ESTIMATING INFLATION UNCERTAINTY, GDS, INFLATION, AND INTEREST RATE EXPECTATIONS

İLAYDA ÇAĞLAR

Master’s Thesis

Graduate School

Izmir University of Economics

Izmir

2022

ESTIMATING INFLATION UNCERTAINTY, GDS, INFLATION, AND INTEREST RATE EXPECTATIONS

İLAYDA ÇAĞLAR

A Thesis Submitted to
The Graduate School of Izmir University of Economics
Master's Program in Financial Economics

Izmir
2022

ABSTRACT

ESTIMATING INFLATION UNCERTAINTY, GDS, INFLATION, AND INTEREST RATE EXPECTATION

Çağlar, İlayda

Master's Program in Financial Economics

Advisor: Prof. Dr. Ayla OĞUŞ BİNATLI

October, 2022

This study estimates inflation, inflation uncertainty, GDS and interest rate expectations using data between July 2013 and April 2021 and a linear state space model. It has been observed whether the forecasts obtained with the Kalman Filter and the actual variables of inflation, inflation uncertainty, GDS and interest rate expectation converge. It has been observed that in the forecasts of GDS returns, the forecasts converge more in relatively stable periods, and the fluctuations are compatible with each other in periods that are not economically stable. It has been observed that the forecasts same with the inflation variance and expectations data.

Keywords: inflation, inflation uncertainty, interest rate expectation, linear state space model, Kalman Filter.

ÖZET

ENFLASYON BELİRSİZLİĞİ, DİBS, ENFLASYON VE FAİZ BEKLENTİSİ TAHMİNLEMESİ

Çağlar, İlayda

Finans Ekonomisi Yüksek Lisans Programı

Tez Danışmanı: Prof. Dr. Ayla OĞUŞ BİNATLI

Ekim, 2022

Bu çalışma, enflasyon, enflasyon belirsizliği, DİBS ve faiz oranı beklentisini Temmuz 2013 ve Nisan 2021 tarihleri arasındaki verileri ve lineer durum uzay modeli kullanarak tahminlemektedir. Kalman Filtresi ile bulunan tahminler ile enflasyon, enflasyon belirsizliği, DİBS ve faiz oranı beklentisini gerçekleşen verilerinin yakınsayıp yakınsamadığı gözlemlenmiştir. DİBS getirileri tahminlerinde ekonomik olarak nispeten durgun dönemlerde tahminlerin daha fazla yakınsadığı, ekonomik olarak durgun olmayan dönemlerde ise dalgalanmaların birbirleri ile uyumlu olduğu gözlemlenmiştir. Enflasyon varyansı ve beklenti verileri ile tahminlerin aynı olduğu gözlemlenmiştir.

Anahtar Kelimeler: enflasyon, enflasyon belirsizliği, faiz beklentisi, lineer durum uzay modeli, Kalman Filtresi.

ACKNOWLEDGEMENTS

First of all, I would like to thank my valuable supervisor Prof. Dr. Ayla OĞUŞ BİNATLI, whom I respect not only for her deep knowledge but also for her kind approach, for what she has given me, for encouraging and supporting me and for dedicating her Sundays to me while writing this thesis.

I would also like to thank my beloved family, who has as always stood beside me, for their support throughout the preparation of this thesis. So glad I have you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Since the invention of money, many countries have faced inflation, and if inflation and inflation uncertainty were high, they have felt the negative consequences of this situation. With its general definition, inflation refers to a noticeable and perpetual increase in the prices of goods and services in an economy. In economies where there is no price stability and high inflation, there is a decrease in social welfare and accordingly an increase in social unrest.

Nowadays, inflation is a more important issue for the world. In 2021 the global inflation rate recorded the highest value in the last few years, rising from rates seen around 3% to 4.71% when we look at the country basis, the top three countries with the highest inflation rate in 2021 are Venezuela, Sudan and Zimbabwe. According to Statistica (2021), Turkey is the 11th country in this ranking.

If we consider this issue for Turkey, inflation has always been a problem. High inflation in the 80s and 90s dropped to single digits in the 2000s, but remained high at all times, and inflation targets were never met. However today, not only Turkey but the whole world faces the problem of inflation. As a natural result of this, inflation uncertainty has become a current issue for all countries.

Even though most countries are experiencing high inflation today, when compared worldwide, the situation in Turkey is much worse. Inflation affects all financial indicators. This situation leads to a serious decline in purchasing power, impoverishment, and the dissolution of the middle class, causing a big difference in people's quality of life.

In today's world, as a result of globalization the depreciation of the national currency which is one of the effects of inflation, commercial activities such as imports, exports, agriculture, livestock, production, etc., and industries are adversely affected.

Due to the increase in the prices of both goods and services, the consumer has difficulty in securing these goods and services, while the people and companies that provide this cannot maintain their sustainability due to the decrease in earnings. Again, this unpredictability causes people and companies to avoid investing in the real economy to provide goods or services. In addition, institutions like banks increase loan interest rates due to this uncertainty, which makes it more expensive to invest. While this situation harms the existing ones, it also prevents economic growth by preventing new initiatives.

The uncertainty in the market decreases the confidence in the market. Especially in long-term investments, the unpredictability of the future causes shying away from investing, which results in decrease in investments.

In cases where inflation is volatile and increasing, there is an increase in the inflation expectation. According to the Central Bank of the Republic of Turkey (CBRT), the increase in inflation expectations is one of the reasons for inflation.

The CBRT claims that inflation uncertainty is an important indicator in terms of its relationship with price stability and social welfare. For this reason, the CBRT organizes an expectation survey in order to analyze certain financial indicators. As mentioned above, real financing costs increase in periods when inflation uncertainty increases. Investment planning, and hence the investment becomes difficult. While price increases are unpredictable, they are uneven. Such situations cause a heavy cost for both the state and the public.

In general, we understand that inflation and inflation uncertainty are related to many financial instruments and financial indicators. For all these reasons, forecasting inflation and the economic indicators that affect it, is an important point to form an idea of what awaits us in the future.

Importance of inflation prompts us to forecast inflation. A useful tool will be the Survey of Expectations which is published by CBRT and which shows us the expectation of some basic macroeconomic indicators. In this survey, expectations (especially inflation and interest rate expectations) are observed according to the economic environment at that time.

In this thesis, we are going to forecast Government Debt Securities (GDS) returns, inflation expectations and interest rate expectations based on the Linear Gaussian State Space Model using the Kalman Filter. In the next chapter we will review the literature, followed by understand methodology and data, after that we will examine empirical results and conclusion.

CHAPTER 2: LITERATURE REVIEW

Inflation uncertainty has been the subject of economics for many years. In particular, there are many publications on the problems arising from this uncertainty and the consequences of these problems. Many econometric models have been used to make predictions for this uncertainty. Forecasts have been made to determine the relationship between many econometric indicators, especially the effects of inflation uncertainty on inflation and vice versa. While most of these estimations conclude that there is a positive relationship between inflation and inflation uncertainty, there are also studies showing the opposite.

Inflation uncertainty may have an impact on the yields of Government Debt Securities issued by the Ministry of the Treasury for domestic markets for Turkey. In addition, the results of the expectation surveys are also affected by inflation uncertainty. For this reason, we will examine the studies that show the connection between treasury bonds, treasury bills, interest rate expectations and inflation uncertainty.

In this thesis, estimations of GDS and interest rate expectations were made using the State Space Model. In this section, the literature review is presented with the following perspectives.

First, we will examine the studies covering all the subjects of inflation uncertainty, estimations of inflation, GDS and interest rate expectations. We will analyze the literature categorically as international, emerging markets (Argentina, Brazil, China, India, Indonesia, Mexico, Poland, South Africa, South Korea and Turkey) and Turkey.

Secondly, we will examine the studies that are concerned with these issues separately and likewise go from the general to the specific, international, emerging markets and Turkey.

Thirdly, we will examine the models used in these studies, and we will do this primarily with the studies using the State Space Model.

Although there are many studies on inflation and inflation uncertainty, the studies conducted in the direction we have estimated in the thesis are limited. In these studies, different econometric models were used for predictions. The common goal of all studies is to converge to the real values with the estimates made. In addition, if GDS yields and interest rate forecasts are added, there is no such study in this general issue for emerging markets and Turkey. When we look at the studies in general, we see that the State Space Model is not used except for one example.

2.1 International

When we examine the literature in general, the closest study related to inflation uncertainty and treasury bill yield estimation is the study for inflation uncertainty and US treasury bill returns forecasts by Breach, D'Amico, and Orphanides (2020). When we do this review for emerging markets, there is no study covering GDS and interest rate expectations, however, the relation between inflation and inflation uncertainty was investigated for emerging markets. Breach, D'Amico, and Orphanides (2020) developed an empirical term structure model that clearly explains the changes in inflation uncertainty that affect the estimation of the nominal term structure. They developed a Quadratic Gaussian model that utilizes inflation variances and US Treasury returns over time, as well as individual probability distributions from the US Professional Forecasters Survey (SPF). In this thesis, we make estimations with Linear Gaussian State Space, and we base our uncertainty measurement on the Survey of Expectations published by the Central Bank of the Turkish Republic (CBRT).

According to Breach, D'Amico, and Orphanides (2020), their model can provide reliable estimates of expected real short rates and expected inflation, which depend on long-term returns. This proved to be quite minor at high frequency but crucial for timely policy and investment decisions. Also, their results show that short-term changes in inflation risk and CPI are not largely propagated by the nominal yield curve, consistent with the Federal Reserve's interest rate policy to avoid responding to temporary inflation shocks. The inclusion of survey information helps to understand the links between nominal interest rates and macroeconomic fundamentals.

Ftiti and Jawadi (2018) estimated inflation uncertainty in the US and the euro area between 1997 and 2007. They calculated inflation uncertainty based on three models. These models are; symmetric and asymmetric generalized autoregressive conditional variable variance models and stochastic volatility model, and they did this using monthly data.

Bauer and Rudebusch (2017) analyzed nominal returns and found that expected inflation changes are more significant in longer periods. Also, changes in inflation risk are more relevant at shorter periods.

When we examine the studies of Laubach and Williams (2016), Lubik and Matthes (2015), Kiley (2015), and Johansen and Mertens (2016), aimed to estimate inflation and they discuss and search low inflation in US.

Regarding the effect of different parameters on the estimations about inflation, for example if we consider GDP and unemployment; we can give an example of the article written by Rich and Tracy (2017). They showed in their study that there is no significant connection between inflation and these two parameters.

Giordani and Soderlind (2003) demonstrated that any time-series model estimated only using historical data fails to reflect major increases in uncertainty impacting a regime shift. This is a significant argument in favor of utilizing survey uncertainty measures during structural breaks.

Giordani and Soderlind (2003) furthered their work based on the Professional Forecasters Survey 1969-2001. In their study, they analyzed three of the most well-known uncertainty measures in the context of forecasting and asset pricing models and they show that the inflation uncertainty survey is inline with actual inflation and forecast errors.

Chernov and Mueller (2012) built a model based on data such as nominal returns and inflation expectations according to survey results. They showed that forecasts and returns have an important place for the inflation and returns that will occur. They also concluded that the returns and survey-based estimates observed are inline.

Chernov and Mueller (2012) contrary to other studies, provided substantial evidence that information on the predicted course of inflation was not captured by the inflation history. They concluded that if a latent element was included in a model, the survey data could be used to better predict both projected returns and future inflation. They found that their approach was effective in predicting both inflation and returns. It also beats the model calculated without using survey-based expectations. Their findings link the article to theoretical developments about latent variables. The findings also correlate with numerous empirical publications on the links between inflation and interest rates.

Ang, Bekart, and Wei (2008) argued that expected inflation constitutes a large proportion of the change in nominal returns in both the short and long run. However, they noted that nominal futures spreads, particularly in normal times, are primarily due to changes in expected inflation.

Wachter (2005) taking a different approach, evaluated the nominal term structure of interest rates on a consumption basis which is about external habits. In this article, the model of Campbell and Cochrane (1999) is generalized and the returns of bonds and stocks are modeled. In this modeling, the effects of consumption and inflation data are taken into account. As a result of this model, she was able to explain short-term and long-term bond yields and connect bond and stock returns with the data she used.

Kim and Orphanides (2012) demonstrated that standard estimation of dynamic term structure models incorporating high-likelihood behavior of long-term expectations might encounter a major difficulty that generates ambiguity, bias, and lack of robustness in economic object assessments. As a solution to this problem, they proposed to include short-term interest rates in their survey estimates data. In general, with this solution, they showed that long-term forecasts for surveys are more distant from reality, but inline with results.

Dufresne, Goldstein, and Jones (2009) investigated if USV models can match both cross-section and time-series aspects of bond yields in their study. They discovered that the unconstrained model produces a time series of volatility that is largely unrelated to the short rate process's real volatility. This is the outcome of a linear combination of yields.

Bekaert and Wang (2010) found the following results for inflation risk; Securities such as government bonds and equities are very weak hedges against inflation risk, both in the short and long term. Treasury bills and inflation are directly proportional and index-linked bonds are essential to truly hedge against inflation risk. In addition, the inflation time series and prospects are often sufficient to determine predicted inflation.

2.2 Emerging Markets

When we examine the literature for emerging markets, we see that mostly estimates are made for the connection between inflation and inflation uncertainty. Estimates for different economic and financial variables are not widespread.

Payne (2009) investigated the relationship between inflation and inflation uncertainty using the ARIMA GARCH model and the Granger Causality Test for Thailand. As a result of these tests, he concluded that, if inflation increases, it increases inflation uncertainty. But if inflation uncertainty increases, inflation decreases.

Thornton (2007) analyzed the relation between inflation and inflation uncertainty using Granger-causality tests with the GARCH model for the emerging markets. In regard to Thornton, high inflation increased the inflation uncertainty for all emerging markets. When evaluated monthly, different countries support two different hypotheses. The first hypothesis is that increased inflation uncertainty leads to lower average inflation. The second hypothesis is that inflation uncertainty causes higher inflation.

Baharumshah et al. (2016) examined the relationship between inflation, inflation uncertainty and economic growth in developing countries. They did this based on the system generalized method of moments (SGMM) that controls for instrument proliferation. As a result of this research, it is revealed that inflation harms growth only in countries without an inflation crisis, while inflation uncertainty supports growth. Empirical results based on a three-regime model showed the negative growth effect of high inflation rates and the growth-enhancing effect of low inflation. Secondly, the negative effect of not keeping inflation under control outweighs the positive effect of uncertainty in non-inflationary crisis countries in all three regimes. Third, the existence of a positive effect of the uncertainty in the inflation rate on growth with a cautious motive is seen when inflation reaches moderate ranges.

2.3 Turkey

In the literature, there are also studies to see the connection between inflation and inflation uncertainty in Turkey. However, other than inflation and inflation uncertainty estimations, there is no estimation between any other economic indicators.

Karahan (2012) analyzed the relation between inflation and inflation uncertainty from 2002 to 2011 based on the ARMA-GARCH model and the Granger causality tests between inflation and inflation uncertainty, concluding high inflation causes inflation uncertainty.

