ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

ARE THERE BEHAVIORAL BIASES IN TURKISH GOVERNMENT BOND MARKET?

M.Sc. THESIS

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Department of Mathematical Engineering

Mathematical Engineering Programme

JUNE 2014

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TÜRK DEVLET TAHVİLLERİNDE DAVRANIŞSAL ÖNYARGILAR VAR MIDIR?

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Emine KESİCİ, a **M.Sc.** student of ITU **Institute of / Graduate School of Science Engineering and Technology** student ID **509101014**, successfully defended the **thesis** entitled "**ARE THERE BEHAVIORAL BIASES IN TURKISH GOVERNMENT BOND MARKET?**", which he/she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my love Emre,

FOREWORD

This work is aimed to estimate yield curves of the Turkish government bond market data and to relate behavioral finance concepts to the estimations. It would not have been possible to write this thesis without the support, help and patience of the people around me. Above all, I would like to thank my husband Emre, whom this work is dedicated to, for his great patience, help and guidance all the time. I would like to thank also my parents, brothers and sister for their unconditional support and encouragement of believing the achievement.

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ABBREVIATIONS

AFDEs : Asset Flow Differential Equations
BF : Behavioral Finance
BIST : Borsa İstanbul
CF : Classical Finance
CMB : Capital Market Board
EMH : Efficient Market Hypothesis
FED : United States Federal Reserve System
NS : Nelson Siegel
TSPAKB : Türkiye Sermaye Piyasası Aracı Kuruluşlar Birliği

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ARE THERE BEHAVIORAL BIASES IN TURKISH GOVERNMENT BOND MARKET?

SUMMARY

In this thesis, it is aimed to find whether there are behavioral biases in Turkish government bond market. The Turkish government bond data are used in the period from 1 January to 31 December 2013 to estimate the yield curves by using the extended Nelson-Siegel method, which is the Svensson method. Firstly, the conceptual framework of the behavioral finance and the classical finance is mentioned in the thesis. Behavioral factors affecting investors' financial decisions, anomalies occurred in the financial markets and the theoretical reasons for anomalies and mathematical models are then mentioned respectively.

What the quantitative finance is and which behavioral biases exist in the Turkish finance market are aimed to be mentioned as well. After giving conceptual and descriptive theory related to behavioral finance, it is aimed to focus on the bond market and the mathematical modeling. Since the main aim of the thesis is to estimate the yield curves of the Turkish government bond market data in the desired period, firstly basic bond market mathematics and mathematical methods related to yield curve modeling are mentioned particularly. Empirical models and parametric models of yield curve estimations are given both theoretically and practically.

The Turkish government bond market's properties and statistics are given to make readers be familiar with the market. Outstanding securities traded in Turkey are given and the Turkish government bond market are examined as well. All conceptual theories related to behavioral finance, mathematical models related to yield curve modeling and the Turkish government bond market sections formed a basis of the application part of the thesis. By the light of this basis, the Svensson method is used to estimate yield curves of the Turkish government bond market in the desired period. It is found that important events occurred in the period of the analysis have impact on the decisions of the investors trading on the Turkish government bonds. The yield curves estimated in the desired period of the analysis show that negative and positive news and events have impacts on the traders' short term and medium term decisions in the Turkish government bond market. This situation can be the indicator of existence of the Turkish government bond market traders' myopic approach while trading in the market.

TÜRK DEVLET TAHVİLLERİNDE DAVRANIŞSAL ÖNYARGILAR VAR MIDIR?

ÖZET

Bu tez çalışmasında Türk devlet tahvillerinde davranışsal önyargıların olup olmadığı araştırılmıştır. 1 Ocak 2013 ile 31 Aralık 2013 tarihleri arasında borçlanma araçları piyasasında işlem gören kuponsuz ve sabit kuponlu Türk devlet tahvillerinin verileri kullanılmıştır. Veriler devlet tahvillerine ait ağırlıklı ortalama fiyat, kupon oranı, kupon dönemi ve vadeye kalan gün bilgilerini içermektedir. Parametrik bir verim eğrisi yöntemi olan Svensson yöntemi kullanarak 2013 yılına ait verim eğrileri elde edilmiş ve bu verim eğrileri davranışsal finans teorisi çerçevesinde yorumlanmıştır. Tezin uygulama kısmına geçmeden önce davranışsal finans teorisi incelenmiştir.

Tezin ikinci kısmında, davranışsal finans teorisinin tanımı ve klasik finans ile arasındaki farklar ele alınmıştır. Klasik finans ve davranışsal finans arasındaki farklar yatırımcı ve piyasa üzerinden açıklanıp, tablo ile özetlenmiştir. Sosyal, duygusal ve bilişsel faktörlerin yatırımcı davranışlarını nasıl etkilediği, bu faktörlere örnek verilerek incelenmiştir. Sosyal faktör olarak sürü davranışı, duygusal faktör olarak panik ve bilişsel faktör olarak da miyop yaklaşım açıklanmıştır. Finans piyasasında gözlemlenen yatkınlık etkisi (disposition effect), demirlemek (anchoring), aşırı güven (overconfidence), aşırı reaksiyon gösterme (overreaction), düşük reaksiyon gösterme (underreaction), aşina olma (familiarity) ve statüko (status quo) önyargıları açıklanmıştır. Bu açıklanan önyargıların dayandırıldığı teorik nedenler ve matematiksel modeller de incelenmiştir. Davranışsal finansta anomalileri açıklayan ve matematiksel modeller sunan teoriler olarak beklenti teorisine (prospect theory), sapma teorisine (deviation theory) ve varlık akış teorisine (asset flow theory) değinilmiştir.

Nicel davranışsal finansın, matematiksel ve istatistiksel yöntemler ile psikolojik kavramları birlikte kullanarak yatırımcı davranışını ve piyasa anomalilerini açıklayan bir bilim dalı olduğundan bahsedilmiştir. Türk finans piyasasında yapılan çalışmalar ve bulunan başlıca önyargılardan da bahsedilmiştir. Aşırı güven, aşırı reaksiyon gösterme, düşük reaksiyon gösterme, aşina olma ve statüko önyargılarının Türk finans piyasasında gözlemlendiği çeşitli çalışmalarla gösterilmiştir.

Tezin üçüncü kısmında, borçlanma araçları piyasası ve verim eğrisi modelleri açıklanmıştır. Temel tahvil piyasası matematiği ve fiyatlaması ile ilgili formüller verilip verim eğrisi modelleri tanıtılmıştır. Normal, ters, sabit ve kambur verim eğrilerinin tanımlarını ve bu eğrilerin yatırımcı açısından ekonomik göstergeleri açıklanmıştır. Verim eğrisi tahmininde kullanılan empirik ve parametrik yöntemler açıklanmıştır. Empirik yöntemlerden doğrusal ve kübik splayn enterpolasyon yöntemlerine, parametrik yöntemlerden de Nelson-Siegel ve Svensson yöntemlerine değinilmiştir.

Lineer enterpolasyon yöntemi kullanılarak verim eğrisi elde etmek için spot oran fonksiyonu, $r(t)$, lineer fonksiyon olarak tanımlanmıştır. $t_i \leq t \leq t_{i+1}$ için, spot oran fonksiyonu:

$$\begin{aligned} r(t) &= a_i + b_i t \\ r(t_i) &= r_i \\ r(t_{i+1}) &= r_{i+1} \end{aligned}$$

olarak modellenmiştir.

O halde, enterpolasyon formülü:

$$r(t) = \frac{t - t_i}{t_{i+1} - t_i} r_{i+1} + \frac{t_{i+1} - t}{t_{i+1} - t_i} r_i$$

olarak bulunur.

Bu durumda vadeli oran fonksiyonu, $f(t)$:

$$f(t) = \frac{d}{dt} r(t)t = a_i + 2b_i t \quad \text{for} \quad t_i \leq t \leq t_{i+1}$$

olarak elde edilir.

Kübik splayn enterpolasyon yöntemi kullanılarak verim eğrisi elde etmek için spot oran fonksiyonu, $r(t)$, 3. dereceden polinom olarak tanımlanmıştır. $t_i \leq t \leq t_{i+1}$ için, spot oran fonksiyonu:

$$r_i(t) = a_i + b_i(t - t_i) + c_i(t - t_i)^2 + d_i(t - t_i)^3$$

olarak tanımlanır.

