periods of time in the future.

## 3.2. Shapes of Yield Curves

Yield curves may have the shapes of normal, flat, inverted, S-Shaped or humped curves. The graphical representations of these shapes are given in Figure 3.1 1.

Normal yield curve is the most common yield curve observed in the financial markets. This type of yield curve implies that the market players demand low interests for short maturities and they demand a little more for longer maturities. The difference between short and long term yields is called term premium which includes opportunity cost of money to invest money for longer maturity and the other risks associated with long maturity time, i.e. inflation, credit default risks etc. A normal yield curve is a sign of normal economy and players expect that the economy will grow in the future and this growth will be accompanied by inflation and thus interest rates will grow up. If the mid maturity interest rates demanded are greater than both short and long maturity rates then the curve is called humped.

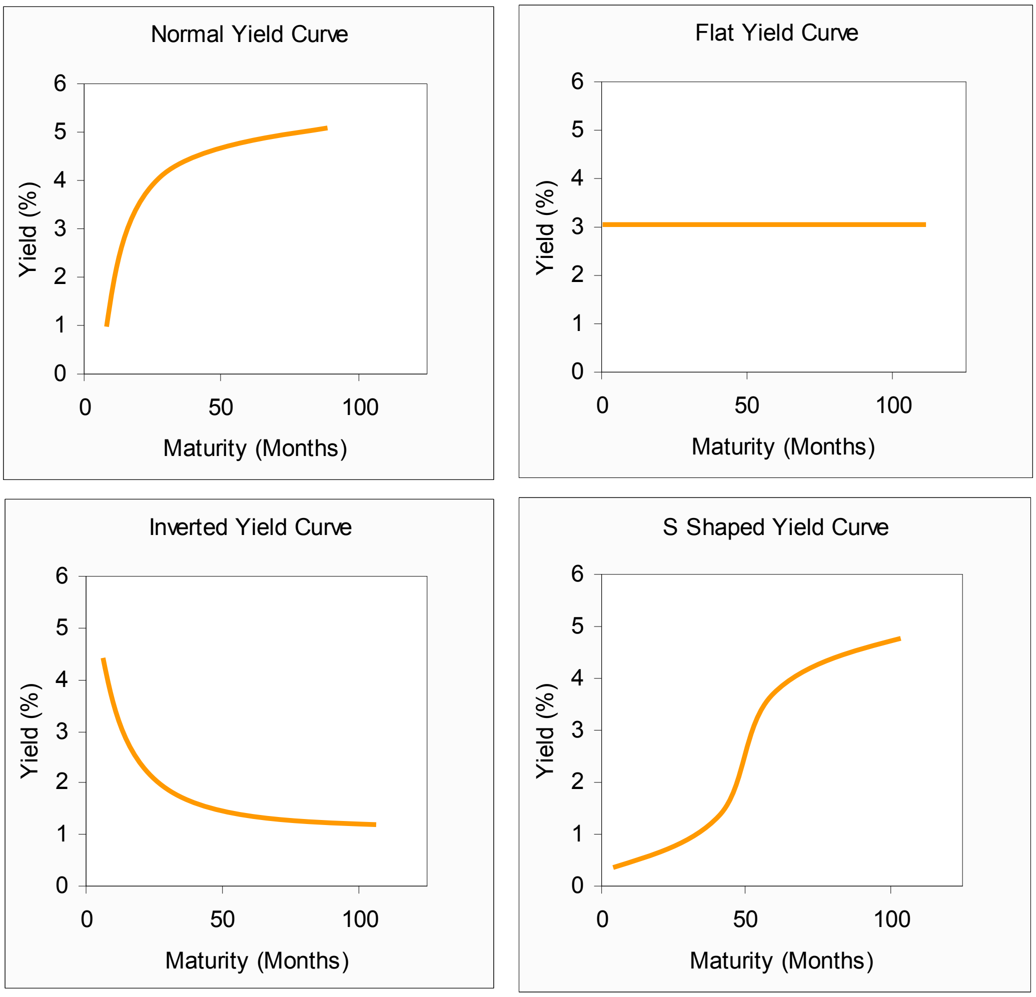


**Figure 3.1 Types of Yield Curves: Normal, Flat, Inverted and S shaped Yield Curves**

Flat yield curves are in between the normal yield curves and inverted yield curves. Thus, it does not provide clear signal about economy. After a flat yield curve, it may be followed by a normal yield curve or an inverted curve.

Inverted yield curve may occur when the long maturity interest rates fall below the short rates. This type of yield curves may take place if the players expect that interest rates will be much lower than that they expect. In fact this may be an indication of an economic recession coming. Harvey (1986)[5] showed that inverted yield curve can

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[5] See also Cwik (2005) "The Inverted Yield Curve and the Economic Downturn”

predict U.S economic recessions and he mentioned that the inverted yield curve has indicated a worsening economic situation in the future 6 out of 7 times since 1970 in U.S.

S shaped yield curve a kind of normal yield curve but it contains convex and concave curves together in its body. Up to the first twist, it has a convex curve part and after the twist it has a concave part. This type of a curve may be observed if the players expect that current short rates are too low after an economic recession and the economy will grow faster than expected and the inflation will rise unexpectedly but Central Bank won't let it grow fast and the interest rates will be increased fast at mid maturity. After intervention of Central Bank, economic and inflationary boom is expected to be reduced to its normal levels.

## 3.3. The Uses of Yield Curves

The relationship between yield and maturity has critical importance for policy makers, investors and economists. Yield curves can be used for a range of purposes. For example, government bond yields can reflect the tightness of the monetary policy, and they can be useful in pricing new securities issued and comparing the bonds traded in the market and also in deriving the forward rates and understanding the risks in the market. (Place, 2000)

Yield curves are used mostly by investors to see the differences in yields of different maturities and to detect if there is arbitrage opportunity. In addition, by yield curve information, investors can have opportunity of making immunization of their investment portfolio against financial risks if they have to make investment on some determined time of maturity.

Investors may get interest rate information for different maturities. They can get information about how much interest rate to demand due to the risks in the market. Sometimes in the market some bonds may have low liquidity, low demand but high return. If the investors compare the bond with the ones in the market and if the liquidity is not a problem for the investors, then they can gain more by investing these types of bonds. (Thau, 2000)

Private sector firms can use yield curves if they want to issue bonds. They can look at yields of different maturities and they can choose their borrowing strategy according to information got from the yield curve. (Teker and Gümüşsoy, 2004)

The differences in yields for long maturity and short maturities (for instance: 10 years and 3 months yield differences) may show the tightness of the government monetary policy. This difference can be monitored and recession coming next years can be predicted. An upward sloping yield curve (a normal but steep yield curve) implies money is cheap that is, a loose monetary policy and high interest rate return due to high inflation rate. A downward sloping yield curve implies a tight monetary policy, that is, credit opportunities are so much and low interest rates due to low inflation rates. Downward sloping or inverted yield curves may be observed in recession times. (Teker and Gümüssoy, 2004)

Central banks have the ability of changing short rates (overnight interest rates). The interest rates for the longer periods are determined by path of interest rate expectations and risk perceptions of market players for the future. As monetary transmission mechanism is considered to be determined by the relationship between short rate changes and long run changes, yield curve becomes an important indicator for Central Bank to use in monetary policy process. (Akıncı et. al. 2006)

In addition to the investors and policy makers, macro economists often use the yield curves since the yield curves contain plenty of valuable information about macro economic variables such as growth rate, inflation and time of recessions, exchange rates etc. This study will focus on the information about macro economic variables that yield curves include rather than the bond pricing issues. The connection between macro economic variables and yield curve will be mentioned in the next chapters.

# CHAPTER 4

# LITERATURE REVIEW AND THEORETICAL BACKGROUND

## 4.1. Modeling the Yield Curve

The graphical representation of yields with their maturity dates is called yield curve and modeling the yield curves has a prominent importance in finance literature. Analysts have formed several yield curve models namely equilibrium models and statistical yield curve models. In the equilibrium models, yields are assumed to follow a stochastic process and parameters of yield curves are estimated by the time series analysis. “Equilibrium models focus on the short rates and other interest rates are estimated based on short rates.” (Memiş, 2006) However, these models are not useful in the sense that the equilibrium model based yield curves are not successful in bond pricing and yield curves may have more complicated shapes than equilibrium models can explain. (Vasicek and Fong, 1982)

In the statistical models, a functional form is defined for the yield curves and the parameters of the form are estimated by statistical and econometric methods. The most prominent statistical models are McCulloch’s spline model, Vasicek and Fong’s exponential spline model, parsimonious Nelson-Siegel model and Svensson’s extended Nelson-Siegel model. This study covers the statistical models in brief.

McCulloch (1971) suggests measuring the term structure by estimating the discount function first and then, the term structure is estimated from discount function afterwards. McCulloch defines the discount function as a linear combination of k continuously differentiable functions f(t) and a constant term.

$$\delta(t) = a_0 + a_j \sum_{j=1}^{k} f_j(t) \quad \textbf{(4.1)}$$

Then, the price of a bond making continuous payments at a coupon rate *c* and maturing at time *T* can be expressed as:

$$P = \delta(T) + c\int_0^T \delta(t)dt \quad \textbf{(4.2)}$$

and finally McCulloch defines yield as $y = \sum_{j=1}^{k} a_j x_j$ **(4.3)**

where y=P-1-cT and $x_j = f_j(T) + c\int_0^T f_j(t)dt$ **(4.4)**

by applying linear regression techniques unknown parameters $a_j$ s can be estimated.

Vasicek and Fong model is a piecewise exponential function and these pieces are linked so as to make the function and its derivatives continuous. To form a linear model to get rid of the difficulties of nonlinear models, they apply transformation to the argument of discount function and they define the discount function as:

$$\delta(t) = \delta\left(-\frac{1}{a}\log(1-x)\right) \text{ where } x = 1\text{-}\exp(\text{-}at) \text{ so that} \quad \textbf{(4.5)}$$

$$t = -\frac{1}{a}\log(1-x), \quad 0 \leq x < 1 \quad \textbf{(4.6)}$$

They use the discount function above and they form spot rate curve and forward rate curves accordingly. Statistical models are mostly aim to represent the properties of each bond and they try to fit the model to the data as much as possible. Thus, statistical models are affected by the properties of individual bonds as compared to the parametric models.

The famous parametric models are Nelson-Siegel (NS) model and Extended Nelson Siegel (ENS) model. Nelson and Siegel (1987) introduced a parametrically parsimonious model for the yield curves that has the ability to represent the shapes generally associated with yield curves instead of complex equilibrium and spline models. Their model was quite simple but quite successful in that their model could capture 96% of the variation in bill yields. The principal difference between parsimonious models and spline based models is the fact that parsimonious models use a unique functional form for all maturities.

Nelson and Siegel (1987) claim that a class of functions which generate typical yield curve shapes are associated with the solutions to differential or difference equations. Heuristic motivation provided by the expectation theory of term structure of interest rates suggests investigating this class of equations since if the spot rates are generated by a differential equation then forward rates, being forecasts will be solution to that equations.

They assumed that if the instantaneous forward rate is *r(m)* at maturity *m* is a solution to second order differential equation with real and equal roots, then forward rate curve can be defined as:

$$r(m) = \beta_0 + \beta_1 * \exp(-m/\tau_1) + \beta_2 * \exp(-m/\tau_2) \quad \textbf{(4.7)}$$

where $\beta_0, \beta_1, \beta_2$ are determined by initial conditions and $\tau_1$, $\tau_2$ are time constants. The above formula given for the instantaneous forward rates generates monotonic, humped and S-shaped curves. The yield to maturity for a bond *R(m)* is the average of forward rates, **(4.7)** that is:

$$R(m) = 1/m \int_0^m r(x)dx \quad \textbf{(4.8)}$$

Thus, the yield curve defined by **(4.8)** has a range of monotonic, humped and S-shaped shapes.

Nelson and Siegel find that this model is over parameterized and they state that a more parsimonious model which can also produce the same shapes is given by the solution equation for the case of equal roots:

$$r(m) = \beta_0 + \beta_1 * \exp(-m/\tau) + \beta_2 * \left[(m/\tau) * \exp(-m/\tau)\right] \quad \textbf{(4.9)}$$

To get yield curve, **(4.9)** is integrated from zero to *m* and divided by *m*. Then the resulting function is obtained by:

$$R(m) = \beta_0 + (\beta_1 + \beta_2) * [1 - \exp(-m/\tau)]/(m/\tau) - \beta_2 * [\exp(-m/\tau)] \quad \textbf{(4.10)}$$

The above yield curve parameterization in **(4.10)** is called Nelson-Siegel (NS) model in this study. The limiting value of **(4.10)** as *m* gets larger is $\beta_0$ and as m gets small is $(\beta_0 + \beta_1)$.

Nelson-Siegel model has three components $\beta_0, \beta_1, \beta_2$ and these components have a clear interpretation as short, medium and long term components. Contribution of long term component in the model is $\beta_0$ since it is a constant and does not decay to zero in the limit as time to maturity increases in the model. As can be seen in **Figure 4.1**, its coefficient is constant at 1 and same for every maturity. The medium term component is $\beta_2$ in the model since its coefficient starts from zero (then it is not short term) and decays to zero after some time. The short term component is $\beta_1$. The short term curve has the fastest decay all functions in the model that decay monotonically to zero. By choosing appropriate weights to the components above, the shapes that a yield curve may have can be obtained.

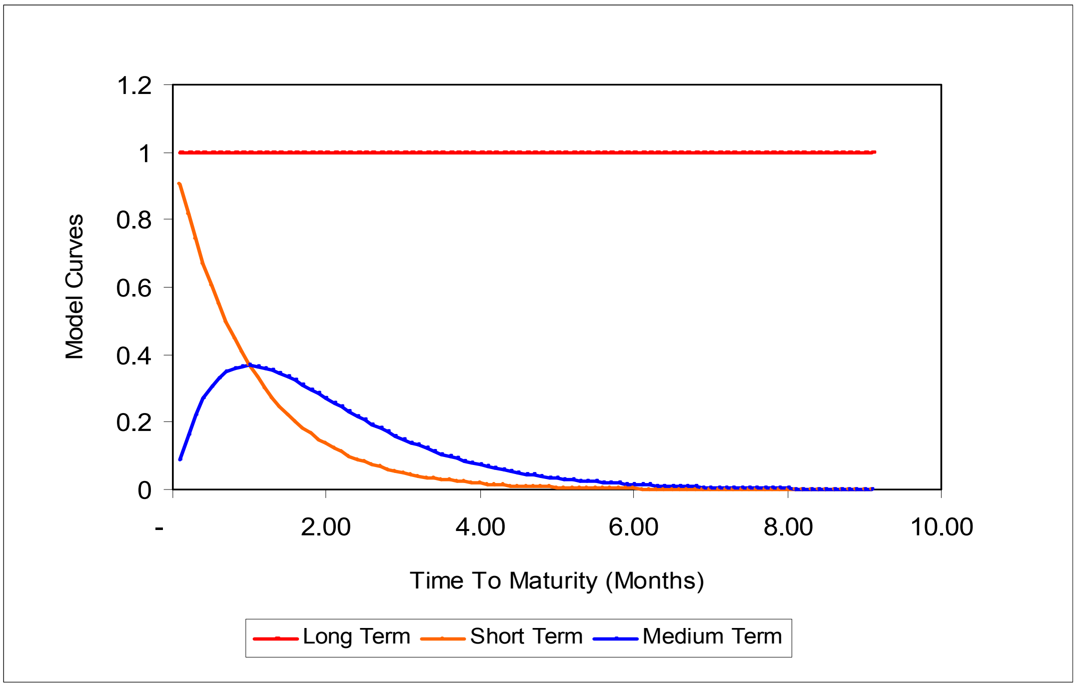


**Figure 4.1 Components of Nelson-Siegel Model**

In the NS model, the term $\beta_2 * (m/\tau) * \exp(-m/\tau\ )$ generates a hump shape (or a U shape if $\beta_2$ is a negative number) in the yield curve. Svensson (1994) extends the NS model to increase the flexibility and improve the fit by adding a fourth term $\beta_3 * (m/\tau_2) * \exp(-m/\tau_2)$ to the model **(4.9)** which generates a second hump shape (or a U shape if $\beta_3$ is negative) with two additional parameters $\beta_3$ and $\tau_2$ where ( $\tau_2$ must be positive).

Then the forward rate curve defined in **(4.9)** becomes

$$r(m) = \beta_0 + \beta_1 * \exp(-m/\tau) + \beta_2 * \left[(m/\tau_1) * \exp(-m/\tau_1)\right] + \beta_3 * \left[(m/\tau_2) * \exp(-m/\tau_2)\right]$$

**(4.11)**

Integrating **(4.11)** curve and dividing by m we get yield curve as

$$R(m) = \beta_0 + \beta_1 * [1 - \exp(-m/\tau_1)]/(m/\tau_1) + \beta_2 * \{[1 - \exp(-m/\tau_1)]/(m/\tau_1) - \exp(-m/\tau_1)\} + \beta_3 * \{[1 - \exp(-m/\tau_2)]/(m/\tau_2) - \exp(-m/\tau_2)\}$$

**(4.12)**

Svensson expands the NS model and reaches an extended version of the NS model. Thus, this parameterization is called Extended Nelson-Siegel (ENS) model. ENS model suggests more flexible structure for yield curve estimation. In other words, "Svensson model does not affected by the large fluctuations that can be seen in some bonds in the data sets. Thus, Svensson model can give more reliable information about the general path of the interest rates. This also represents the market's expectations about interest rates and risk prime." (Akıncı et. Al., 2006)As in the case of NS model, interest rate reaches $(\beta_0 + \beta_1)$as *m* gets small and $(\beta_0)$ as *m* gets infinity in ENS model.

Indeed, the above three principal components of NS model ($\beta_0, \beta_1, \beta_2$) typically closely match the simple empirical proxies for level (e.g., the long rate), slope (e.g., a long minus short rate), and curvature (e.g., a mid-maturity rate minus a short- and long-rate average).In other words, the short, medium and long term components can also be interpreted in terms of the aspects of the yield curve they govern. (Diebold, Lie 2006)

The long term component, $\beta_0$, governs the yield curve level. From the figure below, it can be seen that $R(\infty) = \beta_0$. $\beta_0$ increases all the yields equally since the loading is identical at all maturities. The short term component $\beta_1$ is closely related to yield curve slope. That is, the longest maturity yield minus shortest maturity yield $[R(\infty) - R(0)]$ is exactly equal to $-\beta_1$.

Increase in $\beta_1$ increases short yields more than long yields since short rate load on $\beta_1$ is heavier. Therefore, we can say that $\beta_0$ governs the level of the yield curve and $\beta_1$ governs the slope of the yield curve. Finally $\beta_2$ is closely related to the yield curve curvature. An increase in $\beta_2$ in very short or very long yields will have a little effect but will increase medium term yields which have more heavy load on it, thereby increasing the yield curve curvature.

Three Nelson-Siegel factors which are interpreted as level, slope and curvature are represented and they can be seen in the figure below.

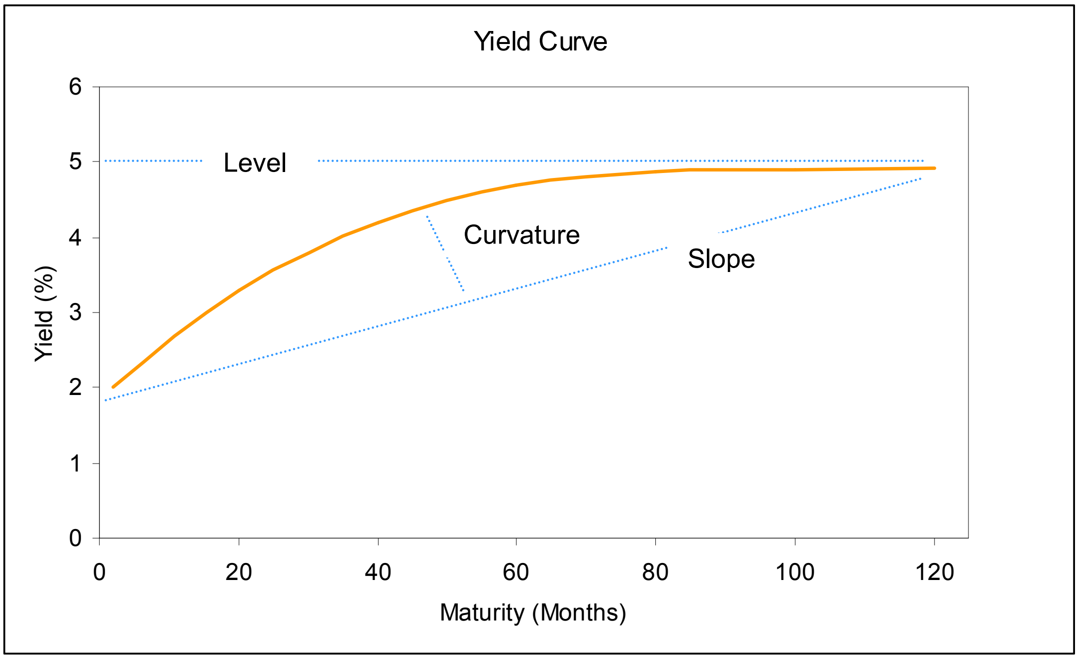


**Figure 4.2 Level, Slope and Curvature in a Yield Curve**

## 4.2. Yield Curves and Macro Economic Variables

As mentioned before, investors, policy makers and macro economists use the yield curves to get some valuable information from them. Investors try to form optimal strategy in investment decisions and policy makers try to use yield curves as a tool to shape their economic decisions accordingly. In the past, the term structure literature first focused on the subject that forecasting future short term or spot interest rates by using current yields or forward rates. Macro economists however, try to take out some information about macro economy hidden in the yield curves. The studies which analyze the relationship between macro economic variables and the term structure of interest rates (or yield curves) emerged and expanded at last twenty years. These studies can be clustered mainly into five groups. In other words, researchers analyzed the relationship between yield curves and real economic activity, also yield curves and economic growth, yield curves and inflation, yield curves and monetary policy, yield curves and economic recessions as well. Some of these studies are referred below.

Estrella and Hardouvelis (1991) analyze the connection of yield curve with real economic activity such as consumption and investment. They find that positive slope of yield curve is associated with a future increase in real economic activity. They also indicate that the slope of the yield curve has predictive power over real short-term interest rates, lagged growth in economic activity, and lagged rates of inflation. Similarly Hu (1993) finds the measure of the slope of the yield curve, that is the yield spread or term spread, is a good predictor of future economic growth for G–7 countries[6]. Harvey (1991) also analyzes the relation between the term structure of interest rates and real economic growth in the G-7 countries and finds that the term structure of interest rates can account for over half of the variation in GNP growth in many G-7 countries. Haubrich and Dombrosky (1996) also follow the question that yield curve can accurately predict the real economic growth and they find that 10-year - 3-month spread has substantial predictive power. They run regression for the period 1961 to 1996 and find over the past 30 years, yield curve based model provides one of the best (in sample, the best) forecasts of real growth four quarters into the future as compared to other forecasting methods. Harvey (1997) studies the Canadian economic growth and he finds that the term structure of interest rates in

[6] See also Clinton (1995) for why the term spread predicts economic activity well.

Canada can forecast Canadian economic growth over and above the information contained in the U.S. term structure. Ang, Piazessi and Wei (2006) build a dynamic model for GDP growth and yields which completely characterizes expectations of GDP. They find that short rate has more predictive power than any term spread and they also find that yield curve model produce superior out of sample GDP forecasts than unconstrained OLS regressions at all horizons.

Inflation is one of the major concerns of the economists and researchers studied the relation between yield curves and inflation as well. For instance, Fama (1990) finds that the interest rate spread on a five year bond over one year bond forecasts the changes in one year inflation rate.[7] Mishkin (1990) focuses on the question "what does the term structure tell about future inflation?" and he found that although the shortest end of term structure (maturities shorter than 6 months) does not provide any information about future path of inflation, there is significant information in term structure about the future path of inflation at the longer end. He finds that the slope of term structure is significant in prediction of future changes in inflation and the results indicate that steeping of the term structure is a signal for an increase in the inflation rate. Hardouvelis and Malliaropulos (2005) find that an increase in the slope of the nominal term structure predicts an increase in output growth and a decrease in inflation of equal magnitude. Their model also predicts the slope of the real yield curve is negatively associated with future output growth and positively associated with future inflation.

Macro economists also investigated relations between both term structure of interest rates and monetary policy and how yield curve is affected by the monetary policy actions. For instance, Evans and Marshall (1998) investigate the effects of exogenous shocks to monetary policy to the yield curves. They find that main effect of monetary policy shock is to shift the slope of the yield curve. Besides, Feroli (2004) points out that expectation of monetary policy actions are crucial for the spread to predict output conditional on the short-rate. Thus monetary policy and the ability of the yield

[7] Ichiue (2004) also finds evidence that term spreads can be useful in predicting output growth, inflation and interest rates.

curve to forecast real economic variables are closely related. On the other hand, Berk (1998) indicates that using the yield curve as an information variable for monetary policy must be done in a very cautious way since the yield curve is very sensitive to the nature of the underlying shocks hitting the economy and to institutional and structural factors influencing the speed of price adjustments.