Önder (2014) aimed to make inflation forecasts for Turkey, which is a high-inflation and developing country. While doing this, she used the 3-month inflation data between 1987 and 2001 using the ARIMA model based on the Philips Curve estimation method. As a result, she stated that the inflation forecasts obtained from the Phillips curve are more accurate than the forecasts based on other macroeconomic variables.

Mangır et al. (2020) concluded that inflation uncertainty does not cause an increase in inflation using and the ARMA-GARCH model for the period 2005 ~ 2020.

In this thesis, we generate forecasts for GDS returns, inflation expectations and inflation uncertainty using a state space model. To the best of our knowledge, this is the first analysis of its kind for Turkey.

CHAPTER 3: METHODOLOGY

In this section, we will examine the State Space Models that we have used in our study. In general State Space means Euclidean space in which the variables on the axes are the state variables. These variables are expressed as vectors to be independent of the number of inputs, outputs, and states. This approach commonly applied for financial and economic problems such as model transition from one economic structure to another, to model time-varying monetary reaction functions and forecasting problems about estimate expected inflation.

3.1 Linear Gaussian State Space Modeling

According to Kitagawa and Gersch (1996), the state of a system is a summary of the previous behavior of the system. All future states and outputs are determined by the state in relation to future inputs. Also, the current output is only affected by the current state and current input data. According to Schweppe (1965), the suitability of state space systems for time series analysis derives from the Markov process property of the state, which allows the estimation of the probability of the state space model of the observed data.

Consider the following general linear state space model:

$$y_n = Hx_n + \mathcal{E}_n \text{ (observation equation)} \quad (1)$$

$$x_n = Fx_{n-1} + Gw_n \text{ (state equation)} \quad (2)$$

where x_n is the state at time n, the state noise process, and the observation noise process respectively are;

$$w_n \sim N(0,P_w) \text{ and } \mathcal{E}_n \sim N(0, P_\epsilon.) \quad (3)$$

In other words, it is often considered that the system noise and observation noise might have arbitrary distributions. For the sake of simplicity, we assume that E $(w_n, \mathcal{E}_m) = 0$ for every n and m. For these equations, Equation 1 referred to observation equation and Equation 2 referred to state equation.

The state space is the set of all possible values of x_n, where n = 1, 2, …, and F, G and H are MxM , MxL and 1xM matrices respectively. w_n and ε_n are each assumed to be zero mean independent normally distributed random variables. For any particular model of time series, the matrices F, G and H are known. ε_n is the observation error process n = 1 ,..., N and w_n the input process n = 1,..., N. The input process is vertical to the primary state x_0.

The system theory community was exposed to stochastic state space approaches by Kalman (1960) and Kalman and Bucy (1961). The Kalman Filter is a prediction algorithm. The Kalman filter is an algorithm that predicts the next states of the system based on previous states.

The state space model of time series helps to easily perform algebraic calculations of state means and development of covariances. Schweppe (1965) used state space model with Kalman filter to determine correct probabilities for given values of unknown parameters under Gaussian shocks. Also, Duncan and Horn (1972), (filtered) Kalman state estimator's minimum mean square linear estimator and minimum variance unbiased showed that it is a state estimator and random effects can be added by adding random parameters to the state vector of the Kalman filter.

The Gaussian disturbances linear state space model is the focus of most modern literature on state space modeling. The Kalman filter method is generally used in such modeling.

3.2 Kalman Filter and Smoother for Exponential Family State Space Models in R

We use KFAS package in R (Kalman Filter and Smoother for Exponential Family State Space Models) for implementation. KFAS State Space Modeling is an efficient and flexible model used for statistical extraction of a large class of time series and other data. This model includes computationally efficient functions for Kalman filtering, smoothing, prediction and simulation of multivariate exponential family state space models with observations from Gaussian, Poisson, binomial, negative binomial and gamma distributions.

3.3 Gaussian State Space Model in KFAS

This chapter provides an overview the notation of Gaussian state space modeling in KFAS. The basic notation is similar, as the methods for KFAS are mostly based on Durbin and Koopman (2012) and similar works by the same authors. The general representation of the linear Gaussian state space model with continuous states and discrete time periods t = 1,..., n is as follows.

$$y_t = Z_t \alpha_t + \varepsilon_t, \text{ (observation equation)} \quad (4)$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t, \text{ (state equation)} \quad (5)$$

where $\varepsilon_t \sim N(0,H_t)$, $\eta_t \sim N(0,Q_t)$ and $\alpha_1 \sim N(\alpha_1,P_1)$ are independent.

y_t is a ‘p x 1’, α_{t+1} is an ‘m x 1' and η_t is a ‘k x 1’ vector. We also define $\alpha = (\alpha_1^T,\ldots, \alpha_n^T)^T$ and similarly $y = (y_1^T,\ldots, y_n^T)^T$ where y_t represents the observations at time t.

The system matrices Z_t, T_t, and R_t, as well as the covariance matrices H_t and Q_t, are determined by the model description and are frequently time invariant, i.e., do not rely on t. Typically, at least some of these matrices have unknown parameters that must be calculated.

The primary purpose of state space model is to learn about the latent states given the observations y. This is accomplished through the use of two fundamental recursive algorithms, Kalman filtering and smoothing. The Kalman filtering process yields one-step-ahead forecasts and prediction errors.

$$\alpha_{t+1} = E(\alpha_{t+1} \mid y_t,\ldots\ldots,y_1), \quad (6)$$

$$v_t = y_t - Z_t\alpha_t \quad (7)$$

and the related covariance matrices:

$$P_{t+1} = VAR\,(\alpha_{t+1} \mid y_t,\ldots\ldots,y_1), \quad (8)$$

$$F_t = VAR\,(v_t) = Z_t P_t Z_t^T + H_t \quad (9)$$

The state smoothing equations are computed moving backwards in time using the Kalman filtering findings.

$$\hat{\alpha} = E(\alpha_t \mid y_t,.....,y_1), \quad (10)$$

$$v_t = VAR(\alpha_t \mid y_t,.....,y_1), \quad (11)$$

Similarly, smoothed estimates for the disturbance terms ε_t and η_t, and straightly for the signal $\theta_t = Z_t\, \alpha_t$.

For the following simple state space model, where $y_t \sim N(\mu_t,\sigma_\epsilon)$ for all $t = 1,...,n$, and μ_t is a random variable with drift process such that $\mu_{t+1} = \mu_t + \nu + \eta_t$ $\eta_t \sim N(0,\sigma_\eta^2)$. Assume we have no prior knowledge of the beginning state μ_1. This model could be defined in the KFAS package as below:

$$Z = (1\ 0)\ ,\ H = \sigma_\epsilon^2\ ,\ T = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}, \quad (12)$$

$$\alpha_t = \begin{pmatrix} \mu_t \\ \nu_t \end{pmatrix},\ R = \begin{pmatrix} 1 \\ 0 \end{pmatrix},\ Q = \sigma_\eta^2, \quad (13)$$

$$a_1 = \begin{pmatrix} 0 \\ 0 \end{pmatrix},\ P_{*,1} = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix},\ P_{\infty,1} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad (14)$$

Here, $P_{\infty,1}$ is a diagonal matrix with ones on those diagonal elements which relate to the diffuse elements of α_1 and $P_{\infty,1}$contains the covariances of the nondiffuse elements of α_1 (and zeros elsewhere).

3.4 State Space Model for Financial Variables and Inflation

In this section, firstly we mention about our model then, we show the different notation equivalences between our theoretical model and KFAS model are shown due to the notation differences in our theoretical and KFAS representations.

3.4.1 Forecast Models

Our purpose is to forecast GDS returns, interest expectations, and inflation variance with using Gaussian State Space Model.

The forecast, for x_t has the following equation of motion;

$$x_t=\kappa+\gamma x_{t-1}+\eta_t \quad (15)$$

The state space model for Yi could be written as below:

$$Y^i_t = a^i + b^{i\prime} x_t + \varepsilon^i_t \text{ (observation equation)} \quad (16)$$

$$x_t = \kappa^i + \gamma^i x_{t-1} + \eta^i_t \text{ (state equation)} \quad (17)$$

$$\varepsilon_t^i \sim N(0,\sigma_i^2) \quad (18)$$

$$\eta_t^i \sim N(0,\delta_i^2) \quad (19)$$

The state space models for the variables analyzed are:

1) State Space Model for Expectations of the Short Rate (for 6 Months)

$$F_t^{(6m)} = a^{f,6m}+ b^{6m\prime}x_t+\varepsilon^{6m}_t \text{ (observation equation)} \quad (20)$$

$$x_t = \kappa^{f,6m} + \gamma^{f,6m} x_{t-1} + \eta^{f,6m}_t \text{ (state equation)} \quad (21)$$

$$\varepsilon_t^{f,6m} \sim N(0,\sigma^2_{f,6m}) \quad (22)$$

$$\eta_t^{f,6m} \sim N(0,\delta^2_{f,6m}) \quad (23)$$

2) State Space Model for Expectations of the Short Rate (for 12 Months)

$$F_t^{(12m)} = a^{f,12m} + b^{12m\prime}x_t + \varepsilon^{12m}_t \text{ (observation equation)} \quad (24)$$

$$x_t = \kappa^{f,12m} + \gamma^{f,12m} x_{t-1} + \eta^{f,12m}_t \text{ (state equation)} \quad (25)$$

$$\varepsilon_t^{f,12m} \sim N(0,\sigma^2_{f,12m}) \quad (26)$$

$$\eta_t^{f,12m} \sim N(0,\delta^2_{f,12m}) \quad (27)$$

3) State Space Model for Expectations of the Medium Rate (for 24 Months)

$$F_t^{(24m)} = a^{f,24m} + b^{24m\prime}x_t + \varepsilon^{24m}_t \text{ (observation equation)} \quad (28)$$

$$x_t = \kappa^{f,24m} + \gamma^{f,24m} x_{t-1} + \eta^{f,24m}_t \text{ (state equation)} \quad (29)$$

$$\varepsilon_t^{f,24m} \sim N(0,\sigma^2_{f,24m}) \quad (30)$$

$$\eta_t^{f,24m} \sim N(0,\delta^2_{f,24m}) \quad (31)$$

4) State Space Model for Inflation Expectations (1 year)

$$EI_t^{(1y)} = a^{EI,1yr} + b^{EI,1yr\prime}x_t + \varepsilon^{1y}_t \quad (32)$$

$$x_t = \kappa^{EI,1y} + \gamma^{EI,1y} x_{t-1} + \eta^{EI,1y}_t \text{ (state equation)} \quad (33)$$

$$\varepsilon_t^{EI,1y} \sim N(0,\sigma^2_{\mathrm{EI,1y}}) \quad (34)$$

$$\eta_t^{EI,1y} \sim N(0,\delta^2_{\mathrm{EI,1y}}) \quad (35)$$

5) State Space Model for Inflation Expectations (2 years)

$EI_t^{(2y)} = a^{EI,2yr} + b^{EI,2yr\prime} x_t + \varepsilon^{2y}_t$ (36)

$x_t = \kappa^{EI,2y} + \gamma^{EI,2y} x_{t-1} + \eta^{EI,2y}_t$ (state equation) (37)

$\varepsilon_t^{EI,2y} \sim N(0, \sigma^2_{EI,2y})$ (38)

$\eta_t^{EI,2y} \sim N(0, \delta^2_{EI,2y})$ (39)

6) State Space Model for Inflation Uncertainty (for 1 year)

$IU_t^{(1y)} = a^{EU,1yr} + b^{EU,1yr\prime} x_t + \varepsilon^{1y}_t$ (40)

$x_t = \kappa^{EU,1y} + \gamma^{EU,1y} x_{t-1} + \eta^{EU,1y}_t$ (state equation) (41)

$\varepsilon_t^{EU,1y} \sim N(0, \sigma^2_{EU,1y})$ (42)

$\eta_t^{EU,1y} \sim N(0, \delta^2_{EU,1y})$ (43)

3.4.2 Theoretical and KFAS Notation

There are differences in the theoretical and KFAS model notations in the expression of our model. You can refer to Table 1 and notes below for the equivalents of these notations.

Table 1. Notation Equivalences

Theoretical Notation	KFAS Notation
x_t	α_t
b^i	Z_t
1	R_t
$\kappa^i + \gamma^i x_{t-1}$	$T_t\alpha_t$

For α_t, T_t and Q_t in KFAS ;

$$\alpha_t = \begin{bmatrix} x_t \\ \kappa_t \end{bmatrix} \quad (44)$$

$$T_t = \begin{bmatrix} 1 & \gamma \\ 0 & 1 \end{bmatrix} \quad (45)$$

$$Q_t = \begin{bmatrix} \delta_i^2 & 0 \\ 0 & 0 \end{bmatrix} \quad (46)$$

CHAPTER 4: DATA

In this chapter, the data used for the study will be explained. In addition, a data table is presented so that the used data can be seen as a summary.

Firstly, the data used was provided by the Central Bank of the Republic of Turkey Electronic Data Distribution System (TCMB EVDS) and Stock Market BIST Indexes. All the data for the period of July 2013 to April 2021 are collected as explained below. The data of EVDS are used for Survey of Expectation and show expectations of regarding the relevant topics of approximately 60 participants. The State Space Model in the R Program for the forecasts is used. Before that, the variance of Consumer Price Index (CPI) is calculated. The list of data is as follows;

Table 2. Data Summary

Definition	Variable	Data Construction	Data Series	Date Range
1E.(Arithmetic Mean) Expectation of 12 Months Ahead Annual CPI (%)	x	CPI expectation 1 year ahead between 06.2013 and 04.2021	The average of the intervals showing the CPI expectations of the people in the raw data in the CPI expectation survey.	TCMB-EVDS (07.2013-04.2021)
1F.(Arithmetic Mean) Expectation of 24 Months Ahead Annual CPI (%)	y	CPI expectation 2 year ahead between 06.2013 and 04.2021	The average of the intervals showing the CPI expectations of the people in the raw data in the CPI expectation survey.	TCMB-EVDS (07.2013-04.2021)
Survey of Market Participants Probability Distributions of Consumer Inflation Expectations (Monthly)	E(x)	CPI expectation between 06.2013 and 04.2021	The arithmetic mean value found in the expectation survey	TCMB-EVDS (07.2013-04.2021)
Survey of Market Participants Probability Distributions of Consumer Inflation Expectations (Monthly)	P(x)	CPI expectation between 06.2013 and 04.2021	Percentage of people who voted for "x" value	TCMB-EVDS (07.2013-04.2021)
Realized CPI	rcpi	Realized CPI between 06.2013 and 04.2021	Realized CPI	TCMB-EVDS (07.2013-04.2021)
Consumer Price Index (CPI) Variance	v	Var(x)=Σ ((x-E(x))^2p(x))	x-The average of the intervals showing the CPI expectations of the people in the raw data in the CPI expectation survey. E(x)- The arithmetic mean value found in the expectation survey P(x) - number of people who voted for "x" value (*0,01)	BIST (07.2013-04.2021)
2J.(Arithmetic Mean) Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	m6	Average of expectation between 06.2013 and 04.2021		TCMB-EVDS (07.2013-04.2021)

Table 2. Data Summary (continued)

Definition	Variable	Data Construction	Data Series	Date Range
2K.(Arithmetic Mean) Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	m12	Average of expectation between 06.2013 and 04.2021		TCMB-EVDS (07.2013-04.2021)
2L.(Arithmetic Mean) Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	m24	Average of expectation between 06.2013 and 04.2021		TCMB-EVDS (07.2013-04.2021)
BIST-KYD GDS 91 DAYS (Index Code: TD91G)	gds91	Average value between 06.2013 and 04.2021		BIST (07.2013-04.2021)
BIST-KYD GDS 182 DAYS (Index Code:T182G)	gds182	Average value between 06.2013 and 04.2021		BIST (07.2013-04.2021)
BIST-KYD GDS 365 DAYS (Index Code: T365G)	gds365	Average value between 06.2013 and 04.2021		BIST (07.2013-04.2021)
BIST-KYD GDS 547 DAYS (Index Code: T547G)	gds547	Average value between 06.2013 and 04.2021		BIST (07.2013-04.2021)
BIST-KYD GDS LONG (Index Code: TUZUN)	gdst	Average value between 06.2013 and 04.2021		BIST (07.2013-04.2021)

4.1 The Calculations for Consumer Price Index (CPI) Variance

For our estimations, we calculated for the CPI variance between July 2013 and April 2021;

$$\text{Var}(x) = \Sigma((x - E(x))^2 p(x)) \tag{47}$$

where “x” is the average of the intervals showing the CPI expectations of the people in the raw data in the CPI expectation survey, “E(x)” is the arithmetic mean value found in the expectation survey and “p(x)” is the percentage of people who voted for "x" value.