Parametrik yöntemlerden Nelson-Siegel ve Svensson yöntemlerine de değinilmiştir. Nelson-Siegel yöntemi kullanılarak verim eğrisi elde etmek için vadeli oran fonksiyonu, $f(t)$:

$$f(\tau) = \beta_0 + \beta_1 e^{-\tau/\lambda} + \beta_2(\frac{\tau}{\lambda})e^{-\tau/\lambda}$$

$\beta_0, \beta_1, \beta_2$ ve λ katsayılar, τ vadeye kadar zaman ve $\lambda > 0$ olarak tanımlanmıştır.

Eğer λ biliniyorsa, Nelson-Siegel yöntemi lineer bir modele dönüşür. Bu yüzden, λ değerlerini sabitleyerek ona karşılık gelen denklem en küçük kareler yöntemi ile hesaplanır. En yüksek R^2 değerine sahip denklemin parametreleri verim eğrisi için seçilir.

Svensson yöntemi kullanılarak verim eğrisi elde etmek için vadeli oran fonksiyonu, $f(t)$:

$$f(\tau) = \beta_0 + \beta_1 e^{-\tau_1/\lambda} + \beta_2(\frac{\tau_1}{\lambda})e^{-\tau_1/\lambda} + \beta_3(\frac{\tau_2}{\lambda})e^{-\tau_2/\lambda}$$

$\beta_0, \beta_1, \beta_2, \beta_3$ ve λ katsayılar, τ_1 ve τ_2 vadeye kadar zaman ve $\lambda > 0$ olarak tanımlanmıştır. Svensson yöntemi için maksimum olabilirlik, lineer olmayan en küçük kareler veya genel momentler yöntemlerinden biri kullanılarak katsayılar tahmin edilir.

Parametrik yöntemlerin empirik yöntemlere göre verim eğrilerinin ekonomik özellikleri daha iyi yansıttığı için ve Svensson yöntemi Nelson-Siegel yönteminin genişletilmiş versiyonu olduğu için bu tez çalışmasında parametrik yöntem olan Svennson yöntemi veri setine uygulanmıştır.

Tezin dördüncü kısmında, Türk finans piyasasında devlet tahvili piyasasının yeri açıklanmıştır. Borçlanma araçları piyasasında en çok devlet tahvillerinin işlem gördüğü istatistiki verilerle belirtilmiş olup, tez çalışmasında bu nedenden dolayı devlet tahvillerinin incelendiği belirtilmiştir.

Tezin beşinci kısmında, Türk devlet tahvillerinin verim eğrileri tahmin edilmiştir. Svensson yöntemi 1 Ocak 2013 ile 31 Aralık 2013 tarihleri arasında borçlanma araçları piyasasında işlem gören Türk devlet tahvillerinin verilerine uygulanmış ve verim eğrileri elde edilmiştir. Analiz döneminde meydana gelen önemli olayların verim eğrileri üzerinde herhangi bir etkiye sahip olup olmadığı elde edilen verim eğrileri üzerinden yorumlanmıştır. Gezi parkı olayları, FED tutanakları ve FED kararları, 2013 yılında finans piyasası üzerinde etkilere sahip olduğu gözlemlenmiştir.

Tezin son kısmında, elde edilen verim eğrileri ile analiz döneminde meydana gelen Gezi parkı olayları, FED tutanakları ve FED kararları haberlerinin ilişkisi incelenmiştir. Bu olayların Türk devlet tahvilleri piyasaında işlem yapan yatırımcıların kısa dönem ve orta dönem kararlarını etkilediği ama uzun dönem kararlarını daha az etkilediği elde edilen verim eğrileri üzerinden gösterilmiştir. Bu durum Türk devlet tahvili piyasasında işlem yapan yatırımcının miyop yaklaşım sergilediği ve yatırımlarının davranışsal önyargı içerdiğini göstermiştir.

1. INTRODUCTION

Mathematical finance is the field that studies financial markets by the light of mathematical and numerical models. There exist many researches studying financial phenomena by establishing mathematical modelings. Therefore, it can be said that there is strong relation between mathematics and finance fields.

Moreover, for recent years, a new finance field emerged that studies financial behavior in the market by using psychological phenomena, which is the behavioral finance. According to behavioral finance, financial market anomalies, bubbles and crashes, all of finance markets experience, can be explained by the psychological phenomena which has great impact on the people's decision makings.

The researchers who are studying financial markets by using mathematical and numerical modeling should take into consideration the psychological aspects as well. The study including mathematics, finance and psychology fields is named the quantitative behavioral finance.

In this thesis, it is planned to give brief definitions of behavioral factors, anomalies, theoretical reasons related to behavioral finance, bond market and yield curve modeling. The chapters in this thesis is organized as follows:

Chapter 1 is the introduction part of the thesis in which the organization of the thesis is given briefly.

In chapter 2, what the behavioral finance is explained by mentioning behavioral factors, market anomalies, and the theories explaining those anomalies. Behavioral biases examined in the Turkish finance market is also covered in the chapter 2.

In chapter 3, what the bond market is and how yield curves are modeled are covered. Empirical models and parametric models of yield curve estimations are given both theoretically and practically.

In chapter 4, outstanding securities traded in Turkey are given and the Turkish government bond market are examined.

The chapter 5 is the application part of the thesis. The Svennsson method, which is also covered in the yield curve modeling section of the thesis, is applied to the Turkish government bond data in order to construct yield curves. The important events occurred in the period of our analysis and the yield curves that is constructed are examined and their relations are considered in this chapter as well.

Lastly, the conclusion part of the thesis is mentioned in chapter 6.

2. WHAT ARE BEHAVIORAL FINANCE AND ECONOMICS?

In order to define the Behavioral Finance (BF) and the Behavioral Economics (BE), it is needed to know what the Classical Finance (CF) and Efficient Market Hypothesis (EMH) are. The CF is a field that explain market dynamics on the assumption based on EMH. According to EMH, investors are fully rational and all relevant information related to market are reflected on the prices fully and instantaneously. Therefore, it is not possible for an investor to beat the market.

However, in recent years, market anomalies show that people have biases that effect their economic decisions and avoid them behave rationally. This situation brings about need of a new paradigm which have ability to explain both market anomalies and investor behaviors. The BF differs from the CF in a sense of having assumption that individuals are not rational as the EMH states. Thus, the BF theory become new paradigm has capability of explaining market anomalies and investor behaviors.

The BE is a field that study how psychological factors effect financial behaviors [2]. According to BF; or BE which are similar fields, social, emotional and cognitive factors have effects on individuals' and institutions' economic decisions, and therefore they also have effects on market's prices and returns [3].

Table 2.1: Difference between the CF and the BF.

Case	Classical Finance	Behavioral Finance
$Investor/Manager$	Fully rational	Limited rationality
$Market$	Reflects all relevant information	Information inefficient

2.1 Behavioral Factors

As noted earlier, social, emotional and cognitive factors have effects on investors' and institutions' economic decisions according to the BF. Therefore, which social, emotional and cognitive factors effecting economic decisions will be covered in this section.

2.1.1 Social factor

Investors are not disconnected from the society. Social factors, societal norms have effects on investors' decisions. For example, herd behavior is a social factor that is seen in the financial market.

2.1.1.1 Herd behavior

The investor having herd behavior in their economic decision usually has the opinion that crowd can not be wrong and they know something that he or she do not. Herd behavior is an anomaly in which investors behave together without questioning the action. Thus, it is seen that this market anomaly is caused by investor's irrational behavior. Individual investors often buy shares irrationally in bubble cases and sell irrationally in crash cases in the market. That is why, the BF literature defines herd behavior as the collective irrational behaviors of investors [4].

2.1.2 Emotional factor

Emotions also have effects on one's decisions on the financial market. Investor's panic behavior is seen in the financial market which is an emotional factor.

2.1.2.1 Panic

Panic selling/buying is an investor behavior which is based on purely emotion and fear rather than assessment of the firm fundamentals. In panic selling case, investors sell their stock shares which result in sharp decline in the price. Moreover, in panic buying case, investors buy the stock shares which result in rapid increase in the price. Investors engaged with panic buying and selling behavior in financial market have greed and fear emotion, respectively.

2.1.3 Cognitive factor

Investors' decisions in the financial market are affected by their cognitive abilities. Myopic approach is the cognitive factor that have effects on investors' market decisions.