On the other hand, Diebold, Rudebusch and Aruoba (2006) characterize dynamic interactions between macro economy and the yield curve. That is, they formed a yield curve model which summarizes yield curve latent factors (level, slope and curvature) and which also includes observable macro economic variables (real activity, inflation, and the monetary policy instrument) and they improve classical yield curve modeling one step ahead. In other words, they use latent factor model of the yield curve, but they also explicitly incorporate macroeconomic factors and they analyzed the potential bidirectional feedback from the yield curve to the economy and economy to yield curve back again and they find strong evidence of macroeconomic effects on the future yield curve[8] and somewhat weaker evidence of yield curve effects on future macroeconomic developments.

Last but not least, it is a well known phenomenon that yield curves can predict the future economic recessions. This is a fertile area in economics for yield curves and there are plenty of studies in this field. Furlong (1989), Estrella and Mishkin (1998) Bernard and Gerlach (1998), Funke (1997), Dueker (1997), Chauvet and Potter (2001) are some examples which all claim that flattening of yield curve or an inverted yield curve is a signal for coming recession and the slope of the yield curve (or the yield spread) is one of the most useful indicator to forecast economic recessions for up to 4 quarter horizon.

[8] Diebold et al. analyzed correlations between Nelson-Siegel yield factors and macroeconomic variables. They find that the level factor is highly correlated with inflation, and the slope factor is highly correlated with real activity. They found curvature factor to be unrelated to any of the main macroeconomic variables.

## 4.3. Exchange Rate Prediction and Yield Curves

Exchange rate means the quotation of national currency in terms of foreign currencies. In other words, exchange rate is a price and if it is free to move, it can be the fastest moving price in economy. Exchange rate movement has become an important subject of studies of macro economy since the collapse of Breton Woods of fixed exchange rates system among major industrial countries. However, as Lam, Fung and Yu (2008) also mentioned, empirical results from many of the exchange rate forecasting models in the literature, no matter they are based on the economic fundamentals or sophisticated statistical construction, have not yielded satisfactory results. In other words, exchange rate prediction is one of the main interests of economists but it is still a very difficult task since economists could not define which factors affect the exchange rate movement especially in short run yet.

Exchange rate prediction models are grouped into three in the empirical literature namely, fundamental approach or structural models, technical approach and time series models.[9] Structural models are based on a wide range of economic variables such as GNP, consumption, trade balance, inflation rates, interest rates, unemployment, and productivity indexes etc. Lam et. al. (2008) investigate many candidates of structural models and summarize four most prominent theoretical models based on fundamental economic variables namely Purchasing Power Parity model (PPP), Uncovered Interest Rate Parity (UIP), Sticky Price Monetary (SP) Model and Bayesian Model Averaging (BMA) method.

PPP model explains the exchange rate movement with changes in price levels of the countries. That is, if Japanese goods are cheaper than the U.S. goods then demand for Japanese goods will increase and thus Japanese yen will appreciate until to US and Japanese goods have equal price. PPP can be expressed simply as:

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[9] Technical models and time series models are not in the scope of this study. This study tests the connection of macro fundamentals with exchange rate and their changeability by yield curve factors.

$$\ln e_t = \ln p_t - \ln p_t^* \quad \textbf{(4.13)}$$

where $e_t$ is nominal exchange rate, $p_t$ and $p_t^*$ are domestic and foreign prices respectively.

UIP model states that exchange rates move according to the expected returns of holding assets in two different currencies. That is, UIP states that arbitrage mechanism will bring exchange rate to a value that equalizes the returns on holding both the domestic and foreign assets. That is,

$$E_t(\ln e_{t+h} - \ln e_t) = i_t - i_t^* \quad \textbf{(4.14)}$$

where $E_t(\ln e_{t+h} - \ln e_t)$ is the market expectation of the exchange rate return from time $t$ to time $t+h$, and $i_t$ and $i_t^*$ are the interest rates of the domestic and foreign currencies respectively.

SP model is well known exchange rate model in literature which was developed and improved by Dornbusch (1976) and Frankel (1979). This model includes macro economic variables that capture the money demand. In Frankel (1979) SP model is stated as in the following form:

$$\ln e_t = \ln m_t - \ln m_t^* - \phi(\ln y_t - \ln y_t^*) + a(\ln i_t - i_t^*) + \beta(\pi_t - \pi_t^*) \quad \textbf{(4.15)}$$

where $m_t$ is the domestic money supply, $y_t$ is the domestic output, $i_t$ is the domestic interest rate, $\pi_t$ is the domestic current rate of expected long-run inflation, and all variables in asterisk denote variables of the foreign country.

Moreover, BMA method is specified as[10]:

$$\ln e_{t+h} - \ln e_t = X_t \beta + \in_t \qquad \textbf{(4.16)}$$

where $X_t$ is a T × (k +1) matrix of exchange rate determinants including the constant term, k is the number of exchange rate determinants, T is the number of observations,

β is a (k +1) ×1 matrix of parameters to be estimated. In this model 16 economic and financial variables are used as determinants of the model. These determinants are stock price, change in stock price, long-term interest rate, short-term interest rate, term spread, oil price, change in oil price, exchange rate return of the previous period, sign of exchange rate return of the previous period, seasonally adjusted real GDP, change in seasonally adjusted real GDP, seasonally adjusted money supply, change in seasonally adjusted money supply, consumer price level, inflation rate, ratio of current account to GDP.

In short, standard fundamental models found that standard exchange rate models hold that exchange rates are influenced by fundamental variables such as relative money supplies, outputs, inflation rates and interest rates. However, such variables do not help much to predict changes in floating exchange rates. In other words, exchange rate models perform poorly in out-of-sample prediction analysis, even though some of them have good fit in-sample analysis. That is, predicting exchange

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[10] See for details Leamer (1978) and Wright (2003).

rates by fundamental models is difficult and exchange rates rather follow random walk[11] and there is still much to do to form a better model to forecast exchange rates.

In previous section, the relationship between yield curve factors and macro variables are mentioned. Yield curve factors especially term spread or slope of the yield curve have the ability of predicting real activity, future path of inflation and recessions etc. The connection between yield curves and macro economic variables draw analysts to the question that “Can exchange rates be estimated by term structure of interest rates or yield curve factors?” since they include valuable macro economic information inside. Inci and Lu (2003) analyzed the term structure of interests and exchange rates together and found that term structure factors alone cannot satisfactorily explain exchange rate movements for US, UK and German markets. However, Chen and Tsang (2009) extract Nelson-Siegel factors of relative level, relative slope and relative curvature factors from cross country yield differences to forecast exchange rate change for UK, Canada, and Japan currencies relative to US currency. They found that the yield curve factors can be helpful in predicting exchange rates from 1 month to 2 years ahead and in fact, their model outperform the random walk in forecasting short-term exchange rate returns out of sample.

The relationship with exchange rates and yield curves may be very productive in contemporary economics and this study follows Chen and Tsang (2009) and tests the applicability of their model to Turkish financial market.

### 4.4. Studies in Yield Curve Estimation for Turkish Financial Market and Model Selection

Turkish Secondary Bonds and Bills Market were established in June 17, 1991. In the first years of the market it was not deep and broad enough to extract appropriate information from it. The average maturity of the transactions in the market was

[11] See Meese and Rogoff (1983a) which explains that exchange rates follow rather random walk and exchange rate models do not provide better forecast in out of sample analysis

considerably short. This was because of macroeconomic instabilities as well as the public borrowing policy of the Turkish Government. By the help of macro economic stabilization programs performed after 2000s, Turkey caught a series of low inflation and high growth rate periods. After the inflation rates reduced to low levels (even below 10%) Turkey had the opportunity of issuing bonds with long maturity last years. Therefore the information hidden in the bonds market grew up and this attracted the especially Turkish economists' interests. The studies related to bonds market increased after 2000s and some of them are mentioned below to extract an opinion of which yield curve model is the most appropriate for both yield curve estimation and exchange rate prediction for Turkish financial market.

To start, it can be said that there is not a clear consensus in the results of yield curve studies. That is, some of the studies found that spline methods are better for Turkey and some advised parametric methods to use. For instance;

Yoldaş (2002) used the yield data between 1994 and 2002 and he compared McCulloch cubic spline, Nelson-Siegel and Chambers-Carleton-Waldman exponential polynomial methods and he compared model performances by various metrics following the methodology developed by Bliss (1997). He found that in-sample fit of the exponential polynomial model is superior to the other two methods, especially on the longer end of the term structure.

Alper, Akdemir and Kazimov (2004) used both spline based method of McCulloch and parsimonious model of Nelson-Siegel to estimate monthly yield curves for the period between 1992 and 2004. They compared in sample and out-sample properties of the models and found that McCulloch method has superior in-sample properties, whereas Nelson-Siegel method has superior out-of-sample properties.

Beyazıt (2004) estimated zero coupon bond yield curve of next day by using Vasicek yield curve model with zero coupon bond yield data of previous day. He used the daily data for the period 1999 to 2004 and he completed missing data with Nelson-Siegel model. He concluded that by taking the Nelson-Siegel model as a benchmark he measured the performance of Vasicek model as a predictor and he found a considerable difference.

Memiş (2006) evaluated the performances of McCulloch cubic spline, Nelson-Siegel and Extended Nelson Siegel (ENS) yield curve models for the period 2002 and 2005. He compared in-sample and out sample performances of the models and he found that ENS model has the best performance both in in-sample and out-sample prediction properties.

Akıncı, Gürcihan, Gürkaynak, Özel (2006) estimated yield curve for Turkish secondary bond market by adding coupon bonds into data sets since there are not sufficient zero coupon bonds having long maturities. They estimated the yield curve in high frequency for the period February 2005 and December 2006. They used Extended Nelson Siegel (ENS) model to estimate the yield curve. They chose ENS model since ENS has a few parameters to be estimated and these parameters would not be affected from prices of individual bonds. They also pointed out that ENS could capture differences in the short and long segments of maturity horizon. In the study, they analyzed ENS model by some graphical representations and compared it with NS model and they concluded that ENS yield curve estimation is quite suitable for Turkish secondary bond market.

Baki (2006) compared the spline based model developed by McCulloch and parsimonious modeling of Nelson-Siegel model to estimate yield curve zero coupon Treasury bonds for the period between January 2005 and June 2005. He compared the performance of the models using in-sample goodness of fit and found that McCulloch model is better in model fitting than Nelson-Siegel model for Turkish secondary bond market.

Tarkoçin (2008) used four types of curve estimation methods for zero coupon bond yield namely Nelson-Siegel, Svensson (ENS), Cubic Spline and Smoothing Cubic Spline method. He compared the methods in terms of in sample and out sample performances by Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Weighted Mean Absolute Error (WMAE) values. He found that the better performing method is Smoothing Cubic Spline both in in-sample and out-sample properties. In addition, he suggested using Svensson method if a parametric method is to be used.

In this study, Extended Nelson Siegel model is used to estimate yield curve. Since it is quite appropriate for less liquid Turkish financial market[12] as mentioned above and it is not affected by idiosyncratic behavior of individual bonds and it can capture information of macro economic conditions which Turkey may face.

[12] See Chou, Su, Tang and Chen (2009) which uses ENS model to estimate yield curve for illiquid Taiwan bond market just as Turkish one.

# CHAPTER 5

# RELATIVE YIELD CURVES AND EXCHANGE RATE PREDICTION

## 5.1. The Approach

The main focus of the study is on the question "if relative yield curves can explain exchange rate movements or not" in Turkey (TR).

As a first step to do this, yield curve for the Turkish secondary bond market is needed to be estimated. To estimate the Turkish yield curve, bond data are gathered from Istanbul Stock Exchange (ISE) secondary bond market web site[13] and a complete bond database is constructed. Then, the data are filtered and redundant bonds are excluded from the database in order to have a similar data set for each day. Afterwards, the yield curve for each day is estimated by the ENS model by use of MATLAB.

Second, it is necessary to know United States (US) yield curves. To estimate the US yield curves, there are two ways. First, from database of Federal Reserve Bank of New York necessary data sets can be obtained and estimation can be made by the selected models. (However, this creates a heavy load on the study.) As a second way, we need to find the estimated parameters for the US bond market. Gurkaynak, Sack and Wright (2006) estimate yield curve parameters for US bond market by the ENS model on a daily basis and they publish the parameters. The yield curve parameter estimates Gurkaynak et. al. (2006) provide are valuable in the sense that yield curve can capture the macro economic conditions which US faces. Thus, in this study,

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[13] http://www.imkb.gov.tr/DailyBulletin/DailyBulletin.aspx

yield curve parameter estimates are used to determine the constant maturity yields for US Treasury bond market.

Third, the European Union (EU) yield curve is required as well. European Union Central Bank (ECB) estimates the Treasury bond market yield curve by the ENS model and publishes the ENS model parameters in its web site[14]. As the same manner done for US bond market the parameters are obtained and yields for constant maturities are calculated.

After estimating the yield curve for Turkish bond market and gathering the necessary parameters for US and EU market, it is easy to compute the yields for any maturity date desired. To compare TR–US–EU yields, yields for constant maturities of (30,60,90,120,150,180,210,240,270,300,330,360,390,420,450,480,510,540,570,600, 630,660,690,720,750,780,810,840,870,900,930,960,990,1020,1050,1080 days) are computed by the model formulations. Then US and EU yields are subtracted from the TR yields and yield differences are computed. These yield differentials are called as relative yields which are [Yield (TR) – Yield (US)] and [Yield (TR) – Yield (EU)] for the same maturity.

Although relative yields are not yields themselves, they are still important for exchange rate modeling since Uncovered Interest Parity (UIP) model explains exchange rate changes by interest rate differentials. Thus relative yields and corresponding maturity dates are used and relative yield curves are estimated by the Nelson-Siegel model for TR-US and TR-EU relative market. The parameters gathered from the NS model are called relative factors which are relative level, relative slope and relative curvature factors which will be discussed later in this chapter.

To model relative factors and exchange rate differentials, annualized log exchange rate differentials are computed and exchange rate differentials are regressed over the relative factors and results are discussed.

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[14] http://www.ecb.int/stats/money/yc/html/index.en.html

### 5.2. Yield Curve Estimation for Turkish Secondary Bond Market

#### 5.2.1. Data Description

The data are gathered from the Istanbul Stock Exchange (ISE) website[15] secondary bond market daily bulletin. In Turkey, secondary bond market is operated by ISE and it is improving year by year but it is not as deep as the ones in developed countries. Transaction volume of secondary bond market is illustrated for the past ten years in Figure A.1 in Appendix A. Total daily transaction volume was around 2 billion Turkish Liras (TL) at the beginning of 2000s and it had a peak in 2004 by 7 billion TLs. Transaction volume decreased to its normal level around 2-3 billion TLs in last two years. The Figure A.2 in Appendix A illustrates daily transaction volume (at around 2-3 Billion TL's) for the last two years. Each day at around 40 securities (government and private sector bonds and bills) are traded at ISE secondary bond market. The number of bonds and bills are not so much and the longest maturity which traded is not more than 5 years. In this study, data for the securities which traded last 3 years are used.

After January 1, 2006 Turkish Treasury imposed withholding tax on the issued bonds and bills. "Especially in the countries where the number of bonds issued are limited as in Turkey, using bonds with withholding tax and without holding tax together may distort the yield curves" (Akıncı, Gurcihan, Gurkaynak and Özel, 2006) Therefore, to focus only on the bonds with withholding tax and in order to form a similar data set with the data of US and EU secondary bond market which is published after 2007, this study includes the bond data after January 1, 2007.

The data contains 162 weekly datasets from 09.01.2007 to 16.03.2010. Second day of the week, that is, "Tuesday" daily bulletin data is used in the analysis in order to overcome the effects of weekends and undesired effects of starting day of week. It is also possible to use Wednesdays or Thursdays datasets. We think that, it will not

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[15] http://www.imkb.gov.tr/DailyBulletin/DailyBulletin.aspx

make much difference in the yield curve estimation since we believe that interest rate expectation does not change very much day by day in a week.

To estimate the yield curve properly, it is crucial to form a dataset containing the similar bonds in types, risk and liquidity. After gathering the data from the web site, a complete database containing all the data is formed and the database is filtered by the help of macro codes prepared in EXCEL which uses the rules explained below:

To filter the database and get a dataset containing similar bonds for each week, firstly coupon bonds, floating rate notes and inflation indexed bonds are excluded from the database. In other words, only the discount bonds are left in the database since coupon bonds, floating rate notes and inflation indexed bonds have different pricing approach and risk appearance. Then the private sector bonds are excluded that is, just government bonds are used to estimate the yield curve. Besides, the bonds which were issued in foreign currency and the bonds having forward effective date are also excluded from the database. In other words, the bonds issued in TL currency and the bonds whose agreement and transaction are made on same date are selected and the others are omitted. In addition, to overcome the well known liquidity problem, the bonds having time to maturity less than 10 days (some authors exclude the bonds having maturity less than 30 days or more) are excluded in the same manner as Alper, Akdemir and Kazimov (2004) suggested. Moreover, the bonds having the transaction volume less than 5% of the total transaction volume are also excluded since illiquid securities distort the yield curves.

After filtering operation, 162 distinct datasets containing yield and maturity pairs are constructed. An example dataset constructed is given in the Table 5.1 which includes day to maturity and yield information for 09.01.2007.

**Table 5.1 Dataset Obtained after Filtering Operation for 09.01.2007**

| Date | Day To Maturity | Weighted Average Yearly Compounded (Discrete) Yield | Weighted Average Price | Weighted Average Yearly Simple Yield | Transaction Volume (TL) | Continuously Compounded Yield |
|---|---|---|---|---|---|---|
| 09.01.2007 | 43 | 19,50 | 97,923 | 18,00 | 6.986.826 | 0,1781 |
| 09.01.2007 | 64 | 19,77 | 96,886 | 18,33 | 36.089.226 | 0,1804 |
| 09.01.2007 | 85 | 19,74 | 95,891 | 18,40 | 6.626.997 | 0,1802 |
| 09.01.2007 | 99 | 19,82 | 95,215 | 18,53 | 13.916.624 | 0,1808 |
| 09.01.2007 | 127 | 19,81 | 93,906 | 18,65 | 573.767 | 0,1807 |
| 09.01.2007 | 155 | 19,72 | 92,644 | 18,70 | 1.482.306 | 0,1800 |
| 09.01.2007 | 176 | 20,33 | 91,463 | 19,36 | 66.052.494 | 0,1851 |
| 09.01.2007 | 239 | 20,21 | 88,645 | 19,56 | 21.091.354 | 0,1841 |
| 09.01.2007 | 302 | 20,63 | 85,625 | 20,29 | 3.735.805 | 0,1876 |
| 09.01.2007 | 337 | 20,68 | 84,064 | 20,53 | 7.481.694 | 0,1880 |
| 09.01.2007 | 456 | 21,15 | 78,690 | 21,68 | 13.540.956 | 0,1919 |
| 09.01.2007 | 554 | 21,50 | 74,406 | 22,66 | 111.424.702 | 0,1947 |
| 09.01.2007 | 582 | 21,35 | 73,454 | 22,67 | 877.431.850 | 0,1935 |

ISE publishes the yield data in the form of “weighted average yearly compounded (discrete) yield” and “weighted average yearly simple yield”. However, in yield curve modeling “continuously compounded yields” in annual basis are used more often since calculations based on continuously compounded interest rates enable us to define some basic variables related to yield curves in terms of others. Thus in this study, continuously compounded interest rates are used.

“Continuously compounded interest rates” means that the interest rates are compounded for infinitesimally small period of times. In other words, interest is compounded infinitely many times. Converting the yearly compounded interest rate in discrete times to the continuously compounded one is simple process.

If "$r(m)$" is yearly compounded interest rate in discrete times for the maturity date $m$, then continuously compounded interest rate "$R(m)$" can be calculated simply by the following formula:

$$R(m) = \ln(1 + r(m)) \quad \textbf{(5.1)}$$

ISE provides interest rates compounded in discrete times. In this study, continuously compounded interest rate is calculated and used as zero coupon bond yields since continuously compounded interest rates are more often preferred in empirical literature. Bond yields are represented in the last column of the Table 5.1 above. As can be seen from the table, continuously compounded yields are less than weighted average yearly compounded (discrete) yield since compounding period is infinitesimally small.

In Table 5.2, number of bonds and bills and transaction volume before and after filtering operation are presented. After filtering operation according to the rules mentioned above, more than half of the bills and bonds are excluded from the database. Although most of the bonds are excluded, selected bonds are the most liquid ones and their transaction volume constitutes more than 55% of the total transaction volume. Thus, information hidden in the bond market does not vanish by filtering operation.

**Table 5.2 Comparison of Data Sets before and after Filtering Operation**

| | TOTAL BONDS AND BILLS | | FILTERED (SELECTED) BONDS | | |
|---|---|---|---|---|---|
| | Number of Bonds and Bills | Transaction Volume (TV) | Number of Bonds and Bills | Transaction Volume (TV) | Selected Bonds TV / Total TV |
| MAX | 51 | 3.774.642.618 | 16 | 2.254.406.544 | 89.5% |
| MIN | 28 | 364.921.614 | 11 | 200.201.824 | 22.1% |
| AVERAGE | 37 | 1.542.710.504 | 14 | 840.351.626 | 55.8% |

### 5.2.2. Model Formulation and Yield Curve Estimation Specifications

In previous chapters, it is mentioned that using parametric methods to estimate yield curve for the purpose of investigating macro economic variables is more appropriate. In addition, as mentioned in previous chapters, Extended Nelson Siegel model is better in sample fitting and out sample prediction than Nelson Siegel model in Turkish financial market.

To estimate the yield curve for Turkish secondary bond market, the parameters of Extended Nelson Siegel model must be determined by an optimization procedure. By the methodology defined and MATLAB code provided by Tarkoçin (2007), optimization process has been done and the parameters of the model are estimated.

Tarkoçin (2007) describes MATLAB procedures as the following explanations:

In MATLAB model, lsqcurvefit.m built-in function is used. This function uses minimum sum of squares of errors method to solve the nonlinear problems according to the form represented below.

$$\min_x \frac{1}{2}\left|\left|F(x,xdata)\text{-}ydata\right|\right| = \frac{1}{2} F(x,xdata_i)\text{-}ydata_i)^2 \quad \textbf{(5.2)}$$

[beta,resnorm,residual,exitflag,output,lambda]=lsqcurvefit('ens',beta0,xdata,ydata,lb,

ub,options);

The lsqcurvefit function above includes “ens” model formulization. Beta0 contains the initial values of the parameters which will be estimated, “xdata” contains the day to maturity which is independent variable in the model, “ydata” is dependent variable which is zero coupon bond yield. “lb” and “ub” are abbreviations for the lower bounds and upper bounds for the parameters which will be estimated. These bounds help the optimization procedure work faster. Finally the “options” includes the other properties given below.

options= optimset('Display','iter','MaxFunEvals',10000,'MaxIter',200,'TolFun',1e-8);

The “options” menu states that the calculation iterations will be represented, the maximum number of calculation of the function 10.000, maximum number of iteration is 200 and the tolerance for the value of function is 1e-8.

By using the procedure mentioned above and the MATLAB code given in Appendix B the yield curve is estimated for each week. But first, to estimate the yield curve for each week Day To Maturity (DTM) and Yield matrices are constituted in MATLAB. These matrices include 162 rows and 20 columns. Each row has data for each week and the MATLAB procedure uses each week data which are day to maturity and its corresponding yield data gathered from the matrices. The initial values of parameters are taken as defined by Tarkoçin (2008). Thus,

beta0 = [0.17 0,005 4.2 -4.2 136 135] for the first week optimization. For the following weeks the beta0 values are updated with the previous week’s parameter estimates.

Lower and upper bounds are also used and represented below:

lb = [0 -0.09 -25 -25 45 45 ]

ub = [0.30 0.03 25 25 450 450 ]

Using the initial values and lower and upper bounds given above the parameters of the ENS model are estimated for each Tuesday. The parameter estimates for 162 weeks after optimization are given in Appendix C.

The summary of the estimates are given in Table 5.3. According to Svensson parameterization $\beta_0$ shows the long run rates that the zero coupon yields will converge to. $\beta_0 + \beta_1$ can represent short rates and $\beta_2$ which is called the medium term component can explain the strength and direction of the first hump which will be expected to be exist in $\tau_1$ days. These parameters are also the parameters which exist in the Nelson-Siegel model. The additional parameters $\beta_3$ and $\tau_2$ in the model explain the strength and direction of second hump and where it will exist.