For CPI Variance calculation we use 36 prediction interval for x values. The prediction intervals dates start from July 2013 and end in April 2021. In this calculation, we use “after 12 CPI expectation rates” and the variance of the "12-Month Observed CPI" variables from TCMB EVDS. The CPI variance calculation covering a total of 95 months is based on this data. (Appendix A)

4.2 BIST-KYD Indexes

Borsa İstanbul publishes BIST-KYD Indexes to measure the daily returns of different investment instruments such as debt instruments, gold, deposits, dividends and funds. Previous name KYD Information Management and Communication Inc. (KYD) indexes. These indexes started to be published as of 2015, collaboration of Borsa İstanbul A.Ş. and KYD. Although these indices are the continuation of the KYD Indices calculated by KYD, they were named BIST-KYD Indexes with the agreement made in 2015.

BIST-KYD DIBS Indices are published to show the yields of discounted and fixed-rate coupon government domestic debt securities (GDS) traded on the Borsa Istanbul Debt Securities Market on the basis of different maturities. Indices are divided into two main groups according to the relevant maturity division. In the first group, BIST–KYD DIBS 91 Days, BIST-KYD DIBS 182 Days, BIST-KYD DIBS 365 Days, BIST-KYD DIBS 547 Days and BIST-KYD DIBS All Indices are calculated for shorter maturity intervals. In the second group, there are BIST-KYD DIBS Short, BIST-KYD DIBS Medium and BIST-KYD DIBS Long Indices, which are calculated for longer maturity intervals. The maturity structures of the indices are shown in Table 3. When calculating the maturities of couponed GDS, the maturities found by the "Macaulay Duration" method are taken into account. (Borsa Istanbul Publications, 2021)

4.3 Government Debt Securities (GDS)

Government debt securities are borrowing instruments issued in the domestic market by the Turkish Treasury. In this debt instrument, government repays the borrowed amount to the holders of Government Debt Securities on the coupon payment days and maturity. Government debt instruments may be exchanged in secondary markets by both real and legal persons during their maturity period. Government debt instruments are classed based on their maturity period, issuing method, currency denominated, interest payment mechanism, and whether or not they contain coupons.

According to their maturities:

- Government debt securities having maturities of one year or more are referred to as "Government Bonds," and
- Treasury Bills are government debt securities with maturities of less than one year. (Borsa Istanbul Publications, 2021)

Table 3. GDS Index Names and Maturities

Index Name	**Maturity**
BIST-KYD GDS 91 DAYS	0-180
BIST-KYD GDS 182 DAYS	122-242
BIST-KYD GDS 365 DAYS	243-488
BIST-KYD GDS 547 DAYS	365-729
BIST-KYD GDS LONG	1096 and above

4.4 Survey of Expectation (SoE)

The Expectation Survey (SoE) is a survey conducted by the Central Bank of the Republic of Turkey (CBRT) by asking people in the financial and real sectors about their expectations about basic macroeconomic indicators such as consumer inflation, exchange rate, current account balance.

This descriptive section is based on the Survey of Expectation dated February 2021. This expectation survey was answered by 60 participants consisting of representatives of the real sector such as employers and companies, financial sector such as banks, also professionals such as lecturers and journalists, and the results were evaluated by summing up the answers of the participants. The survey results are calculated based on the expectations of the participants and do not reflect the views and estimates of the Central Bank of the Republic of Turkey.

4.4.1 Yearly Inflation Expectations

Figure 1 shows the CPI expectation comparison for 2020 and 2021. When we examine it, we see that the current period expectation has increased from 11.15 percent to 11.23 percent. For 12-month CPI expectation, we observe that this rate has decreased from 10.53 percent to 10.36 percent. Finally, Next 24- month CPI expectation decreases from 9.14 percent to 9.03 percent for 24 months.

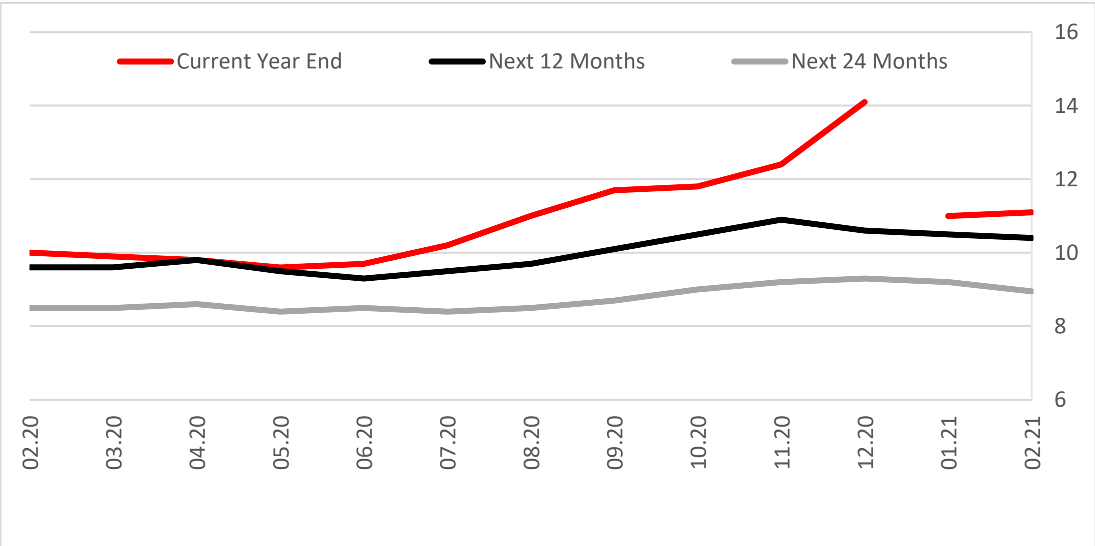

Figure 1. Distribution of 12-Month and 24-Month Post-Inflation Expectations

When the surveys for the next period are analyzed, it is observed that there is no data for current year-end inflation expectation for January. For this reason, January is seen as a blank in the relevant table.

Inflation Expectations After 12 Months

In the February 2021 survey period, when the probability estimates of the participants for the next 12 months are evaluated, the CPI will be between 9.00 - 9.99 percent with 29.63 percent probability, and 10.00 - 10.99 percent with 35.29 percent probability, on average with a 21.89 percent probability, it is predicted that it will increase in the range of 11.00 - 11.99 percent (Figure 2).

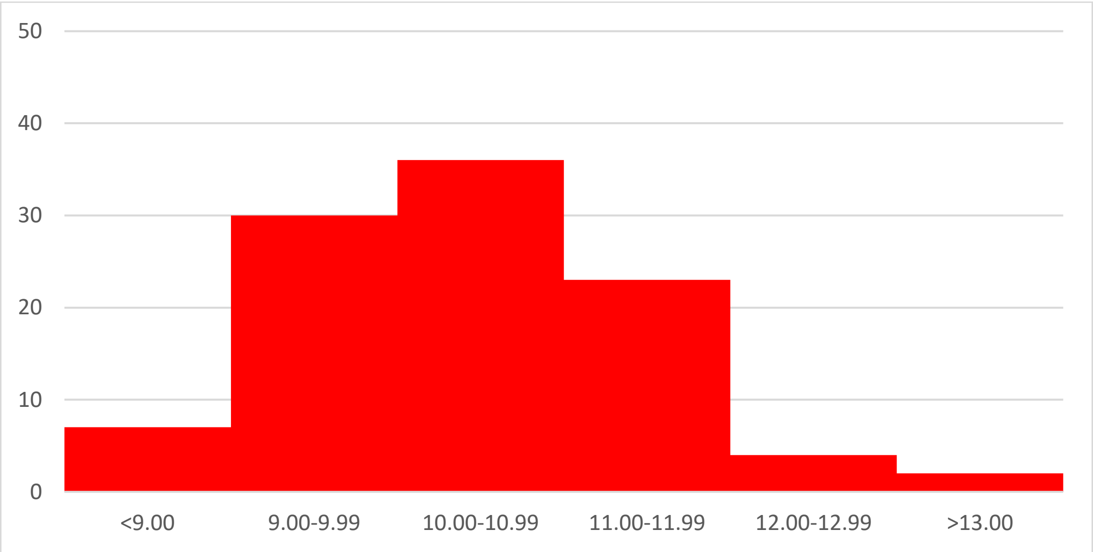

Figure 2. Expected CPI Over The Next 12 Months Probability Distribution (%)

According to the evaluation made on the basis of point estimates (Point estimate refers to the estimate given as a single value for each variable.) in the same survey period, 28.85 percent of the participants' expectations were between 9.00 - 9.99 percent, 44.23 percent of them were between 10.00 - 10.99 percent, 19.23 percent of respondents had their expectations between 11.00 and 11.99 percent (Figure 3).

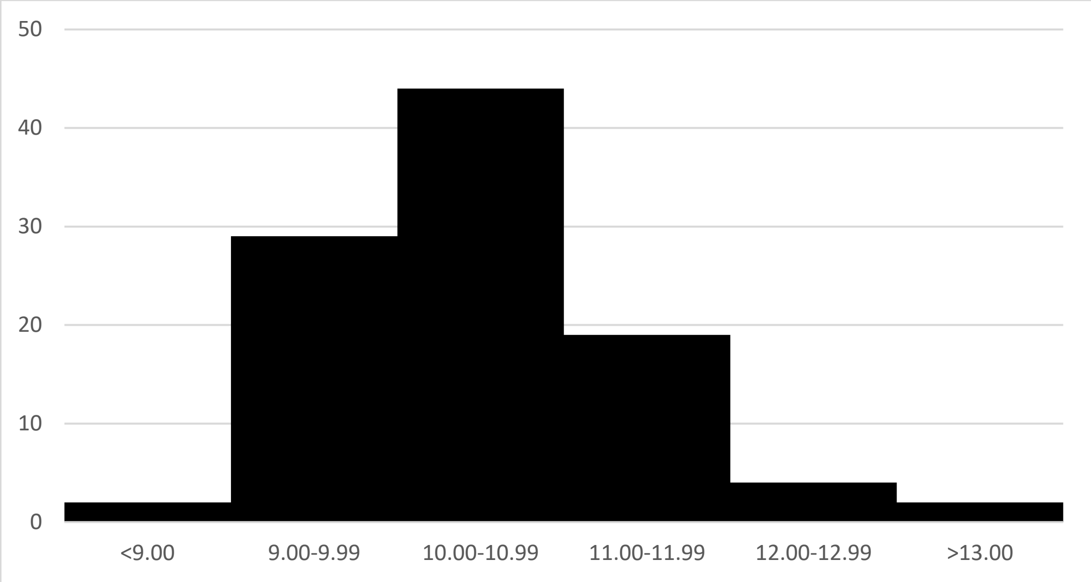

Figure 3. Expected CPI Over The Next 12 Months Point Estimates Distribution (%)

Inflation Expectations After 24 Months

In the survey period of February 2021, when the probability estimates of the participants for the next 24 months are evaluated, the CPI will be between 8.00 - 8.99 percent with 27.17 percent probability, and 9.00 - 9.99 percent with 36.80 percent probability. With a probability of 13.24 percent, it is predicted that it will increase in the range of 10.00-10.99 percent (Figure 4).

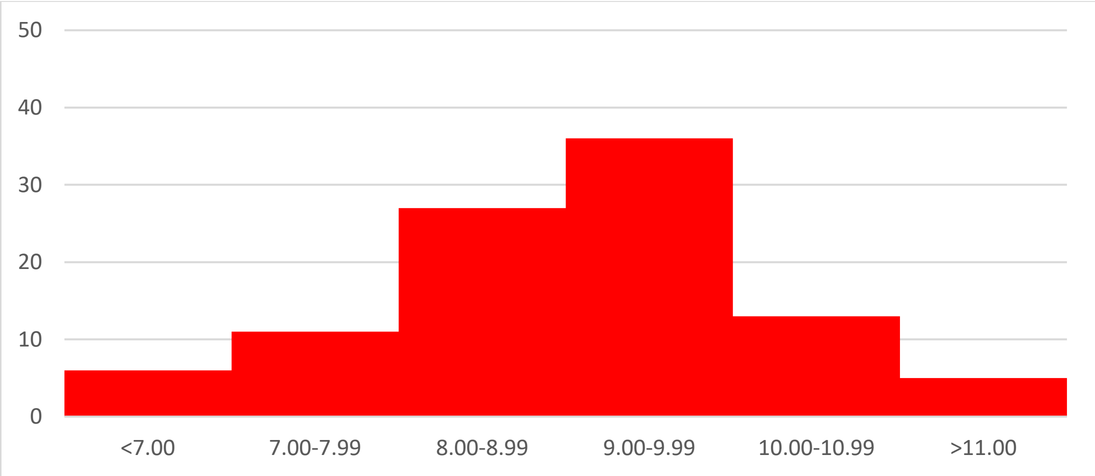

Figure 4. Expected CPI Over The Next 24 Months Probability Distribution (%)

According to the evaluation made on the basis of point estimates (Point estimate refers to the estimate given as a single value for each variable.) in the same survey period, when the CPI inflation expectations after 24 months are evaluated, the expectations of 25 percent of the participants are in the range of 8.00 - 8.99 percent, the expectations of 45.83 percent of participants are 9.00-9.99 percent and the expectations of 14.58 percent of participants are in the range of 10.00 - 10.99 percent (Figure 5).