2.1.3.1 Myopic approach

Myopic approach is a cognitive factor that investors are considered to be nearsighted. The investors which are myopic experience the market risk by relying only on the short-term movements of the securities rather than the long-term movements [2].

2.2 Anomalies

There exist many researches in the behavioral finance literature showing that individuals behave irrationally in their economic decisions and that situation make market prices deviate from the fundamental values. For example, Daniel et al. (2002) state in their study that investors' biases effects market prices mostly [5]. Anomalies existed in markets are the consequences of the irrational behaviors of investors and their biases. Therefore, which anomalies exist in market will be covered in this section.

2.2.1 Disposition effect

Disposition effect is an anomaly in BF theory in which investors have tendency to sell winning securities too early, but hold losing securities too long [6]. Odean (1998) studied 10000 account traders and found that investors are reluctant to realize their losses, they rather give more importance to their winnings [7].

2.2.2 Anchoring

Anchoring is a anomaly that investors make their decisions by the light of the first information they have encountered. It is a tendency of investors relying only on one piece of information they have before when making their financial decisions. For example, investors have tendency to buy stock shares which have fallen recently and believe that this stock's price will increase to the last high price it reached. However, it may not be the case and the stock price can continue to decrease. Investors having anchoring bias fix their decisions on the past information and they make their investment decisions irrationally according to this past information.

2.2.3 Overconfidence

Overconfidence is an anomaly in which investors overestimate their abilities. It is shown in the study that overconfident investors give more emphasis on their special knowledge than the common knowledge [8]. They believe that they are better than others in a sense of choosing the best stocks in the market.

2.2.4 Overreaction

Overreaction is an anomaly that exists in financial market which affects securities' prices larger than the expected in case of the new information about the security. It is known that new information related to a specific security have impact on stock's price more or less instantly. According to the EMH, this impact on the price should survive if no new information is released. However, in the overreaction case, it is seen that the impact on the price is not permanent, it reverses themselves after a period of time [9]. Therefore, overreaction can be defined to be the price change that exceeds the change in valuation [9]. This price change can be a positive or a negative change.

2.2.5 Underreaction

Underreaction is an anomaly in which investors rely heavily on their prior beliefs and they underreact to new information. The undereaction behavior of the investors affect securities' prices less than the expected.

2.2.6 Familiarity Bias

Familiarity bias is an anomaly exist in financial market in which investors have tendency to invest on the securities that they are familiar with. Investors having familiarity bias expect higher expected return and lower risk while investing on the securities they are familiar with. By investing to the familiar securities, it is most probable that investors underestimate the risk of investing on those securities and that make them face more risk they desired. It is also found that familiarity bias affects the individual investors more than professional investors [10].

2.2.7 Status Quo Bias

Status quo is investor bias in which investors have tendency to maintain their economic decision when they have chance to change. Investors see their current status quo more favorable than the other options. Therefore, while changing their economic decision to an alternative security give opportunity of getting more gain, status quo biased investors insist on staying their current decision.

2.3 Possible Theoretical Reasons for Anomalies and Mathematical Models

After mentioning anomalies existed in market, it is important to state the theoretical reasons for those anomalies according to the BF. Therefore, some of the possible theoretical reasons and mathematical models in the BF will be covered in this section.

2.3.1 Prospect theory

Prospect theory is the theory in the BF which is an alternative model to expected utility theory in classical finance. Kahneman and Tversky developed the prospect theory in 1979 which describes investors as behaving consistent with psychological based theory, and inconsistent with Expected utility theory as the CF suggest [11]. According to the theory, investors have tendency to decide on the outcomes that are certain rather than the outcomes that are probable. Therefore, it can be inferred that investors choose their economic decisions with heuristics according to this theory.

2.3.2 Deviation theory

Deviation theory explains overreaction and other behavioral biases effecting stock prices by subtracting the relative changes in the net asset value from the market price [9]. It aims to explain behavioral biases by examining significant deviation between the market price return and the fundamental value return on a particular day [12]. From classical finance perspective, it is not reasonable to have opposite direction price change before the price ascent/descent event day. However, it is statistically significant to have opposite direction changes in the prices before and after the event of the significant rise or fall in the price deviation.

2.3.3 Asset flow theory

According to EMH, the market price is in equilibrium since investors have common information. However, asset flow theory argues that the market may have limited information or the limited number of new investors at a particular time [13]. Therefore, there exists uncertainty about the other investors' strategies and decisions. This uncertainty thus results in the behavioral biases, especially overreaction bias, in the financial market [12]. Asset flow theory have used differential equations in order to study investor biases and their strategies within the market system having a prescribed number of shares and cash supply [13]. Such differential equations are named as asset flow differential equations (AFDEs). AFDs are used to study quantitative price behavior, momentum, bubbles, overreaction and crashes in experimental and real asset markets [14]. Caginalp and collaborators have developed AFDS and analyzed them asymptotically to study asset market dynamics with finite cash and asset. Asset flow theory assumption of finiteness of asset and cash differs from the CF assumption of having infinite arbitrage [15], [13].

2.4 Quantitative Behavioral Finance

Quantitative behavioral finance is a new discipline that aims to explain relationship between behavioral biases and market valuation by using mathematical and statistical methodologies [16]. This new discipline is composed of the economy, mathematics and psychology. Gunduz Caginalp, Vernon Smith, David Porter, Don Balenovich, Ahmet Duran and Ray Sturm are the important pioneers in this new discipline who have applied statistical and mathematical methods on both the real market data and experimental economics data to understand behavioral impacts on the finance and to predict quantitative relations [17].

2.5 Behavioral Biases in Turkish Finance Market

After examining behavioral anomalies and their possible theoretical reasons, it is important to note that whether these biases exist in Turkish finance market. Most of the researches in behavioral finance literature focus on the developed markets such as USA, UK and Western Europe. However, it become also very popular among developing countries' researchers to analyze behavioral biases and anomalies. In Turkey, which is also a developing country, some researches are done about the behavioral factors and anomalies effecting investors decisions.

Some important researches related to behavioral biases and anomalies exist in Turkish finance market should be mentioned in this section. One important research related to behavioral finance done in Turkish finance market is the study examining Turkish individual stock investor data for $244,146$ investors in 2011. It is found in this study that overconfidence, disposition effect, status quo, and familiarity biases exist in the BIST [18].

Another interesting study is done with banking sector data of BIST-100 index in the period of $2008-2012$ and it is found that no herding behavior exists among the investors trading on the banking sector in BIST-100 index [19].

In another research, overreaction anomaly is studied in the BIST stock market data within the period of $1992-2004$ and it is found that investors have overreaction bias and the BIST stock market violates the Efficient Market Hypothesis [20]. The another anomaly examined in Turkish finance market is the overconfidence. The study is done by examining closed prices and trading volumes of the 114 firms traded in the BIST stock market in the period of May 1995 to October 2006. It is found that overconfident investors have tendency to trade more aggressively after they get market gains [21].

3. BOND MARKET AND YIELD CURVE MODELING

In this chapter, some basic definitions and relations related to bond market will be covered in order to interpret and understand yield curves.

3.1 Basic Bond Market Mathematics

Bonds if hold until maturity are risk-free securities which are issued by governments, financial institutions or companies. Bond is an agreement in which the company, government or financial institution borrow money from the investor with predetermined interest rate and pay back at predetermined maturity day. If the bond holder get one payment at only maturity day, this bond is called *zero coupon bond*. However, if the bond has a maturity payment and sequence of coupon payments such as quarterly, semi-annually, annually, etc..., this bond is called *coupon bond*.

The yield curve is the curve that describes the relationship between interest rates and different maturities of the bonds. The yield curve reflects the markets participants' expectations about the future changes in the interest rates and monetary policy conditions.

There are four types of yield curves; which are normal, inverted, flat and humped yield curves. The *normal yield curve* generally has positive upward slope. The higher yields are expected for the longer maturity days in the normal yield curve.

The *inverted yield curve* is considered as signal for economic recession, since it gives less yields for longer maturity days. It generally occurs when investors demand for short term loans much more than that the long term loans. It can be inferred that economy can decline and slow down in the future for that case.

The *flat yield curve* is the case when yields for short term and the long term are similar. This is an indication of economic slowdown as well. It is uncertain whether interest rates will increase or decrease in the flat yield curve.

The *humped yield curve* is encountered when the medium term yields are higher than both long and short term yields. It is also known as bell-shaped curve.

The yield curves also known as the term structure of interest rates which is constructed by spot rates, forward rates or discount function, so it is needed to present the relationship between these three concepts [22].