**Table 5.3 Summary of ENS Model Estimation Results**

| | $\beta_0$ | $\beta_1$ | $\beta_0 + \beta_1$ | $\beta_2$ | $\beta_3$ | $\tau_1$ | $\tau_2$ |
|---|---|---|---|---|---|---|---|
| AVERAGE | 0,146 | -0,024 | 0,122 | 4,191 | -4,180 | 98,11 | 97,61 |
| MINUMUM | 0,088 | -0,065 | 0,023 | 4,175 | -4,204 | 77,05 | 76,34 |
| MAXIMUM | 0,207 | 0,010 | 0,214 | 4,210 | -4,155 | 136,31 | 136,06 |
| STANDART DEVIATION | 0,032 | 0,025 | 0,057 | 0,008 | 0,010 | 19,67 | 19,60 |

As can be seen from the table above, zero coupon bond yields are expected to converge to %14,6 and short rates will be %12,2 on the average. $\beta_2$ has always positive sign. Thus, it can be expected that the first twist will be in the form of hump shape (not U shape) and it will occur when day to maturity is 98,11 days on the average. In the same manner, since $\beta_3$ has always negative sign then we can expect that the second twist in the curve will be in the form of U shape (not humped shape) and it will occur when day to maturity is 97,61, interestingly very close to the place of the first twist.

To interpret the estimated parameters of the model further, some graphical representations are given below. From the figures, the change of parameters by time can be seen.

In the Figure 5.1, the long and short term components are illustrated. According to this figure, long term component is usually above the short term component and they are nearly constant and very close to each other until 2009. But at that time, short and long term components started to decline where the decline in short rate is sharper. This is mostly because of the fact that, in parallel with the economic conditions' necessities, Central Bank of the Republic of Turkey (CBRT) continuously decreased the overnight borrowing and lending interest rates. These rates and the time when CBRT decreased them are given in Table D.1 in Appendix D. As can be seen from the table, CBRT decreased interest rates last years in parallel with the decline in the inflation rates. CBRT decreased interest rates in 2009 much more[16] compared to the last years due to the fact that inflation rates became very low (6,25 % in 2009). Moreover, the global financial crisis that hit the economy (GDP growth rate was 0,7 % in 2008 and -4,7 % in 2009) make it compulsory for CBRT to decrease the interest rates to stimulate the economy back.

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[16] In 19.12.2008 O/N interest rate was 15%. CBRT decreased the interest rates ten times in 2009 and O/N interest rates became 6,5% at the end of the year 2009.

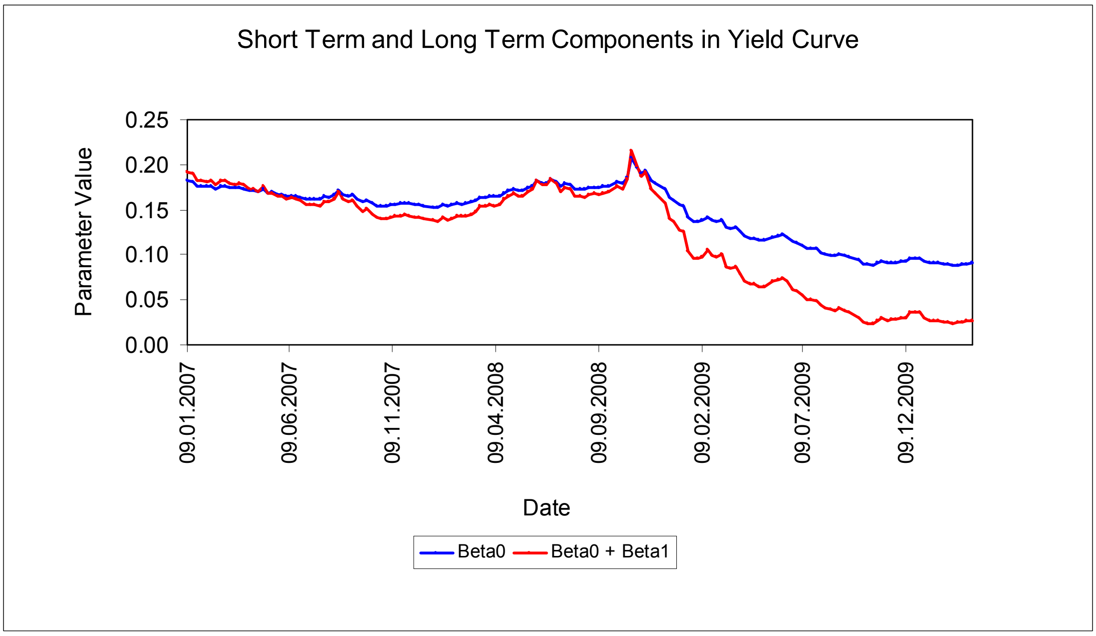


**Figure 5.1 Short Term and Long Term Components of Yield Curve Estimates by Date**

As can be seen from the figure above, the difference between long term and short term component is increasing steadily by the time. In fact, the differences in the NS and ENS models are called "term premium". The term premium itself is illustrated in Figure 5.2. The increase in the term premium can be interpreted as the players see the future as more risky (in terms of inflation or other economic risks) and they demand more yield from the bonds having longer maturities. In addition, it can be said that the players expect that the interest rates would increase back in the future because they expect that inflation rate may increase in the future again.

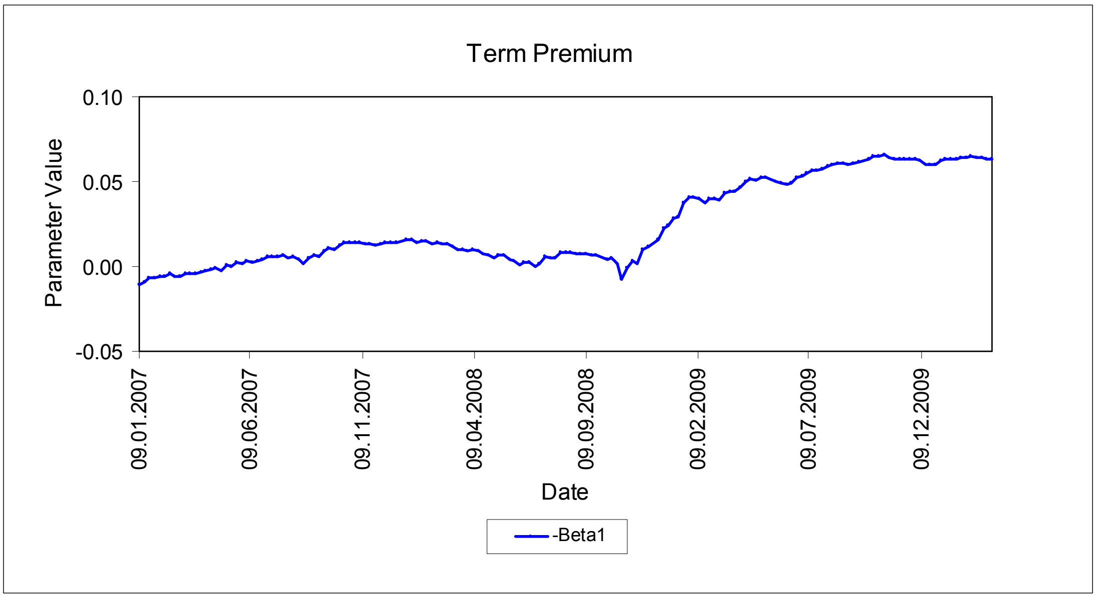


**Figure 5.2 Term Premium Estimates by Date**

From Figure 5.5 and Figure 5.6, it can be seen that $\beta_2$ and $\beta_3$ are nearly constant over the weeks and their absolute values are nearly the same. Similarly $\tau_1$ and $\tau_2$ are very close to each other. One can state that there is no need for the second hump and Nelson Siegel parameterization may be sufficient. This is mostly because of the fact that there are not many bonds which mature at longer horizons i.e. 5 or 10 years or more. But still, the practices and the literature suggest that Svensson parameterization is better for Turkish Secondary bond market since it gives less sum of square of yield error in applications.

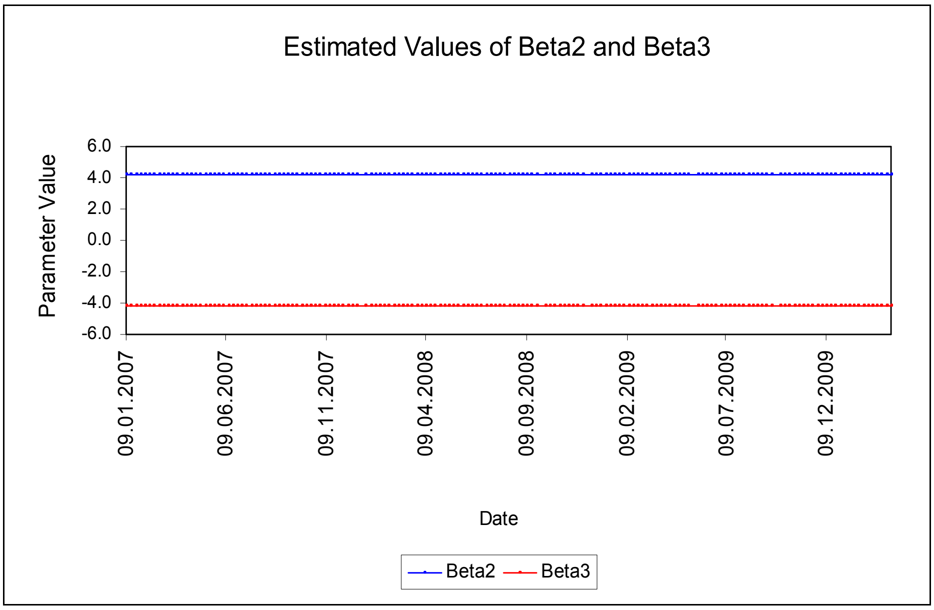


**Figure 5.3 Estimates of Beta2 and Beta3 values by date**

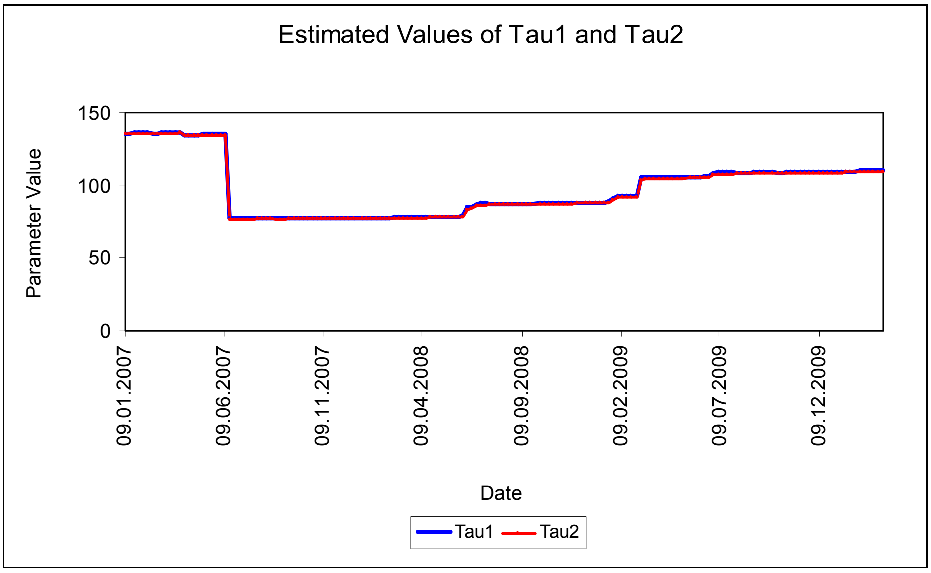


**Figure 5.4 Estimates of Tau1 and Tau2 values by date**

The Svensson parameterization is quite flexible for Turkish bond market and it can capture all the shapes which can exist in the market. Bond yields and corresponding yield curve estimations are illustrated below in Figures 5.5 to 5.8 for some selected days.

For 09.01.07 bond market data, the yield curve is estimated as monotonically increasing function. From the yield curve, we can infer that players demanded more interest rate as the day to maturity increased. For 08.01.2008, the yield curve is estimated as an increasing function up to DTM is 200 days where it twists and it has linear tile after then. For 06.01.2009, bond yield is decreasing with the day to maturity and yield curve is estimated as a decreasing function up to day to maturity is 200 days and it turns and it became an upward sloping function. For 16.03.2010, the yield curve is estimated as S-shaped curve. It has two twists. First one exists where DTM is 100 days and the second one is at 400 days.

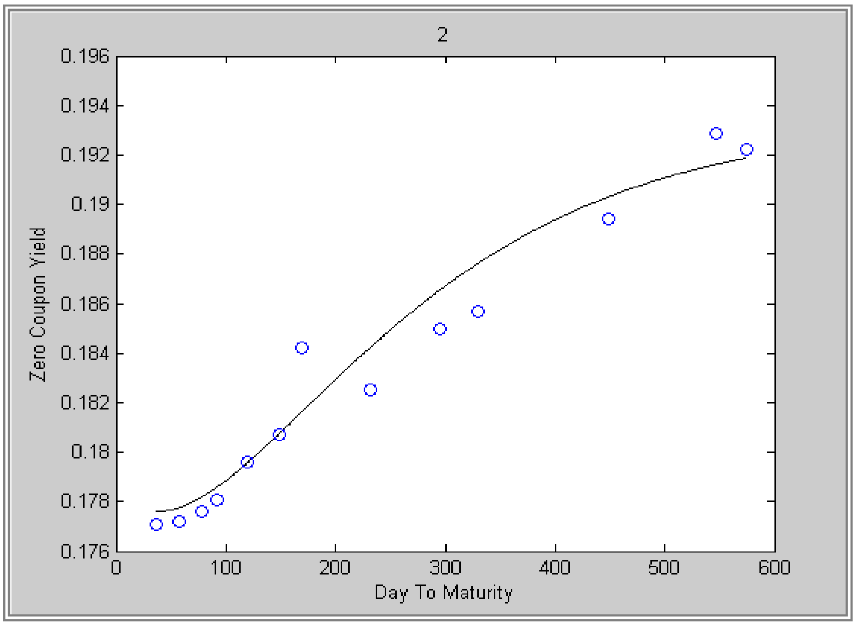


**Figure 5.5 Estimated Yield Curve for 09.01.2007**

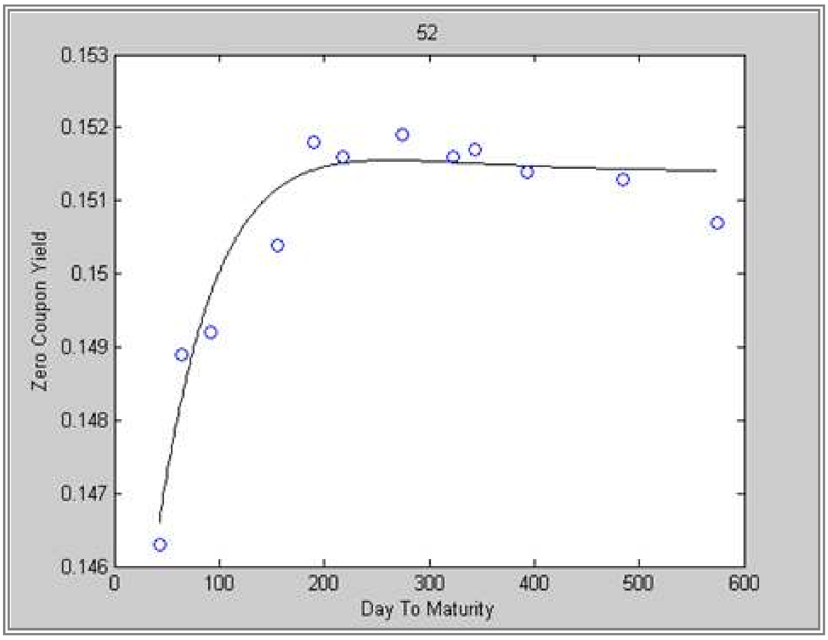


**Figure 5.6 Estimated Yield Curve for 08.01.2008**

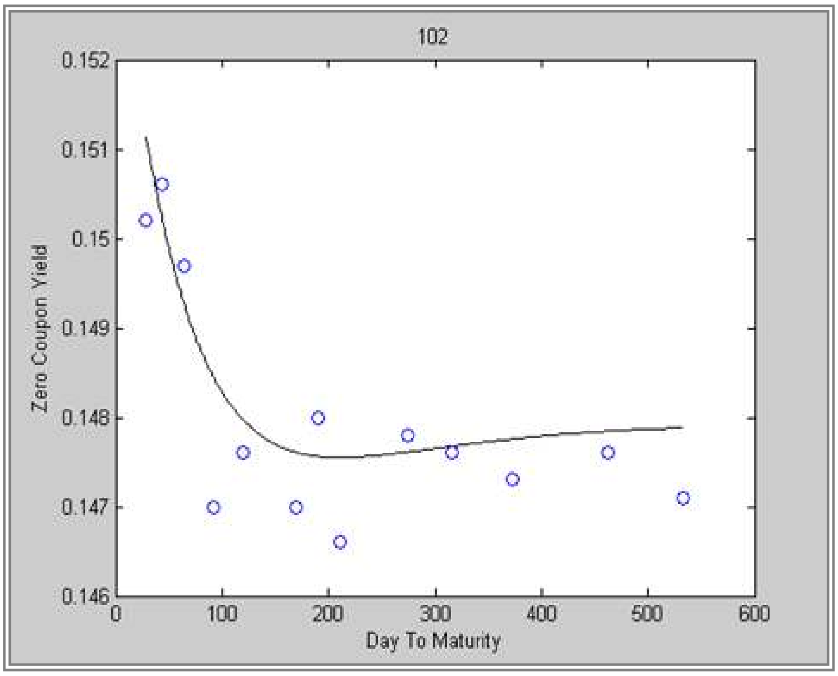


**Figure 5.7 Estimated Yield Curve for 06.01.2009**

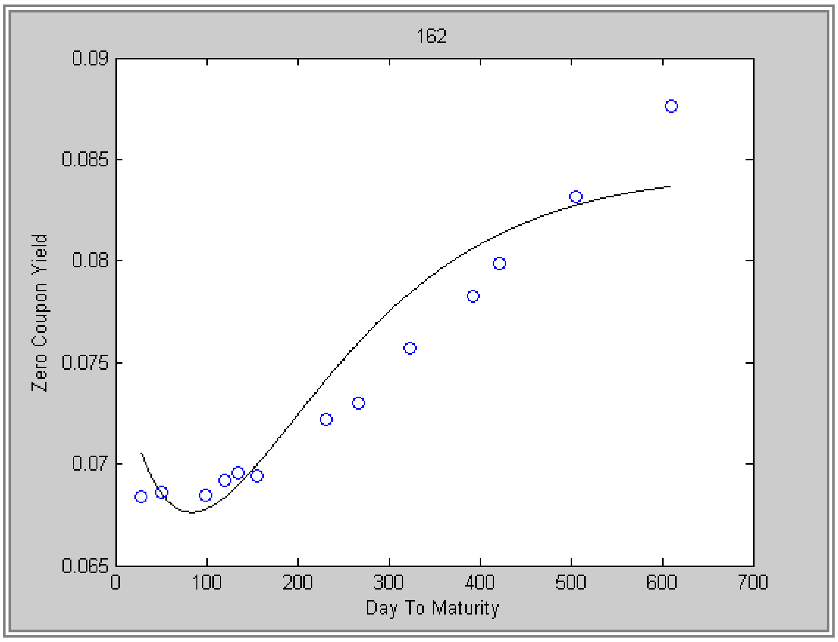


**Figure 5.8 Estimated Yield Curve for 06.01.2009**

## 5.3. Relative Yield Curve Estimation

### 5.3.1 Relative Yield Curve

For the rest of the study, Turkey (TR) is the home country; United States (US) and European Union (EU) are called foreign countries. The differences in the interest rates for the same maturity between countries are called relative yields.

In other words;

If we define $R(m)^{TR}$ as the yield computed for the maturity date $(m)$ for the Turkish secondary bond market and $R(m)^{US}$ and $R(m)^{EU}$ are the yields computed for the United States and European Union bond markets respectively. Then, Relative yield between Turkey and US is defined as

$$R(m)^{\mathrm{Re}l1} = R(m)^{TR} - R(m)^{US} \qquad \textbf{(5.3)}$$

Similarly, relative yield between Turkey and EU is defined as

$$R(m)^{\mathrm{Re}l2} = R(m)^{TR} - R(m)^{EU} \qquad \textbf{(5.4)}$$

where $R(m)^{\mathrm{Re}l1}$ and $R(m)^{\mathrm{Re}l2}$ are the relative yields.

The yield curve that relates the relative yields with their maturities can be called as relative yield curves. The relative yield curve has the same components and calculation methods as normal yield curves and they are estimated by the Nelson-Siegel model since the matter of the research is the analysis of the relationship between exchange rates and the relative factors of parsimonious Nelson-Siegel model.

To estimate relative yield curves, zero coupon bond yields for the constant maturities 30,60,90,120,150,180,210,240,270,300,330,360,390,420,450,480,510,540,570,600,630,660,690,720,750,780,810,840,870,900,930,960,990,1020,1050,1080 days for each week from 09.01.2007 to 16.03.2010 are calculated by ENS parameterization of each country. Afterwards, relative yields are calculated. Then, 36 data pairs containing relative yields and their corresponding maturities for each week are obtained. Finally, relative yield curves are estimated by the Nelson-Siegel parameterization.

The relative yield curve for TR – US can be parameterized as follows:

$$R(m)^{Rel1} = \beta_{0(r1)} + (\beta_{1(r1)} + \beta_{2(r1)}) * \left[1 - \exp(-m/\tau_{(r1)})\right] / (m/\tau_{(r1)}) - \beta_{2(r1)} * \left[\exp(-m/\tau_{(r1)})\right] \quad \textbf{(5.5)}$$

and relative yield curve for TR –EU can be defined follows:

$$R(m)^{Rel2} = \beta_{0(r2)} + (\beta_{1(r2)} + \beta_{2(r2)}) * \left[1 - \exp(-m/\tau_{(r2)})\right] / (m/\tau_{(r2)}) - \beta_{2(r2)} * \left[\exp(-m/\tau_{(r2)})\right] \quad \textbf{(5.6)}$$

The Nelson-Siegel factors obtained from the relative yield curves can be called as relative factors namely, relative level, relative slope, and relative curvature factors.

### 5.3.2. TR - US Relative Yield Curve

To estimate the TR - US relative yield curve, it is necessary to get the yield curve data for US Treasury bond market. Gurkaynak, Sack and Wright (2006) estimated US Treasury yield curve and they provided high frequency yield curve estimates. They made public the Treasury yield curve estimates of Federal Reserve Board at a daily frequency from 1961 to present in FED's website[17].

They get bond data from two sources. For the period 14 June 1961 to end of 1987 they use the CRSP daily Treasury file and since December 1987 they use Federal

[17] http://www.federalreserve.gov/pubs/feds/2006

Reserve Bank of New York (FRBNY) database constructed from several sources of market information.

They chose a set of securities which are similar in terms of liquidity and which do not have special features that would affect their prices. In other words, they constituted dataset ideally have securities that only differ in terms of their coupons and maturities.

To some extent, they exclude option like features, including callable bonds and flower bonds, all securities with less than three months to maturity and Treasury bills are out of concern. As to segmented markets, some twenty-year bonds and some securities which are decided by ad hoc basis were excluded.

Their primary objective in estimating the yield curve is to understand its fundamental determinants such as macroeconomic conditions monetary policy prospects, perceived risks and investors risk preferences. Therefore, they used a parametric yield curve specification rather that than non-parametric estimation methods which can be affected by the idiosyncratic behavior of a small number of the securities. Thus, they applied Extended Nelson Siegel functional form that was proposed by the Svensson (1994) and they estimated the U.S. Treasury yield curve from June 1961 to the present.

The way Gurkaynak et. Al. (2006) applied to estimate US yield curve is analogous to the approach we used to determine the Turkish Treasury yield curve. Moreover, they used ENS model and they aimed to analyze and follow macroeconomic information that yield curve contains. Thus, this yield curve estimation is quite appropriate for us to use for relative yield curve estimation.

Gürkaynak et. Al. (2006) published ENS model parameters for zero coupon yield curve, par yield curve and forward rate curves. To calculate the yields for constant maturities which were defined above, we used zero coupon yield curve parameters since we estimated zero coupon yield curve for Turkish treasury.

For each Tuesdays between 09.01.2007 and 16.03.2010 (158 weeks, two weeks are missing according to TR yield curve data) US treasury yield estimates for the constant maturities defined above are calculated from the zero coupon yield curve which was estimated by ENS model.

Zero coupon yields for some maturity dates between 30 days and 1080 days are calculated from the ENS model for US and represented in Table 5.4 below for the US bond market.