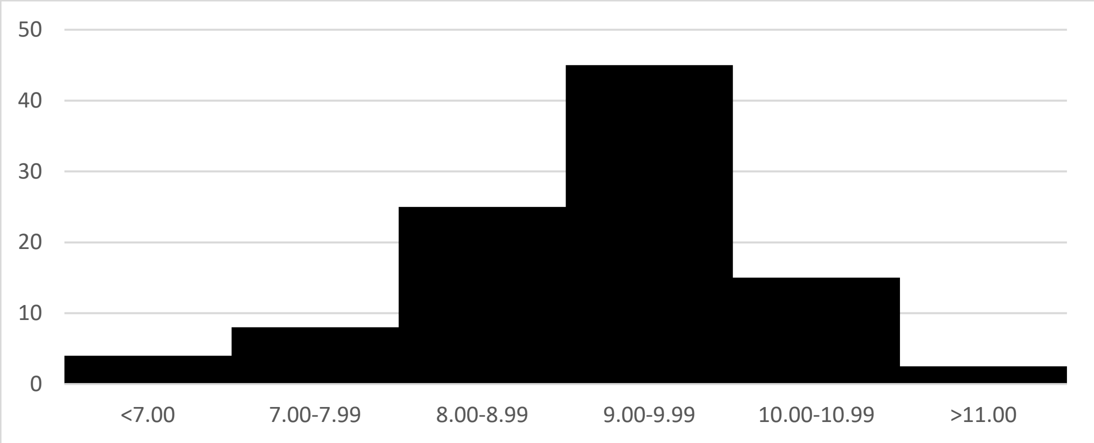

Figure 5. Expected CPI Over The Next 24 Months Point Estimates Distribution (%)

4.4.2 Interest Rate Expectations

In Figures 6 and 7, the overnight interest rate expectation for the end of the current month in the BIST Repo and Reverse Repo Market, the CBRT Weighted Average Funding Cost expectation for the end of the current month and the one-week repo rate expectation of the CBRT for the end of the current month for 2020 and 2021 are shown comparatively.

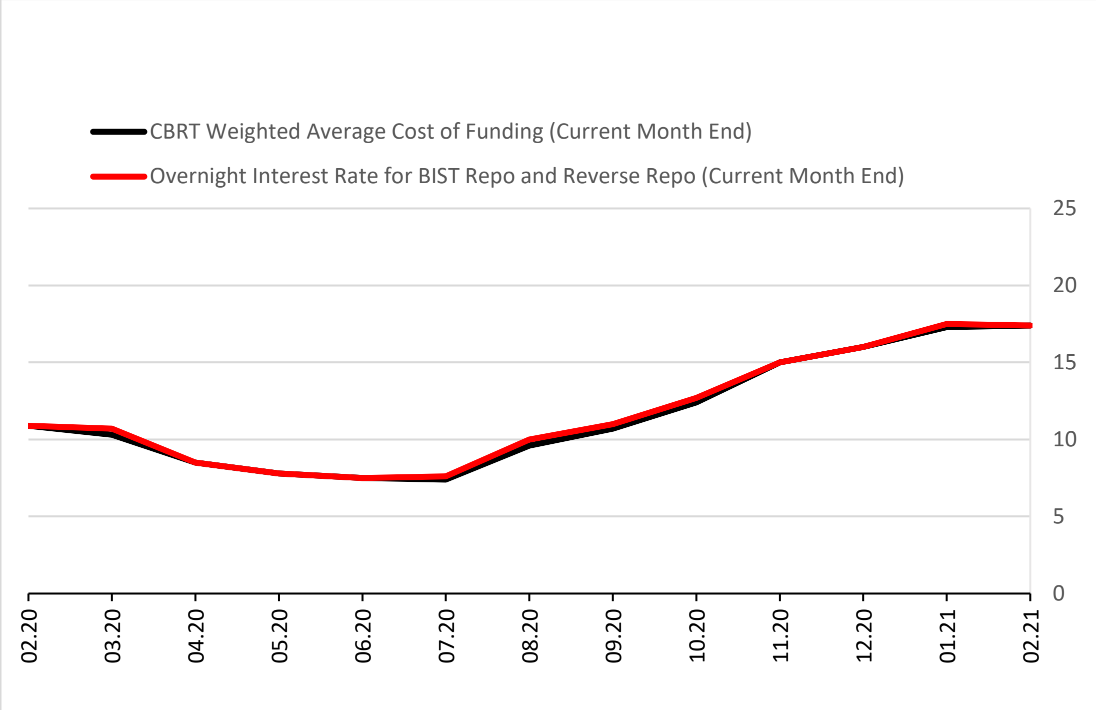

Figure 6. CBRT Weighted Average Cost of Funding and BIST Repo and Reverse Repo Overnight Rates (%)

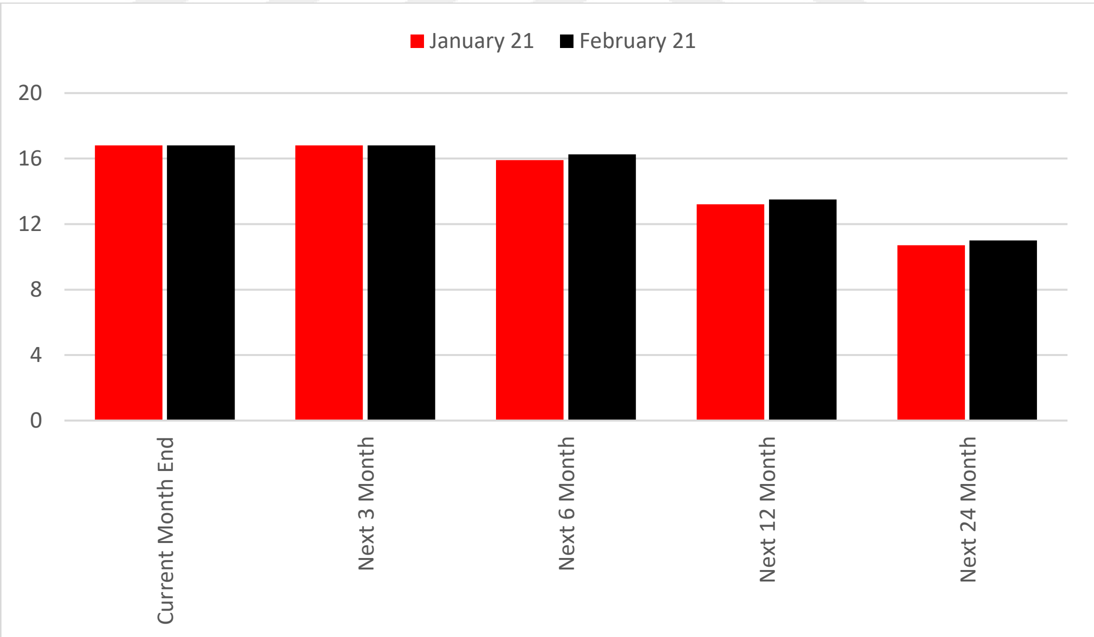

Figure 7. CBRT One-Week Repo Interest Rate (%)

While the secondary market annual compound interest rate expectation after 12 months for GDS, whose maturity is five years or close to five years, was 12.59 percent in 2020, it decreased to 12.37 percent in 2021. On the other hand, the secondary market annual compound interest rate expectation after 12 months for government securities with a maturity of ten or nearly ten years was realized as 12.30 percent and 12.05 percent, respectively, during the 2021 (Figure 8).

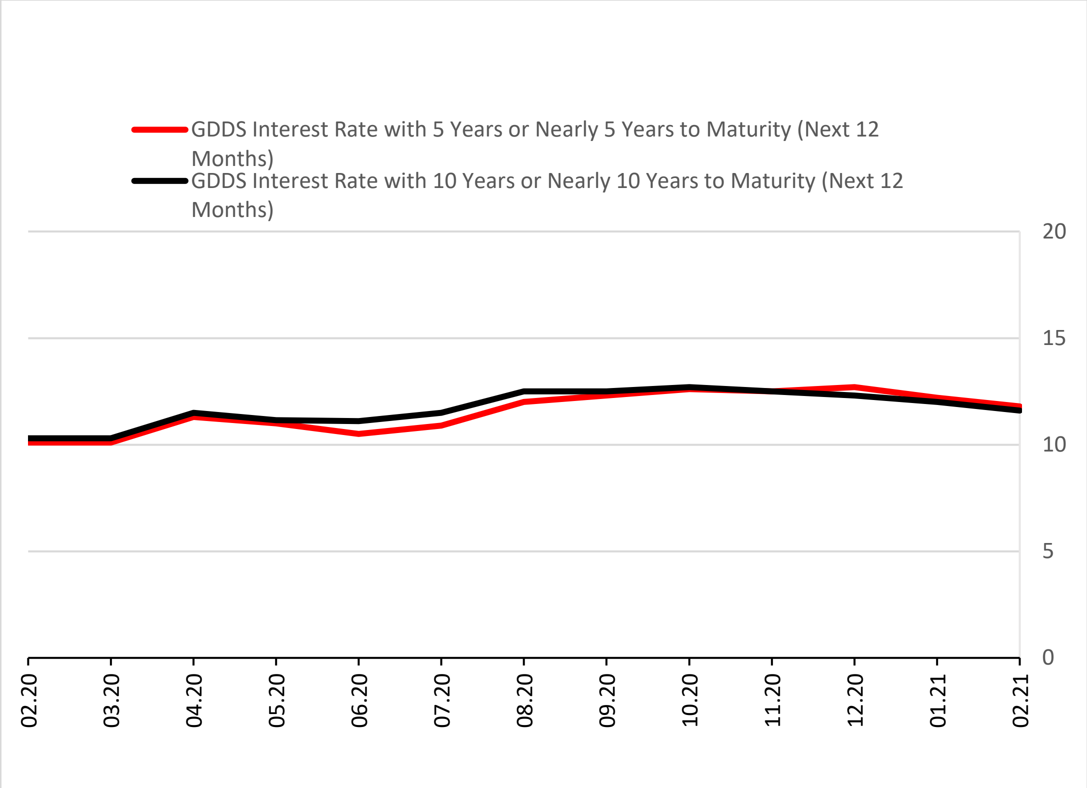

Figure 8. Government Domestic Debt Securities Secondary Market Annual Compound Interest Rate (%)

4.4.3 Exchange Rate Expectations

While the current year-end exchange rate (USD/TL) expectation was 8.09 TL in 2020, it became 7.79 TL in 2021. While the expectation for an exchange rate after 12 months was 8.16 TL in 2020, it was 7.94 TL in 2021 (Figure 9).

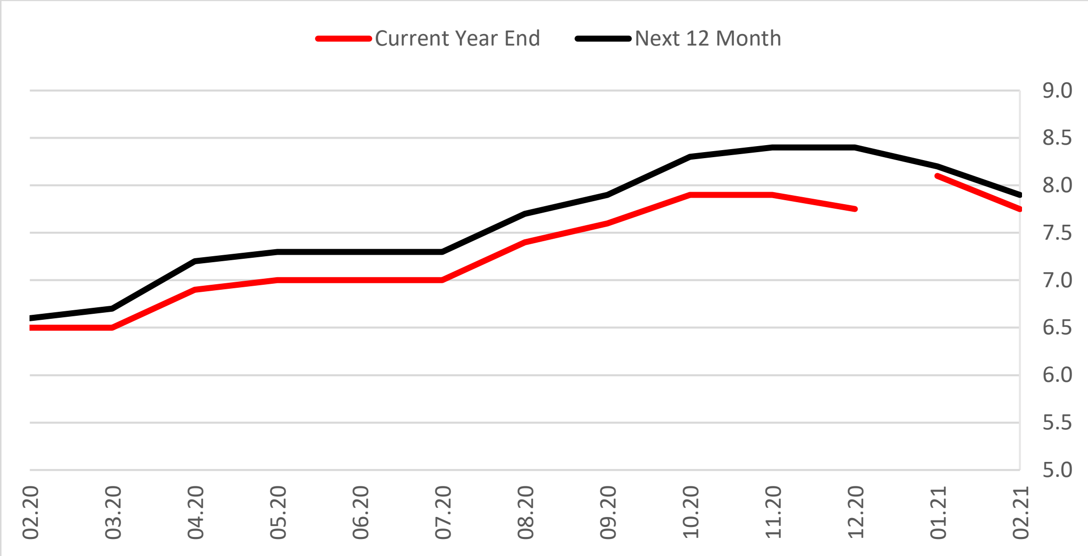

Figure 9. US Dollar Rate Expectations ($/TL)

4.4.4 GDP Growth Expectations

Below, the GDP growth expectation in 2020 until 2021 is given in Figure 10, and the GDP growth expectation for the first 2 months of 2022 is given in Figure 11. Here, while the expectation is 3.9 percent in 2020, the expectation rate for 2021 is 4.1 percent, and this expectation has increased to 4.3 percent for the first 2 months of 2022.

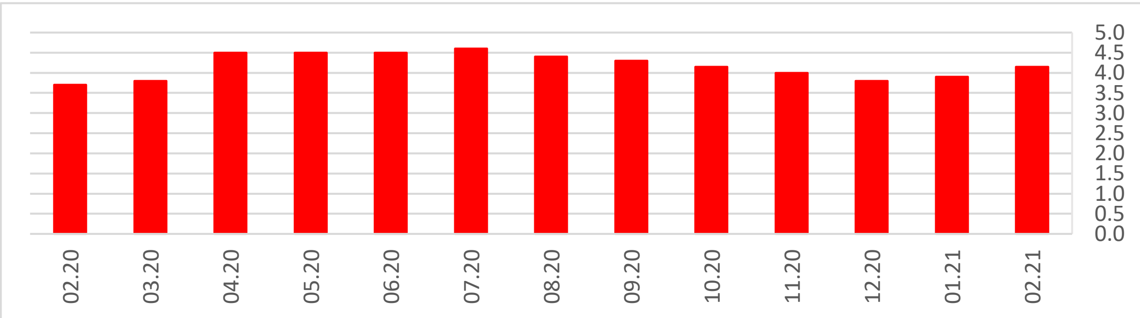

Figure 10. GDP Growth Expectations for 2021 (%)

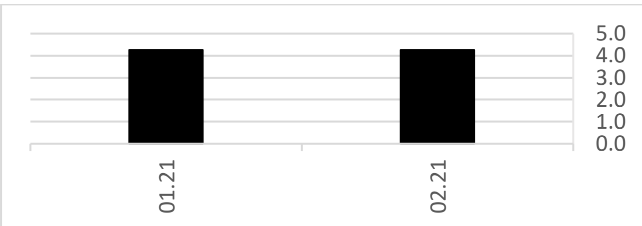

Figure 11. GDP Growth Expectations for 2022 (%)

CHAPTER 5: EMPIRICAL RESULTS

In this section, we present our econometric results from the Gaussian state space models. We analyzed time series for expectations. Our time series are between July 2013 and April 2021.