Firstly, it is needed to define the followings:
$r(t)$ is the *continuously compounded risk free rate* of the bond for the maturity t.
$Z(0,t)$ is the *price of an bond* which pays 1 unit of currency at time t issuing at time 0.

$$r(t) = -\frac{ln(Z(0,t))}{t} \quad \textbf{(3.1)}$$

$$Z(0,t) = e^{-r(t)t} \quad \textbf{(3.2)}$$

Note that $Z(0,t)$ must be decreasing in t in order not to have arbitrage opportunity in the market. Otherwise, if $Z(0,t_1) < Z(0,t_2)$ for some $t_1 < t_2$, then the arbitrageur can buy bond for time t_1 and sell for time t_2 and get $Z(0,t_2) - Z(0,t_1) > 0$.

$Z(t)$ is also known as the discount function and $r(t)$ as the spot rate of the bond.

Let
$Z(0;t_1,t_2)$ be the *discount factor* from t_1 to t_2.
$f(0;t_1,t_2)$ be the *forward rate* directing the period from t_1 to t_2.

$$Z(0,t_1)Z(0;t_1,t_2) = Z(0,t_2)$$

$$Z(0;t_1,t_2) = e^{-f(0;t_1,t_2)(t_2-t_1)} \quad \textbf{(3.3)}$$

By the equations below, we can get:

$$f(0;t_1,t_2) = -\frac{ln(Z(0,t_2)) - ln(Z(0,t_1))}{t_2 - t_1}$$

or

$$f(0;t_1,t_2) = \frac{r(t_2)t_2 - r(t_1)t_1}{t_2 - t_1} \quad \textbf{(3.4)}$$

The *instantaneous forward rate* at t is defined as:

$$f(t) = \lim_{\varepsilon \to 0} f(0;t,t+\varepsilon) \quad \text{for whichever t this limit exists}$$

Hence, it is easy to give the relation between the spot rate and the forward rate:

$$\begin{aligned} f(t) &= -\frac{d}{dt} ln(Z(t)) \\ &= \frac{d}{dt}[r(t)t] \\ &= r(t) + r'(t)t \end{aligned} \quad \textbf{(3.5)}$$

Notice that the equation **3.5** implies that forward rate lies above (below) the zero coupon yield when the yield curve has positive (negative) slope at a given maturity [23].

After giving all relations, the following diagram summarizes the equations:

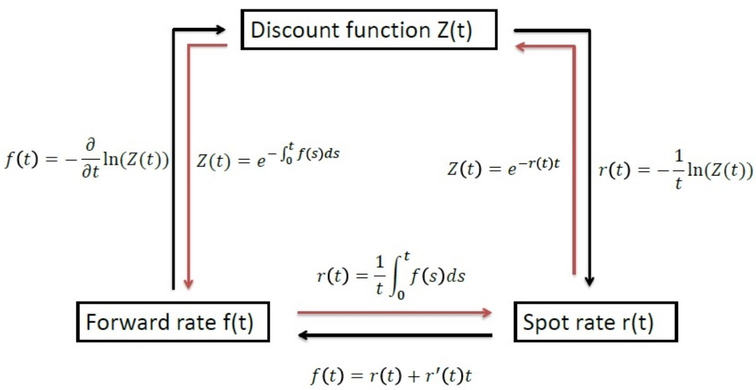

Figure 3.1: Relationship diagram for discount function, spot and forward rates.

3.2 Yield Curve Modeling

Modeling the term structure of interest rates, the yield curve, is based on the two approaches which are the parametric modeling and the empirical modeling. Yield curves constructed by empirical models often lack economic appeal, such as having negative and discontinuous forward rates. Parametric models are developed in order to construct yield curve by single parametric model which also addresses economic properties of yield curves.

3.2.1 Empirical models

3.2.1.1 Linear interpolation

In the linear interpolation method, the spot rate function is defined to be a linear function. For $t_i \leq t \leq t_{i+1}$, the spot rate function is modeled as

$$\begin{aligned} r(t) &= a_i + b_i t \\ r(t_i) &= r_i \\ r(t_{i+1}) &= r_{i+1} \end{aligned} \quad (3.6)$$

Hence the interpolation formula becomes:

$$r(t) = \frac{t - t_i}{t_{i+1} - t_i} r_{i+1} + \frac{t_{i+1} - t}{t_{i+1} - t_i} r_i \quad (3.7)$$

Then, the forward rate function becomes:

$$f(t) = \frac{d}{dt} r(t) t = a_i + 2b_i t \quad \text{for} \quad t_i \leq t \leq t_{i+1} \quad (3.8)$$

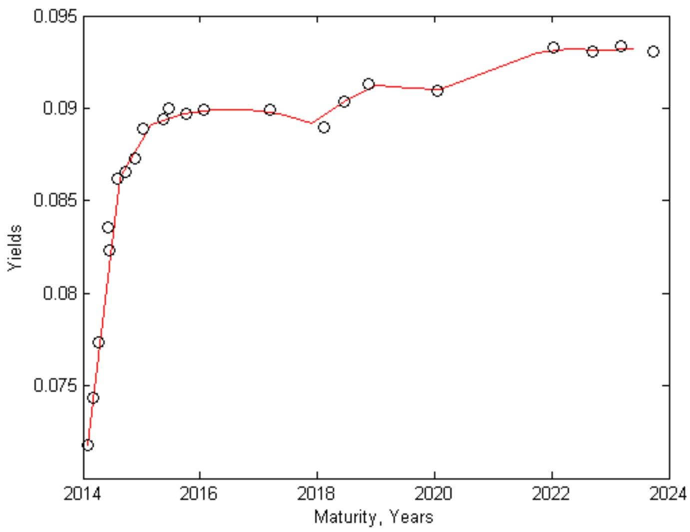

Figure 3.2: Linear interpolation estimation of the yield curve for 4 December 2013.

3.2.1.2 Cubic spline interpolation

The cubic spline interpolates the given data points by defining third degree polynomial for intervals between two consecutive data points. For $t_i \leq t \leq t_{i+1}$, the spot rate function is defined as

$$r_i(t) = a_i + b_i(t - t_i) + c_i(t - t_i)^2 + d_i(t - t_i)^3 \quad (3.9)$$

Given n data points $(maturity, yield)$, the cubic spline function requires to satisfy the following conditions:

- the cubic spline function should satisfy the given data points:

$$r_i(t_i) = r_i \quad \text{and} \quad r_i(t_{i+1}) = r_{i+1} \quad \text{for all} \quad i = 1, 2, \ldots, n-1. \tag{3.10}$$

- the cubic spline function should be continuous:

$$r'_{i-1}(t_i) = r'_i(t_i) \quad \text{for all} \quad i = 2, \ldots, n-1. \tag{3.11}$$

- the cubic spline function should be differentiable:

$$r''_{i-1}(t_i) = r''_i(t_i) \quad \text{for all} \quad i = 2, \ldots, n-1. \tag{3.12}$$

These three conditions give $3n-5$ equations. However, there are $3n-3$ unknowns in the system of equations constructed by cubic spline interpolation method. That is why two additional equations are needed to find the all unknowns in the system. Last two additional equations are named as "boundary conditions". For the natural boundary condition, the first and the last term values are both set equal to zero:

$$r''_1(t_1) = 0 \quad \text{and} \quad r''_{n-1}(t_n) = 0 \tag{3.13}$$

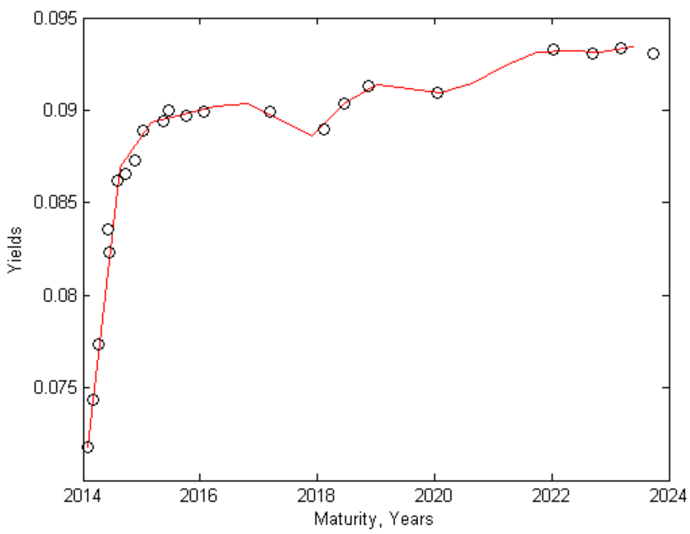

Figure 3.3: Cubic spline interpolation estimation of the yield curve for 4 December 2013.