**Table 5.4 Zero Coupon Yields Calculated for US Bond Market for Some Selected Maturities**

| MATURITY (DAYS) | 30 | 150 | 300 | 450 | 600 | 750 | 900 |
|---|---|---|---|---|---|---|---|
| MIN | 0,01% | 0,09% | 0,23% | 0,33% | 0,34% | 0,39% | 0,48% |
| MAX | 5,24% | 5,18% | 5,08% | 5,03% | 5,04% | 5,04% | 5,05% |
| AVERAGE | 1,85% | 2,10% | 2,12% | 2,16% | 2,23% | 2,32% | 2,41% |

Similarly by ENS model estimated for Turkish Treasury bond market, Turkish zero coupon yields are calculated for the same constant maturities and some yields for the maturity pairs are summarized in the Table 5.5.

**Table 5.5 Zero Coupon Yields Calculated for TR Bond Market for Some Selected Maturities**

| MATURITY (DAYS) | 30 | 150 | 300 | 450 | 600 | 750 | 900 |
|---|---|---|---|---|---|---|---|
| MIN | 3,01% | 5,40% | 6,81% | 7,51% | 7,88% | 8,10% | 8,24% |
| MAX | 21,92% | 22,63% | 22,45% | 22,07% | 21,78% | 21,57% | 21,43% |
| AVERAGE | 12,38% | 13,57% | 14,35% | 14,60% | 14,67% | 14,67% | 14,67% |

After calculating TR yields and US yields, TR-US relative yields are calculated by TR yield minus US yield for each constant maturity defined. Some relative yields and maturity pairs are summarized in the table below.

**Table 5.6 Relative Yields Calculated for TR-US Relative Market**

| MATURITY (DAYS) | 30 | 150 | 300 | 450 | 600 | 750 | 900 |
|---|---|---|---|---|---|---|---|
| MIN | 3,0% | 5,3% | 6,5% | 7,0% | 7,1% | 7,2% | 7,1% |
| MAX | 21,5% | 20,9% | 20,9% | 20,6% | 20,3% | 20,1% | 19,8% |
| AVERAGE | 10,5% | 11,5% | 12,2% | 12,4% | 12,4% | 12,4% | 12,3% |

Using relative yields calculated and constant maturities defined above the TR – US relative yield curve is estimated by the NS model specification with the help of MATLAB code prepared by Tarkoçin (2008). Since Nelson Siegel factors contain information about macro economic variables, they can be useful in predicting exchange rates. The estimated NS relative factors for relative yield curve for each week are summarized in Table 5.7 and TR-US relative factors are illustrated in Figure 5.9.

**Table 5.7 Relative Yield Curve Factors Calculated for TR-US Relative Market**

| | $\beta_{0(r1)}$ | $\beta_{1(r1)}$ | $\beta_{0(r1)}+\beta_{1(r1)}$ | $\beta_{2(r1)}$ | $\tau_{(r1)}$ |
|---|---|---|---|---|---|
| AVERAGE | 0,127 | -0,037 | 0,089 | 0,025 | 221,91 |
| MINUMUM | 0,075 | -0,074 | 0,001 | -0,019 | 43,81 |
| MAXIMUM | 0,202 | 0,005 | 0,208 | 0,061 | 600,00 |
| STANDART DEVIATION | 0,029 | 0,021 | 0,051 | 0,023 | 160,13 |

Relative factors above have the same definitions for NS factors defined before. For instance; $\beta_{0(r1)}$ represents long term component and relative level of relative TR-US yield curve. The subscript (r1) stands for "first relative yield curve" representation that is for TR-US

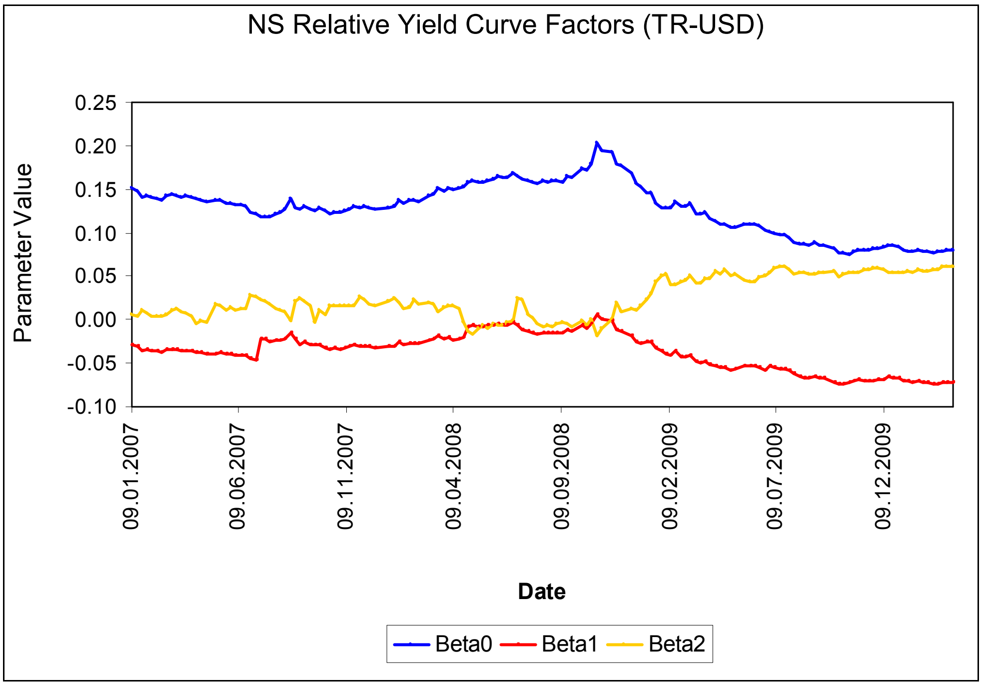


**Figure 5.9 Relative Factors Estimated for TR-US Relative Yield Curves**

### 5.3.3. TR - EUR Relative Yield Curve

Euro Area (EUR) yield curve is estimated by the European Central Bank (ECB) by ENS model and the parameters are published at ECB website.[18] Therefore, instead of estimating EUR yield curve itself, the published yield curve parameters are used in this study.

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[18] http://www.ecb.int/stats/money/yc/html/index.en.html

ECB estimates the zero coupon yield curves for Euro Area and derives forward and par yield curves. To estimate the curve, ECB uses zero coupon bonds and fixed coupon bond prices and yields.

ECB gathers bond and price information from EuroMTS Ltd. and uses following criteria when selecting bonds:

- Only bonds issued in Euro by Euro Area central government (European System of Accounts 1995: sector code 'S.1311') are selected.
- Only bonds with an outstanding amount of at least € 5 billion are included.
- Bonds with special features, including ones with specific institutional arrangements, are excluded.
- Only fixed coupon bonds with a finite maturity and zero coupon bonds are selected, including STRIPS. Variable coupon bonds, including inflation-linked bonds, and perpetual bonds, are not included.
- Only fixed coupon bonds with a finite maturity and zero coupon bonds are selected, including STRIPS (Separate Trading of Registered Interest and Principal of Securities). Variable coupon bonds, including inflation-linked bonds, and perpetual bonds, are not included.
- Only actively traded central government bonds with a maximum bid-ask spread per quote of three basis points are selected. The prices/yields are those at close of market on the reference day.
- In order to reflect a sufficient market depth, the residual maturity brackets have been fixed as ranging from three months up to and including 30 years of residual maturity.

Moreover bonds are removed if their yields deviate by more than twice the standard deviation from the average yield in the same maturity bracket. Afterwards, the same procedure is repeated.

In ECB web site, daily yield curves and the yield curve parameters are available from 29 December 2006, the last trading day in 2006, and are calculated and released on a daily basis.

ECB estimates the yield curve by means of a modeling algorithm that minimizes the sum of the quadratic difference between the yields that can be computed from the curve and the yields actually measured. ECB uses the interest rates as continuously compounded and they do not do any adjustments for tax and coupon effects. The bank uses Svensson methodology and applies ENS model to estimate the yield curve. Thus, it is analogous to the way we apply to estimate the TR yield curve and Gurkaynak et. Al. (2006) did to estimate the US yield curve.

ENS model parameters are gathered and EU yields are computed for the constant maturities defined before for each Tuesdays, for the weeks between 09.01.2007 and 16.03.2010. Estimates of the yields for some maturities between 30 days and 1080 days are represented in Table 5.8.

**Table 5.8 Zero Coupon Yields Calculated for EU Bond Market for Some Selected Maturities**

| MATURITY (DAYS) | 30 | 150 | 300 | 450 | 600 | 750 | 900 |
|---|---|---|---|---|---|---|---|
| MIN | 0,24% | 0,21% | 0,29% | 0,42% | 0,54% | 0,65% | 0,75% |
| MAX | 4,76% | 4,64% | 4,49% | 4,56% | 4,62% | 4,65% | 4,67% |
| AVERAGE | 2,50% | 2,56% | 2,65% | 2,74% | 2,84% | 2,93% | 3,02% |

After calculating EUR yields, TR-EUR relative yields are calculated as Yield (TR) minus Yield (EUR) for each constant maturity and some relative yields and the maturity pairs are summarized in Table 5.9.

**Table 5.9 Relative Yields Calculated for TR-EU Relative Market**

| MATURITY (DAYS) | 30 | 150 | 300 | 450 | 600 | 750 | 900 |
|---|---|---|---|---|---|---|---|
| MIN | 2,54% | 4,91% | 6,20% | 6,63% | 6,75% | 6,72% | 6,64% |
| MAX | 20,67% | 19,61% | 19,46% | 19,35% | 19,15% | 18,91% | 18,66% |
| AVERAGE | 9,88% | 11,01% | 11,70% | 11,86% | 11,83% | 11,74% | 11,65% |

As the same approach used to determine the TR-US yield curve, TR – EUR relative yield curve is estimated by Nelson Siegel model specification with the help of MATLAB code. The estimated Nelson Siegel factors for the relative yield curve for each week are summarized in Table 5.10 and how the relative factors changed by the time is illustrated in Figure 5.10.

**Table 5.10 Relative Yield Curve Factors Calculated for TR-EU Relative Market**

| | $\beta_{0(r2)}$ | $\beta_{1(r2)}$ | $\beta_{0(r2)}+\beta_{1(r2)}$ | $\beta_{2(r2)}$ | $\tau_{(r2)}$ |
|---|---|---|---|---|---|
| AVERAGE | 0,123 | -0,051 | 0,071 | 0,026 | 174,11 |
| MINUMUM | 0,070 | -0,079 | -0,009 | -0,019 | 38,70 |
| MAXIMUM | 0,199 | -0,021 | 0,177 | 0,063 | 600,00 |
| STANDART DEVIATION | 0,029 | 0,015 | 0,044 | 0,024 | 124,13 |

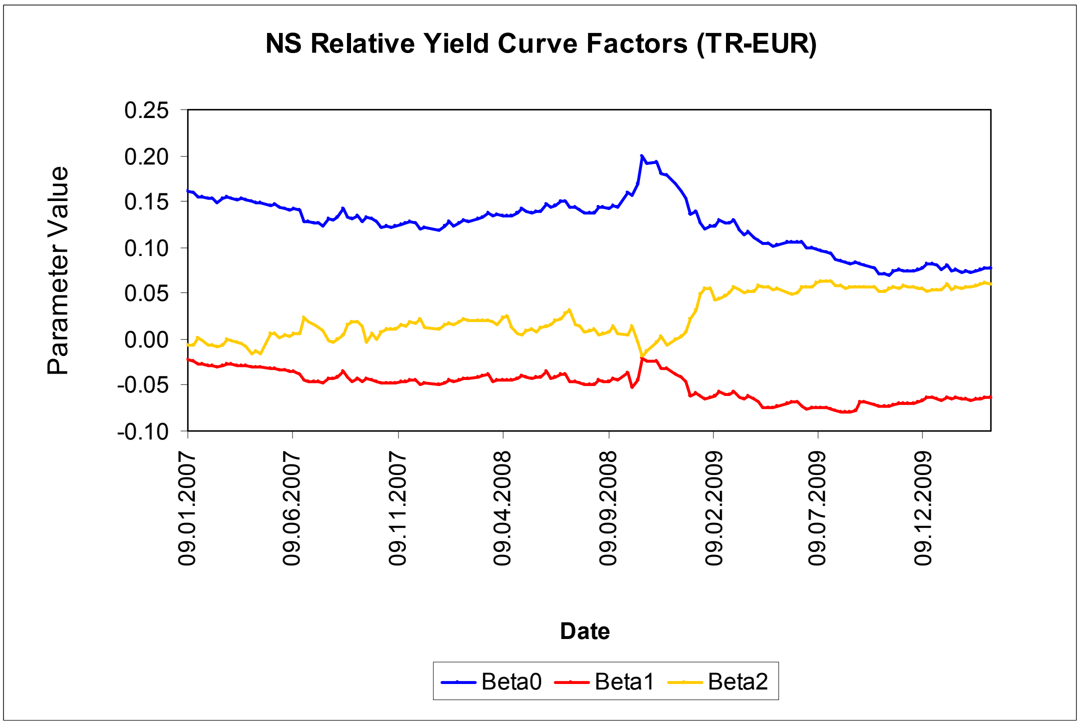


**Figure 5.10 Relative Factors Estimated for TR-EUR Relative Yield Curves**

As can be seen from Figure 5.9 and 5.10 relative factors do not have a fluctuating behavior until 2009 and they start to change at that time. This is mostly because of the fact that CBRT in Turkey decreased the interest rates so much and interest rate differentials are reduced after that time.

## 5.4. Exchange Rate Prediction

### 5.4.1. Exchange Rates and Relative Yield Curve Factors

In the study, Turkey (TR) is home country; United States (US) and European Union (EU) are foreign countries. The currency unit for home country is Turkish Lira and abbreviation for it is TL. Dollar (USD) is the currency used in United States and Euro (EUR) is the currency in the Euro Area countries.

Exchange rate is measured as Turkish Lira price of per unit of foreign currency. Thus, TL/USD and TL/EUR are exchange rates. A lower number means appreciation of home country and higher number means depreciation. In this study, exchange rate is defined by "*S*" and log exchange rate is defined by "*s*". In addition, exchange rate change is defined by annualized change of the log exchange rate *s*. This study uses log exchange rate -*s*- instead of exchange rate itself.

Exchange rate values are published by the Central Bank of the Republic of Turkey (CBRT). CBRT announces exchange rates at 15.30 everyday. The bank determines the exchange rates according to the purchasing and selling prices of foreign currency at interbank exchange rate market. Each day the bank gets exchange rate information from interbank exchange rate market 6 times a day at predetermined times. At the end of the day, it calculates the exchange rate by averaging the 6 exchange rate data to compute overall day value. The bank publishes four types of exchange rates namely, purchasing exchange rate, lending exchange rate, effective purchasing exchange rate, and effective lending exchange rate. In this paper, purchasing exchange rates are used and the data are obtained from Electronic Data Distribution System (EDDS) of CBRT.[19]

Exchange rate values for the period 09.01.2007 - 16.03.2010 are given in Table E.1 in Appendix E. Table 5.11 below summarizes the exchange rates in Turkey. In the period mentioned above TL/USD exchange rate is realized as 1,39 and TL/EUR is realized as 1,95 on the average. As can be seen from the table, deviation of exchange rates are not very small and TL/USD exchange rate changes between 1,15 and 1,80. TL/EUR has the similar deviation pattern and it deviated between the values 1,66 and 2,27 as well.

[19] http://tcmbf40.tcmb.gov.tr/cbt.html

**Table 5.11 Relative Yield Curve Factors Calculated for TR-US Relative Market**

| | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) |
|---|---|---|---|---|
| AVERAGE | 1,39 | 0,32 | 1,95 | 0,67 |
| MINUMUM | 1,15 | 0,14 | 1,66 | 0,51 |
| MAXIMUM | 1,80 | 0,59 | 2,27 | 0,82 |
| STANDART DEVIATION | 0,16 | 0,11 | 0,17 | 0,09 |

The Figure 5.11 below represents the exchange rates over the time selected in Turkey. From the figure, it can be seen that TL/USD and TL/EUR exchange rates move mostly together. That is, exchange rate lines are mostly in parallel. The starting values of exchange rates are 1,44 and 1,87 for TL/USD and TL/EUR respectively. Exchange rates declined in 2008 up to the 1,15 and 1,73. However, by the economic crisis that hit in 2008, the exchange rates started to increase by the end of the year 2008 and it declined a little back in 2009. Thus the radical change in the exchange rates occurred between the period 23.09.2008 and 10.03.2009. Exchange rates took their maximums at 10.03.2009. After that time exchange rates declined a little and it can be said that, they maintained their levels up to the date 09.12.2009.

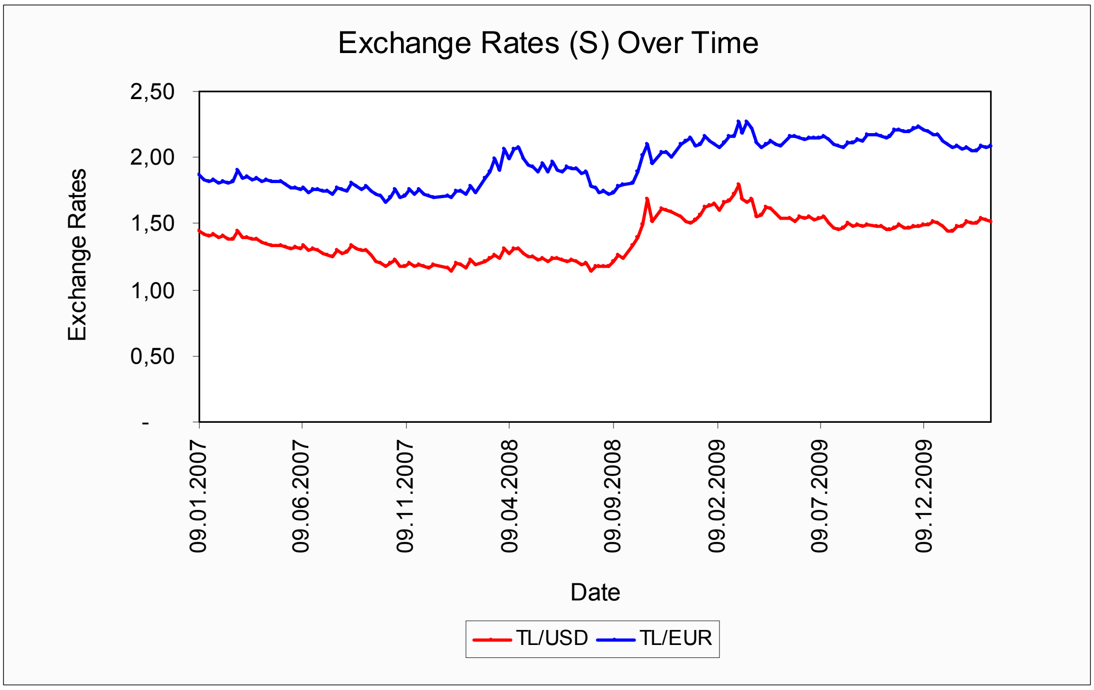


**Figure 5.11 Exchange Rates between the Period 2007 and 2010**

In the study, log exchange rate is used for regression analysis and log exchange rates are represented in Figure 5.12. The movements of log exchange rates are very similar to the exchange rates themselves since taking logarithm of any data does not change the structure of the data. That is ln(TL/USD) and ln(TL/EUR) lines are parallel and they take their minimums and maximums at the same point where TL/USD and TL/EUR takes.

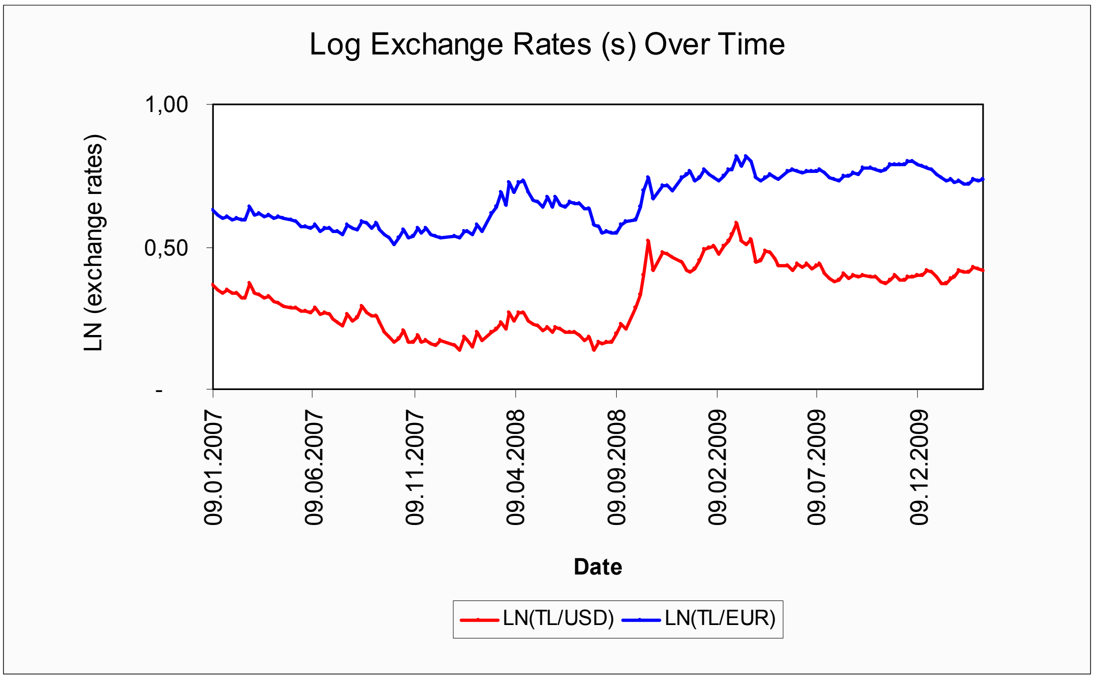


**Figure 5.12 Log Exchange Rates between the Period 2007 and 2010**

As mentioned in the previous chapters, we used continuously compounded interest rates in annual basis for Treasury bond yields. For convenience, exchange rate change is defined by annualized change of the log exchange rate s. Since the data we used has the frequency of a week, we need to convert the exchange rate change to annual basis.

To compute continuously compounded returns on exchange rate we can use following intuition.

If we define log exchange rate change is continuously compounded weekly return; $z_t = (s_t - s_{t-1})$ [20], then annual continuously compounded return is just the sum of 52 weekly continuously compounded returns:

$$z_t(52) = z_t + z_{t-1} + ....... + z_{t-51} \tag{5.7}$$

$$= \sum_{i=0}^{51} z_{t-i}$$

Then the average continuously compounded weekly return is defined as

$$\overline{z_t} = \frac{1}{52} * \sum_{i=0}^{51} z_{t-i} \tag{5.8}$$

Notice that,

$$52 * \overline{z_t} = \sum_{i=0}^{51} z_{t-i} \tag{5.9}$$

So that we may alternatively express $z_A$ as

---

[20] If nominal exchange rate is , $S_t$ Turkish Lira price of per unit of foreign currency, then continuously compounded return on exchange rate is $ln(S_t / S_{t-1})$ which equals to $ln(S_t) - ln(S_{t-1})$ That also equals to $(s_t - s_{t-1})$ where small letter s defines log exchange rates.

$$z_A = 52 * \overline{z_t} \qquad \textbf{(5.10)}$$

In other words; if we assume that we receive the same return $z = \overline{z_t}$ for every week in a year, then the annual continuously compounded return is just 52 times the weekly continuously compounded return:

$$z_A = z_t(52) = 52 * \overline{z_t} \qquad \textbf{(5.11)}$$

By the same manner, if $z$ is continuously compounded *m*-weeks exchange rate return then it can be annualized by the formula:

$$z_A = 52 * \frac{z}{m} \qquad \textbf{(5.12)}$$

As mentioned before, Nelson-Siegel factors obtained from the relative yield curves **(5.5)**, **(5.6)** can be called as relative factors namely, relative level, relative slope, and relative curvature factors.

$\beta_{0(r1)}$ is the relative level factor ($L_t^{R1}$) obtained from TL-USD relative yield curve and similarly $\beta_{1(r1)}$ is the relative slope factor ($S_t^{R1}$) (minus slope of yield curve), $\beta_{2(r1)}$ is the relative curvature factor ($C_t^{R1}$). Similarly, $\beta_{0(r2)}$ is the relative level factor ($L_t^{R2}$) obtained from TL-EUR relative yield curve and $\beta_{1(r2)}$ is the relative slope factor

($S_t^{R2}$) (minus slope of yield curve), $\beta_{2(r2)}$ the relative curvature factor ($C_t^{R2}$). Descriptive statistics for relative factors are given in Table F.1 in Appendix F.