Our aim is to estimate GDS returns, interest expectations as well as inflation variance using Gaussian State Space Model for Turkey. We also estimate H and Q as goodness-of-fit measures for our forecasts where;

$$H = \sigma_{\epsilon}^2 , \tag{48}$$

$$Q = \sigma_{\eta}^2 , \tag{49}$$

According to variables which are used for estimations, from July 2013 to June 2018, the fluctuations progress at a certain level, and the increases and decreases are close to each other. In the period after the end of June 2018, we observe that the distance between fluctuations has increased. After this period, there are significant peaks, both positive and negative, until November 2019. As of the end of November 2019 until April 2021, although the fluctuations are not as stable as the first period, they still show a decrease (Figure 12 ~ Figure 28).

We assumed the economic environment stable in the equations we used to make our forecasts. When we examine the figures (Figure 12 ~ Figure 28) showing the results, it is seen that the estimations regarding the GDS, "BIST-KYD GDS 91 Days", that is, the shortest-term index for the GDS returns, are much closer to the real returns. However, with the increase in the maturity period, it is seen that the differences between the forecasts and the actual ones increase. In the meantime, during peak periods, there are also peaks in our forecasts.

5.1 Economic Environment

In this part, we will summarize the general economic environment of Turkey related to inflation, and interest rates between our time period of July 2013 and April

2021 to understand the reasons for the fluctuations in our expectations and forecasts. (Also, please see Appendix B for CPI Changes)

In 2013, the dollar fell to its lowest level since May 2012. The Dollar-Turkish Lira parity became 1.7568. The Central Bank Monetary Policy Committee lowered the policy rate by 50 basis points and the compound interest rate of the benchmark bond fell to the historical low of 4.81 percent. The Central Bank's Monetary Policy Committee increased the lending rate by 50 basis points to 7.75 percent. In December, the Turkish lira parity to the dollar was 2.0974, which was the highest level until that time.

In 2014, The Turkish lira showed the highest depreciation in euro and dollar parities until 2014. In January, while the Dollar was 2.3769 Turkish Liras, the Euro was 3.2564 Turkish Liras. In this period, the Central Bank's Monetary Policy Committee increased the interest rates by 5 points. Consumer Confidence Index decreased by 2.4 percent in November compared to the previous month, and the index, which was 70.3 in October, decreased to 68.7 in November.

In 2015, the interest rate of the 2-year benchmark bond, which declined to 9.58% in July, rose to double-digit levels in the following period due to the deterioration in risk perception. As of the end of July, the interest rate of the bond was at the level of 9.98%.

In 2016, there are effects on the economic environment in Turkey due to the political environment in general. After that, in 2017, these effects continued. For this reason, the Central Bank of the Republic of Turkey tried to maintain financial stability while fighting inflation by using the monetary policy tools at its disposal throughout the year within its mandate. Although the CBRT gave confidence to the markets with the steps it took to prevent sharp fluctuations in exchange rates and to stabilize the Turkish Lira, the Turkish Lira performed negatively among emerging market currencies. During this period, the Dollar rose from 3.52 to 3.98 Turkish Liras. The CBRT Monetary Policy Committee did not change the policy rate, but increased the marginal funding rate, the upper band, from 8.50 percent to 9.25 percent.

When we examine the figures (Figure 12 ~ Figure 28), we can observe that the highest peak was in the second half of 2018. Looking at the economic events in this period will help to understand the reasons for these peaks.

Firstly, the currency crisis emerged in 2018. While the dollar was in the range of 3-4 Turkish Liras in 2017, as of the end of June 2018, with the effect of the political events in Turkey (presidential and general elections), it exceeded the limit of 5 Turkish Liras. The Central Bank Monetary Policy Committee, which convened extraordinarily in the face of the sudden increase in the exchange rate before the elections, increased the interest rates.

Secondly, the sudden increase in the exchange rate also affected the economic balances such as inflation and CPI. In this period, inflation has risen to over 20% after years. Likewise, there is a high increase in the CPI on an annual basis. For CPI, the table showing the annual and monthly changes in CPI in year of 2018 according to the CBRT in TCMB EVDS (2021) is as follows;

Table 4. CPI Changes in 2018

2018	**CPI (Year to Year % Changes)**	**CPI (Month to Month % Changes)**
January	10.35	1.02
February	10.26	0.73
March	10.23	0.99
April	10.85	1.87
May	12.15	1.62
June	15.39	2.61
July	15.85	0.55
August	17.90	2.30
September	24.52	6.30
October	25.24	2.67
November	21.62	-1.44
December	20.30	-0.40

As can be seen in the table, while the annual CPI change increased by approximately 2 points in the first two quarters, the annual change increased by 3 points in just 1 month in June. When evaluated on a monthly basis, it also showed the highest increase up to that period.

In 2019, inflation, which rose in 2018 and reached its peak with 25.24 percent, decreased due to the relatively stabilization of the exchange rate. According to TURKSTAT, the economic confidence index increased from 79.4 to 81.9 in March compared to the previous month. Inflation increased by 0.99 percent in September and became 9.26 percent annually.

In 2020 according to Bloomberght (2021), the effects of the pandemic began to be felt. Annual inflation rose to 14% in November. The depreciation of the Turkish lira from previous years caused fluctuations in inflation.

5.2 Forecast Results

We analyze difference between real data and our expectations shown as a time series graph. From now on, we will designate the period from July 2013 to June 2018 as "part 1", the period late June 2018 to November 2019 as "part 2", and the period after November 2019 until April 2021 as "part 3". Information about these dates and our expectation results can be seen below.

We will first present the results for, started with GDS data and forecasts. For the "*BIST-KYD GDS 91 Days*" data which is show 0-180 days maturities GDS (for maturity details please refer to Table 3), estimations based on Gaussian State Space Model close to real values. Below, the explanations of these figures will be made and the relevant figures will be demonstrated.

In time period part 1, the actual values move in the range of 0.002 and 0.004, likewise, the forecasts are in these value ranges. (Figure 12)

In time period part 2, which is mentioned before, peaks are observed. There are also peaks in our estimation results. However, the approximation of the estimations to the real values is less than part1. In this period, real values are moving between 0.003 and 0.0012, while our estimates are between 0.005 and 0.009. Even so, it is seen that they intersect at some points. Also, ups and downs are in line each other. (Figure 12)

In time period part 3, with the decrease of inflation and CPI compared to the values in part 2, the gap between our estimates and actual values has closed again. While the actual values are approximately 0.002 to 0.005, the predictions of our model are also observed in close ranges.(Figure 12)

Generally, our estimations are very close to the real values, except for the economically unstable periods due to the fact that we cannot realize our estimations in the same environment. Nevertheless, even though the forecast and actual value intervals have moved away from each other, the actual peaks observed in the relevant time intervals are also seen in our forecasts.

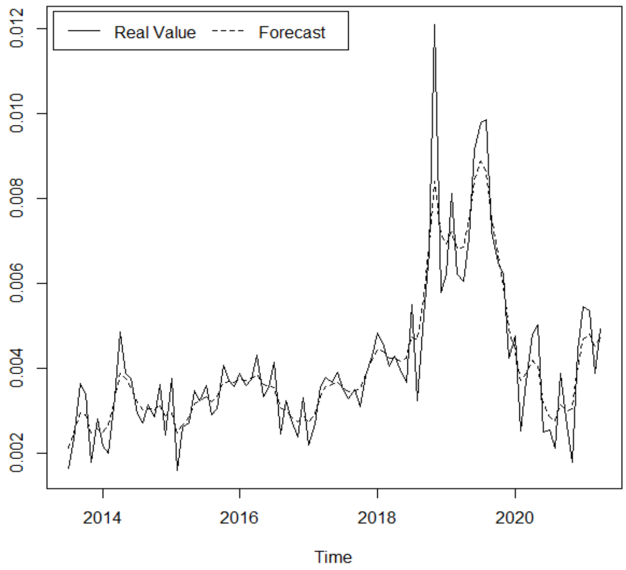

Figure 12. BIST-KYD GDS 91 Days

Due to the fact that they are in the same time frame, there are the same fluctuations in other GDS maturities. For this reason, State Space equations and figures are given together for the remaining 4 terms and their evaluations are made jointly.

Before that, the maturities of the related GDS are as follows:

a) The data named “BIST-KYD DIBS 182 Days” shows the maturity GDS in the range of 122-242 days.

b) The data named “BIST-KYD GDS 365 Days” shows the maturity GDS in the range of 243-488 days,

c) The data named “BIST-KYD GDS 547 Days” shows the maturity GDS in the range of 365-729 days,

d) The data named “BIST-KYD GDS Long” shows the GDS maturity 1096 days and above,

Although the ups and downs of the estimations are in line with real values, there is a difference between the actual values and the estimations. However, it can be seen that there are intersections at some points for each period.

In time period part 1, the actual values and estimations fluctuations in line with each other for 4 different data. But, there are slight differences relatively time period 2 in the value ranges. These differences can be seen in the table below (approximate values);

Table 5. Actual value and forecast range for "Part 1" time period

Time Period Part 1	**Actual Value Range (min-max)**	**Estimation Range (min-max)**
BIST-KYD GDS 182 Days	0.001 – 0.006	0.002 – 0.003
BIST-KYD GDS 365 Days	-0.002 – 0.009	0.001 – 0.004
BIST-KYD GDS 547 Days	-0.005 – 0.01	0.001 – 0.005
BIST-KYD GDS Long	-0.02 – 0.02	-0.01 – 0.01

In time period part 2, the period with more fluctuations and peaks compared to other periods. There are also peaks in our estimations results for these 4 data like “BIST-KYD GDS 91 Days”. However, the approximation of the estimations to the actual values is less than time period part 1. These differences can be seen in the table below (approximate values);

Table 6. Actual value and forecast range for "Part 2" time period

Time Period Part 2	Actual Value Range (min-max)	Estimation Range (min-max)
BIST-KYD GDS 182 Days	0.001-0.019	0.004-0.009
BIST-KYD GDS 365 Days	-0.005 – 0.0025	0.001 – 0.010
BIST-KYD GDS 547 Days	-0.02 – 0.03	0.00-0.015
BIST-KYD GDS Long	-0.049 – 0.049	-0.01 – 0.02

In time period part 3, as mentioned before, with the decrease of inflation and CPI compared to the time period part 2, the gap between our estimates and actual values has closed again. These differences can be seen in the table below (approximate values);

Table 7. Actual value and forecast range for "Part 3" time period

Time Period Part 3	Actual Value Range (min-max)	Estimation Range (min-max)
BIST-KYD GDS 182 Days	-0.0009 – 0.006	0.003-0.005
BIST-KYD GDS 365 Days	0.0059 – 0.013	0.003 – 0.009
BIST-KYD GDS 547 Days	-0.01 – 0.015	0.00 – 0.01
BIST-KYD GDS Long	-0.03 – 0.03	-0.02 – 0.01

The figures showing the real values and forecasts of the results mentioned above are as follows;