3.2.2 Parametric models

3.2.2.1 Nelson-Siegel method

In 1987, Nelson and Siegel [24] developed the parametric model for estimating the term structure of interest rates, which has ability to represent shapes of yield curve: monotonic, humped, and S-shaped.

In their model, forward rate curve $f(\tau)$ is specified as follows:

$$f(\tau) = \beta_0 + \beta_1 e^{-\tau/\lambda} + \beta_2 (\frac{\tau}{\lambda}) e^{-\tau/\lambda} \qquad \textbf{(3.14)}$$

where $\beta_0, \beta_1, \beta_2$ and λ are coefficients, τ is time to maturity and $\lambda > 0$.

Three parts defined in the model; a constant, an exponential decay function and a Laguerre function, reflect three factors; level, slope and curvature of the curve, respectively [25]. The coefficient λ is defined to be the shape parameter. The role of three factors can be seen by investigating the limiting behavior when $\tau \to \infty$ and $\tau \to 0$

$$\begin{aligned} \lim_{\tau \to \infty} f(\tau) &= \beta_0 \\ \lim_{\tau \to 0} f(\tau) &= \beta_0 + \beta_1 \end{aligned} \qquad \textbf{(3.15)}$$

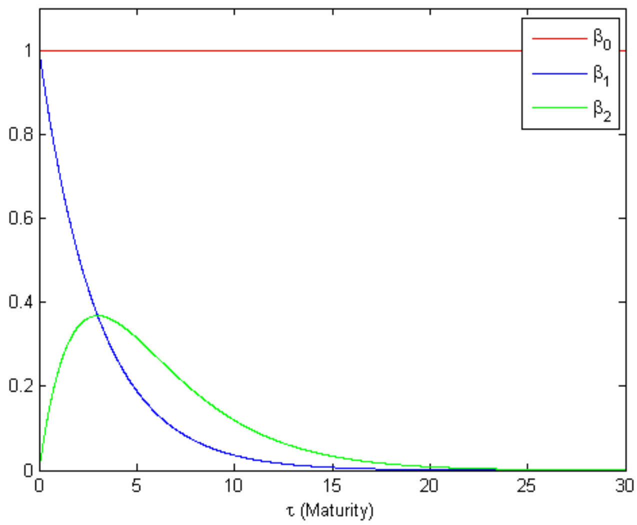

Figure 3.4: Limiting behaviors of the three factors in the NS method for the forward rate curve.

It can be seen in the figure 3.4 that β_0 is interpreted as the long-term interest rate since it is independent of τ. The β_1 is interpreted as the short-term interest rate since the exponential decay function approaches to zero as τ tends to infinity and approaches to β_1 as τ tends to zero. The β_2 is interpreted as medium-term interest rate since it approaches to zero as both τ tends to infinity and zero.

The spot rate function, $r(\tau)$, equals to the equally weighted-average of the forward rates

$$r(\tau) = \frac{1}{\tau}\int_0^{\tau} f(u)du \tag{3.16}$$

with continuous compounding.

Nelson-Siegel model for the spot rate curve then equals

$$\begin{aligned} r(\tau) &= \frac{1}{\tau}\int_0^{\tau}(\beta_0+\beta_1 e^{-u/\lambda}+\beta_2(\frac{u}{\lambda})e^{-u/\lambda})du \\ &= \frac{1}{\tau}(\beta_0\tau+\beta_1\frac{1-e^{-\tau/\lambda}}{\frac{1}{\lambda}}+\beta_2\int_0^{\tau}\frac{u}{\lambda}e^{-u/\lambda}du) \\ &= \frac{1}{\tau}(\beta_0\tau+\beta_1\frac{1-e^{-\tau/\lambda}}{\frac{1}{\lambda}}+\beta_2(-e^{-\tau/\lambda}+\frac{1-e^{\tau/\lambda}}{\lambda})) \\ &= \beta_0+\beta_1\frac{\lambda}{\tau}(1-e^{-\tau/\lambda})+\beta_2\frac{\lambda}{\tau}(1-e^{-\tau/\lambda})-\beta_2 e^{-\tau/\lambda} \end{aligned} \tag{3.17}$$

If we also look at the limiting behavior of the spot rate curve, we get the similar results:

$$\begin{aligned} \lim_{\tau\to\infty} r(\tau) &= \beta_0 \\ \lim_{\tau\to 0} r(\tau) &= \beta_0+\beta_1 \end{aligned} \tag{3.18}$$

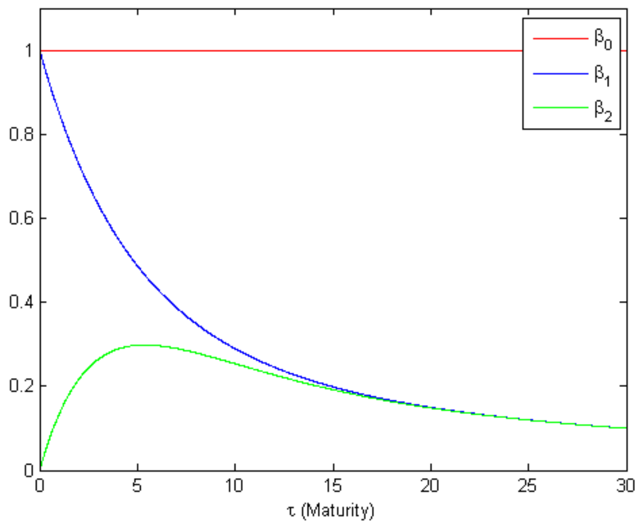

Figure 3.5: Limiting behaviors of the three factors in the NS method for spot rate curve.

Similarly, if the figure 3.5 is examined, it is investigated that β_0 is long-term, β_1 is short-term and β_2 is medium-term interest rate.

If the λ is known, the Nelson-Siegel method becomes a linear model. Therefore, Nelson and Siegel [24] used ordinary least squares estimation in order to estimate the equation **3.17** by fixing possible λ values. Highest R^2 estimate for the corresponding λ value is chosen to be the the optimal parameter set [25] for the yield curve. Diebold and Li (2006) fixed the λ value as 0.0609, by doing this they estimated the values of betas by using ordinary least squares [26].

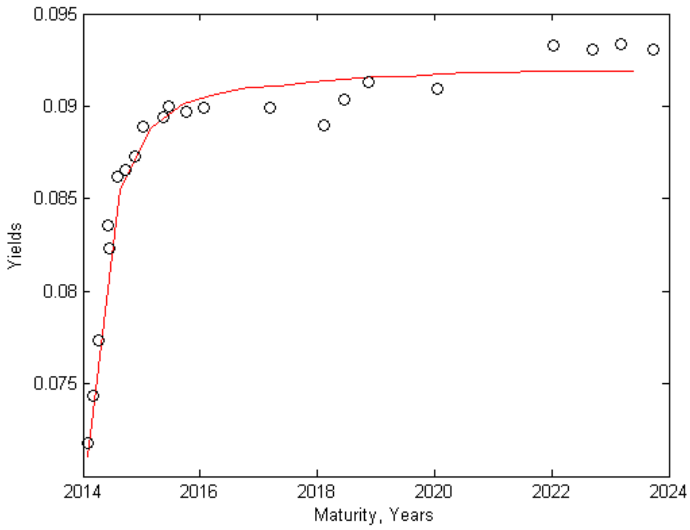

Figure 3.6: Nelson-Siegel estimation of the yield curve for 4 December 2013.

The figure 3.6 is the example of the yield curve obtained by NS method.

3.2.2.2 Svensson method

The Svensson method is the extended version of the NS method [27].

Forward rate function $f(\tau)$ constructed by Svensson method is specified as follows:

$$f(\tau) = \beta_0 + \beta_1 e^{-\tau_1/\lambda} + \beta_2(\frac{\tau_1}{\lambda})e^{-\tau_1/\lambda} + \beta_3(\frac{\tau_2}{\lambda})e^{-\tau_2/\lambda} \quad \textbf{(3.19)}$$

where $\beta_0, \beta_1, \beta_2, \beta_3$ and λ are coefficients, τ_1 and τ_2 is time to maturity and $\lambda > 0$.