The relative factors and log exchange rates are simultaneously represented in Figures F.1 to Figures F.6 in Appendix F. From the figures it can be seen that relative level and slope factors are increasing up to the end of year 2008. By the beginning of 2009 although exchange rates begin to increase the relative level and slope factors diminishes. Among the three relative factors, the relative curvature factor is most fluctuating one and from the figures, we do not see a consistent pattern between the relative factors and log exchange rates.

To get deeper insight between relative factors and log exchange rates, we provided the correlation matrices in Table F.2 and in Table F.3 in Appendix F. From the tables it can be said that, almost there is no correlation between relative factors and exchange rate change. However, there are high correlations between relative factors each other. For instance, correlation between relative curvature and relative level is 0,95 and for TR-USD relative yield curve. There is also correlation between other variables which may cause multicollinearity problem in regression analysis which will be discussed later.

### 5.4.2. Regression Analysis

To test if the relative factors can predict the exchange rate changes in sample, the regression models given in **(5.13)** and **(5.14)** are to be run for the horizons m = 1 (where "*m*" is horizons in weeks) and 2, 3, 4, 5, 6, 7, 8, 9, 10, 26, 52, 104.

For TL/USD

$$\frac{52(s_{(t+m)} - s_t)}{m} = \beta_0 + \beta_1 L_t^{R1} + \beta_2 S_t^{R1} + \beta_3 C_t^{R1} + u_t \qquad \textbf{(5.13)}$$

For TL/EUR

$$\frac{52(s_{(t+m)} - s_t)}{m} = \beta_0 + \beta_1 L_t^{R2} + \beta_2 S_t^{R2} + \beta_3 C_t^{R2} + v_t \qquad \textbf{(5.14)}$$

### 5.4.2.1. Correlation between Variables and Multicollinearity

For a good regression model, there is an implicit assumption that the explanatory variables are independent of each other. That is, explanatory variables should be orthogonal to each other. Indeed the explanatory variables are not always independent and correlation between the variables usually occurs. However, a problem may occur when the explanatory variables are very highly correlated with each other, and this problem is known as multicollinearity (Brooks, 2008)

Some problems may occur if multicollinearity exists between variables and if it is ignored. To some extent, Rsquare may be high but coefficient estimates will have high standard errors and individual variables are not significant. Second, the regression becomes very sensitive to small changes in the specification. Finally, multicollinearity will make confidence intervals for the parameters very wide, and significance tests might therefore give inappropriate conclusions, and so make it difficult to draw sharp inference (Brooks, 2008)

Thus, we need to check if there exists multicollinearity between the explanatory variables. In Table F.2 and Table F.3 in Appendix F correlation matrices for all variables (exchange rate change and relative factors) are given. According to Table 6.2, there is high correlation between relative factors. In fact, the correlations between TL-USD relative factors are so high that we can say that there exists a perfect multicollinearity between variables. For instance correlation between relative slope and relative curvature factor is 0, 95.

Similarly, in Table 6.3 correlation matrix for TL-EUR relative factors is given. The table shows that there is high correlation between relative factors such that correlation between relative curvature and relative slope factor is -0, 93.

Since there is multicollinearity between explanatory variables, regression analysis will not be trustable. Therefore, we may use some ad hoc methods to deal with the multicollinearity issue, such as ignoring it, dropping one of the collinear variables or transforming the highly correlated variables into a ratio. However, we need to check if the data series are stationary or not before trying to get rid of multicollinearity.

#### 5.4.2.2. Testing for Unit Root in Variables

Before we make regression analysis,we also need to check if the variables are stationary or not. A stationary data series is defined as one with a constant mean, constant variance and constant autocovariances for each given lag. Testing data if it is stationary or not is very crucial in regression analysis since the use of non-stationary data can lead to spurious regressions. If two variables are trending over time, a regression of one on the other could have a high $R^2$ even if the two are totally unrelated. So, if standard regression techniques are applied to non-stationary data, the end result could be a regression that 'looks' good under standard measures (significant coefficient estimates and a high RSquare), but which is really valueless. Such a model would be termed a 'spurious regression' (Brooks, 2008)

If the data is not stationary then it can be said that it includes unit root. To test whether the variables have unit root or not; a popular unit root test, which is Augmented Dickey-Fuller (ADF) test is applied to exchange rate changes and the relative factors data series by E-views software. In testing process, unit root is tested for all levels and lag length is automatically selected by Schwarz Information Criterion (SIC). Maximum lag length is selected as 14 given as default by the E-views program.

Unit root test result for TL/USD log exchange rate change is given in Figure G.1 in Appendix G. In the figure, Augmented Dickey-Fuller test statistic is represented as -13,41 and the test critical values are given as -3,47, -2,88, -2,57 for 1%, 5% and 10% significance level respectively. Since ADF test statistic is more negative than the critical values for all significance level then $H_0$[21] is rejected for all levels.

The test is repeated for all variables (exchange rate changes and the relative factors) including for intercept, trend and intercept and none options given in the Unit Root Test menu. Test results are summarized in Table G.1 and Table G.2 in Appendix G. In these tables, ADF test statistic values and test critical values at 5% significance level are given. For a series to be non-stationary, ADF test statistic value must be more negative than the critical value. Thus according to Table G.1 only TL/USD exchange rate change is stationary and relative factors of TL-USD relative yield curve include unit root. Similarly, according to Table G.2 TL/EUR exchange rate change is stationary and relative factors of TL-EUR relative yield curve include unit root.

Stationary or non-stationary properties of a series may powerfully affect the behavior and properties of the data series. Moreover, the use of non-stationary data may cause a spurious regression. That is, coefficient estimates of variables may be significant under standard measures and regression may have high $R^2$ even if the dependent and independent variables are totally unrelated. Thus, using a non-stationary data in regression analysis is unsafe. Thus we need stationary series and we need to remove the unit root from data series.

"If Yt a non-stationary series, Yt must be differenced d times before it becomes stationary, then it is said to be integrated of order d. This would be written Yt ~ I(d). So if Yt ~ I(d) then $\Delta^d$ Yt ~ I(0)" (Brooks, 2008) In other words even if a data series is non-stationary, it can be made stationary by differencing method.

---

[21] For ADF test: $H_0$ : Yt ~ I(1) (series is not stationary)

$H_1$ : Yt ~ I(0) (series is stationary)

Before removing unit root from data series of relative factors, unit root test is repeated for differenced variables. That is, we checked unit root process in the first difference of explanatory variables $L_t^{R1}(-1)$, $S_t^{R1}(-1)$, $C_t^{R1}(-1)$, $L_t^{R2}(-1)$, $S_t^{R2}(-1)$, $C_t^{R2}(-1)$ Test results are summarized in Table G.3 and Table G.4 in Appendix G. As can be seen from the tables, calculated ADF test statistics are more negative than critical values at 5% level. Thus, we can conclude that relative variables are non-stationary but first difference variables are stationary. Therefore we can use first difference variables in regression analysis.

$L_t^{R1}(-1)$, $S_t^{R1}(-1)$, $C_t^{R1}(-1)$, $L_t^{R2}(-1)$, $S_t^{R2}(-1)$, $C_t^{R2}(-1)$ are first differenced relative factors. Descriptive statistics of these variables are given in Figure H.1 in Appendix H. We need also to check multicollinearity between the explanatory variables of the regression equations. Thus, correlation matrices between explanatory variables are given in Table H.2 and Table H.3 in Appendix H. As can be seen from the tables, Relative Slope (-1) and Relative Curvature (-1) variables can be called as correlated but in general, there is not much correlation between the explanatory variables. Then we can run regressions **(5.13)** and **(5.14)** given above. With the first differenced data series we get regression equations **(5.15)** and **(5.16)** and we run them for the forecasting horizons m = 1 (where "m" is horizons in weeks) and 2, 3, 4, 5, 6, 7, 8, 9, 10, 26, 52, 104.

$$\frac{52(s_{(t+m)} - s_t)}{m} = \beta_0 + \beta_1 L_t^{R1}(-1) + \beta_2 S_t^{R1}(-1) + \beta_3 C_t^{R1}(-1) + u_t \qquad \textbf{(5.15)}$$

$$\frac{52(s_{(t+m)} - s_t)}{m} = \beta_0 + \beta_1 L_t^{R2}(-1) + \beta_2 S_t^{R2}(-1) + \beta_3 C_t^{R2}(-1) + v_t \qquad \textbf{(5.16)}$$

### 5.4.2.3. Overlapping Data Problem

As Chen and Tsang (2009) stated "It is well known that in longer horizon predictive analyses, one need to address inference bias due to overlapping data". That is, when the horizon *(m)* for exchange rate change is more than 1 month, left hand side variable overlaps across observations and errors in regression equations will be moving average process of order *m-1*.Therefore, statistics such as the standard errors will be biased. Chen and Tsang tried two alternative methods to get rid of inference bias. First, they followed Parker and Julliard (2005) and set up Monte Carlo experiment under the null hypothesis that the exchange rate follows a random walk. They expected that Monte Carlo experiment would determine if the exchange rate is truly unpredictable as a random walk, the experiment results would tell the probability that the predictability found is spurious. An alternative method they used for correcting the long-horizon bias is to use the re-scaled t-statistic suggested by Moon, Rubia and Valkanov (2004) and Valkanov (2003).

Moon, Rubia and Valkanov (2003) mentioned that the larger the forecasting horizon the larger bias for predictability of variables is observed. They also mentioned $\frac{t}{\sqrt{m}}$ (re-scaled t-statistic) has well defined limiting distribution. They found that re-scaled *t*-statistic is approximately standard normal.

Chen and Tsang (2009) compared both Monte Carlo experiment and re-scaled t-statistic approach and found that re-scaled t-statistic delivered more conservative inferences than the Monte Carlo experiments and they concluded to use re-scaled t-statistic to evaluate the significance of the variables for long horizon prediction process. In the same manner as Chen and Tsang used, re-scaled t-statistic is used in this study to evaluate the significance of variables for long horizon prediction analysis. To do this, regression equations were run for the first differenced variables and t-statistics are obtained. The calculated t-statistics are re-scaled by the factor $\frac{1}{\sqrt{m}}$ and re-scaled t-statistic is compared by the critical t values at 10% significance level. In other words, calculated t-statistic is divided by the square root of the prediction horizons.

Main results of the regression analysis are given in the next section.

#### 5.4.2.4. Main Results

The results of regression analysis are given in Table 5.12 and Table 5.13. As can be seen from the tables, for TL/USD exchange rate $L_t^{R1}(-1)$ is significant up to six weeks (for $m \leq 6$) prediction horizon, $C_t^{R1}(-1)$ is significant up to 2 weeks (for $m \leq 2$). However $S_t^{R1}(-1)$ is not significant for any prediction horizon[22]. That is, we can conclude that the first differenced relative level and relative curvature are statistically important for exchange rate change prediction only in short horizon, but slope coefficient does not bring any information about exchange rate prediction. The $R^2$ statistics (Rsquared and Adjusted R-squared) which shows how well the model fits to the data are 0,3 and less as the forecasting horizon gets larger.

[22] Residual analysis shows that error terms are normally distributed and there is no autocorrelation in error terms DW statistics is 2.1577 for (5.15) and 2.3826 for (5.16)

**Table 5.12 Regression Results for TL/USD Exchange Rate Difference over First Differenced Relative Factors**

| TL/USD | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Prediction Horizon | Included Observations | Parameter Coefficient | | | Rescaled T-Statistics [ T / Square(M) ] | | | R-Squared | Adjusted R-Squared | T critical 0.1 |
| | | LT | ST | CT | LT* | ST | CT* | | | |
| M=1 | 157 | 202,83 | -12,01 | 50,56 | 6,72 | -0,34 | 3,23 | 0,33 | 0,31 | 1,29 |
| M=2 | 156 | 100,29 | -30,69 | 22,78 | 3,14 | -0,82 | 1,37 | 0,14 | 0,13 | 1,29 |
| M=3 | 155 | 81,28 | -17,72 | 13,01 | 2,60 | -0,48 | 0,80 | 0,16 | 0,14 | 1,29 |
| M=4 | 154 | 81,76 | -31,66 | 13,12 | 2,50 | -0,83 | 0,77 | 0,17 | 0,15 | 1,29 |
| M=5 | 153 | 48,40 | -17,84 | 7,62 | 1,41 | -0,44 | 0,43 | 0,08 | 0,06 | 1,29 |
| M=6 | 152 | 51,60 | -25,67 | 4,57 | 1,52 | -0,65 | 0,26 | 0,10 | 0,08 | 1,29 |
| M=7 | 151 | 34,57 | -18,37 | 2,80 | 0,97 | -0,44 | 0,15 | 0,05 | 0,03 | 1,29 |
| M=8 | 150 | 31,97 | -21,56 | 0,67 | 0,91 | -0,53 | 0,04 | 0,05 | 0,03 | 1,29 |
| M=9 | 149 | 15,05 | -14,04 | -2,14 | 0,42 | -0,34 | -0,12 | 0,01 | -0,01 | 1,29 |
| M=10 | 148 | 10,94 | -9,99 | 0,32 | 0,30 | -0,24 | 0,02 | 0,01 | -0,01 | 1,29 |
| M=26 | 132 | -7,30 | -2,22 | 1,71 | -0,13 | -0,03 | 0,08 | 0,02 | 0,00 | 1,29 |
| M=52 | 106 | -5,83 | -3,65 | 0,91 | -0,11 | -0,05 | 0,04 | 0,05 | 0,02 | 1,29 |
| M=104 | 54 | -1,79 | -0,91 | 2,22 | -0,08 | -0,04 | 0,19 | 0,10 | 0,04 | 1,30 |

* Grey shaded variables are significant at 0,1 significance level

Similarly, Table 5.13 shows the outcome for TL/EUR exchange rate regression model. In the same way, relative level and curvature factors are statistically important up to 4 weeks ($m \leq 4$) and 1 week ($m = 1$) prediction horizon respectively. The prediction horizon for TL/EUR exchange rate change is even shorter than the one for TL/USD exchange rate. The $R^2$ statistics calculated for the regression equation are 0,2 and less.

**Table 5.13 Regression Results for TL/EUR Exchange Rate Difference over First Differenced Relative Factors**

| TL/EUR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Prediction Horizon | Included Observations | Parameter Coefficient | | | Rescaled T-Statistics [ T / Square(M) ] | | | R-Squared | Adjusted R-Squared | T critical 0.1 |
| | | LT | ST | CT | LT* | ST | CT* | | | |
| M=1 | 157 | 125,83 | -18,40 | 47,10 | 3,70 | -0,43 | 2,87 | 0,20 | 0,19 | 1,288 |
| M=2 | 156 | 54,30 | -11,14 | 11,94 | 1,63 | -0,27 | 0,74 | 0,08 | 0,07 | 1,288 |
| M=3 | 155 | 48,84 | -4,64 | 11,13 | 1,47 | -0,11 | 0,69 | 0,12 | 0,10 | 1,288 |
| M=4 | 154 | 48,66 | -25,52 | 9,32 | 1,44 | -0,60 | 0,57 | 0,08 | 0,06 | 1,288 |
| M=5 | 153 | 28,48 | -11,36 | 6,05 | 0,80 | -0,26 | 0,35 | 0,04 | 0,02 | 1,288 |
| M=6 | 152 | 21,96 | -8,62 | 2,69 | 0,61 | -0,19 | 0,15 | 0,03 | 0,01 | 1,288 |
| M=7 | 151 | 17,07 | -11,26 | -0,60 | 0,47 | -0,25 | -0,03 | 0,02 | 0,00 | 1,288 |
| M=8 | 150 | 12,52 | -2,29 | 1,13 | 0,35 | -0,05 | 0,07 | 0,02 | 0,00 | 1,288 |
| M=9 | 149 | 3,17 | -0,10 | -3,95 | 0,09 | 0,00 | -0,23 | 0,01 | -0,01 | 1,289 |
| M=10 | 148 | -2,34 | 5,24 | -2,04 | -0,07 | 0,12 | -0,12 | 0,00 | -0,02 | 1,289 |
| M=26 | 132 | -1,40 | -0,80 | 1,34 | -0,05 | -0,02 | 0,09 | 0,01 | -0,02 | 1,289 |
| M=52 | 106 | -5,35 | 6,61 | 0,87 | -0,25 | 0,26 | 0,07 | 0,04 | 0,01 | 1,292 |
| M=104 | 54 | 0,07 | 0,03 | -0,05 | 0,62 | 0,28 | -0,34 | 0,03 | -0,03 | 1,296 |

* Grey shaded variables are significant at 0,1 significance level

The most outstanding result of the regression analysis is that relative level and relative curvature factors are significant in exchange rate prediction for Turkish financial market. However these factors are only significant in short horizons and none of the factors are significant in long run.

### 5.4.3. Robustness Check

It is well known that the ability of an economic model to remain valid under different assumptions, parameters and initial conditions is called the robustness of the model. In other words, as Wimsatt (1981) uses the term, robustness means stability of a result under different and independent forms of determination, such as methods of observation, measurement, experiment or mathematical derivation. Finding out the same results by independent ways decrease invalid results due to errors or biases which may occur in individual way of the getting the result.

To make robustness check for the regression models **(5.15)** and **(5.16)** and to test the re-scaled t-statistics significance, non-overlapping data series are formed. That is, data series of exchange rate, and first differenced relative factors for second week of each month is used and regression model was run for prediction horizon as two weeks *(m=2)*. Similarly, the data series of last week of each month is used to predict exchange rate change for 4 weeks *(m=4)*. The procedure is repeated for *m=6* and regression equations were run. The results are given in Table 5.14. Since the data series used for regression analysis is non-overlapping, p-value is used to determine the significance of the variables. That is, re-scaled t-statistics is not used.

From the table, it can be seen that for regression **(5.15)** relative level is significant up to six week prediction horizon ($m \leq 6$) and relative curvature variable is significant up to two weeks' prediction horizon. ($m \leq 2$). This is the same result that we obtained by overlapping data. Thus, we can conclude that, the relative level and relative curvature factors are robust estimators for exchange rate change. Here again, relative slope factor is not significant for any horizon.

The results for TL/EUR prediction by non-overlapping data are somewhat different from the results obtained by overlapping data. By overlapping data, relative level is significant up to 4 weeks prediction horizon and relative curvature factor is significant for just 1 week prediction horizon. On the contrary, by overlapping data the case is the reverse. That is, relative curvature factor is significant up to 6 weeks and relative level factor is significant for just only 1 week and as in the case mentioned before, the relative slope factor does not contain any information about exchange rate change. From the robustness check, we can infer that, the relative level and the relative curvature contain about the exchange rate change but their prediction horizon differs according to the type of data series (overlapping or non-overlapping) used. Thus, we can say that the variables contain information but they are not robust in terms of prediction horizon.

**Table 5.14 Regression Results by Non-Overlapping Data (p-values)**

| | USD | | | EUR | | |
|---|---|---|---|---|---|---|
| | M=2* | M=4* | M=6* | M=2* | M=4* | M=6* |
| CONSTANT | 0,593 | 0,100 | 0,257 | 0,528 | 0,973 | 0,952 |
| RELATIVE LEVEL | 0,001 | 0,002 | 0,025 | 0,006 | 0,216 | 0,450 |
| RELATIVE SLOPE | 0,634 | 0,524 | 0,791 | 0,053 | 0,954 | 0,114 |
| RELATIVE CURVATURE | 0,000 | 0,058 | 0,247 | 0,017 | 0,032 | 0,013 |

* Grey shaded values are smaller than 0.1 and the variables are significant at 10% significance level

### 5.4.4 Discussion and Comparison with Random Walk Model

Exchange rate prediction is a very sophisticated issue and the analysts could not reach a high-quality prediction model for any economy yet. As the literature accepts, like weather forecasting, exchange rate forecasting has turned out to be notoriously difficult. In fact, Meese and Rogoff (1983a, 1983b, and 1985) found that any of structural exchange rate prediction models could not outperform simple random walk model in out of sample prediction analysis[23]. Meese and Rogoff studies formed a

[23] Although some structural models suggests that random walk model can be beaten at long horizon, number of studies showed that the behavior of foreign exchange rate market participants is to a large extent based on technical analysis of short-term trends or other patterns in the observed behavior of

breaking point in literature and almost all following exchange rate studies tried to reach a model better than random walk[24] and comparing the performance of a prediction model with random walk -especially in out sample analysis- became a famous trend among economists.

In the study, following Chen and Tsang (2009), a rolling window of with a size of five years is formed and constructed out-of-sample forecasts for one, two, and three weeks ahead and for each forecast squared prediction error is calculated. The first regression uses 60+*m* observations and forecasts spot exchange rate value of 60+2*m* (next period). Second regression moves forward and includes one more period data and forecasts the next exchange rate. This is continued up to end and Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) are calculated to compare with Random walk results.

In a random walk model, the series itself does not have to be random. However, its differences, the changes from one period to the next, are random. In other words, "The random walk hypothesis tells us that period to period changes in spot exchange rates are random and unpredictable. The spot exchange rate tomorrow is likely for to be above today's level as to be below it. Hence, the best forecast for tomorrow's exchange rate is today's rate." (Moosa, 2000 p. 134)

Driftless random walk model can be represented as following equation.

$$S_t = S_{t-1} + \in_t$$

---

the exchange rate and forecasting exchange rates in the short term using fundamentals is, indeed, more difficult than to forecast in the medium and long term. Taylor and Allen (1992).

[24] See for example Gandolfo, Padoan and Paladino (1990) "Structural Models vs Random Walk : The Case of the Lira/USD Exchange Rate"

in other words, exchange rate will differ from exchange rate of previous period's rate by a white noise where $\in_t$ satisfies the following conditions:

$$E(\in_t) = 0$$

$$E(\in_t \in_{t-j}) = \sigma^2_{\in} \quad \text{for j = 0}$$

$$E(\in_t \in_{t-j}) = 0 \quad \text{for j} \neq 0$$

Then the above equation can be rewritten as $\Delta S_t = \in_t$ That is, period to period changes in spot exchange rates are random and unpredictable.

Thus, it is accepted that best forecast value for tomorrow exchange rate is the today's rate especially in short run.

In fact forecasting horizon does not change the forecasts in random walk model. To extent, "The forecast value is the same irrespective of how far into the future we are forecasting (that is irrespective of the value of j) However, the forecasting error variance increases as the value of j increases." (Moosa, 2000 p. 135). In mathematical representation forecasting with random walk model can be represented by following form:

$$\hat{S}_{t+j} = S_{t-1} + \in_t$$

Relative factors in exchange rate model are significant up to maximum 6 weeks. (6 weeks for TL/USD and 4 weeks TL/USD) Therefore, we compared the performance of the model for 1, 2 and 3 weeks horizon with random walk. That is, forecasting performance of the model is tested over simple random walk (without drift) model for only very short end of horizon.

In the study, the out-of-sample accuracy of the forecasts is measured by two statistics; Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE). These are defined as follows:

$$RMSE = \left( \sqrt{\sum_{s=0}^{N-1} \frac{(F_s - A_s)^2}{N}} \right) \quad \text{and } MAE = \left( \sum_{s=0}^{N-1} \frac{|F_s - A_s|}{N} \right)$$

where s =1,2..3 means forecast steps in weeks, N is total number of forecast iterations, $A_s$ is actual and $F_s$ is forecast value of exchange rate.

Table 5.15 below summarizes Root Mean squared Error (RMSE) and the Mean Absolute Error (MAE) for Relative Factors Model (RFM) and simple Random Walk model (RW). The root mean square error is main criterion to compare the forecast performance but MAE is more useful if exchange rates follow a non-normal stable Paretian process with infinite variance or exchange rate distribution has fat tails with finite variance (Meese and Rogoff, 1983a)

**Table 5.15 Comparison of Performance of RFM and RW Models for TL/USD Exchange Rate Prediction**

| | Relative Factors Model | | Random Walk | |
|---|---|---|---|---|
| | RMSE | MAE | RMSE | MAE |
| M=1 | 0,045183 | 0,033095 | 0,039859 | 0,021675 |
| M=2 | 0,052610 | 0,037910 | 0,055106 | 0,036275 |
| M=3 | 0,065466 | 0,044636 | 0,065385 | 0,042863 |

* Grey shaded values are smaller in RMSE and MAE

**Table 5.16 Comparison of Performance of RFM and RW Models for TL/EUR Exchange Rate Prediction**

| | Relative Factors Model | | Random Walk | |
|---|---|---|---|---|
| | RMSE | MAE | RMSE | MAE |
| M=1 | 0,055995 | 0,043266 | 0,047312 | 0,034548 |
| M=2 | 0,061150 | 0,046569 | 0,059537 | 0,042398 |
| M=3 | 0,079008 | 0,056593 | 0,076063 | 0,053875 |

* Grey shaded values are smaller in RMSE and MAE

As can be seen from Table 5.15 and 5.16, forecast performances of RFM and RW model are not much different from each other since RMSE and MAE values are very close to each other. Although, errors are close, RFM model could not beat RW model since RMSE and MAE values obtained from RFM model are greater than RW model. In the table above grey shaded values are smaller in RMSE and MAE for both TL/USD and TL/EUR. Thus, we can conclude that, RFM model does not provide better forecast performance than random walk model in Turkish financial market.

Although, relative factor model could not beat random walk in short run (up to 3 weeks) it does not mean that RFM do not include any information since random walk models do not provide long horizon prediction performance well since forecasting error variance increases as forecasting horizon increases in random walk model. Thus, using RFM instead of RW model for longer horizons can provide better forecasting performance.

In fact, in Figure 5.13 and 5.14 actual and forecast values of TL/USD and TL/EUR exchange rates are illustrated. From the figures, it can be seen that RFM forecasts exchange rates quite well for 1 week horizon. That is, RFM model quite fits to actual values and follows the changes in exchange rates.

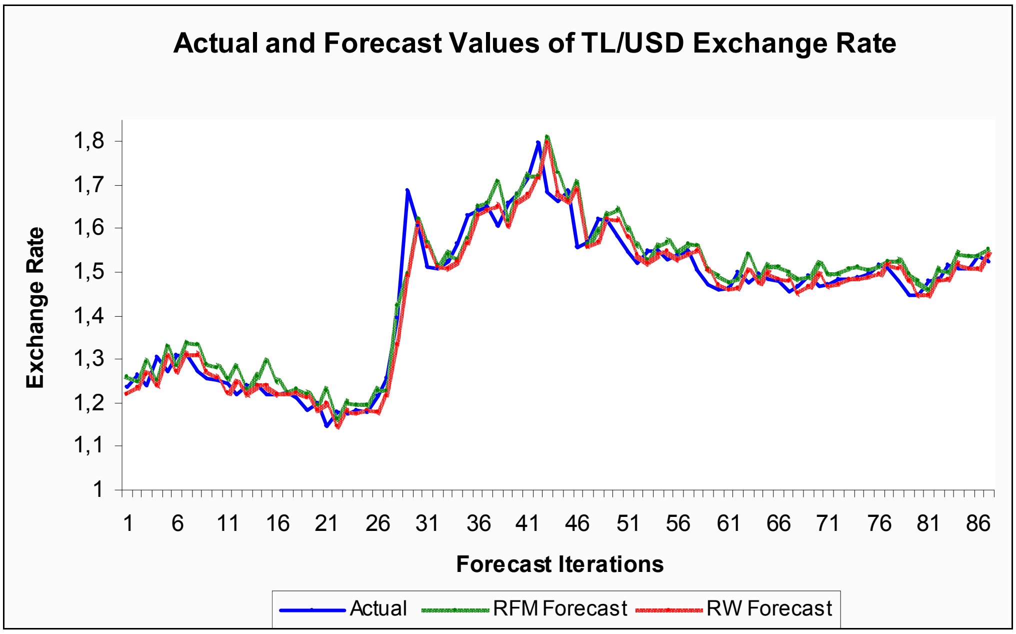


**Figure 5.13 Actual and Forecasted values of USD/TL Exchange Rate**

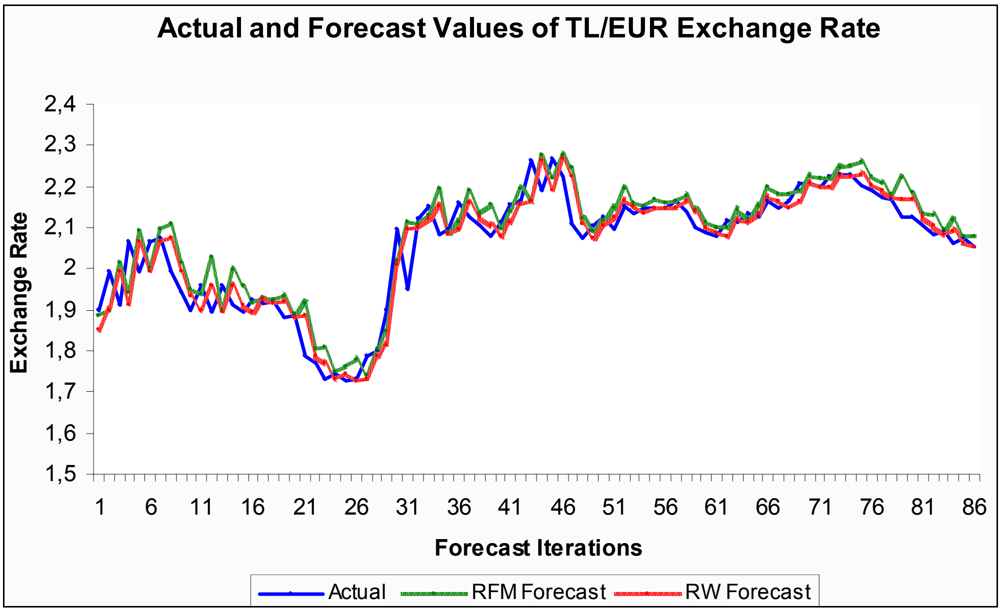


**Figure 5.14 Actual and Forecasted values of EUR/TL Exchange Rate**

# CHAPTER 6

# CONCLUSION

In this study, answer to the question “Can relative factors explain exchange rate movements?” in Turkish financial market is searched as Chen and Tsang (2009) suggests. Term structure of interest rates, or yield curves, includes precious macro economic information inside, such as GDP growth, inflation rate etc. Following Chen and Tsang (2009), this study constitutes a relative factor model to explain movements in TL/USD and TL/EUR exchange rates. Generally, exchange rate models are based upon directly to the macro economic variables. That is, exchange rate change is modeled by the level or change of some macro economic variables. However, relative factor model benefits from the information in yield curves and explains the exchange rate changes by relative factors namely, relative level, slope and curvature factors estimated from yield curves.

From the study, it is concluded that, relative level and relative curvature factors are significant in explaining both TL/USD and TL/EUR exchange rate changes. On the other hand, relative slope factor do not bring any information in exchange rate forecasting process. Regression analysis to forecast exchange rate change is made for both short horizons and long horizons, from 1 week and 2 years. The analysis shows that relative factor model is significant up to 6 weeks horizon for TL/USD and 4 weeks horizon for TL/EUR and the model could not a significant forecast for longer horizon in Turkish financial market. Although the results of the model fits to the actual values of exchange rates quite good, the comparison analysis shows that relative factor models do not provide a better performance than random walk up to 3 weeks horizon in Turkish financial market.

To sum up, the relative factors are significant in the sense that they can be useful in forecasting spot exchange rate for the future but they do not provide better forecasts than random walk for short horizon. Therefore, we can conclude an exchange rate model that fits to a market well may not be very appropriate for another. This may be result of structure of that economy. Turkish financial market was fragile up to last years but it is deepening year by year but it is still in infantry age. Thus, if the Turkey continues its low inflation rate and low interest rate period the information content in bond market may get widen and performance of relative factors model may be improved in the future.

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# APPENDICES

# APPENDIX A

# DAILY TRANSACTION VOLUME OF ISE

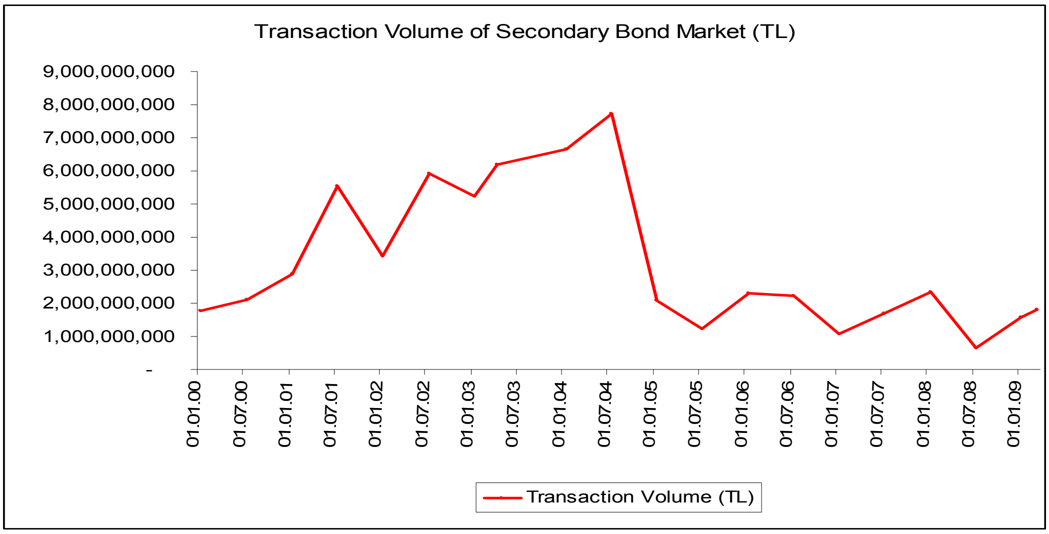


**Figure A.1: Transaction Volume in ISE Bond Market for Selected Days in between 2000 -2010**

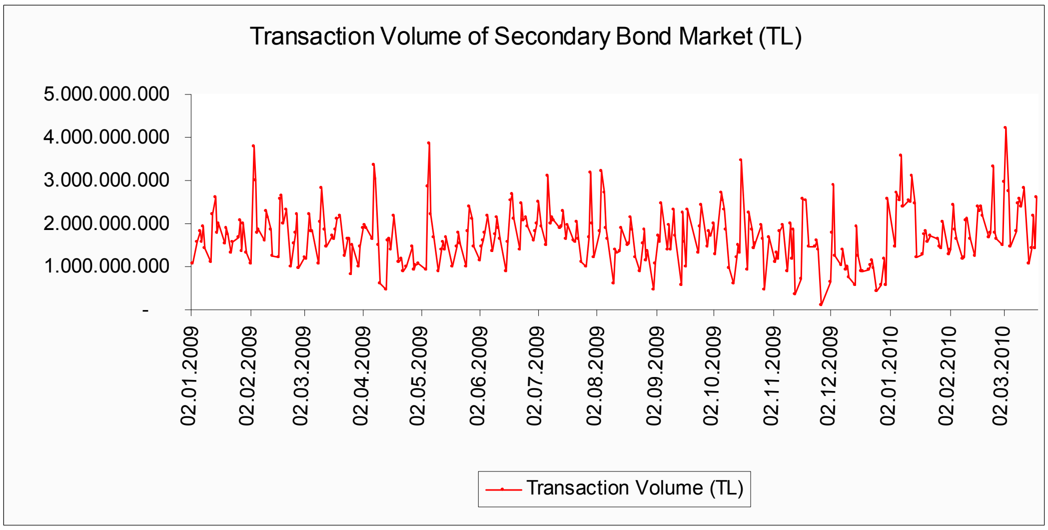


**Figure A.2: Daily Transaction Volume in ISE Bond Market from 2009 -2010**

# APPENDIX B

# MATLAB CODE FOR YIELD CURVE ESTIMATION BY SVENSSON MODEL (ENS)

```
close all; %

clear all ;%

load Sali %                    Loads the bond database. Containg DTM and Yield data.

disp(' ')

disp('ens4 -Svensson Method (Extented Nelson&Siegel)')



k=1;

l=162;

[m,n]=size(yield);

[a,b]=size(DTM);

if m ~= a || n~=b;

   error( 'yield and DTM vectors size should be same for a date ');

end

res_norm=zeros((l-k+1),1);

b=zeros((l-k+1),6);

aa=zeros((l-k+1),700);

resd=zeros((l-k+1),n);
```

```
v=length(vade);

ret=zeros((l-k+1),v);

resd=zeros(l-k+1,n);

beta0=[0.17  on(1)-0.17  4.2  -4.2  136  135] ;

for i=k:l;

lb=[0     -0.09   -25  -25   45   45 ];

ub=[0.30   0.03    25   25   450  450 ];

indices=find(yield(i,:));

ydata=yield(i,1:length(indices));

indices2=find(DTM(i,:));

xdata=DTM(i,1:length(indices2));

aa(i-k+1,1:(max(xdata)-min(xdata)+1))=min(xdata):1:max(xdata);

indices_dtm(i,1)=length(indices2);

options= optimset('Display','iter','MaxFunEvals',10000,'MaxIter',200,'TolFun',1e-8);

[beta,resnorm,residual,exitflag,output,lambda]
=lsqcurvefit('ens',beta0,xdata,ydata,lb,ub,options);

ret(i-k+1,:)=ens(beta,vade);

residual=[residual zeros(1,n-length(residual))];

res_norm(i-k+1,:)= resnorm;

resd(i-k+1,:)=residual;

b(i-k+1,:)=beta;

beta0=beta ;
```

```
end

%%

for i=1:162;

figure(i);

indices=find(yield(i,:));

ydata=yield(i,1:length(indices));

indices2=find(DTM(i,:));

xdata=DTM(i,1:length(indices2));

indices_v=find(aa(i,:));

aa_1=aa(i,1:length(indices_v));

plot(aa_1, ens(b(i,:),aa_1),'k')

hold on, plot(xdata,ydata,'o');

title(i)

xlabel('Day To Maturity')

ylabel('Zero Coupon Yield')

end;
```

# APPENDIX C

# YIELD CURVE PARAMETER ESTIMATES

**Table C.1 Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 09.01.2007 | 0,1817 | 0,0106 | 0,1922 | 4,2068 | -4,1931 | 135,94 | 135,14 |
| 16.01.2007 | 0,1803 | 0,0096 | 0,1898 | 4,2074 | -4,1923 | 135,90 | 135,23 |
| 23.01.2007 | 0,1762 | 0,0066 | 0,1828 | 4,2030 | -4,1960 | 136,25 | 135,16 |
| 30.01.2007 | 0,1763 | 0,0066 | 0,1829 | 4,2050 | -4,1936 | 136,19 | 135,28 |
| 06.02.2007 | 0,1754 | 0,0059 | 0,1812 | 4,2026 | -4,1955 | 135,98 | 135,65 |
| 13.02.2007 | 0,1756 | 0,0060 | 0,1816 | 4,2016 | -4,1964 | 135,98 | 135,66 |
| 20.02.2007 | 0,1732 | 0,0043 | 0,1774 | 4,2000 | -4,1978 | 135,87 | 135,86 |
| 27.02.2007 | 0,1761 | 0,0056 | 0,1817 | 4,2027 | -4,1945 | 135,96 | 135,81 |
| 06.03.2007 | 0,1764 | 0,0057 | 0,1821 | 4,2046 | -4,1923 | 136,31 | 135,62 |
| 13.03.2007 | 0,1748 | 0,0046 | 0,1793 | 4,2062 | -4,1904 | 136,27 | 135,70 |
| 20.03.2007 | 0,1738 | 0,0039 | 0,1777 | 4,2063 | -4,1903 | 136,19 | 135,84 |
| 27.03.2007 | 0,1745 | 0,0041 | 0,1786 | 4,2065 | -4,1899 | 136,16 | 135,89 |
| 03.04.2007 | 0,1736 | 0,0035 | 0,1771 | 4,2070 | -4,1894 | 136,07 | 136,06 |
| 10.04.2007 | 0,1716 | 0,0021 | 0,1737 | 4,2108 | -4,1849 | 134,05 | 134,73 |
| 17.04.2007 | 0,1708 | 0,0015 | 0,1723 | 4,2072 | -4,1879 | 134,21 | 134,63 |
| 24.04.2007 | 0,1698 | 0,0008 | 0,1706 | 4,2083 | -4,1867 | 134,07 | 134,89 |
| 01.05.2007 | 0,1737 | 0,0027 | 0,1763 | 4,2091 | -4,1858 | 134,31 | 134,76 |
| 08.05.2007 | 0,1685 | -0,0007 | 0,1678 | 4,1998 | -4,1938 | 135,22 | 134,27 |
| 15.05.2007 | 0,1691 | -0,0004 | 0,1687 | 4,2008 | -4,1927 | 135,22 | 134,20 |
| 22.05.2007 | 0,1666 | -0,0021 | 0,1645 | 4,2015 | -4,1918 | 135,04 | 134,54 |
| 29.05.2007 | 0,1671 | -0,0019 | 0,1651 | 4,1988 | -4,1940 | 135,28 | 134,40 |

**Table C.1 (Continued) Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 05.06.2007 | 0,1655 | -0,0031 | 0,1624 | 4,1979 | -4,1948 | 135,24 | 134,46 |
| 12.06.2007 | 0,1659 | -0,0029 | 0,1630 | 4,2000 | -4,1923 | 135,48 | 134,31 |
| 19.06.2007 | 0,1653 | -0,0037 | 0,1616 | 4,1918 | -4,2022 | 77,24 | 76,42 |
| 26.06.2007 | 0,1642 | -0,0044 | 0,1598 | 4,1905 | -4,2041 | 77,51 | 76,34 |
| 03.07.2007 | 0,1622 | -0,0059 | 0,1562 | 4,1956 | -4,1982 | 77,47 | 76,44 |
| 10.07.2007 | 0,1618 | -0,0062 | 0,1557 | 4,2012 | -4,1910 | 77,27 | 76,48 |
| 17.07.2007 | 0,1620 | -0,0061 | 0,1559 | 4,2037 | -4,1881 | 77,23 | 76,49 |
| 24.07.2007 | 0,1612 | -0,0067 | 0,1545 | 4,1977 | -4,1928 | 77,14 | 76,78 |
| 31.07.2007 | 0,1644 | -0,0053 | 0,1591 | 4,1996 | -4,1911 | 77,07 | 77,02 |
| 07.08.2007 | 0,1639 | -0,0057 | 0,1582 | 4,2003 | -4,1904 | 77,05 | 77,06 |
| 14.08.2007 | 0,1663 | -0,0044 | 0,1619 | 4,1988 | -4,1918 | 77,10 | 77,01 |
| 21.08.2007 | 0,1719 | -0,0015 | 0,1703 | 4,2008 | -4,1893 | 77,22 | 76,97 |
| 28.08.2007 | 0,1666 | -0,0051 | 0,1615 | 4,1960 | -4,1933 | 77,47 | 76,90 |
| 04.09.2007 | 0,1647 | -0,0065 | 0,1581 | 4,1940 | -4,1950 | 77,53 | 76,87 |
| 11.09.2007 | 0,1662 | -0,0058 | 0,1604 | 4,1966 | -4,1918 | 77,51 | 76,91 |
| 18.09.2007 | 0,1622 | -0,0089 | 0,1533 | 4,1979 | -4,1912 | 77,46 | 77,07 |
| 25.09.2007 | 0,1589 | -0,0111 | 0,1479 | 4,2088 | -4,1816 | 77,30 | 77,62 |
| 02.10.2007 | 0,1604 | -0,0102 | 0,1502 | 4,1931 | -4,1947 | 77,37 | 77,37 |
| 09.10.2007 | 0,1568 | -0,0126 | 0,1442 | 4,1999 | -4,1866 | 77,19 | 77,43 |
| 16.10.2007 | 0,1548 | -0,0139 | 0,1409 | 4,1930 | -4,1923 | 77,50 | 77,34 |
| 23.10.2007 | 0,1545 | -0,0141 | 0,1403 | 4,1938 | -4,1914 | 77,48 | 77,39 |
| 30.10.2007 | 0,1546 | -0,0140 | 0,1406 | 4,1929 | -4,1922 | 77,47 | 77,44 |
| 06.11.2007 | 0,1550 | -0,0138 | 0,1412 | 4,1927 | -4,1924 | 77,53 | 77,42 |
| 13.11.2007 | 0,1559 | -0,0134 | 0,1425 | 4,1942 | -4,1907 | 77,66 | 77,38 |
| 20.11.2007 | 0,1567 | -0,0129 | 0,1437 | 4,1949 | -4,1899 | 77,64 | 77,44 |
| 27.11.2007 | 0,1575 | -0,0125 | 0,1449 | 4,1919 | -4,1924 | 77,78 | 77,38 |
| 04.12.2007 | 0,1566 | -0,0131 | 0,1435 | 4,1936 | -4,1903 | 77,75 | 77,47 |

**Table C.1 (Continued) Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 11.12.2007 | 0,1554 | -0,0139 | 0,1415 | 4,1939 | -4,1900 | 77,73 | 77,55 |
| 18.12.2007 | 0,1555 | -0,0139 | 0,1415 | 4,1941 | -4,1899 | 77,77 | 77,53 |
| 25.12.2007 | 0,1547 | -0,0145 | 0,1402 | 4,1935 | -4,1903 | 77,75 | 77,58 |
| 08.01.2008 | 0,1531 | -0,0155 | 0,1376 | 4,1977 | -4,1868 | 77,69 | 77,78 |
| 15.01.2008 | 0,1530 | -0,0156 | 0,1373 | 4,1948 | -4,1892 | 77,80 | 77,75 |
| 22.01.2008 | 0,1559 | -0,0140 | 0,1420 | 4,1978 | -4,1856 | 77,82 | 77,74 |
| 29.01.2008 | 0,1541 | -0,0152 | 0,1389 | 4,1958 | -4,1872 | 77,79 | 77,87 |
| 05.02.2008 | 0,1552 | -0,0146 | 0,1406 | 4,1954 | -4,1876 | 77,79 | 77,87 |
| 12.02.2008 | 0,1570 | -0,0137 | 0,1433 | 4,1958 | -4,1869 | 77,89 | 77,84 |
| 19.02.2008 | 0,1564 | -0,0140 | 0,1424 | 4,1951 | -4,1875 | 77,87 | 77,90 |
| 26.02.2008 | 0,1574 | -0,0135 | 0,1438 | 4,1942 | -4,1882 | 77,92 | 77,89 |
| 04.03.2008 | 0,1583 | -0,0130 | 0,1453 | 4,1950 | -4,1872 | 77,96 | 77,87 |
| 11.03.2008 | 0,1603 | -0,0119 | 0,1484 | 4,1961 | -4,1859 | 78,09 | 77,84 |
| 18.03.2008 | 0,1636 | -0,0101 | 0,1535 | 4,1980 | -4,1841 | 78,18 | 77,81 |
| 25.03.2008 | 0,1637 | -0,0100 | 0,1537 | 4,1958 | -4,1859 | 78,16 | 77,88 |
| 01.04.2008 | 0,1650 | -0,0093 | 0,1557 | 4,2003 | -4,1806 | 78,18 | 77,89 |
| 08.04.2008 | 0,1645 | -0,0098 | 0,1547 | 4,1923 | -4,1875 | 78,38 | 77,83 |
| 15.04.2008 | 0,1650 | -0,0095 | 0,1555 | 4,1933 | -4,1868 | 78,46 | 77,83 |
| 22.04.2008 | 0,1690 | -0,0073 | 0,1617 | 4,1960 | -4,1833 | 78,40 | 78,03 |
| 29.04.2008 | 0,1709 | -0,0064 | 0,1645 | 4,2001 | -4,1781 | 78,33 | 78,26 |
| 06.05.2008 | 0,1731 | -0,0053 | 0,1678 | 4,2031 | -4,1746 | 78,33 | 78,28 |
| 13.05.2008 | 0,1715 | -0,0063 | 0,1652 | 4,1990 | -4,1780 | 78,48 | 78,24 |
| 20.05.2008 | 0,1716 | -0,0063 | 0,1653 | 4,1956 | -4,1809 | 78,57 | 78,20 |
| 27.05.2008 | 0,1744 | -0,0044 | 0,1699 | 4,1968 | -4,1799 | 78,58 | 78,24 |
| 03.06.2008 | 0,1761 | -0,0037 | 0,1724 | 4,1922 | -4,1839 | 78,81 | 78,17 |
| 10.06.2008 | 0,1822 | -0,0005 | 0,1816 | 4,1959 | -4,1792 | 79,39 | 78,35 |
| 17.06.2008 | 0,1797 | -0,0023 | 0,1774 | 4,1937 | -4,1788 | 84,70 | 83,67 |
| 24.06.2008 | 0,1799 | -0,0022 | 0,1777 | 4,1904 | -4,1828 | 85,61 | 84,41 |
| 01.07.2008 | 0,1837 | -0,0002 | 0,1835 | 4,1937 | -4,1797 | 87,54 | 86,16 |
| 08.07.2008 | 0,1813 | -0,0020 | 0,1793 | 4,1932 | -4,1805 | 87,71 | 86,14 |

**Table C.1 (Continued) Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 15.07.2008 | 0,1761 | -0,0057 | 0,1703 | 4,1932 | -4,1801 | 87,70 | 86,25 |
| 22.07.2008 | 0,1785 | -0,0046 | 0,1738 | 4,1956 | -4,1777 | 87,55 | 86,67 |
| 29.07.2008 | 0,1775 | -0,0053 | 0,1722 | 4,1935 | -4,1792 | 87,46 | 86,92 |
| 05.08.2008 | 0,1733 | -0,0079 | 0,1653 | 4,1902 | -4,1819 | 87,34 | 87,28 |
| 12.08.2008 | 0,1730 | -0,0081 | 0,1649 | 4,1930 | -4,1786 | 87,25 | 87,31 |
| 19.08.2008 | 0,1725 | -0,0085 | 0,1641 | 4,1903 | -4,1808 | 87,23 | 87,38 |
| 26.08.2008 | 0,1743 | -0,0075 | 0,1668 | 4,1917 | -4,1792 | 87,22 | 87,41 |
| 02.09.2008 | 0,1748 | -0,0072 | 0,1676 | 4,1879 | -4,1824 | 87,24 | 87,33 |
| 09.09.2008 | 0,1740 | -0,0077 | 0,1663 | 4,1864 | -4,1837 | 87,23 | 87,38 |
| 16.09.2008 | 0,1758 | -0,0068 | 0,1690 | 4,1884 | -4,1813 | 87,45 | 87,30 |
| 23.09.2008 | 0,1765 | -0,0065 | 0,1700 | 4,1874 | -4,1821 | 87,41 | 87,42 |
| 07.10.2008 | 0,1806 | -0,0042 | 0,1764 | 4,1911 | -4,1778 | 87,80 | 87,28 |
| 14.10.2008 | 0,1790 | -0,0054 | 0,1736 | 4,1902 | -4,1786 | 87,81 | 87,28 |
| 21.10.2008 | 0,1858 | -0,0017 | 0,1841 | 4,1968 | -4,1707 | 87,80 | 87,30 |
| 28.10.2008 | 0,2068 | 0,0079 | 0,2147 | 4,2088 | -4,1556 | 87,74 | 87,42 |
| 04.11.2008 | 0,1968 | 0,0006 | 0,1973 | 4,2038 | -4,1600 | 87,75 | 87,41 |
| 11.11.2008 | 0,1903 | -0,0036 | 0,1866 | 4,1954 | -4,1670 | 88,13 | 87,28 |
| 18.11.2008 | 0,1936 | -0,0018 | 0,1917 | 4,1978 | -4,1640 | 88,23 | 87,25 |
| 25.11.2008 | 0,1827 | -0,0097 | 0,1730 | 4,1935 | -4,1678 | 88,20 | 87,35 |
| 02.12.2008 | 0,1797 | -0,0115 | 0,1682 | 4,1967 | -4,1648 | 88,01 | 87,90 |
| 16.12.2008 | 0,1730 | -0,0160 | 0,1569 | 4,1853 | -4,1744 | 87,97 | 88,01 |
| 23.12.2008 | 0,1634 | -0,0228 | 0,1406 | 4,1852 | -4,1744 | 87,93 | 88,13 |
| 30.12.2008 | 0,1607 | -0,0245 | 0,1362 | 4,1789 | -4,1796 | 87,98 | 88,12 |
| 06.01.2009 | 0,1551 | -0,0284 | 0,1267 | 4,1766 | -4,1824 | 88,15 | 88,06 |
| 13.01.2009 | 0,1545 | -0,0288 | 0,1257 | 4,1782 | -4,1805 | 88,43 | 87,97 |
| 20.01.2009 | 0,1419 | -0,0373 | 0,1045 | 4,1807 | -4,1779 | 88,71 | 87,90 |
| 27.01.2009 | 0,1369 | -0,0406 | 0,0963 | 4,1788 | -4,1797 | 91,05 | 89,88 |
| 03.02.2009 | 0,1365 | -0,0409 | 0,0955 | 4,1838 | -4,1745 | 92,79 | 91,58 |

**Table C.1 (Continued) Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 10.02.2009 | 0,1376 | -0,0402 | 0,0974 | 4,1877 | -4,1706 | 92,61 | 92,06 |
| 17.02.2009 | 0,1419 | -0,0373 | 0,1046 | 4,1891 | -4,1688 | 92,73 | 92,09 |
| 24.02.2009 | 0,1382 | -0,0397 | 0,0986 | 4,1931 | -4,1642 | 92,79 | 92,10 |
| 03.03.2009 | 0,1371 | -0,0403 | 0,0969 | 4,1917 | -4,1655 | 92,91 | 92,06 |
| 10.03.2009 | 0,1391 | -0,0391 | 0,1000 | 4,1942 | -4,1665 | 105,36 | 103,94 |
| 17.03.2009 | 0,1307 | -0,0435 | 0,0872 | 4,1972 | -4,1635 | 105,12 | 104,52 |
| 24.03.2009 | 0,1289 | -0,0446 | 0,0843 | 4,1918 | -4,1681 | 105,10 | 104,59 |
| 31.03.2009 | 0,1301 | -0,0438 | 0,0863 | 4,1900 | -4,1702 | 105,31 | 104,51 |
| 07.04.2009 | 0,1253 | -0,0466 | 0,0787 | 4,1876 | -4,1722 | 105,35 | 104,52 |
| 14.04.2009 | 0,1206 | -0,0499 | 0,0707 | 4,1859 | -4,1738 | 105,72 | 104,54 |
| 21.04.2009 | 0,1182 | -0,0513 | 0,0669 | 4,1853 | -4,1742 | 105,69 | 104,65 |
| 28.04.2009 | 0,1186 | -0,0511 | 0,0676 | 4,1782 | -4,1805 | 105,83 | 104,43 |
| 05.05.2009 | 0,1163 | -0,0521 | 0,0642 | 4,1800 | -4,1784 | 105,68 | 104,77 |
| 12.05.2009 | 0,1160 | -0,0523 | 0,0638 | 4,1830 | -4,1748 | 105,69 | 104,79 |
| 26.05.2009 | 0,1198 | -0,0497 | 0,0701 | 4,1883 | -4,1683 | 105,63 | 105,02 |
| 02.06.2009 | 0,1211 | -0,0489 | 0,0722 | 4,1893 | -4,1674 | 105,56 | 105,17 |
| 09.06.2009 | 0,1219 | -0,0484 | 0,0735 | 4,1898 | -4,1668 | 105,94 | 105,31 |
| 16.06.2009 | 0,1197 | -0,0494 | 0,0703 | 4,1865 | -4,1697 | 106,39 | 105,39 |
| 23.06.2009 | 0,1143 | -0,0526 | 0,0616 | 4,1852 | -4,1707 | 106,47 | 105,59 |
| 30.06.2009 | 0,1126 | -0,0535 | 0,0590 | 4,1863 | -4,1693 | 108,65 | 107,63 |
| 07.07.2009 | 0,1097 | -0,0551 | 0,0546 | 4,1832 | -4,1720 | 108,93 | 107,66 |
| 14.07.2009 | 0,1072 | -0,0566 | 0,0506 | 4,1850 | -4,1700 | 108,98 | 107,67 |
| 21.07.2009 | 0,1070 | -0,0567 | 0,0503 | 4,1871 | -4,1675 | 108,95 | 107,68 |
| 28.07.2009 | 0,1062 | -0,0571 | 0,0491 | 4,1850 | -4,1692 | 108,94 | 107,74 |
| 04.08.2009 | 0,1025 | -0,0588 | 0,0436 | 4,1817 | -4,1719 | 108,82 | 108,05 |
| 11.08.2009 | 0,1010 | -0,0596 | 0,0414 | 4,1824 | -4,1710 | 108,87 | 108,03 |
| 18.08.2009 | 0,0991 | -0,0606 | 0,0386 | 4,1834 | -4,1701 | 108,82 | 108,23 |
| 25.08.2009 | 0,0987 | -0,0608 | 0,0379 | 4,1856 | -4,1674 | 108,76 | 108,37 |
| 01.09.2009 | 0,1002 | -0,0598 | 0,0404 | 4,1828 | -4,1698 | 108,88 | 108,32 |

**Table C.1 (Continued) Yield Curve Parameter Estimates for Turkish Secondary Bond Market by Svensson Model**

| Date | Beta0 | Beta1 | Beta0 +Beta1 | Beta2 | Beta3 | Tau1 | Tau2 |
|---|---|---|---|---|---|---|---|
| 08.09.2009 | 0,0985 | -0,0607 | 0,0378 | 4,1813 | -4,1711 | 108,88 | 108,33 |
| 15.09.2009 | 0,0971 | -0,0615 | 0,0356 | 4,1817 | -4,1707 | 108,90 | 108,33 |
| 29.09.2009 | 0,0937 | -0,0633 | 0,0305 | 4,1772 | -4,1745 | 108,94 | 108,26 |
| 06.10.2009 | 0,0896 | -0,0650 | 0,0245 | 4,1758 | -4,1755 | 108,77 | 108,62 |
| 13.10.2009 | 0,0893 | -0,0652 | 0,0241 | 4,1797 | -4,1709 | 108,82 | 108,61 |
| 20.10.2009 | 0,0887 | -0,0655 | 0,0232 | 4,1784 | -4,1720 | 108,94 | 108,56 |
| 27.10.2009 | 0,0911 | -0,0639 | 0,0271 | 4,1809 | -4,1691 | 108,99 | 108,54 |
| 03.11.2009 | 0,0926 | -0,0629 | 0,0296 | 4,1828 | -4,1669 | 109,02 | 108,59 |
| 10.11.2009 | 0,0912 | -0,0637 | 0,0275 | 4,1763 | -4,1725 | 109,25 | 108,56 |
| 17.11.2009 | 0,0912 | -0,0636 | 0,0276 | 4,1792 | -4,1689 | 109,16 | 108,60 |
| 24.11.2009 | 0,0913 | -0,0636 | 0,0277 | 4,1775 | -4,1704 | 109,33 | 108,63 |
| 01.12.2009 | 0,0923 | -0,0630 | 0,0293 | 4,1788 | -4,1688 | 109,30 | 108,70 |
| 08.12.2009 | 0,0929 | -0,0625 | 0,0303 | 4,1795 | -4,1679 | 109,32 | 108,70 |
| 15.12.2009 | 0,0967 | -0,0600 | 0,0367 | 4,1823 | -4,1647 | 109,31 | 108,74 |
| 22.12.2009 | 0,0960 | -0,0603 | 0,0357 | 4,1813 | -4,1655 | 109,40 | 108,71 |
| 29.12.2009 | 0,0960 | -0,0603 | 0,0357 | 4,1822 | -4,1645 | 109,49 | 108,81 |
| 05.01.2010 | 0,0926 | -0,0623 | 0,0303 | 4,1781 | -4,1681 | 109,48 | 108,86 |
| 12.01.2010 | 0,0908 | -0,0633 | 0,0274 | 4,1782 | -4,1682 | 109,49 | 108,86 |
| 19.01.2010 | 0,0905 | -0,0635 | 0,0270 | 4,1788 | -4,1676 | 109,44 | 108,98 |
| 26.01.2010 | 0,0908 | -0,0633 | 0,0275 | 4,1808 | -4,1653 | 109,62 | 109,03 |
| 02.02.2010 | 0,0895 | -0,0640 | 0,0255 | 4,1794 | -4,1664 | 109,65 | 109,15 |
| 09.02.2010 | 0,0896 | -0,0639 | 0,0257 | 4,1790 | -4,1668 | 109,84 | 109,28 |
| 16.02.2010 | 0,0879 | -0,0648 | 0,0231 | 4,1776 | -4,1681 | 109,90 | 109,29 |
| 23.02.2010 | 0,0888 | -0,0643 | 0,0244 | 4,1780 | -4,1676 | 109,98 | 109,27 |
| 02.03.2010 | 0,0892 | -0,0640 | 0,0252 | 4,1760 | -4,1693 | 110,20 | 109,33 |
| 09.03.2010 | 0,0904 | -0,0633 | 0,0271 | 4,1765 | -4,1688 | 110,38 | 109,35 |
| 16.03.2010 | 0,0904 | -0,0632 | 0,0272 | 4,1769 | -4,1683 | 110,63 | 109,68 |

# APPENDIX D

# OVERNIGHT BORROWING AND LENDING RATE

**Table D.1 Central Bank of Republic of Turkey Overnight Borrowing and Lending Rate**

| Date | Borrowing Rate | Lending Rate |
|---|---|---|
| 28.04.2006 | 13,3% | 16,3% |
| 08.06.2006 | 15,0% | 18,0% |
| 26.06.2006 | 17,3% | 20,3% |
| 28.06.2006 | 17,3% | 22,3% |
| 21.07.2006 | 17,5% | 22,5% |
| 14.09.2007 | 17,3% | 22,3% |
| 17.10.2007 | 16,8% | 21,5% |
| 15.11.2007 | 16,3% | 20,8% |
| 14.12.2007 | 15,8% | 20,0% |
| 18.01.2008 | 15,5% | 19,5% |
| 15.02.2008 | 15,3% | 19,3% |
| 16.05.2008 | 15,8% | 19,8% |
| 17.06.2008 | 16,3% | 20,3% |
| 18.07.2008 | 16,8% | 20,3% |
| 23.10.2008 | 16,8% | 19,8% |
| 20.11.2008 | 16,3% | 18,8% |
| 19.12.2008 | 15,0% | 17,5% |
| 16.01.2009 | 13,0% | 15,5% |
| 20.02.2009 | 11,5% | 14,0% |
| 20.03.2009 | 10,5% | 13,0% |
| 17.04.2009 | 9,8% | 12,3% |

**Table D.1 (Continued)Central Bank of Republic of Turkey Overnight Borrowing and Lending Rate**

| Date | Borrowing Rate | Lending Rate |
|---|---|---|
| 15.05.2009 | 9,3% | 11,8% |
| 17.06.2009 | 8,8% | 11,3% |
| 17.07.2009 | 8,3% | 10,8% |
| 19.08.2009 | 7,8% | 10,3% |
| 18.09.2009 | 7,3% | 9,8% |
| 16.10.2009 | 6,8% | 9,3% |
| 20.11.2009 | 6,5% | 9,0% |

# APPENDIX E

# EXCHANGE RATES

**Table E.1 Exchange Rates and Log Exchange Rates for Selected Dates**

| DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) | DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) |
|---|---|---|---|---|---|---|---|---|---|
| 09.01.2007 | 1,44 | 0,36 | 1,87 | 0,63 | 12.08.2008 | 1,18 | 0,16 | 1,77 | 0,57 |
| 16.01.2007 | 1,42 | 0,35 | 1,84 | 0,61 | 19.08.2008 | 1,18 | 0,16 | 1,73 | 0,55 |
| 23.01.2007 | 1,40 | 0,34 | 1,82 | 0,60 | 26.08.2008 | 1,18 | 0,17 | 1,74 | 0,56 |
| 30.01.2007 | 1,42 | 0,35 | 1,83 | 0,61 | 02.09.2008 | 1,18 | 0,16 | 1,73 | 0,55 |
| 06.02.2007 | 1,40 | 0,34 | 1,81 | 0,59 | 09.09.2008 | 1,22 | 0,20 | 1,73 | 0,55 |
| 13.02.2007 | 1,40 | 0,34 | 1,82 | 0,60 | 16.09.2008 | 1,26 | 0,23 | 1,79 | 0,58 |
| 20.02.2007 | 1,38 | 0,32 | 1,81 | 0,59 | 23.09.2008 | 1,24 | 0,21 | 1,80 | 0,59 |
| 27.02.2007 | 1,38 | 0,32 | 1,82 | 0,60 | 07.10.2008 | 1,33 | 0,29 | 1,81 | 0,59 |
| 06.03.2007 | 1,45 | 0,37 | 1,90 | 0,64 | 14.10.2008 | 1,39 | 0,33 | 1,90 | 0,64 |
| 13.03.2007 | 1,40 | 0,34 | 1,84 | 0,61 | 21.10.2008 | 1,49 | 0,40 | 2,01 | 0,70 |
| 20.03.2007 | 1,39 | 0,33 | 1,85 | 0,62 | 28.10.2008 | 1,69 | 0,52 | 2,10 | 0,74 |
| 27.03.2007 | 1,38 | 0,32 | 1,83 | 0,60 | 04.11.2008 | 1,52 | 0,42 | 1,95 | 0,67 |
| 03.04.2007 | 1,38 | 0,32 | 1,85 | 0,61 | 18.11.2008 | 1,61 | 0,48 | 2,04 | 0,71 |
| 10.04.2007 | 1,37 | 0,31 | 1,83 | 0,60 | 25.11.2008 | 1,61 | 0,47 | 2,04 | 0,71 |
| 17.04.2007 | 1,35 | 0,30 | 1,83 | 0,61 | 02.12.2008 | 1,59 | 0,46 | 2,01 | 0,70 |
| 24.04.2007 | 1,34 | 0,29 | 1,82 | 0,60 | 16.12.2008 | 1,56 | 0,44 | 2,10 | 0,74 |
| 08.05.2007 | 1,33 | 0,29 | 1,82 | 0,60 | 23.12.2008 | 1,51 | 0,41 | 2,12 | 0,75 |
| 15.05.2007 | 1,33 | 0,28 | 1,80 | 0,59 | 30.12.2008 | 1,51 | 0,41 | 2,15 | 0,77 |
| 22.05.2007 | 1,32 | 0,27 | 1,77 | 0,57 | 06.01.2009 | 1,53 | 0,42 | 2,08 | 0,73 |

**Table E.1 (Continued) Exchange Rates and Log Exchange Rates for Selected Dates**

| DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) | DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) |
|---|---|---|---|---|---|---|---|---|---|
| 29.05.2007 | 1,32 | 0,28 | 1,77 | 0,57 | 13.01.2009 | 1,57 | 0,45 | 2,10 | 0,74 |
| 05.06.2007 | 1,31 | 0,27 | 1,76 | 0,56 | 20.01.2009 | 1,63 | 0,49 | 2,16 | 0,77 |
| 12.06.2007 | 1,33 | 0,29 | 1,78 | 0,58 | 27.01.2009 | 1,64 | 0,50 | 2,13 | 0,75 |
| 19.06.2007 | 1,30 | 0,26 | 1,74 | 0,55 | 03.02.2009 | 1,65 | 0,50 | 2,10 | 0,74 |
| 26.06.2007 | 1,31 | 0,27 | 1,76 | 0,57 | 10.02.2009 | 1,61 | 0,47 | 2,08 | 0,73 |
| 03.07.2007 | 1,30 | 0,26 | 1,76 | 0,57 | 17.02.2009 | 1,66 | 0,51 | 2,11 | 0,75 |
| 10.07.2007 | 1,28 | 0,25 | 1,74 | 0,56 | 24.02.2009 | 1,68 | 0,52 | 2,16 | 0,77 |
| 17.07.2007 | 1,27 | 0,24 | 1,74 | 0,56 | 03.03.2009 | 1,72 | 0,54 | 2,16 | 0,77 |
| 24.07.2007 | 1,25 | 0,22 | 1,72 | 0,55 | 10.03.2009 | 1,80 | 0,59 | 2,26 | 0,82 |
| 31.07.2007 | 1,30 | 0,26 | 1,78 | 0,58 | 17.03.2009 | 1,68 | 0,52 | 2,19 | 0,78 |
| 07.08.2007 | 1,27 | 0,24 | 1,76 | 0,57 | 24.03.2009 | 1,66 | 0,51 | 2,27 | 0,82 |
| 14.08.2007 | 1,28 | 0,25 | 1,75 | 0,56 | 31.03.2009 | 1,69 | 0,52 | 2,23 | 0,80 |
| 21.08.2007 | 1,34 | 0,29 | 1,81 | 0,59 | 07.04.2009 | 1,56 | 0,44 | 2,11 | 0,75 |
| 28.08.2007 | 1,31 | 0,27 | 1,79 | 0,58 | 14.04.2009 | 1,57 | 0,45 | 2,07 | 0,73 |
| 04.09.2007 | 1,29 | 0,26 | 1,77 | 0,57 | 21.04.2009 | 1,62 | 0,48 | 2,10 | 0,74 |
| 11.09.2007 | 1,30 | 0,26 | 1,79 | 0,58 | 28.04.2009 | 1,62 | 0,48 | 2,12 | 0,75 |
| 18.09.2007 | 1,26 | 0,23 | 1,75 | 0,56 | 05.05.2009 | 1,58 | 0,46 | 2,10 | 0,74 |
| 25.09.2007 | 1,22 | 0,20 | 1,72 | 0,54 | 12.05.2009 | 1,55 | 0,44 | 2,09 | 0,74 |
| 02.10.2007 | 1,20 | 0,18 | 1,71 | 0,53 | 26.05.2009 | 1,54 | 0,43 | 2,15 | 0,77 |
| 09.10.2007 | 1,18 | 0,16 | 1,66 | 0,51 | 02.06.2009 | 1,52 | 0,42 | 2,16 | 0,77 |
| 16.10.2007 | 1,20 | 0,18 | 1,70 | 0,53 | 09.06.2009 | 1,55 | 0,44 | 2,15 | 0,77 |
| 23.10.2007 | 1,23 | 0,21 | 1,76 | 0,56 | 16.06.2009 | 1,54 | 0,43 | 2,14 | 0,76 |
| 30.10.2007 | 1,18 | 0,17 | 1,70 | 0,53 | 23.06.2009 | 1,55 | 0,44 | 2,15 | 0,76 |
| 06.11.2007 | 1,18 | 0,17 | 1,71 | 0,54 | 30.06.2009 | 1,53 | 0,43 | 2,15 | 0,76 |
| 13.11.2007 | 1,20 | 0,19 | 1,76 | 0,56 | 07.07.2009 | 1,54 | 0,43 | 2,15 | 0,76 |
| 20.11.2007 | 1,18 | 0,17 | 1,73 | 0,55 | 14.07.2009 | 1,55 | 0,44 | 2,16 | 0,77 |
| 27.11.2007 | 1,19 | 0,17 | 1,76 | 0,57 | 21.07.2009 | 1,50 | 0,41 | 2,14 | 0,76 |

**Table E.1 (Continued) Exchange Rates and Log Exchange Rates for Selected Dates**

| DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) | DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) |
|---|---|---|---|---|---|---|---|---|---|
| 04.12.2007 | 1,18 | 0,16 | 1,72 | 0,54 | 28.07.2009 | 1,47 | 0,39 | 2,10 | 0,74 |
| 11.12.2007 | 1,16 | 0,15 | 1,71 | 0,54 | 04.08.2009 | 1,46 | 0,38 | 2,09 | 0,74 |
| 18.12.2007 | 1,19 | 0,17 | 1,70 | 0,53 | 11.08.2009 | 1,47 | 0,38 | 2,08 | 0,73 |
| 08.01.2008 | 1,17 | 0,15 | 1,71 | 0,54 | 18.08.2009 | 1,50 | 0,41 | 2,12 | 0,75 |
| 15.01.2008 | 1,15 | 0,14 | 1,70 | 0,53 | 25.08.2009 | 1,48 | 0,39 | 2,11 | 0,75 |
| 22.01.2008 | 1,20 | 0,19 | 1,74 | 0,56 | 01.09.2009 | 1,50 | 0,40 | 2,14 | 0,76 |
| 29.01.2008 | 1,19 | 0,17 | 1,75 | 0,56 | 08.09.2009 | 1,48 | 0,39 | 2,13 | 0,75 |
| 05.02.2008 | 1,16 | 0,15 | 1,72 | 0,54 | 15.09.2009 | 1,50 | 0,40 | 2,18 | 0,78 |
| 12.02.2008 | 1,22 | 0,20 | 1,78 | 0,58 | 29.09.2009 | 1,49 | 0,40 | 2,17 | 0,78 |
| 19.02.2008 | 1,19 | 0,17 | 1,74 | 0,55 | 06.10.2009 | 1,48 | 0,39 | 2,16 | 0,77 |
| 04.03.2008 | 1,22 | 0,20 | 1,85 | 0,62 | 13.10.2009 | 1,46 | 0,38 | 2,15 | 0,76 |
| 11.03.2008 | 1,24 | 0,21 | 1,90 | 0,64 | 20.10.2009 | 1,45 | 0,37 | 2,17 | 0,77 |
| 18.03.2008 | 1,26 | 0,23 | 1,99 | 0,69 | 27.10.2009 | 1,47 | 0,38 | 2,21 | 0,79 |
| 25.03.2008 | 1,24 | 0,21 | 1,91 | 0,65 | 03.11.2009 | 1,49 | 0,40 | 2,21 | 0,79 |
| 01.04.2008 | 1,31 | 0,27 | 2,06 | 0,72 | 10.11.2009 | 1,47 | 0,38 | 2,20 | 0,79 |
| 08.04.2008 | 1,27 | 0,24 | 1,99 | 0,69 | 17.11.2009 | 1,47 | 0,39 | 2,20 | 0,79 |
| 15.04.2008 | 1,31 | 0,27 | 2,07 | 0,73 | 24.11.2009 | 1,49 | 0,40 | 2,23 | 0,80 |
| 22.04.2008 | 1,31 | 0,27 | 2,08 | 0,73 | 01.12.2009 | 1,48 | 0,39 | 2,23 | 0,80 |
| 29.04.2008 | 1,27 | 0,24 | 1,99 | 0,69 | 08.12.2009 | 1,49 | 0,40 | 2,20 | 0,79 |
| 06.05.2008 | 1,26 | 0,23 | 1,94 | 0,66 | 15.12.2009 | 1,50 | 0,40 | 2,19 | 0,78 |
| 13.05.2008 | 1,25 | 0,23 | 1,93 | 0,66 | 22.12.2009 | 1,52 | 0,42 | 2,17 | 0,78 |
| 20.05.2008 | 1,23 | 0,20 | 1,90 | 0,64 | 29.12.2009 | 1,51 | 0,41 | 2,17 | 0,77 |
| 27.05.2008 | 1,24 | 0,22 | 1,96 | 0,67 | 05.01.2010 | 1,48 | 0,39 | 2,13 | 0,75 |
| 03.06.2008 | 1,22 | 0,20 | 1,89 | 0,64 | 12.01.2010 | 1,45 | 0,37 | 2,10 | 0,74 |
| 10.06.2008 | 1,24 | 0,22 | 1,96 | 0,67 | 19.01.2010 | 1,45 | 0,37 | 2,08 | 0,73 |
| 17.06.2008 | 1,24 | 0,21 | 1,91 | 0,65 | 26.01.2010 | 1,48 | 0,39 | 2,09 | 0,74 |

**Table E.1 (Continued) Exchange Rates and Log Exchange Rates for Selected Dates**

| DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) | DATE | TL/USD | Ln(TL/USD) | TL/EUR | Ln(TL/EUR) |
|---|---|---|---|---|---|---|---|---|---|
| 24.06.2008 | 1,22 | 0,20 | 1,90 | 0,64 | 02.02.2010 | 1,48 | 0,39 | 2,06 | 0,72 |
| 01.07.2008 | 1,22 | 0,20 | 1,92 | 0,65 | 09.02.2010 | 1,52 | 0,42 | 2,07 | 0,73 |
| 08.07.2008 | 1,22 | 0,20 | 1,91 | 0,65 | 16.02.2010 | 1,51 | 0,41 | 2,05 | 0,72 |
| 15.07.2008 | 1,21 | 0,19 | 1,92 | 0,65 | 23.02.2010 | 1,51 | 0,41 | 2,05 | 0,72 |
| 22.07.2008 | 1,18 | 0,17 | 1,88 | 0,63 | 02.03.2010 | 1,54 | 0,43 | 2,09 | 0,74 |
| 29.07.2008 | 1,20 | 0,18 | 1,89 | 0,64 | 09.03.2010 | 1,52 | 0,42 | 2,08 | 0,73 |
| 05.08.2008 | 1,15 | 0,14 | 1,79 | 0,58 | 16.03.2010 | 1,52 | 0,42 | 2,09 | 0,74 |

# APPENDIX F

# RELATIVE FACTORS

**Table F.1 Relative Factors: Descriptive Statistics**

| CURRENCY | USD | | | EUR | | |
|---|---|---|---|---|---|---|
| VARIABLES | LT | ST | CT | LT | ST | CT |
| DEFINITION | Relative Level LR | Relative Slope SR | Relative Curvature CR | Relative Level LR | Relative Slope SR | Relative Curvature CR |
| Mean | 0,127 | -0,038 | 0,025 | 0,123 | -0,051 | 0,026 |
| Median | 0,130 | -0,035 | 0,019 | 0,129 | -0,046 | 0,019 |
| Maximum | 0,203 | 0,006 | 0,062 | 0,199 | -0,021 | 0,064 |
| Minimum | 0,075 | -0,074 | -0,019 | 0,070 | -0,079 | -0,020 |
| Std. Dev. | 0,030 | 0,021 | 0,024 | 0,029 | 0,015 | 0,025 |
| Skewness | -0,126 | -0,203 | 0,129 | -0,232 | -0,147 | 0,168 |
| Kurtosis | 2,323 | 1,981 | 1,615 | 2,511 | 1,884 | 1,535 |
| Jarque-Bera | 3,412 | 7,871 | 12,978 | 2,971 | 8,710 | 14,787 |
| Probability | 0,182 | 0,020 | 0,002 | 0,226 | 0,013 | 0,001 |
| Sum | 19,951 | -5,905 | 3,974 | 19,355 | -8,038 | 4,081 |
| Sum Sq. Dev. | 0,139 | 0,071 | 0,086 | 0,133 | 0,037 | 0,094 |
| Observations | 157 | 157 | 157 | 157 | 157 | 157 |

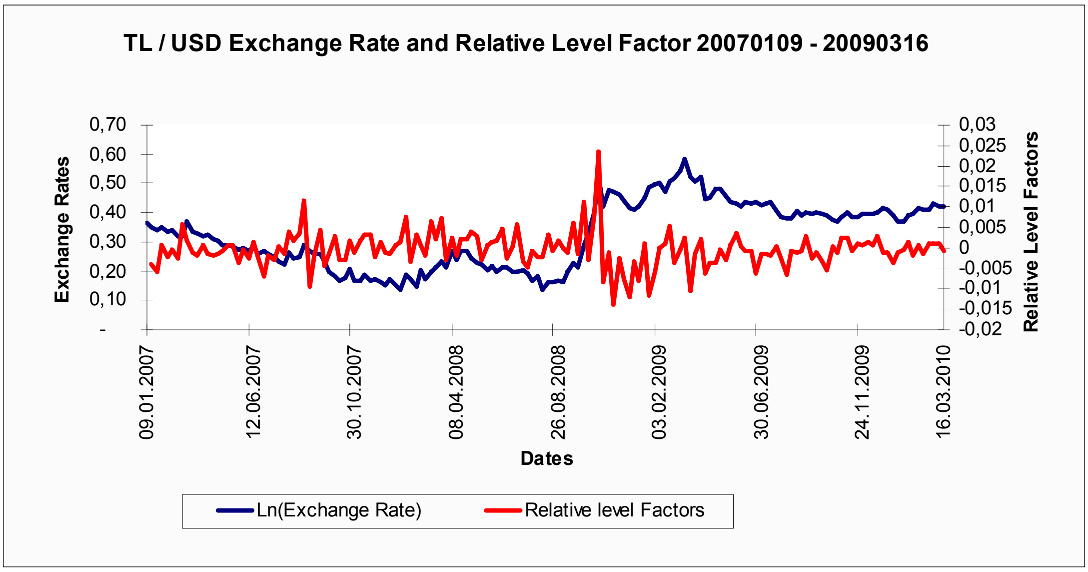


**Figure F.1 TL/USD Exchange and Relative Level Factor**

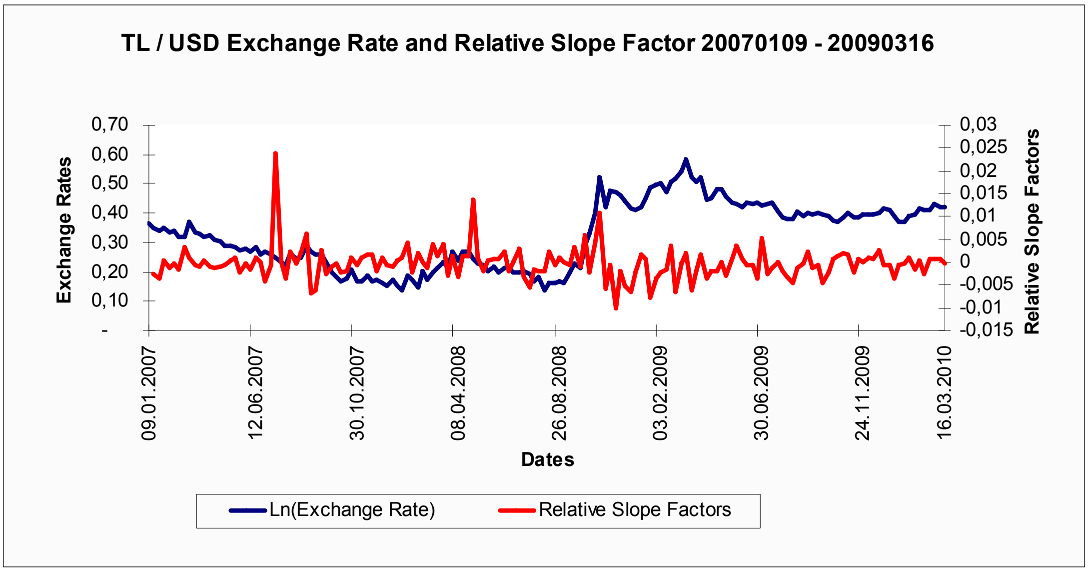


**Figure F.2 TL/USD Exchange and Relative Slope Factor**

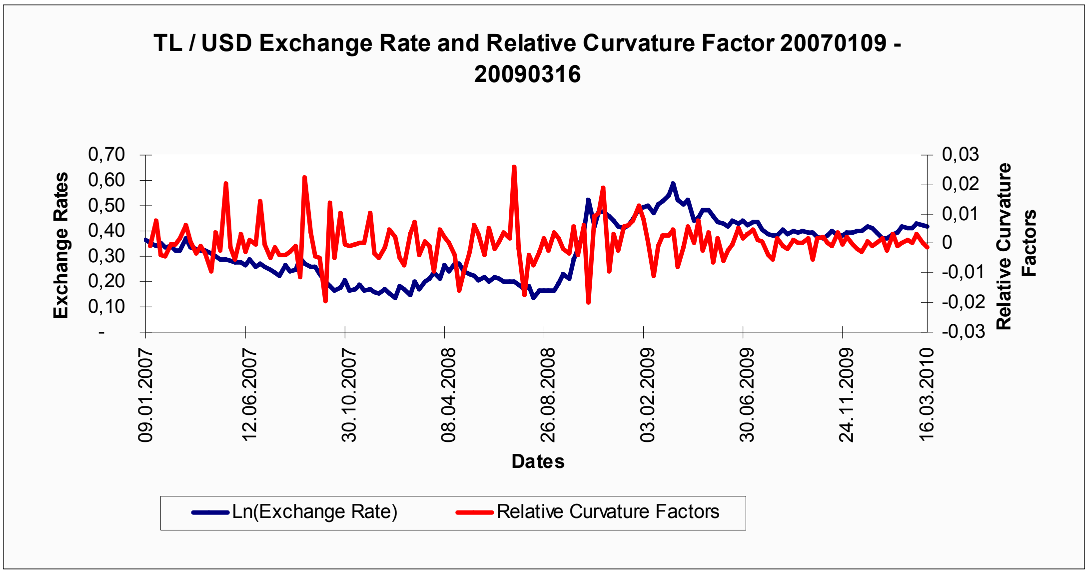


**Figure F.3 TL/USD Exchange and Relative Curvature Factor**

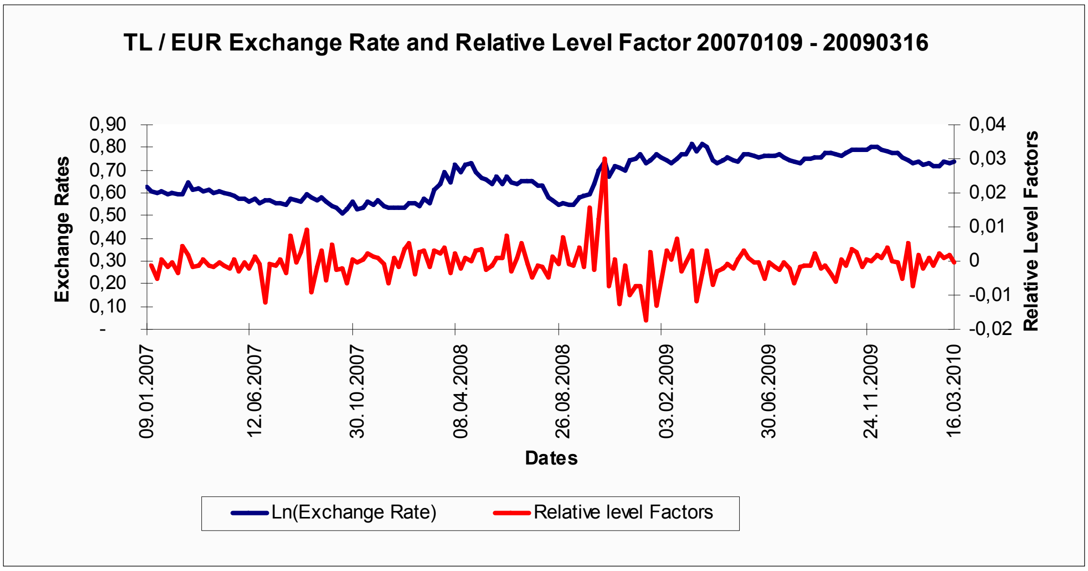


**Figure F.4 TL/EUR Exchange and Relative Level Factor**

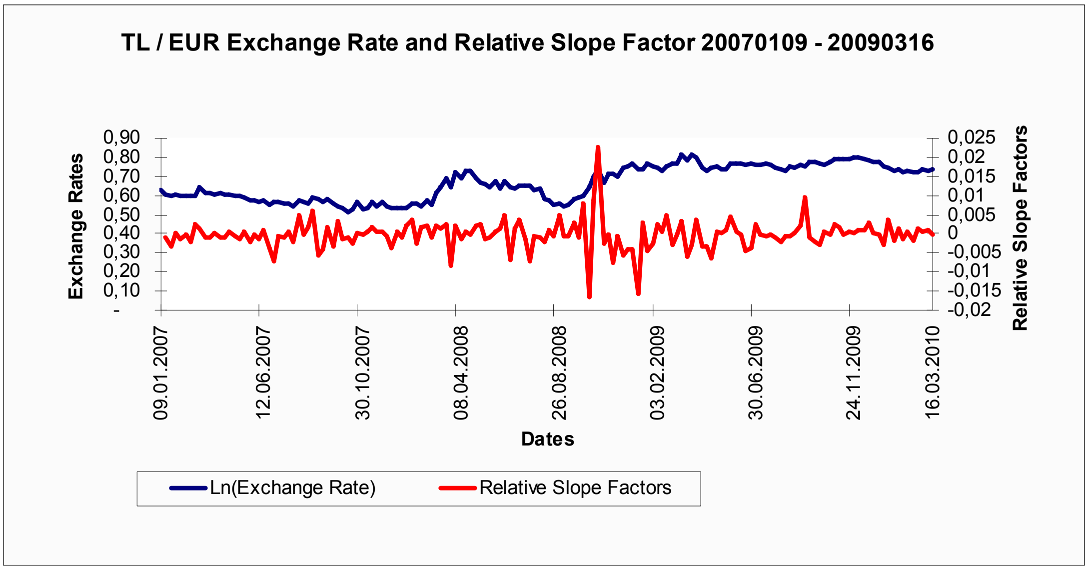


**Figure F.5 TL/EUR Exchange and Relative Slope Factor**

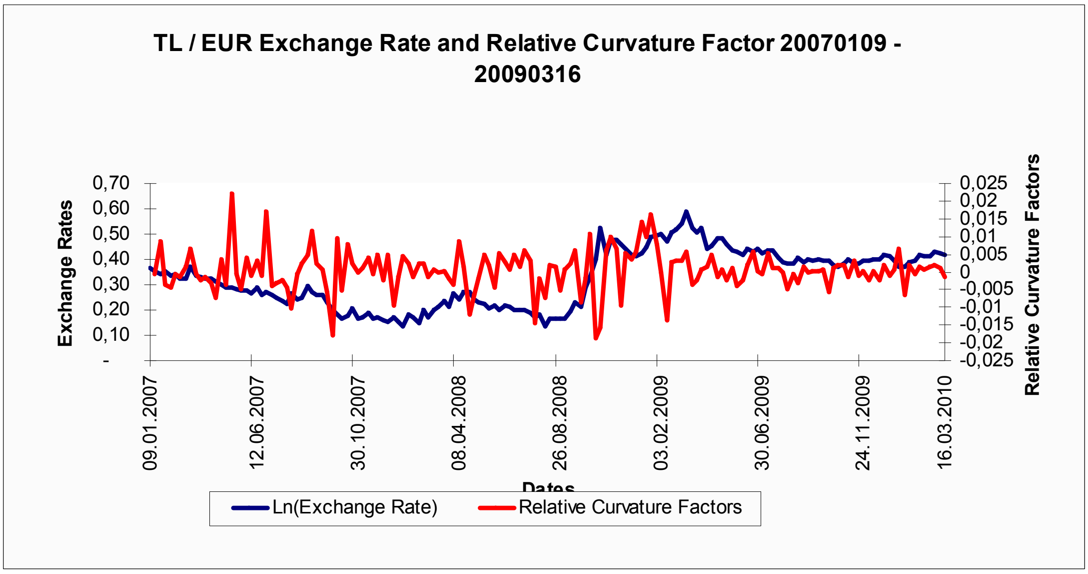


**Figure F.6 TL/EUR Exchange and Relative Curvature Factor**

**Table F.2 Correlation Matrix between Variables of Regression Equations (5.13)**

| | Exchange Rate Change | Relative Level | Relative Slope | Relative Curvature |
|---|---|---|---|---|
| Exchange Rate Change | 1,00 | | | |
| Relative Level | 0,13 | 1,00 | | |
| Relative Slope | 0,12 | 0,95 | 1,00 | |
| Relative Curvature | -0,04 | -0,87 | -0,89 | 1,00 |

**Table F.3 Correlation Matrix between Variables of Regression Equations (5.14)**

| | Exchange Rate Change | Relative Level | Relative Slope | Relative Curvature |
|---|---|---|---|---|
| Exchange Rate Change | 1,00 | | | |
| Relative Level | 0,08 | 1,00 | | |
| Relative Slope | 0,05 | 0,87 | 1,00 | |
| Relative Curvature | -0,01 | -0,87 | -0,93 | 1,00 |

# APPENDIX G

# UNIT ROOT TEST

Null Hypothesis: YT has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic based on SIC, MAXLAG=13)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -13,41303 | 0 |
| Test critical values: | 1% level | -3,474874 | |
| | 5% level | -2,880987 | |
| | 10% level | -2,577219 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(YT)

Method: Least Squares

Date: 07/25/10 Time: 16:45

Sample (adjusted): 1/23/2007 3/16/2010

Included observations: 148 after adjustments

| **Variable** | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** |
|---|---|---|---|---|
| YT(-1) | -1,116034 | 0,083205 | -13,41303 | 0 |
| C | -0,006344 | 0,110734 | -0,057292 | 0,9544 |

| | | | |
|---|---|---|---|
| R-squared | 0,552023 | Mean dependent var | -0,094089 |
| Adjusted R-squared | 0,548955 | S.D. dependent var | 2,002367 |
| S.E. of regression | 1,344788 | Akaike info criterion | 3,443771 |
| Sum squared resid | 264,0343 | Schwarz criterion | 3,484274 |
| Log likelihood | -252,8391 | F-statistic | 179,9095 |
| Durbin-Watson stat | 2,081494 | Prob(F-statistic) | 0 |

**Figure G.1 Unit Root Test Result Obtained From E-views for USD Exchange Rate Change**

**Table G.1 Unit ROOT Test Results (ADF Test Statistics and Critical values at 5%) for the Variables of Regression Equation (5.13)**

| | Exogenous: Constant | | Exogenous: Trend and intercept | | Exogenous: None | |
|---|---|---|---|---|---|---|
| | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% |
| EXCHANGE RATE CHANGE | -13,41 | -2,88 | -13,41 | -3,44 | -13,49 | -1,94 |
| RELATIVE LEVEL | -0,43 | -2,88 | -1,11 | -3,44 | -1,58 | -1,94 |
| RELATIVE SLOPE | 0,08 | -2,89 | -0,97 | -3,44 | 0,43 | -1,94 |
| RELATIVE CURVATURE | -0,86 | -2,88 | -2,13 | -3,44 | -0,43 | -1,94 |

*Grey shaded variables ar stationary. ADF test statistic is more negative than test critical values at 5%. Other variables have unit root.

**Table G.2 Unit ROOT Test Results (ADF Test Statistics and Critical values at 5%) for the Variables of Regression Equation (5.14)**

| | Exogenous: Constant | | Exogenous: Trend and intercept | | Exogenous: None | |
|---|---|---|---|---|---|---|
| | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% |
| EXCHANGE RATE CHANGE | -14,83 | -2,88 | -14,78 | -3,44 | -14,91 | -1,94 |
| RELATIVE LEVEL | -0,85 | -2,88 | -1,60 | -3,44 | -1,63 | -1,94 |
| RELATIVE SLOPE | -1,87 | -2,88 | -2,81 | -3,44 | 0,37 | -1,94 |
| RELATIVE CURVATURE | -0,65 | -2,88 | -2,12 | -3,44 | -0,06 | -1,94 |

*Grey shaded variables ar stationary. ADF test statistic is more negative than test critical values at 5%. Other variables have unit root.

**Table G.3 Unit ROOT Test Results (ADF Test Statistics and Critical values at 5%) for the Variables of Regression Equation (5.15)**

| | Exogenous: Constant | | Exogenous: Trend and intercept | | Exogenous: None | |
|---|---|---|---|---|---|---|
| | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% |
| EXCHANGE RATE CHANGE | -16,55 | -2,88 | -16,48 | -3,44 | -16,64 | -1,94 |
| RELATIVE LEVEL | -6,71 | -2,88 | -6,73 | -3,44 | -6,59 | -1,94 |
| RELATIVE SLOPE | -3,62 | -2,89 | -3,82 | -3,46 | -3,61 | -1,94 |
| RELATIVE CURVATURE | -12,88 | -2,88 | -12,93 | -3,44 | -12,93 | -1,94 |

*First differences of variables are all stationary.

**Table G.4 Unit ROOT Test Results (ADF Test Statistics and Critical values at 5%) for the Variables of Regression Equation (5.16)**

| | Exogenous: Constant | | Exogenous: Trend and intercept | | Exogenous: None | |
|---|---|---|---|---|---|---|
| | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% | ADF test statistic | Test critical values: 5% |
| EXCHANGE RATE CHANGE | -14,02 | -2,88 | -13,97 | -3,44 | -14,04 | -1,94 |
| RELATIVE LEVEL | -11,87 | -2,88 | -11,83 | -3,44 | -11,83 | -1,94 |
| RELATIVE SLOPE | -13,26 | -2,88 | -13,25 | -3,44 | -13,31 | -1,94 |
| RELATIVE CURVATURE | -6,92 | -2,89 | -6,90 | -3,45 | -6,95 | -1,94 |

*First differences of variables are all stationary.

# APPENDIX H

# FIRST DIFFERENCED RELATIVE FACTORS

**Table H.1 Summary Statistics for First Differenced Relative Factors**

| CURRENCY | USD | | | EUR | | |
|---|---|---|---|---|---|---|
| VARIABLES | LT | ST | CT | LT | ST | CT |
| DEFINITION | Relative Level LR | Relative Slope SR | Relative Curvature CR | Relative Level LR | Relative Slope SR | Relative Curvature CR |
| Mean | -0.00055 | -0.00031 | 0.000097 | -0.0006 | -0.0003 | 0.000232 |
| Median | -0.00085 | -0.00052 | -0.000044 | -0.00056 | -0.00025 | 0.000512 |
| Maximum | 0.02332 | 0.023793 | 0.02599 | 0.02979 | 0.022705 | 0.017165 |
| Minimum | -0.01371 | -0.01018 | -0.019798 | -0.01759 | -0.01658 | -0.01882 |
| Std. Dev. | 0.004212 | 0.003539 | 0.00633 | 0.004845 | 0.003847 | 0.005588 |
| Skewness | 0.860398 | 2.411599 | 0.4323 | 1.173854 | 0.505732 | -0.42182 |
| Kurtosis | 10.12141 | 18.20566 | 6.489392 | 13.53829 | 13.891 | 5.102217 |
| Jarque-Bera | 333.2363 | 1579.868 | 80.2327 | 723.6888 | 742.7453 | 31.85531 |
| Probability | 0 | 0 | 0 | 0 | 0 | 0 |
| Sum | -0.08206 | -0.04661 | 0.014448 | -0.08873 | -0.04526 | 0.034522 |
| Sum Sq. Dev. | 0.002626 | 0.001853 | 0.005929 | 0.003474 | 0.002191 | 0.004621 |
| Observations | 149 | 149 | 149 | 149 | 149 | 149 |

**Table H.2 Correlation Matrix between Variables of Regression Equations (5.15)**

| | Exchange Rate Change | Relative Level | Relative Slope | Relative Curvature |
|---|---|---|---|---|
| Exchange Rate Change | 1,00 | | | |
| Relative Level | 0,53 | 1,00 | | |
| Relative Slope | 0,32 | 0,68 | 1,00 | |
| Relative Curvature | 0,02 | -0,36 | -0,33 | 1,00 |

**Table H.3 Correlation Matrix between Variables of Regression Equations (5.16)**

| | Exchange Rate Change | Relative Level | Relative Slope | Relative Curvature |
|---|---|---|---|---|
| Exchange Rate Change | 1,00 | | | |
| Relative Level | 0,39 | 1,00 | | |
| Relative Slope | 0,31 | 0,86 | 1,00 | |
| Relative Curvature | 0,04 | -0,39 | -0,39 | 1,00 |