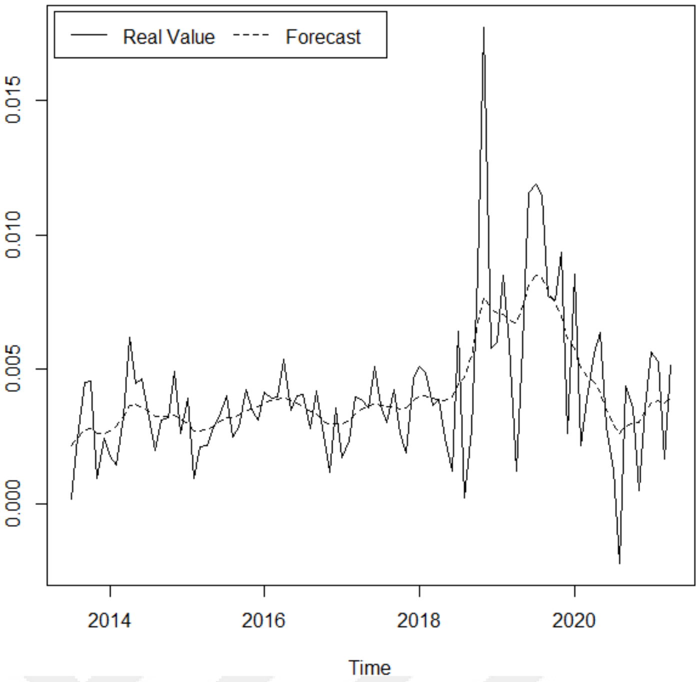

Figure 13. BIST-KYD GDS 182 Days

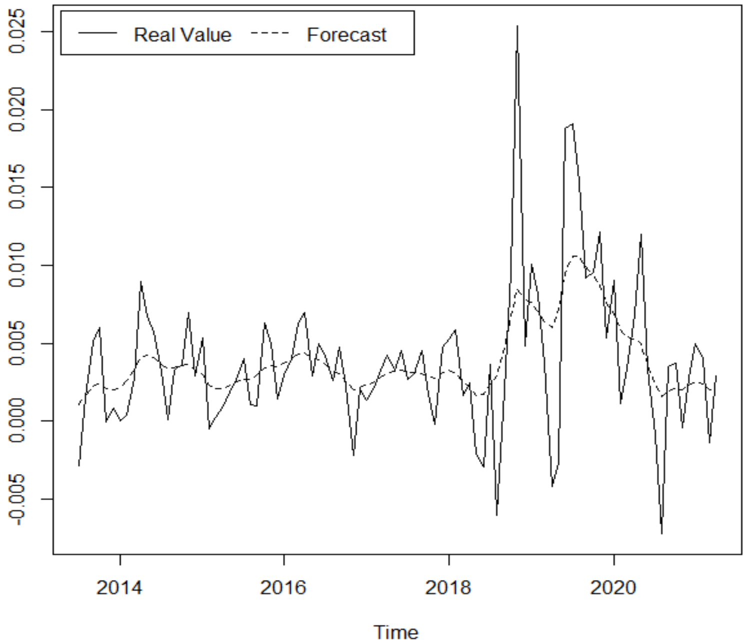

Figure 14. BIST-KYD GDS 365 Days

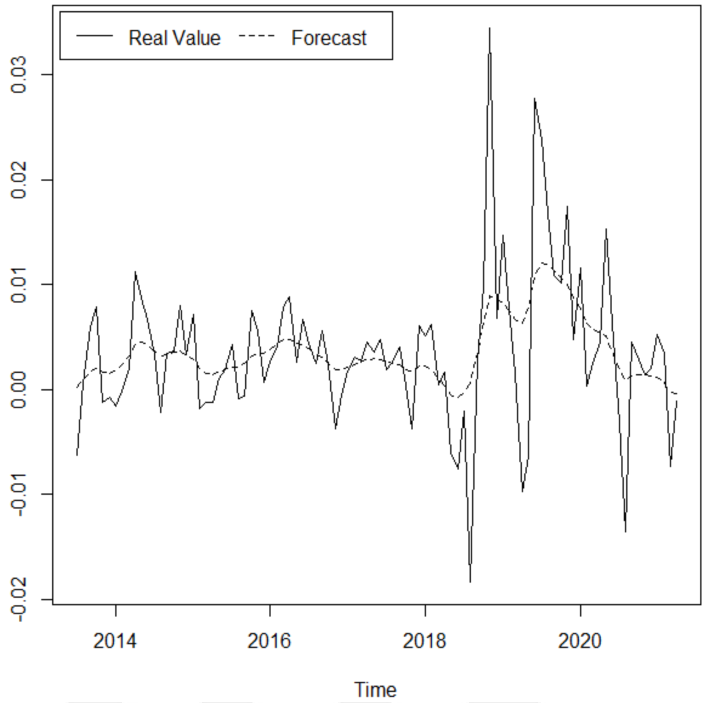

Figure 15. BIST-KYD GDS 547 Days

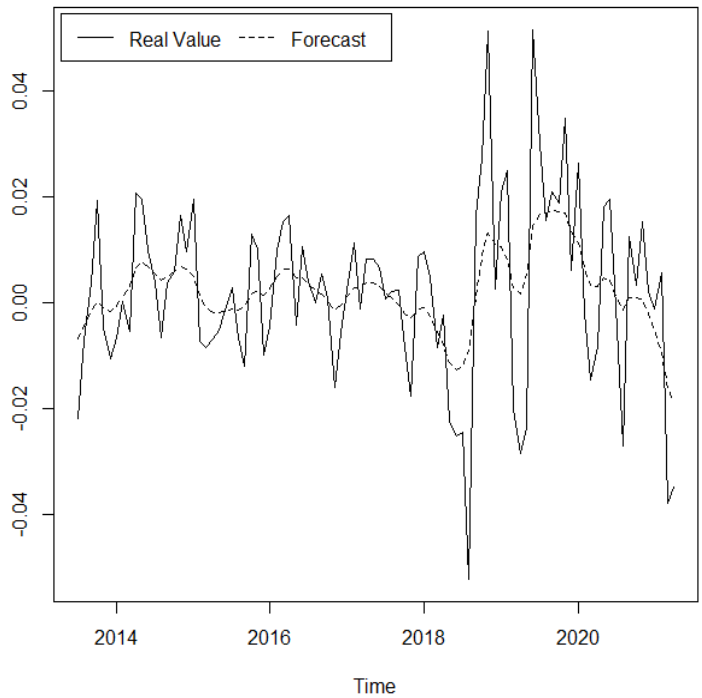

Figure 16. BIST-KYD GDS Long

After the GDS returns and forecasts, now the CPI expectation, CPI variance and the data used for the estimations of these values are as follows;

a) Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

b) Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

c) Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

d) Expectation of 12 Months Ahead Annual CPI (%)

e) Expectation of 24 Months Ahead Annual CPI (%)

f) Consumer Price Index (CPI) Variance (%)

For all expectation of interest rate, expectation of CPI variables, and CPI variance, our estimations are almost totally in line with the actual values. Also, like GDS estimations we observe peaks and downs at the same time period because of the economic environment. In Table 8. we can see the values of variables both as real values and as our estimation results. These values are approximate ranges for minimum and maximum values for relevant variables. After these value ranges, our estimation figures can be seen. In addition, since there is almost no difference between the actual data and the forecasts, we cannot observe the differences on these figures. For this reason, the calculations of the differences between the actual data and the forecast are made separately, and their figures are given after original figures.

The value ranges of the figures can be seen in the table below (approximate values);

Table 8. Actual value and forecast range for CPI variables

Variables	**Value Range (min-max) (%)**
Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	2-29
Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	1-29
Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	2-19
Expectation of 12 Months Ahead Annual CPI (%)	1-19
Expectation of 24 Months Ahead Annual CPI (%)	6-13
Consumer Price Index (CPI) Variance (%)	0.01-5.7

Related figures are shown below.

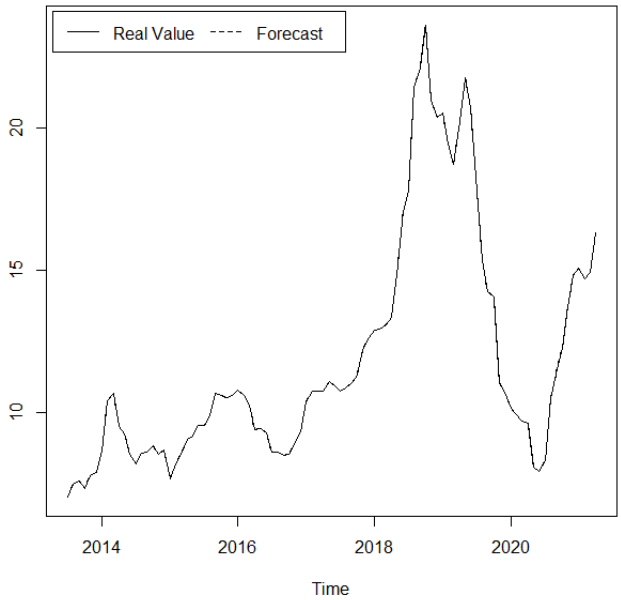

Figure 17. Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

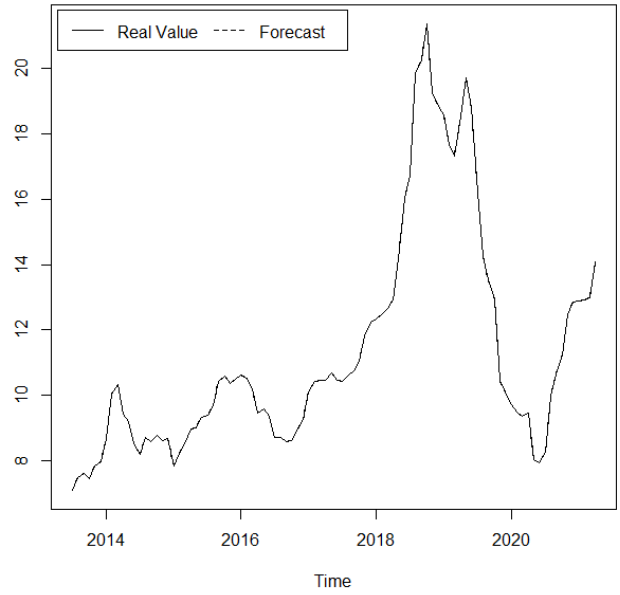

Figure 18. Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

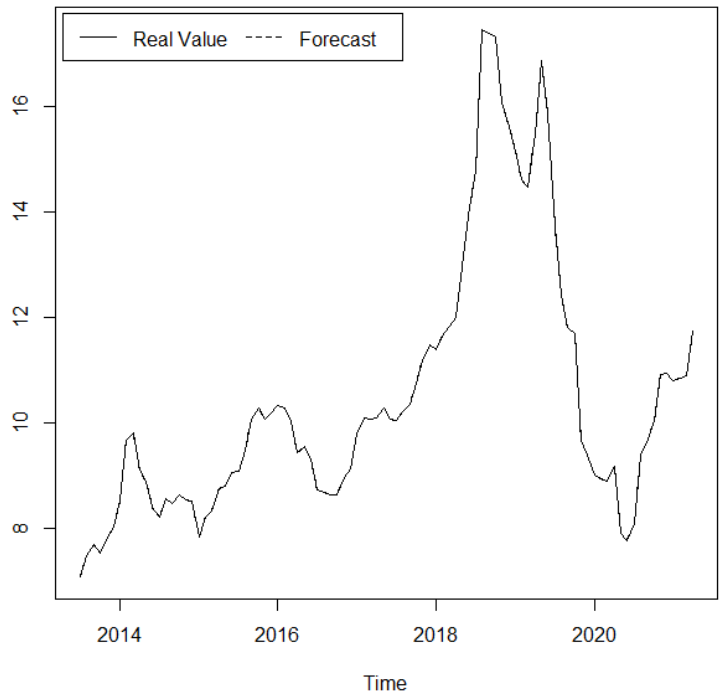

Figure 19. Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

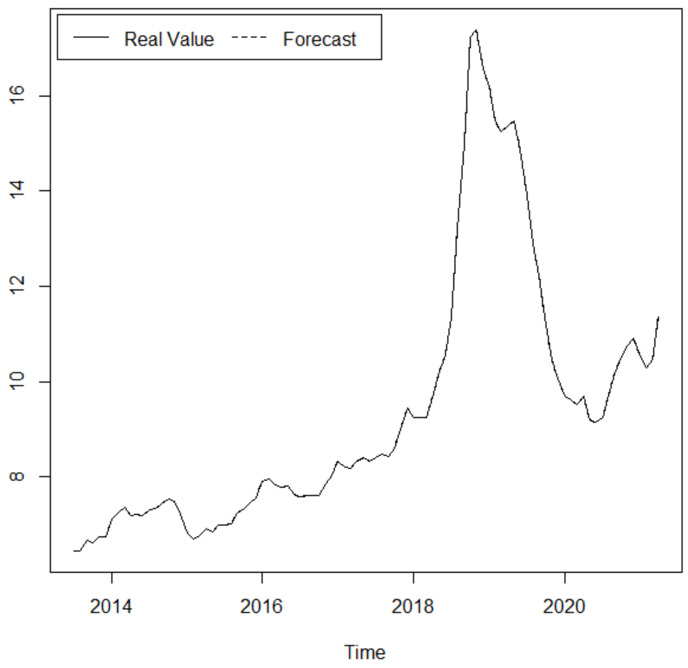

Figure 20. Expectation of 12 Months Ahead Annual CPI (%)

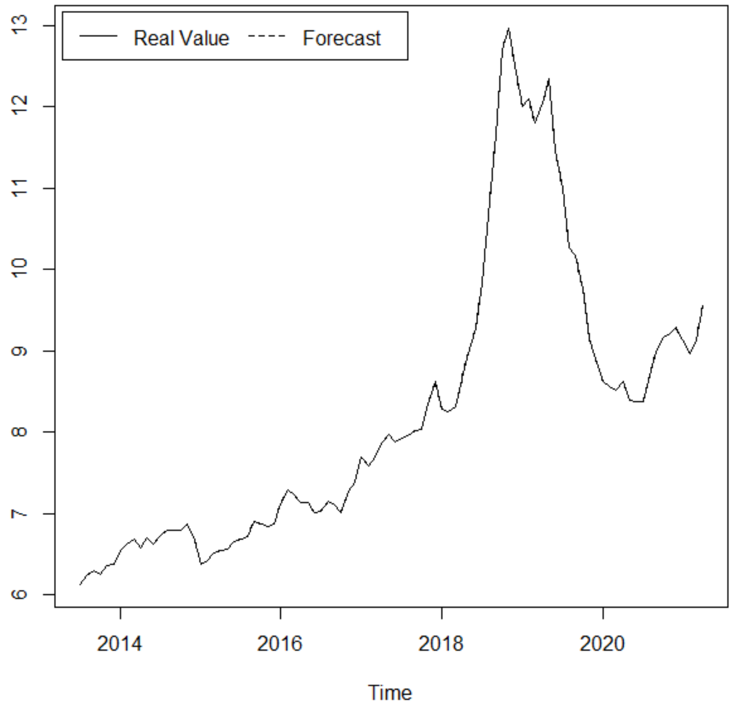

Figure 21. Expectation of 24 Months Ahead Annual CPI (%)

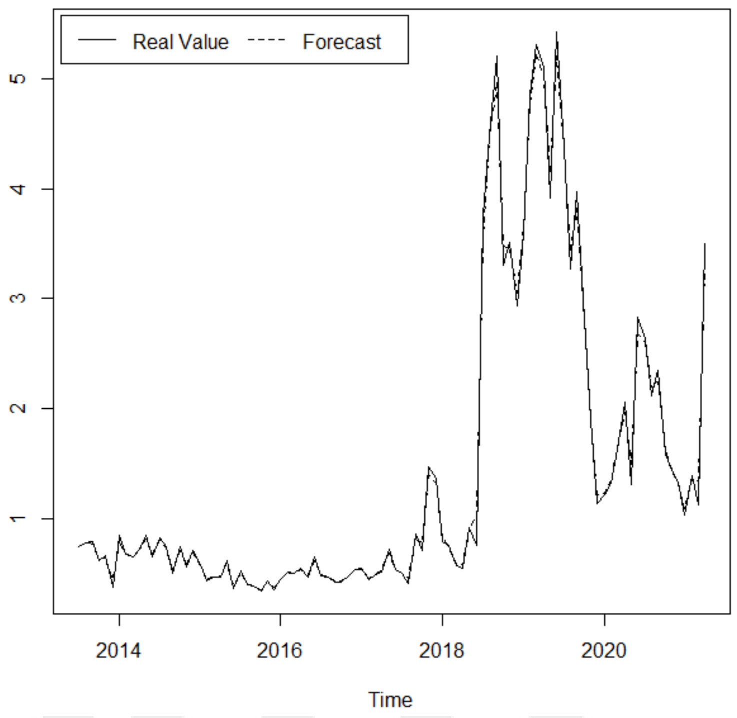

Figure 22. Consumer Price Index (CPI) Variance

Figures for the differences between forecasts and real value below;

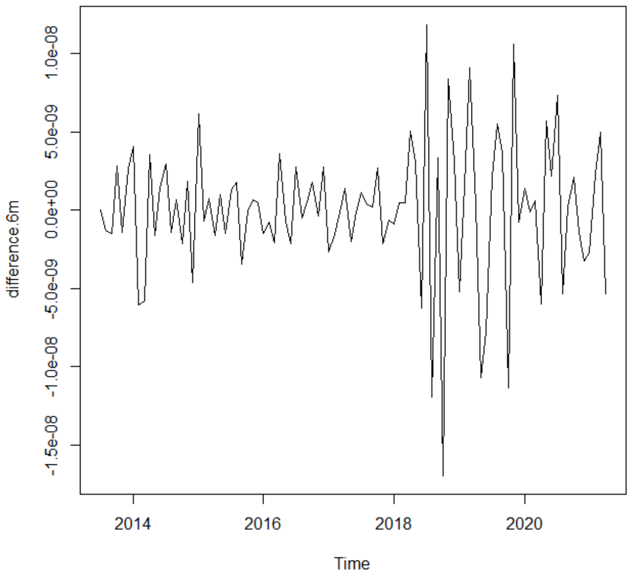

Figure 23. Difference for Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

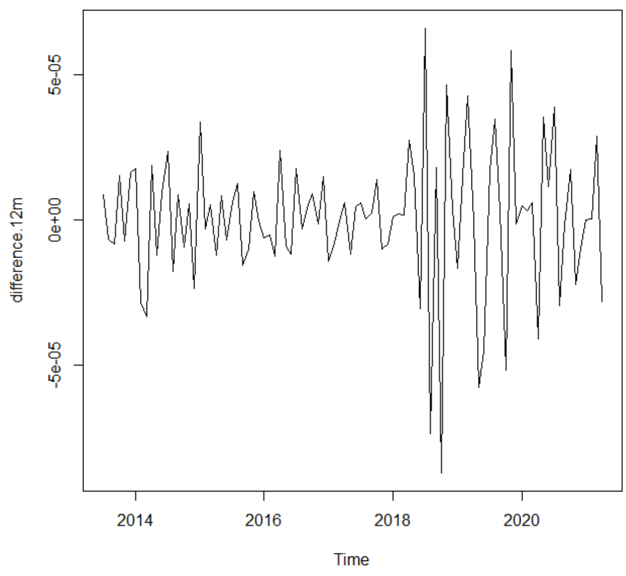

Figure 24. Difference for Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

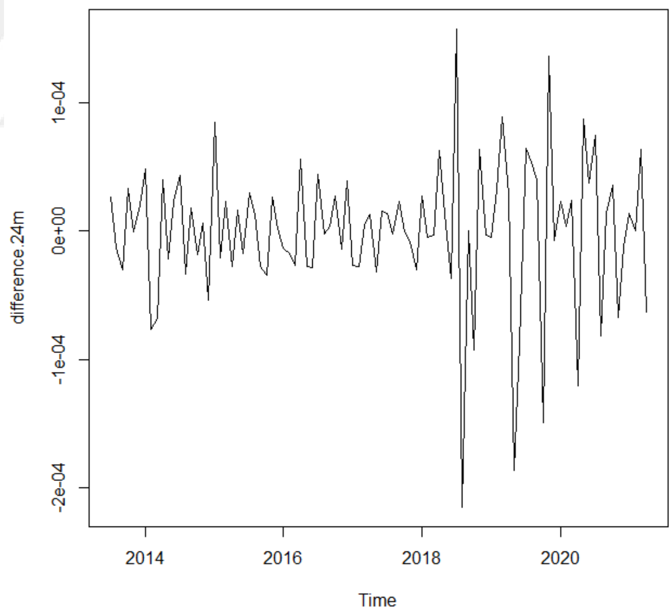

Figure 25. Difference for Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)

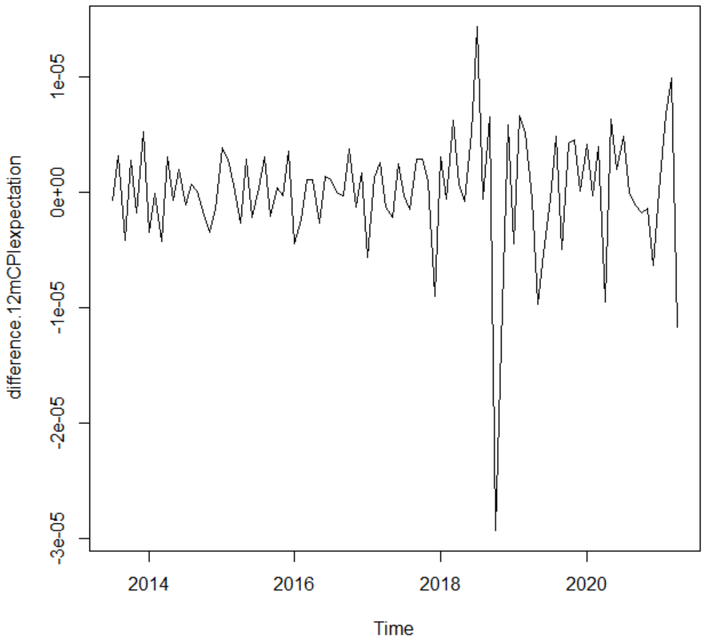

Figure 26. Difference for Expectation of 12 Months Ahead Annual CPI (%)

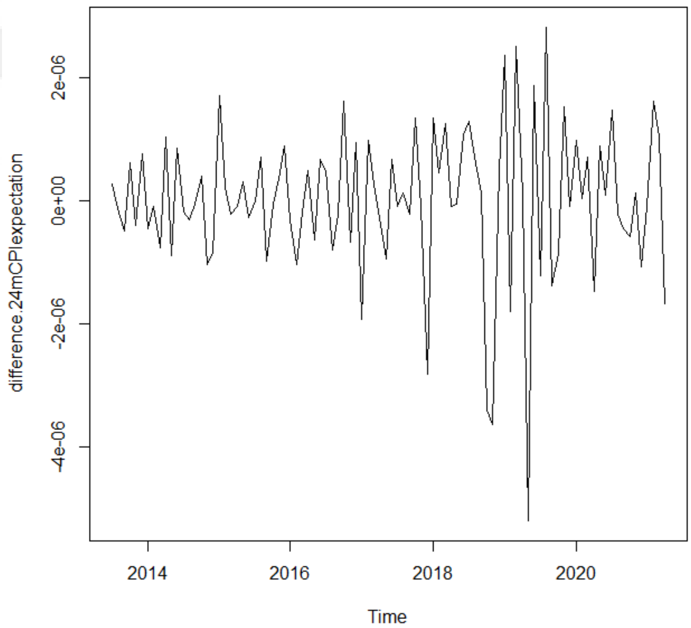

Figure 27. Difference for Expectation of 24 Months Ahead Annual CPI (%)

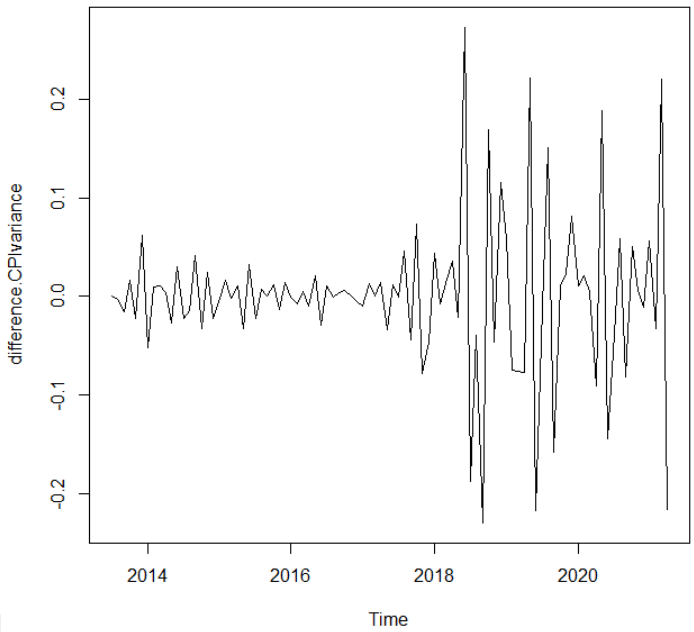

Figure 28. Consumer Price Index (CPI) Variance

Lastly, as we mention previously we also estimate H and Q as goodness-of-fit measures for our forecasts. These results show that our error terms have low values, so our estimations have low deviations. These results can be seen in Table 9.

Table 9. Estimations for “H” and “Q” values

Data	**H**	**Q**
BIST-KYD GDS 91 DAYS	$7.12e^{-7}$ = 0.000000712	$5.22e^{-7}$ = 0.000000522
BIST-KYD GDS 182 DAYS	$4.68e^{-6}$ = 0.00000468	$6.27e^{-7}$ = 0.000000627
BIST-KYD GDS 365 DAYS	$1.65e^{-5}$ = 0.0000165	$2.25e^{-6}$ = 0.00000225
BIST-KYD GDS 547 DAYS	$4.05e^{-5}$ = 0.0000405	$4.59e^{-6}$ = 0.00000459
BIST-KYD GDS LONG	$2.12e^{-4}$ = 0.000212	$3.59e^{-5}$ = 0.0000359
Expectation of 6 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	$4.02e^{-9}$ =0.00000000402	0.985

Table 9. Estimations for "H" and "Q" values (continued)

Data	H	Q
Expectation of 12 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	$1.84e^{-5} = 0.0000184$	0.677
Expectation of 24 Months Ahead Annual Compound Interest Rate of TRY Denominated Government Domestic Debt Securities with Maturities of Three Months or Less (%)	$3.29e^{-5} = 0.0000329$	0.422
Expectation of 12 Months Ahead Annual CPI (%)	$3.34e^{-6} = 0.00000334$	0.242
Expectation of 24 Months Ahead Annual CPI (%)	$3.81e^{-7} = 0.000000381$	0.0853
Consumer Price Index (CPI) Variance	0.0379	0.335

CHAPTER 6: CONCLUSION

In this thesis, we estimated GDS returns, inflation expectations and interest rate expectations based on Linear Gaussian State Space Model using the Kalman Filter.

We obtained data from the BIST and CBRT EVDS systems between July 2014 and April 2021. CBRT conducts an Expectation Survey. The Survey of Expectation (SoE) is a monthly survey conducted by the CBRT to obtain the expectations of financial and real sector decision makers and experts on basic macroeconomic variables such as consumer inflation, exchange rate, current account balance, GDP growth rate, and interest rates. This expectation survey was completed by 60 participants, who included representatives from the real sector, such as employers and companies, the financial sector, such as banks, and professionals such as lecturers and journalists, and the results were evaluated by averaging the participants' responses. Also, BIST publishes an index for GDS and these GDS index has different maturities and different yield.

We divided the time period between July 2014 and April 2021 into three segments. Part 1 covers the period from July 2013 to June 2018, Part 2 covers the period from late June 2018 to November 2019, and Part 3 covers the period from November 2019 to April 2021. Parts 1 and 3 of the time period are more static than Part 2 of the time period. Part 2 is more turbulent owing to the economic circumstances that existed at the time. From late June 2018 to November 2019, the Turkish lira declined significantly against the US dollar, and inflation increased significantly compared to prior times.

We developed our projections based on the assumption of a steady environment. As a result, during the part 2 time period when variations were considerable, our estimations for the GDS were further distant from the real data. However, when we compared the figures for inflation expectations and inflation variance, the difference was minor.

In general evaluation, we can divide the estimation made based on Linear Gaussian State Space Model using the Kalman Filter into two parts;

Firstly, our estimated fluctuations for the GDS data are inline. Our short-term estimates are closer than the long-term ones. However, all maturities have our projections and actual set points of intersection.

Secondly, the inflation variance we calculated with realized inflation, which we used as the basis for our expectations study, was almost exactly the same as our estimates with Kalman Filter.

REFERENCES

Abrahams, M., Adrian, T., Crump, R.K. and Moench, E. (2013) *Pricing TIPS and Treasuries with Linear Regressions*, Federal Reserve Bank of New York Staff Reports, no. 570.

Ahn, D., Dittmar, R. and Gallant, A. (2002) *Quadratic Term Structure Models: Theory And Evidence. Rev. Financ.*, Stud. 15, p. 243–288.

Akaike, H. (1980) *On The Use Of The Predictive Likelihood Of A Gaussian Model*, Ann Inst Stat Math, 32, pp. 311–324

Ang, A., Bekaert, G. and Wei, M. (2008) *The term structure of real rates and inflation expectations*, J. Finance, 63, pp. 797–849.

Baharumshah, A.Z., Slesman, L. and Wohar, M. E. (2016) *Inflation, Inflation Uncertainty, And Economic Growth In Emerging And Developing Countries: Panel Data Evidence*, Economic Systems, 40(4), pp. 638-657.

Bansal, R. and Shaliastovich, I. (2012) *A long-run risks explanation of predictability puzzles in bond and currency markets*, Rev. Financ. Stud., 26, pp. 1–33.

Bauer, M.D. and Rudebusch, G.D. (2017) *Interest Rates Under Falling Stars*, Federal Reserve Bank of San Francisco Working paper 2017-16. Available at https://doi.org/10.24148/wp2017-16. (Accessed 19 May 2021).

Bekaert, G. and Wang, X. (2010) *Inflation risk and the inflation risk premium*, Economic Policy, 25, pp. 755-806.

Bloomberght (2021) [Online]. Available at: https://www.bloomberght.com/. (Accessed 19 May 2021).

Borsa Istanbul Publications (2021). *BIST-KYD Endeksleri Temel Kuralları* [Online]. Available at: https://www.borsaistanbul.com/files/bist-kyd-endeksleri-temel-kurallari .pdf. (Accessed 19 May 2021).

Brotherton, T. and W. Gersch (1981) *A data analytic approach to the smoothing problem and some of its variations*, 20th IEEE Conference on Decision and Control including the Symposium on Adaptive Processes, pp. 1061-1069.

Breach, T., D’Amico, T. and Orphanides, A. (2020) *The Term Structure And Inflation Uncertainty*, Journal of Financial Economics, 138(2), pp. 388-414.

Buraschi, A. and Jiltsov, A. (2005) *Inflation risk premia and the expectations*, Journal of Financial Economics, 75(2), pp. 429-490.

Campbell, J.Y., Sunderam, A. and Viceira, L.M. (2017) *Inflation bets or deflation hedges? The changing risks of nominal bonds*, Critical Finance Rev., 6, pp. 263–301.

Chernov, M. and Mueller, P. (2012) *The term structure of inflation expectations,* J. Financ. Econ., 106, pp. 367–394.

Christensen, J. H. E., Lopez J. A. and Rudebusch, G. D. (2010) *Inflation expectations and risk premiums in an arbitrage-free model of nominal and real bond yields*, Federal Reserve Bank of San Francisco Working Paper 2008-23. Available at https://doi.org/10.24148/wp2008-23. (Accessed 19 May 2021).

Christiano, L., Eichenbaum, M. and Evans, C. (2005) *Nominal rigidities and the dynamic effects of a shock to monetary policy*, Journal of Political Economy, 113, pp. 1–45.

Cochrane, J. and Piazzesi and M. (2005) *Bond risk premia*, American Economic Review, 95, pp. 138–160.

Collin-Dufresne, P., Goldstein, R.S. and Jones, C.S. (2009) *Can interest rate volatility be extracted from the cross section of bond yields*, J. Financ. Econ., 94, pp. 47–66.

D'Amico, S., Kim, D. and Wei, M. (2018) *Tips from TIPS: the informational content of treasury inflation-protected security prices*, Journal of Financial and Quantitative Analysis, 53(1), pp. 395 – 436.

D'Amico, S. and Orphanides, A. (2008) *Uncertainty and disagreement in economic forecasting*, Finance and Economics Discussion Series from Board of Governors of the Federal Reserve System (U.S.) Working paper No 2008-56, Available at http://www.federalreserve.gov/pubs/feds/2008/200856/200856pap.pdf. (Accessed 19 May 2021).

Dai, Q. and Singleton, K. (2000) *Specification analysis of affine term structure models*, Journal of Finance, 55(5), pp. 1943-1978.

Dai, Q. and Singleton, K. (2002) *Expectations puzzle, time-varying risk premia, and affine models of the term structure*, J. Financ. Econ., 63, pp. 415–441.

Duffee, G. (2002) *Term premia and interest rate forecasts in affine models*, J. Finance, 57, pp. 405–443.

Duffee, G. (2011) *Information in (and not in) the term structure*, Rev. Financ. Stud., 24, pp. 2895–2934.

Duffee, G. (2018) *Expected inflation and other determinants of treasury yields*, J. Finance, 73, pp. 2139–2180.

Duncan, D. B. and Horn S. D. (1972) *Linear Dynamic Recursive Estimation from the*

Viewpoint of Regression Analysis, Journal of the American Statistical Association, 67(340), pp. 815-82.

Ehling, P., Gallmeyer, M., Heyerdahl-Larsen, C. and Illeditsch, P. (2018) *Disagreement about inflation and the yield curve*, J. Financ. Econ., 127, pp. 459–484.

Erb, C. and Harvey, C. (2006) *The strategic and tactical value of commodity futures*, Financial Analysts Journal, 62(2), pp. 69–97.

Evans, C., Fisher, J., Gourio, F. and Krane, S. (2015) *Risk management for monetary policy near the zero lower bound*, Brookings Pap. Econ. Act. 19, pp.141-219.

Evans, M.D.D. (1998) *Real rates, expected inflation, and inflation risk premia*, Journal of Finance, 53, pp. 187–218.

Evans, M.D.D. (2003) *Real risk, inflation risk, and the term structure*, Economic Journal, 113(487), pp. 345-389.

Feldman, R., Heinecke, K., Kocherlakota, N., Schulhofer-Wohl, S. and Tallarini, T. (2016) *Market-Based Probabilities: A Tool for Policymakers*, Federal Reserve Bank of Minneapolis Working Paper 2016-15. Available at https://do.org/10.21649/ wp2016-15. (Accessed 19 May 2021).

Fleckenstein, M., Longstaff, F.A. and Lustig, H. (2016) *Deflation risk*, UCLA National Bureau of Economic Research, Inc NBER Working Papers, No 19238, Available at https://www.anderson.ucla.edu/sites/default/files/documents/areas/fac /finance /longstaff%20Deflation.pdf. (Accessed 19 May 2021).

Ftiti, Z. and Jawadi, F. (2018) *Forecasting inflation uncertainty in the United States and Euro Area*, Computational Economics, 54, pp. 455–476.

Gallmeyer, M., Hollifield, B., Palomino, F. and Zin, S. (2007) *Arbitrage free bond pricing with dynamic macroeconomic models*, Federal Reserve Bank of St. Louis Review, 89, pp. 305–326.

Goodfriend, M. (1993) *Interest rate policy and the inflation scare problem: 1979-1992*, Econ. Quart., 79, pp. 1–23.

Grishchenko, O. and Huang, J. (2013) *The Inflation risk premium: Evidence from the TIPS market*, The Journal of Fixed Income, 22(4), pp. 5-30.

Harvey, A.C. and Phillips, G.D.A (1979) *Maximum Likelihood Estimation of Regression Models with Autoregressive- Moving Average Disturbances*, Biometrika, 66(1), pp. 49-58.

Haubrich, J., Pennacchi, G. and Ritchken, P. (2012) *Inflation expectations, real rates, and risk premia: evidence from inflation swaps*, Rev. Financial Stud., 25, pp. 1588–

1629.

Ho, Y.C. and Lee, R.C.K. (1964) *Identification of linear dynamic systems,* Third Symposium on Adaptive Processes, pp. 86-101

Johansen, B. K. and Mertens, E. (2016) *The Expected Real Interest Rate in the Long Run: Time Series Evidence with the Effective Lower Bound,* FEDS Notes from Board of Governors of the Federal Reserve System (U.S.), Available at https://www.federalreserve.gov/econresdata/notes/feds-notes/2016/the-expected-real-interest-rate-in-the-long-run-time-series-evidence-with-the-effective-lower-bound-20160209.html. (Accessed 19 May 2021).

Joslin, S., Priebsch, M. and Singleton, K.J. (2014) *Risk premiums in dynamic term structure models with unspanned macro risks,* J. Finance, 69, pp. 1197–1233.

Kalman, R. (1960) *A New Approach to Linear Filtering and Prediction Problems,* ASME Journal of Basic Engineering, 82, pp. 35-45.

Kalman, R. and Bucy, R.S. (1961) *New Results in Linear Filtering and Prediction Theory,* J. Basic Eng. 83(1), pp. 95-108.

Karahan, O. (2012) *The relationship between inflation and inflation uncertainty: evidence from the Turkish economy*, Procedia economics and finance, 1, pp. 219-228.

Khatır, A.Q., Guvenek, B. and Mangir, F. (2020) *The Relationship between Inflation and Inflation Uncertainty: Empirical Evidence from Turkey*, Journal of Academic Value Studies, 2020, 4, pp. 331-340.

Kiley, M. T. (2015) *Low Inflation in the United States: A Summary of Recent Research,* FEDS Notes from Board of Governors of the Federal Reserve System (U.S.), No. 11-23, Available at https://www.federalreserve.gov/econresdata/notes/feds-notes/2015/low-inflation-in-the-united-states-a-summary-of-recent-research-20151123.html. (Accessed 19 May 2021)

Kim, D.H. and Orphanides, A. (2012) *Term structure estimation with survey data on interest rate forecasts,* J. Financ. Quant. Anal., 47, pp. 241–272.

Kim, D.H. and Singleton, K.J. (2012) *Term structure models and the zero bound: an empirical investigation of Japanese yields,* J. Economet., 170, pp. 32–49.

Kitagawa, G. (1981) *A Nonstationary Time Series Model and its Fitting by a Recursive Filter,* Journal of Time Series Analysis, 2(2), pp. 103 – 116.

Kitagawa, G. (1987) *Non-Gaussian State-Space Modeling of Nonstationary Time Series,* Journal of the American Statistical Association, 82(400), pp. 1032-1041.

Kitagawa, G and Gersch, W. (1996) *Linear Gaussian State Space Modeling In:*

Smoothness Priors Analysis of Time Series, Part of the Lecture Notes in Statistics, 116, pp. 67-89. Available at https://link.springer.com/chapter/10.1007/978-1-4612-0761-0_5. (Accessed 19 May 2021).

Kitsul, Y., Wright, J.H. (2013) *The Economics Of Options-Implied Inflation Probability Density Functions,* Journal of Financial Economics, 110(3), pp. 696-711.

Laubach, T. and Williams, J. C. (2015) *Measuring the Natural Rate of Interest Redux*, Federal Reserve Bank of San Francisco Working Paper 2015-16. Available at https://doi.org/10.24148/wp2015-16. (Accessed 19 May 2021).

Lubik, T. A. and Matthes, C. (2015) *Time-Varying Parameter Vector Autoregressions: Specification, Estimation, and an Application*, Economic Quarterly, 101(4), pp. 323-352.

Ludvigson, S.C. and Ng, S. (2009) *Macro factors in bond risk premia*, Review of Financial Studies, 22, pp. 5027–5067.

Meinhold, R.J. and Singpurwalla, N.D. (1983) *Understanding the Kalman Filter,* The American Statistician, 37(2), pp. 123-127.

Onder, O. (2014) *Forecasting Inflation in Emerging Markets by Using the Phillips Curve and Alternative Time Series Models*, Emerging Markets Finance and Trade, 40(2), pp. 71-82.

Palomino, F. (2012) *Bond Risk Premiums And Optimal Monetary Policy*, Review of Economic Dynamics, 15, pp. 19–40.

Payne, J.E. (2009) *Inflation targeting and the inflation-inflation uncertainty relationship: Evidence from Thailand*, Applied Economics Letters, 16(3), pp. 233-238.

Piazzesi, M. and Schneider, M. (2006) *Equilibrium yield curves. In: Acemoglu, D., Rogoff, K., Woodford, M. (Eds.),* NBER Macroeconomics Annual, 20, pp. 389–496.

Piazzesi, M. and Schneider, M. (2007). *Equilibrium yield curves*, NBER Macroeconomics Annual, 21, 389–472.

Rich, R.W. and Tracy, J.S. (2017) *The Behavior of Uncertainty and Disagreement and Their Roles in Economic Prediction: A Panel Analysis*, Staff Reports of Federal Reserve Bank of New York, 808. Available at https://www.newyorkfed.org/research/staff_reports/sr808.html. (Accessed 19 May 2021).

Rudebusch, G.D. and Swanson, E.T. (2008) *Examining the bond premium puzzle with a DSGE model*, J. Monetary Econ., 55, pp. 111–126.

Rudebusch, G.D. and Swanson, E.T. (2012) *The Bond Premium In A DSGE Model With Long-Run Real And Nominal Risks*, American Economic Journal:

Macroeconomics, 4(1), pp. 105-143.

Schweppe, F. (1965) *Evaluation of likelihood functions for Gaussian signals*, IEEE Transactions on Information Theory, 11(1), pp. 61 – 70.

Statistica (2021) [Online]. Available at: https://www.statista.com/. (Accessed 19 May 2021).

TCMB EVDS (2021). *Elektronik Veri Dağıtım Sistemi* [Online]. Available at: https://evds2.tcmb.gov.tr/. (Accessed 19 May 2021).

Thornton, J. (2007) *The Relationship between Inflation and Inflation Uncertainty in Emerging Market Economies*, Southern Economic Journal, 73(4), pp. 858-870.

Wachter, J.A. (2006) *A consumption-based model of the term structure of interest rates*, Journal of Financial Economics, 79(2), pp. 365-399.

Wecker, W.E. and Ansley, C.F. (1983) *The Signal Extraction Approach to Nonlinear Regression and Spline Smoothing*, Journal of the American Statistical Association, 78(381), pp. 81-89.

Wright, J.H. (2011) *Term premia and inflation uncertainty: empirical evidence from an international panel dataset*, Am. Econ. Rev., 101, pp. 1514–1534.

APPENDICES

Appendix A: Tables of CPI Variances

Date (Year – Month)	Variance
2013-07	0.7505
2013-08	0.7807
2013-09	0.7920
2013-10	0.6201
2013-11	0.6650
2013-12	0.3845
2014-01	0.8543
2014-02	0.6830
2014-03	0.6511
2014-04	0.7220
2014-05	0.8485
2014-06	0.6514
2014-07	0.8327
2014-08	0.7540
2014-09	0.5022
2014-10	0.7431
2014-11	0.5678
2014-12	0.7081
2015-01	0.5818
2015-02	0.4357
2015-03	0.4759
2015-04	0.4742
2015-05	0.6171
2015-06	0.3688
2015-07	0.5289
2015-08	0.4084
2015-09	0.3869
2015-10	0.3459
2015-11	0.4410
2015-12	0.3623
2016-01	0.4478

Date (Year – Month)	Variance
2016-02	0.5185
2016-03	0.5017
2016-04	0.5533
2016-05	0.4709
2016-06	0.6524
2016-07	0.4877
2016-08	0.4691
2016-09	0.4309
2016-10	0.4272
2016-11	0.4846
2016-12	0.5419
2017-01	0.5539
2017-02	0.4502
2017-03	0.4985
2017-04	0.5227
2017-05	0.7274
2017-06	0.5365
2017-07	0.5075
2017-08	0.4170
2017-09	0.8631
2017-10	0.7151
2017-11	1.4778
2017-12	1.3687
2018-01	0.7957
2018-02	0.7541
2018-03	0.5718
2018-04	0.5502
2018-05	0.9253
2018-06	0.7559
2018-07	3.7504
2018-08	4.4847
2018-09	5.2034
2018-10	3.3050

Date (Year – Month)	Variance
2018-11	3.5177
2018-12	2.9385
2019-01	3.5960
2019-02	4.8482
2019-03	5.3084
2019-04	5.1027
2019-05	3.9174
2019-06	5.4260
2019-07	4.3756
2019-08	3.2748
2019-09	3.9784
2019-10	2.8128
2019-11	1.8955
2019-12	1.1371
2020-01	1.2229
2020-02	1.3225
2020-03	1.6312
2020-04	2.0590
2020-05	1.3105
2020-06	2.8322
2020-07	2.6402
2020-08	2.1173
2020-09	2.3498
2020-10	1.5882
2020-11	1.4446
2020-12	1.3303
2021-01	1.0380
2021-02	1.3966
2021-03	1.1288
2021-04	3.4963

Appendix B: Tables of CPI Changes between July 2013 and April 2021 TCMB EVDS (2021)

Year	Month	CPI (Year to Year % Changes)	CPI (Month to Month % Changes)
2013	July	8.88	0.31
2013	August	8.17	-0.1
2013	September	7.88	0.77
2013	October	7.71	1.8
2013	November	7.32	0.01
2013	December	7.4	0.46
2014	January	7.75	1.98
2014	February	7.89	0.43
2014	March	8.39	1.13
2014	April	9.38	1.34
2014	May	9.66	0.4
2014	June	9.16	0.31
2014	July	9.32	0.45
2014	August	9.54	0.09
2014	September	8.86	0.14
2014	October	8.96	1.90
2014	November	9.15	0.18
2014	December	8.17	-0.44
2015	January	7.24	1.10
2015	February	7.55	0.71
2015	March	7.61	1.19
2015	April	7.91	1.63
2015	May	8.09	0.56
2015	June	7.20	-0.51
2015	July	6.81	0.09
2015	August	7.14	0.40
2015	September	7.95	0.89
2015	October	7.58	1.55
2015	November	8.10	0.67
2015	December	8.81	0.21

Year	Month	CPI (Year to Year % Changes)	CPI (Month to Month % Changes)
2016	January	9.58	1.82
2016	February	8.78	-0.02
2016	March	7.46	-0.04
2016	April	6.57	0.78
2016	May	6.58	0.58
2016	June	7.64	0.47
2016	July	8.79	1.16
2016	August	8.05	-0.29
2016	September	7.28	0.18
2016	October	7.16	1.44
2016	November	7.00	0.52
2016	December	8.53	1.64
2017	January	9.22	2.46
2017	February	10.13	0.81
2017	March	11.29	1.02
2017	April	11.87	1.31
2017	May	11.72	0.45
2017	June	10.90	-0.27
2017	July	9.79	0.15
2017	August	10.68	0.52
2017	September	11.20	0.65
2017	October	11.90	2.08
2017	November	12.98	1.49
2017	December	11.92	0.69
2018	January	10.35	1.02
2018	February	10.26	0.73
2018	March	10.23	0.99
2018	April	10.85	1.87
2018	May	12.15	1.62
2018	June	15.39	2.61
2018	July	15.85	0.55
2018	August	17.90	2.30

Year	Month	CPI (Year to Year % Changes)	CPI (Month to Month % Changes)
2018	September	24.52	6.30
2018	October	25.24	2.67
2018	November	21.62	-1.44
2018	December	20.30	-0.40
2019	January	20.35	1.06
2019	February	19.67	0.16
2019	March	19.71	1.03
2019	April	19.50	1.69
2019	May	18.71	0.95
2019	June	15.72	0.03
2019	July	16.65	1.36
2019	August	15.01	0.86
2019	September	9.26	0.99
2019	October	8.55	2
2019	November	10.56	0.38
2019	December	11.84	0.74
2020	January	12.15	1.35
2020	February	12.37	0.35
2020	March	11.86	0.57
2020	April	10.94	0.85
2020	May	11.39	1.36
2020	June	12.62	1.13
2020	July	11.76	0.58
2020	August	11.77	0.86
2020	September	11.75	0.97
2020	October	11.89	2.13
2020	November	14.03	2.30
2020	December	14.60	1.25
2021	January	14.97	1.68
2021	February	15.61	0.91
2021	March	16.19	1.08
2021	April	17.14	1.68

Year	Month	CPI (Year to Year % Changes)	CPI (Month to Month % Changes)
2021	May	16.59	0.89
2021	June	17.53	1.94
2021	July	18.95	1.80
2021	August	19.25	1.12
2021	September	19.58	1.25
2021	October	19.89	2.39
2021	November	21.31	3.51
2021	December	36.08	13.58