The first three parts defined in the equation **3.19** is the same with the parts defined in the equation **3.14**. Hence, β_0, β_1 and β_2 still represent the long-term, the short-term and the medium-term interest rates, respectively. The β_3 in this equation **3.19** represents the medium-term interest rate as well because it has same component with β_2.

Spot rate function $r(\tau)$ hence becomes:

$$r(\tau) = \beta_0 + \beta_1 \frac{\lambda}{\tau_1}(1 - e^{-\tau_1/\lambda}) + \beta_2 \frac{\lambda}{\tau_1}(1 - e^{-\tau_1/\lambda}) - \beta_2 e^{-\tau_1/\lambda} + \beta_3 \frac{\lambda}{\tau_2}(1 - e^{-\tau_2/\lambda}) - \beta_3 e^{-\tau_2/\lambda} \quad \textbf{(3.20)}$$

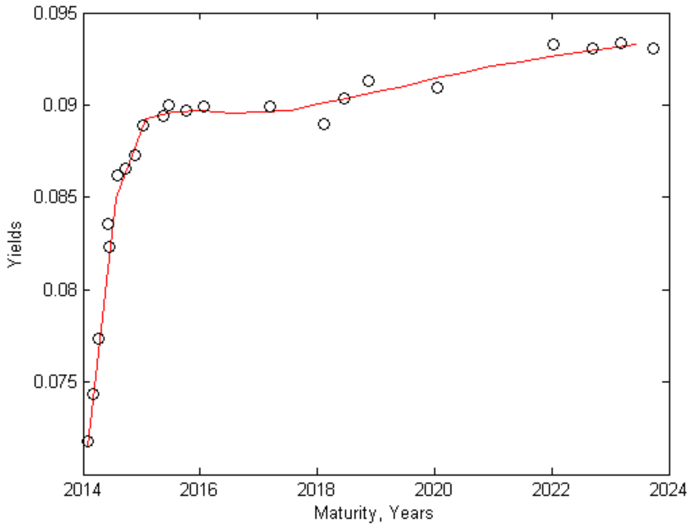

Figure 3.7: Svensson estimation of the yield curve for 4 December 2013.

In the Svensson method, estimation of the parameters can be done by Nonlinear Least-Squares, Maximum Likelihood, or the General Method of Moments [27].

4. TURKISH GOVERNMENT BOND MARKET

Fixed income securities have more trading volume than the other securities traded in Turkey.

Figure 4.1: Outstanding securities in Turkey from 1997 to November 2013 [1].

Fixed income securities in Turkey consist of bonds which have more than one year maturities and bills which have less than one year maturities. They can be issued by public or private sector institutions.

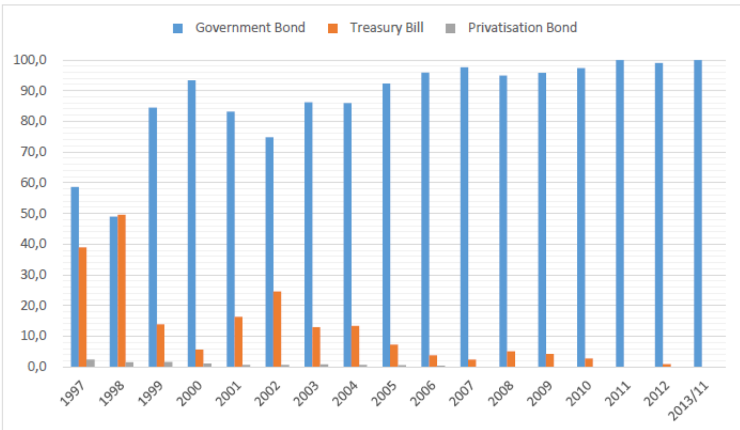

Figure 4.2: Public sector securities in Turkey from 1997 to November 2013 [1].

Dept securities issued by both public and private sector are traded at dept securities market in Borsa Istanbul (BIST) which is the the secondary market in which exchanges of bonds, bills, repo and reverse repo take place. The outstanding public sector securities are government bonds, treasury bills, revenue sharing certificates, foreign exchange indexed bonds and privatization bonds [1].

Figure 4.1 shows that public sector securities are traded more than the private sector securities. Almost all stocks traded in Turkey related to dept securities are government dept securities [28]. In BIST, government bonds are traded more than corporate bonds which are the bonds issued by private sector [29] as seen in the figure 4.1. Moreover, as seen in the figure 4.2, from 1997 to November 2013, government bonds are issued more than the treasury bills and privatisation bonds in Turkey.

Therefore, in this thesis, our data that are analyzed consist of the government bonds traded in Turkey in 2013.

5. APPLICATION

5.1 Data

In this thesis, the yield curves are estimated by the Turkish zero coupon and fixed coupon government bond data which are available on the website of BIST Debt Securities Market and the Republic of Turkey Prime Ministry Undersecretariat of Treasury. The data covers the period from 01 January 2013 to the end of December 2013 in which daily weighted average price, maturity, coupon rate and coupon period of the each government bonds are available.

The government bonds that has maturity less than one month are excluded from the data in the analysis. That is because bonds are inversely weighted by the duration while fitting the yield curve. That means the bonds with less than one month maturity have more weight than the bonds other maturities, which affect the yield curve's accuracy negatively.

In order to calculate yields of zero coupon and fixed coupon government bonds, the Mathworks software Matlab is used in this thesis. The Matlab software has the function [bndyield] in the financial toolbox that takes the price, coupon rate, coupon frequency, maturity and settlement date and gives the yield to maturity for fixed income security.

After calculating the yields of each zero coupon and fixed coupon government bonds' yields, we used the Svensson method, which is the extended Nelson-Siegel method as mentioned in the yield curve modeling chapter 3, to estimate the yield curves of the data in the desired period. In the Matlab, we can fit the yield curve by Svensson method by using [fitSvensson] function in the financial instruments toolbox. The [fitSvensson] function uses nonlinear least-squares method to fit Svensson method's parameters which define the zero yield curve.

5.2 Events

The yield curves are the indicators of the market's participants expectations about the future changes in interest rates and their assessment of monetary policy conditions [30]. Therefore, it can be inferred that there is a relation between the yield curves and the behavioral factors affecting market's participants. That is why, the events that may affect the Turkish market economy happened in the period of our analysis will be covered in this section. The important events occurred in 2013 are given in the table 5.1.

Table 5.1: Important events occurred in 2013.

Number	Events	Dates
1	Gezi Park event	20.05.2013 – 19.06.2013
2	FED report	31.07.2013
3	FED decision	18.09.2013

As seen in the table 5.1, there are three important events that have effects on the Turkish fixed income market in 2013. During these periods of events, there exist several news in the media explaining the possible outcomes of these events onto the Turkish government bond rates.

If the Turkey government benchmark bond yields are examined in 2013, it is seen that the interest rates of the Turkey benchmark bond are increased from 5 percent to 7 percent after Gezi Park event, from 9 percent to 10 percent after FED report and decreased from 9 percent to 8 percent after the FED decision.

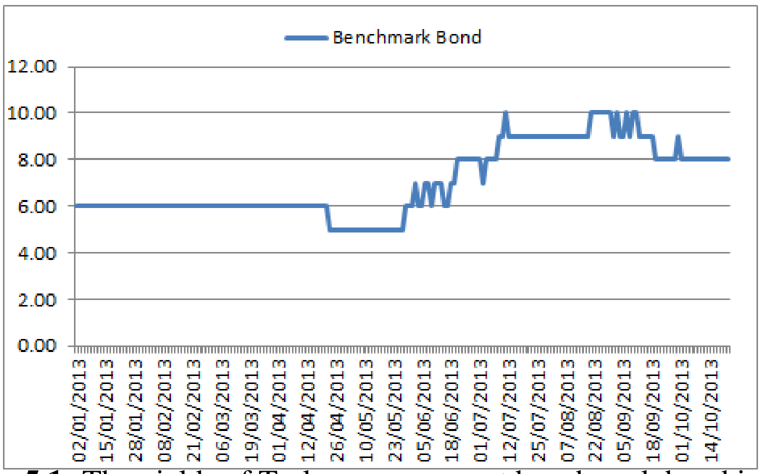

Figure 5.1: The yields of Turkey government benchmark bond in 2013

5.3 Results

It is seen in the figure 5.1 that these three events have impact on Turkish interest rates. Therefore, the Turkey government zero and fixed coupon bonds are examined to fit yield curves from April 2013 to October 2013.

Before the Gezi Park event, it is seen that the yield curve for the date 15 May 2013 in the figure 5.2 is normal yield curve which has positive slope indicating that higher yields are expected for longer maturity days. During the Gezi Park event period in the yield curve for 14 June 2013 in the figure 5.3 is still normal yield curve. However, there exist less yields for some medium term maturity days in the figure 5.3. This can be interpreted as there is an uncertainty about the Turkish government bond interest rates for the near future for investors since they expect less yield for medium term but higher yield for short term. After the Gezi Park event, it is seen that the yield curve for the date 15 July 2013 in the figure 5.4 has similar feature with the yield curve in the figure 5.3. However, there are much more cases when medium term yields less than the short term yields.

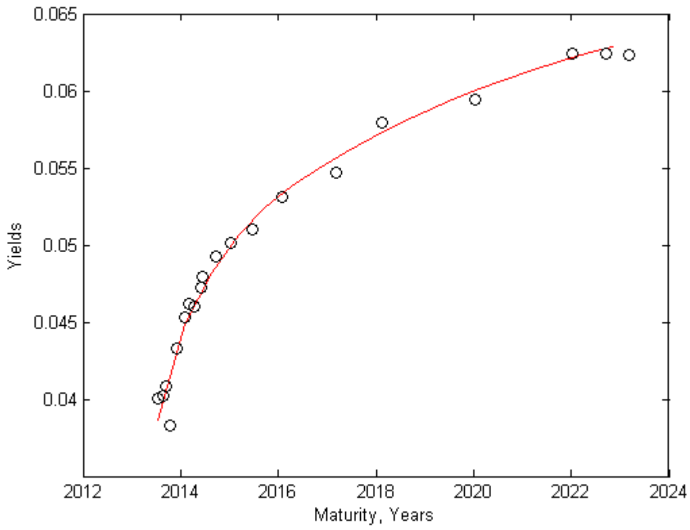

Figure 5.2: Yield curve for the date 15 May 2013.

The FED report indicated that United States Federal Reserve System was planing to have bond tapering [31]. This event resulted uncertainty in Turkish interest rates. After the FED report event, the yield curve for 15 August 2013 in the figure 5.5 has higher yield for medium and long term however, it is almost flat from medium term to long term. The almost flat part in the yield curve can be interpreted as economic slowdown

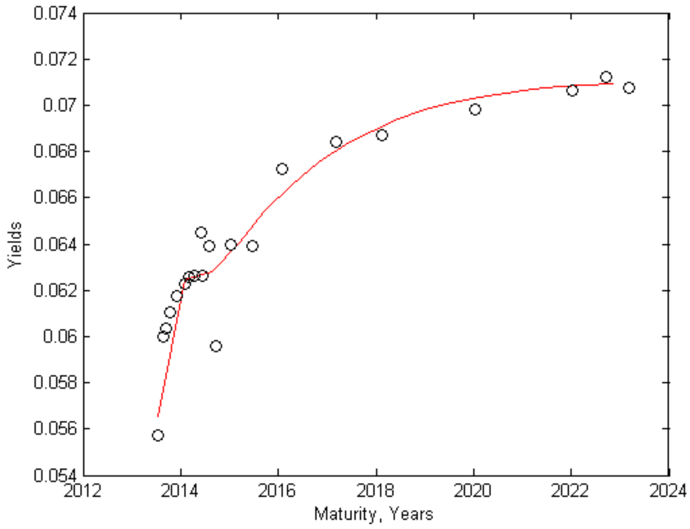

Figure 5.3: Yield curve for the date 14 June 2013.

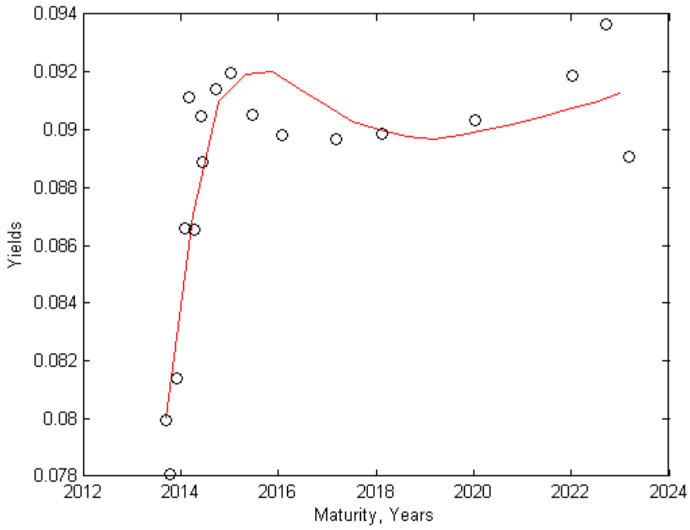

Figure 5.4: Yield curve for the date 15 July 2013.

because it is uncertain whether interest rates will increase or decrease in the flat yield curve.

18 September 2013 dated FED decision indicated that United States Federal Reserve System continue buying bonds in terms of quantitative easing policy [32]. This event resulted relief in Turkish interest rates. After the FED decision event, the yield curve for 11 October 2013 in the figure 5.6 is normal yield curve which has positive slope indicating that higher yields are expected for longer maturity days. It can be inferred that this event result in positivity economy and the Turkey government benchmark bond interest rates decreased from 9 percent to 8 percent.

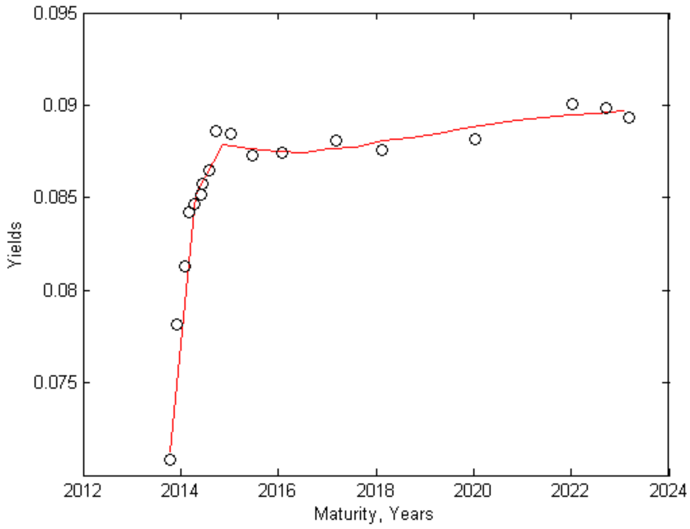

Figure 5.5: Yield curve for the date 15 August 2013.

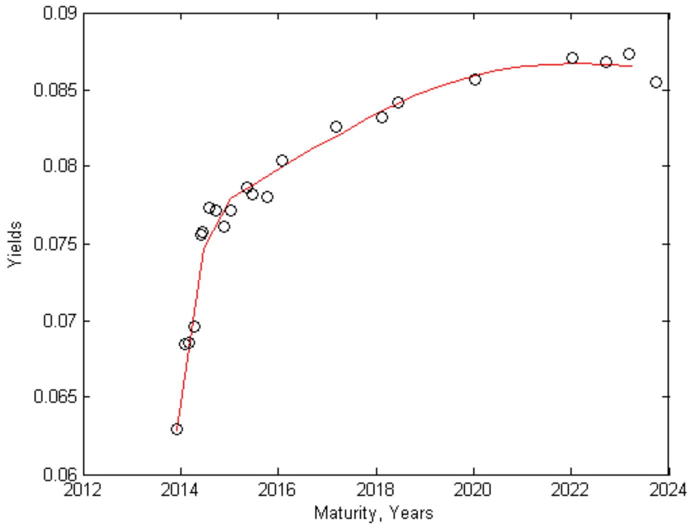

Figure 5.6: Yield curve for the date 11 October 2013.

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APPENDICES

APPENDIX A.1 : Estimated Yield Curves

APPENDIX A.1

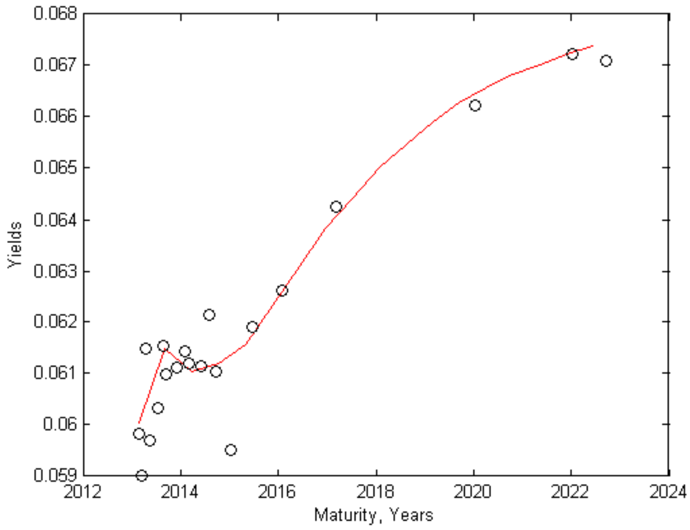

Figure A.1: Yield curve for the date 15 January 2013

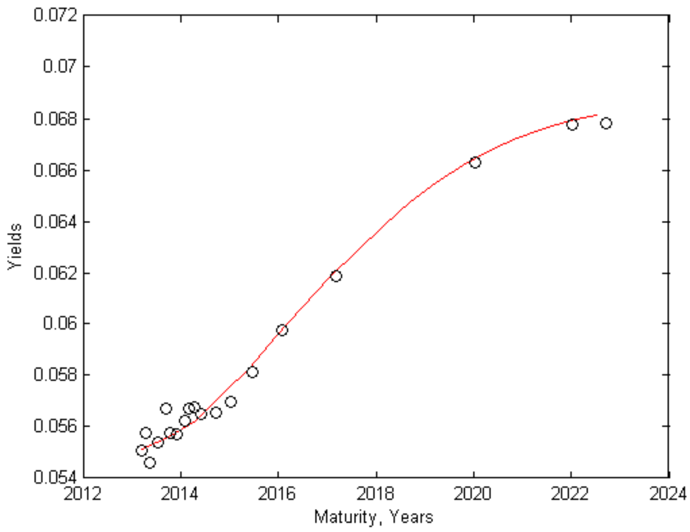

Figure A.2: Yield curve for the date 15 February 2013

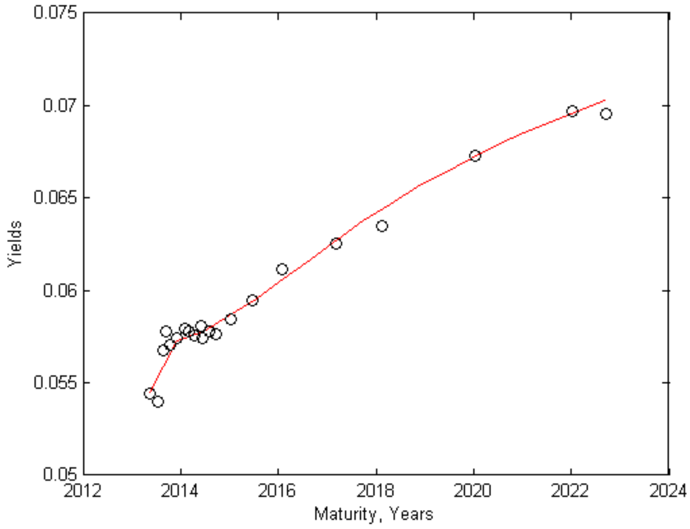

Figure A.3: Yield curve for the date 15 March 2013

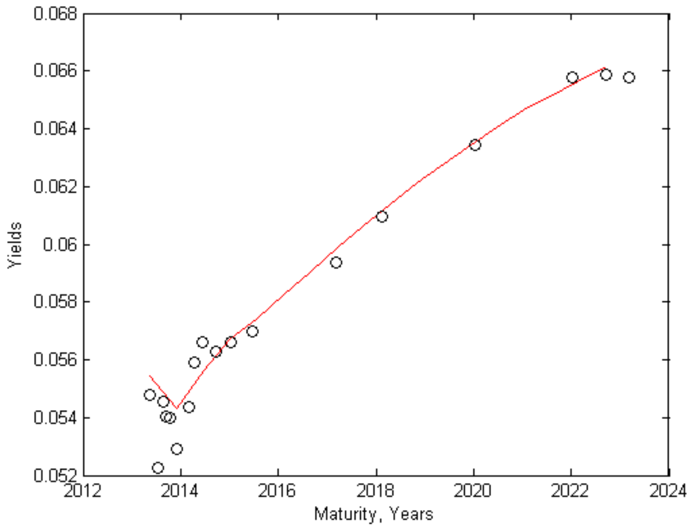

Figure A.4: Yield curve for the date 15 April 2013

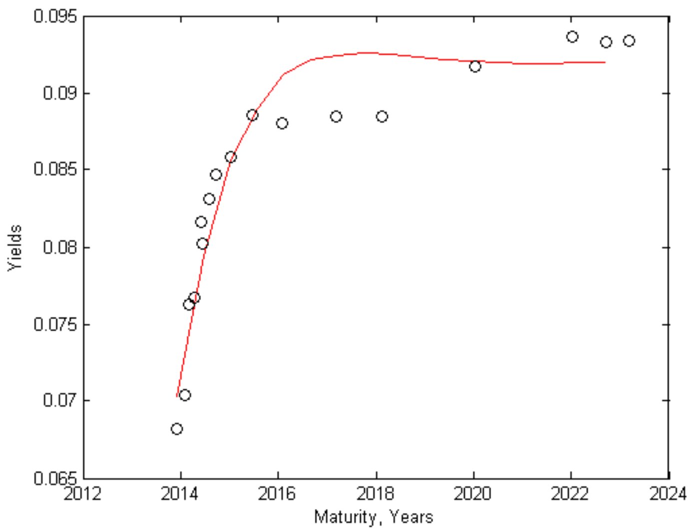

Figure A.5: Yield curve for the date 16 September 2013.

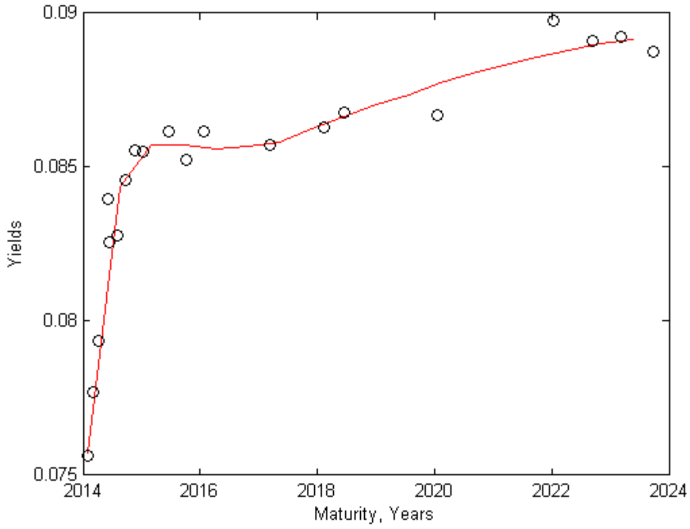

Figure A.6: Yield curve for the date 15 November 2013

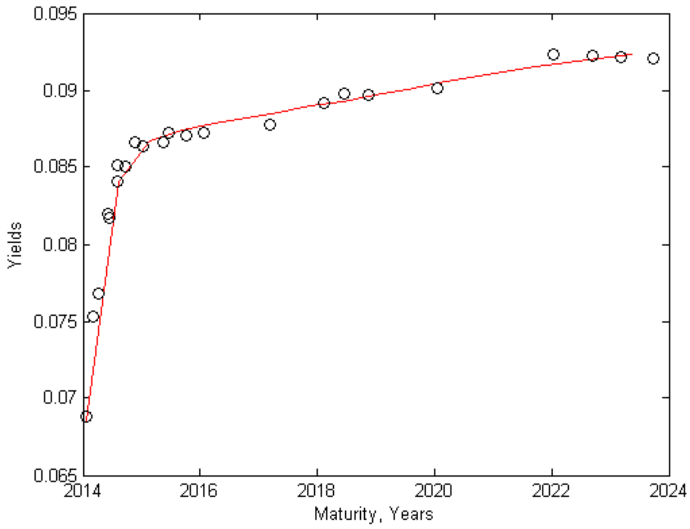

Figure A.7: Yield curve for the date 16 December 2013

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List of Publications and Patents: