EXTRACTING MARKET EXPECTATIONS FOR MONETARY POLICY STANCE USING OVERNIGHT INDEX SWAP: EVIDENCE FROM TÜRKİYE

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ABSTRACT

EXTRACTING MARKET EXPECTATIONS FOR MONETARY POLICY STANCE USING OVERNIGHT INDEX SWAP: EVIDENCE FROM TÜRKIYE

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This thesis analyzes the monetary policy expectations of various market-based instruments and investigates which financial instrument best estimates monetary policy expectations for different periods in Türkiye.
A new approach is adopted, and forward-term policy rates are obtained from the yield curve factors. The Nelson-Siegel method, widely used in literature, is preferred while fitting the yield curve. The predictive power of the implied yields of treasury bonds, foreign currency (FX) swap, and overnight index swap (OIS) are analyzed. Empirical findings reveal that instruments' success in estimating the Central Bank of the Republic of Türkiye (CBRT) policy rate has changed over time. The OIS yield curve successfully predicts the monetary policy stance after the Turkish Lira O/N Reference Rate (TLREF) market becomes active.

Keywords: Monetary policy, Policy rate expectations, Market-based measures of expectations

ÖZ

PARA POLİTİKASI DURUŞUNA İLİŞKİN PİYASA BEKLENTİLERİNİN OVERNIGHT INDEX SWAP İLE TAHMİNİ: TÜRKİYE'DEN DELİLLER

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Bu çalışmada, çeşitli piyasa temelli araçların para politikası beklentileri analiz edilmektedir. Türkiye'de farklı zaman dilimleri için para politikası beklentilerini tahmin etmede hangi finansal aracın daha iyi bir tahmin edici olduğu araştırılmaktadır.
Bu konuda yeni bir yaklaşım benimsenmekte ve getiri eğrisi faktörlerinden ileri vadeli ima edilen politika faizleri elde edilmektedir.
Getiri eğrisi oluşturulurken literatürde yaygın olarak kullanılan Nelson-Siegel metodu tercih edilmiştir. TCMB politika faizi için hangi piyasa faizinin en iyi tahmin gücüne sahip olduğu analiz edilmektedir. Enstrümanların TCMB politika faizini tahmin etme başarısının zaman içerisinde değiştiği ampirik bulgular ile ortaya koyulmaktadır. Türk Lirası Gecelik Referans Faiz Oranı (TLREF) piyasasının aktif hale gelmesinin ardından, OIS getiri eğrisi para politikası duruşunu başarılı şekilde tahmin etmektedir.

Anahtar Kelimeler: Para politikası, Politika faiz beklentileri, Piyasaya bazlı beklenti ölçümleri

To My Family

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I want to express my sincere gratitude to my love Ayşegül for her continuous support eternally in my life. Her support and love have motivated me to achieve my goals since we met. I would also like to thank my daughter Beyza, eagerly waiting for the thesis to be finished.

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LIST OF ABBREVIATIONS

BIST	Borsa Istanbul
BRSA	Banking Regulation and Supervision Agency
CBRT	Central Bank of the Republic of Türkiye
CMB	Capital Markets Board
DTSM	dynamic term structure model
ECB	European Central Bank
Fed	Federal Reserve Board
FFF	Fed Funds futures
FOMC	Federal Open Market Committee
FSB	Financial Stability Board
IOSCO	International Organization of Securities Commissions
LIBOR	London Interbank Offered Rate
LSAP	Large Scale Asset Purchase
MPC	Monetary Policy Committee
NS	Nelson-Siegel
OIS	Overnight Index Swap
TLREF	Turkish Lira Overnight Reference Rate
TRLIBID	Turkish Lira Interbank Bid Rate
TRLIBOR	Turkish Lira Interbank Offered Rate
VAR	Vector Autoregression
WAFC	Weighted Average Funding Cost

CHAPTER 1

INTRODUCTION

Central banks' ability to direct market expectations effectively is one of the most critical factors that ensure an effective monetary policy. While central banks affect the expectations of market participants, interest rate expectations in markets affect monetary policy decisions: data sets measuring market expectations are used in the policy decision-making processes.

Making inferences about the monetary policy stance has long been a topic of interest for investors, academics, and policymakers. Since monetary policy changes impact asset prices, making accurate predictions about monetary policy is vital for investors.

On the other hand, central banks want to know the direction of market expectations regarding their monetary policy stances. It is crucial for policymakers to measure and direct expectations correctly via monetary policy transmission mechanisms. If market participants anticipate monetary policy tightening, then their economic inclinations change. On the one hand, households and real sector firms get inclined to borrow before market borrowing rates rise, on the other hand, banks become prone to raise lending rates. Because market interest rate expectations play an important role in the transmission mechanisms of borrowing and lending rates, policymakers want to know how policy rate decisions and guidance affect market expectations.

For this reason, various methods are followed to measure market expectations. Data terminals such as Bloomberg and Reuters inform market participants through surveys before each monetary policy meeting by asking market experts about their policy rate expectations. The survey data followed by the market regarding the policy interest rate expectations are generated on regular periods. Therefore, survey data is only available on specific dates between two meetings and generally close to policy meetings about interest rates. Besides, market price-based methods offer daily measures compared to survey-based methods and they contain clues for future monetary policy decisions. In other words, published surveys at certain intervals are far from reflecting daily frequency evolutions of interest rate expectations that are tried to be estimated accurately by market participants and policy makers.

A new instrument, TLREF indexed OIS curve, to estimate the expectations of the policy rates of the Central Bank of the Republic of Türkiye (CBRT) is used. Another difference in the study from previous studies for Türkiye is that it tries to predict the future policy interest path through the yield curve information content. The implied policy interest path is obtained from the Overnight Index Swap (OIS) yield curve based on the reference index (TLREF) created in Türkiye after the LIBOR scandal. On the other hand, the policy stances of different instruments are compared by creating expectations for different future horizons from the government bond yield curve and FX swap yield curves.

It should be considered that the predictability of monetary policy may change over time due to market regulations and monetary policy preferences. Considering that the estimation power of policy rates of market-based instruments may change over time, estimation successes for different sample periods are compared.

While various market-based instruments are used in the studies for Türkiye, to the best of our knowledge, this study will be the first to make a policy stance estimation with the TLREF-indexed OIS yield curve. Another prominent aspect of the study is the determination of the similar and differentiating aspects of the bond, currency swap, and OIS yield curves analyzed with a similar method. In addition, it examines whether the OIS curve diverges from the bond and currency swap yield curves, which have been affected by macroprudential measures in recent years.

This study contributes to the existing literature in extracting monetary policy expectations using market-based instruments. (Kuttner [22], Gürkaynak et al. [16]). In forecasting monetary policy decisions, FX swap, treasury bond, and reference rate (TLREF) linked OIS are compared to extract the market-based expectations by focusing on the term structure of interest rates following Nelson and Siegel's [27] methodology. The results indicate that TLREF has superior power in preceding monetary policy decisions in Türkiye within 1-day, 1-week, and 1-month intervals. Therefore, this study emphasizes the importance of money market instruments, TLREF in this thesis, in extracting a market-based monetary policy stance.

The remainder of this work is organized as follows. The transition process to Turkish TLREF is briefly explained in the "Conceptual framework" section. In the "literature review" chapter, a detailed literature review has been done regarding the estimation of monetary policy expectations from market-based instruments.

The "Methodology" part follows the "Data" section. OIS, FX swap and Treasury yield curve construction, implied policy rate calculation, and the predictive power of implied yield comparison are explained in a detailed way. The "Empirical results" section presents the empirical results, the implications of monetary policy measures on the markets, and their policy implications. Finally, the results are discussed in the "Conclusion" section.

CHAPTER 2

CONCEPTUAL FRAMEWORK

2.1. LIBOR Scandal and the Evolution of National Benchmark Rates

London Interbank Offered Rate (LIBOR) is calculated according to the bid and ask quotes given by the banks included in the LIBOR system and is not calculated according to the transactions carried out in an organized market. LIBOR rate on any given day is calculated by taking the simple average of the rates quoted by the banks included in the system. It is measured by averaging the rates offered by the middle eight banks after subtracting the four highest and lowest rates submitted by the banks.

LIBOR moved closely with short-term interest rates before the financial crisis and was realized below expectations compared to other funding rates in the second half of 2008. During the periods when the crisis was felt intensely, LIBOR rates started to show more volatility, while spreads to other funding rates widened. In 2012, LIBOR became the focus of criticism. During the financial crisis, it was alleged that banks deliberately underplayed borrowing costs to appear financially strong and manipulated rates to profit from LIBOR-based contracts. In the investigations carried out after the scandal emerged, large amounts of fines were imposed on banks alleged to be involved in manipulation, while determining the LIBOR rate took its place at the center of criticism.

After the scandal, the FSB (Financial Stability Board) was tasked with working on reforming the LIBOR market and, if necessary, creating alternative reference interest rates. International Organization of Securities Commissions (IOSCO) developed “Principles for Financial Benchmarks,” which cover the essential issues of benchmark criteria. In the ongoing process, a trend toward defining alternative reference interest rates has come to the fore.

2.2. Overview of Turkish Lira Overnight Reference Rate

A National Working Committee was established to carry out this process in Türkiye, and as of June 2019, Borsa Istanbul started to publish the TLREF overnight repo rate.

The regulation of national benchmark rates by some countries, including Türkiye, and the activation of these markets have revealed a new empirical data set for analyzing monetary policy expectations. The OIS yield curve used in this study is priced daily and includes pricing information for up to 10 years. The OIS yield curve includes overnight and longer-term quotes, allowing it to be used to measure short, medium-, and long-term expectations regarding the monetary policy stance.

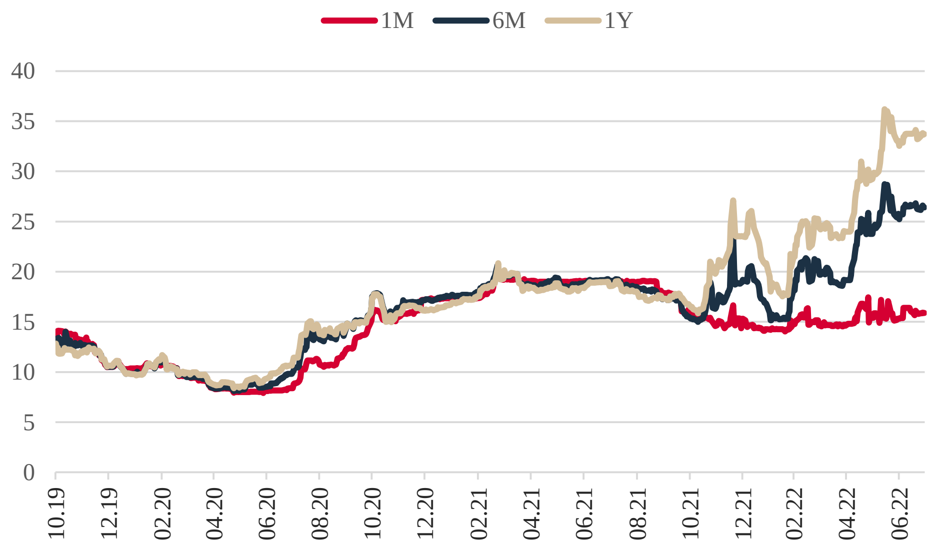

Figure 2.1: TLREF Indexed OIS Yields.

In Figure 2, the evolution of OIS returns can be seen. For instance, the 6-month OIS yield represents the market's overnight short-term interest rate expectations after 6 months from now. Since the beginning of 2022, the 1-month OIS rate has been stable and close to the monetary policy rate. An increase in 6- and 12-month OIS return points to the market's expectations of tightening monetary policy. Different maturities of the OIS yield curve give valuable information about future short-term interest rates.

CHAPTER 3

LITERATURE REVIEW

3.1. Foundations of Market-Based Monetary Policy Indicators

Various studies have been carried out on measuring policy expectations from asset prices. A wide variety of liquid instruments in the asset markets has led the studies to focus on developed countries.

Extant studies are widely cited in the literature, using market interest rates to decompose monetary policy shocks. Krueger and Kuttner [20] demonstrate that Fed funds futures rates can be used to obtain accurate estimates of Fed funds rates at one- and two-month horizons.

Vector Autoregression (VAR) procedures have been frequently used in literature to predict the market response to Federal Reserve policy. Edelberg and Marshall [11] find bill rates had a relatively large and significant response to policy shocks, while bond yields only had a minor response. Evans and Marshall [13] and Mehra [25] are among other examples applying the VAR approach. However, Rudebush [31] questions the reliability of the monetary VAR procedure. Rudebush [31] states that the Fed information set is mischaracterized by the VAR reaction functions and exhibits fragile coefficient estimates.

One essential element that examines the effects of unexpected shocks related to monetary policy decisions on asset prices is the selection of the instruments to be used in the measurement of expectations. Several papers use different instruments. Current month federal funds futures contracts are used by Kuttner [22] and Faust et al. [14]. The month-ahead federal funds futures contracts are examined by Poole and Rasche [28] and Bomfim [4]. The one-month Eurodollar deposit rate is used by Cochrane and Piazzessi [8], the three-month Treasury bill is used by Ellingsen and Soderstrom [12], and the three-month eurodollar futures rate is used by Rigobon and Sack [30]. In addition to the different maturities of the instruments mentioned above, Gürkaynak et al. [16] included term federal funds loans and commercial paper. Federal funds futures have higher predictive power for the future federal funds rate over horizons of up to about six months.

FFF ratios form an essential part of the empirical monetary policy toolkit, but being specific to the US makes it difficult to compare studies with other countries. On the other hand, OIS data is available in many countries and allows for cross-country comparisons of methodological contributions.

Gürkaynak et al. [15], pioneered in many studies, examine the effects of unexpected monetary policy shocks (changes in the federal funds rate) on asset prices with high-frequency event study analysis. The study examines the existence of an additional dimension other than the federal funds rate because it may not be sufficient to explain the effects on asset prices with a single factor. An additional factor is investigated to explain the surprise component. Apart from the federal funds rate, the content included in the FOMC announcements is examined as an additional dimension that helps explain the surprise component. It is found that a single factor is insufficient to explain the movements in asset prices, while an additional factor explains the majority of the movements in the five- and ten-year Treasury returns.

Nakamura and Steinsson [26] identify the first essential component of unexpected asset price changes in 30-minute windows as the policy indicator. They use the FFF and Eurodollar futures data, often preferred in the literature, to measure future interest rate expectations changes. The effects of monetary shocks on nominal and real interest rates behave similarly in similar maturity structures.

Swanson [33] investigates the federal funds rate, forward guidance, and LSAP factor components of FOMC announcements with changes in several asset prices in a 30-minute window from 1991 to 2019. FOMC announcements include many dimensions regarding the future policy rate path, asset purchases, and communication about the economy's direction. Monetary policy effects on the yield curve, although FOMC announcements contain many dimensions, can be well summarized by three factors. The factors' easy separation is mainly because their effects on the yield curve are different and can be observed. Large Scale Asset Purchase (LSAP) affects long-term bond yields, while forward guidance affects short-term bond yields and share prices. The study's low federal funds rate factor is attributed to the predictable increase in Fed interest rates. The predictable rise in Fed interest rates may be effective in the low level of the federal funds rate factor, but a policy rate cut above the market expectations may reveal the importance of the federal funds rate factor again. The fact that consistent monetary policy forecasts reduce the surprise effect on asset prices and suppress the size of the federal funds factor reveals the importance of estimating the policy stance correctly.

Steffensen et al. [32] use a mixed method to detect the error in monetary policy expectations. Using survey expectations of future monetary policy decomposes the term premium and expectation error components of FFF and overnight index swaps excess returns. First, it is shown that future implied short-term rates derived from FFF and OIS derivatives are biased estimators of future realized short-term rates. Based on future monetary policy expectations in the Blue-Chip Financial Forecasts survey, excess returns on FF futures and OIS contracts are decomposed into term premium and expectation error components. The excess returns are mainly due to the expectation error, and the effect of the maturity premium is insignificant and even negative in some periods.

The asymmetric superiority of the information set in the hands of the Central Banks results in the actual and expected policy rates differing from time to time. Instead of determining the policy tool with a fixed data set and rule, Central Banks pay attention to different economic variables. For instance, Rigobon and Sack [29] investigate the Fed's response to changes in stock markets and show that changes in the stock returns increase the probability of tightening or easing. Hoffman [18] investigates the asymmetry of Fed and ECB policy responses to the stock market and foreign exchange markets. Cieslak and Vissing-Jorgensen [7] show that negative stock returns are a good predictor of the changes in the Fed's real growth expectations, and the Fed finds stock market developments informative from the text analysis of the FOMC minutes. Studies imply that the reaction function of central banks evolves, and variables of the monetary policy data set may diversify.

For this reason, it should not be ignored that the factors affecting the policy set of central banks may differ from time to time, and expectations regarding the policy stance may deviate.

3.2. Türkiye Monetary Policy Expectations

Alp et al. [2] tested the predictive power of various market instruments for Türkiye. In the study, 1-week and 1-month Turkish lira interbank buying rate (TRLIBID) and Turkish lira Interbank Selling Rate (TRLIBOR), one-month treasury bill interest, and one-week FX forward interest are used.

The analyses reveal that market-based monetary policy expectations can best be measured from the TRLIBOR market. The one-week TRLIBID rate is the market instrument with the best predictive power of monetary policy decisions between July 2006 and October 2009.

In their study, Akçelik [1] imposes a different approach than Alp et al. [2] and uses CBRT weighted average funding cost (WAFC) as a dependent variable and measures its predictive power for every day of the week instead of only measuring for Monetary Policy Committee (MPC) decision dates.

The empirical dataset comprises 3, 6-month, 1-year, and 2-year government bond yields, TRLIBID, TRLIBOR weighted average deposit interest rates, cross currency swap rates, interest swap rates, forward foreign exchange implied returns and interbank deposit interest rates.

They find different results for different horizons. In predicting 3, 6, 9, 12- and 24-month horizons, FX forward implied rates perform better than other instruments. In addition, they emphasize that the success of market instruments in predicting the CBRT's policy stance changes from time to time due to the implemented monetary policy, and the period between December 2006 and December 2010 stands out as the most predictable period. In the study, it is emphasized that new financial instruments can contribute to the measurement of market expectations due to the changes in market conditions and the specific constraints of each instrument.

This thesis tests the new financial instrument TLREF indexed Overnight Indexed Swap (OIS). In addition, the difference between this thesis from Alp et al. [2] and Akçelik [1] is that, instead of using individual financial instruments, it estimates the policy rate using the information set in the yield curve of the relevant instruments.

3.3. Studies Using Overnight Index Swap (OIS) Instruments

Woodford [35] demonstrates using tick data that OIS returns respond quickly after Bank of Canada draws. For example, the target rate cut and forward guidance in the Bank of Canada decision of April 21, 2009, was quickly reflected in the OIS returns. By giving similar examples for the USA, it is shown that the OIS yields instantly react to the forward guidance that the policy rate will remain low.

Christensen and Rudebusch [6] analyze the response of interest rates to quantitative easing (QE) in the UK and the US. In the study, the response of treasury returns to QE decisions is compared with OIS returns at similar maturities. The purpose of comparing bond rates with OIS rates is the assumption that OIS rates represent average expectations for the effective federal funds rate.

Altavilla et al. [3] use the intraday OIS tick data in their event database for ECB around the press release and the conference windows. 1-month to 10 years of intraday reaction of OIS yields is used to calculate monetary policy surprises around the press release and conference windows. Monetary policy factors (target/timing, forward guidance, and QE) are estimated from OIS yield surprises. In the study, it is assumed that OIS returns are risk-free interest rates.

Lloyd [23] examines OIS rates more extensively in his recent study and compares OIS performances in the US, UK, Eurozone, and Japan. In the study, it is examined whether the overnight indexed swap (OIS), which forms an important part of the monetary economy empirical dataset, is suitable for the risk-free interest rate assumption. Additionally, the study explores which OIS maturities can be trusted as indicators of monetary policy expectations.

Lloyd [24] uses an OIS-enhanced, non-arbitrage dynamic term structure model (DTSMs) to predict the decomposition of US bond yields into interest rate expectations and term premia. The risk-neutral return and term premia decomposition using OIS data give more stable results than other models frequently used in the literature. The study shows that OIS rates can be used to improve future short-term interest rate expectations and term premia.

CHAPTER 4

DATA

In order to measure policy interest expectations from yield curves, by using the Nelson and Siegel [27] method, bond, FX swap, and OIS yield curves are constructed. While creating the bond yield curve, fixed-income and coupon-free bond data on secondary market transactions announced in the Debt Securities Market Data Bulletin published by Borsa Istanbul (BIST) are used. FX swap and OIS returns are obtained from Bloomberg. Meeting dates and monetary policy rates are obtained from the Central Bank's website.

Treasury bond data is obtained daily from January 2011 until July 27, 2022. FX swap yield curve data covers January 1, 2011, and February 28, 2022. The data expires in February 2022 because the publication of LIBOR rates has ceased. The OIS return dataset starts on October 28, 2019, and is acquired daily until July 27, 2022.

Bond, FX swap, and OIS market data are used to fit the zero-coupon yield curve for every business day. One of the advantages of daily estimation of the yield curve with the Nelson and Siegel [27] method can be summarized as follows. Since the annual monetary policy meeting dates are specific, it is possible to calculate the implied policy interest in any meeting with the factors obtained from the yield curve. Thus, the implied returns 1 day, 1 week, 1 month, and 3 months before the meeting can be calculated for the meeting dates.

Even if it is beyond the scope of this study, historical data on the implied policy rate at any given date show in which direction and in what period expectations have evolved. This simple illustration provides an opportunity to observe changes in expectations regarding the policy stance.

CHAPTER 5

METHODOLOGY

5.1. Overnight Index Swap (OIS) and Yield Curve

An OIS contract traded over the counter is an interest rate derivative instrument that provides the exchange of interest payments of fixed and floating legs of the contracts between two participating agents on a notional principal over the contract's life. The "OIS rate" represents the rate on the fixed leg of the contract, while the rate on the floating leg on the Turkish OIS curve is the overnight TLREF rate.

Two agents agree to exchange the difference between accrued interest at a fixed rate and accrued interest through the daily compounding of a floating overnight index rate on the agreed notional amount. Since net interest obligation is the only payment at the swap's maturity and there is no principal exchange, OIS contracts carry little counterparty risk.

One of the essential features of the OIS contract is that they do not involve any initial cash flow that minimizes liquidity premia. Credit risk is also minimized due to the collateralized structure of OIS trades. (Cheng et al. [5], Tabb and Grundfest [34]).

When considering market expectations regarding the monetary policy stance, due to the contracts' features, the OIS curve's term structure reflects the interbank interest rate expectations, which are expected to be close to the policy rate. In other words, over the contract horizon, OIS rates are closely related to the future overnight interest rates. Market participants see the OIS curve as a proxy for the risk-free yield curve (Joyce et al. [19]).

In a recent study on advanced economies, OIS rates provide broadly accurate measures of rate expectations up to a maturity of about two years (Lloyd [24]). The data set, formed after the Türkiye benchmark interest rate began to be published at the end of 2019, offers the opportunity to analyze monetary policy expectations from the OIS yield curve.

5.1.1. OIS and Coupon Structure

In an interest rate swap, the exchange value is the difference between interest accrued at the fixed rate and interest accrued at a compounded floating rate on the notional swap. We can assume that a floating rate payer has a long position in a fixed rate bond and a short position in a floating rate bond.

The value of the swap which receives fixed pay floating is

$$V_{t_0,swap} = B_{t_0,fix} - B_{t_0,flt} \tag{1}$$

where $B_{t_0,fix}$ is the value of the fixed rate bond (payments which are received) and $B_{t_0,flt}$ is the value of the floating rate bond (payments which are paid) at time t_0.

$$B_{t_0,fix} = \sum_{i=1}^{m} N\tau c D(t_0, t_i) + ND(t_0, t_m) \tag{2}$$

$$B_{t_0,flt} = \sum_{i=1}^{m} NL(t_{i-1}, t_i)\tau D(t_0, t_i) + ND(t_0, t_m) \tag{3}$$

N denotes the notional amount of bonds, c represents the fixed leg coupon rates, τ denotes coupon payment periods in terms of years, $D(t_0, t_i)$ stands for discount functions, and $L(t_{i-1}, t_i)$represents the floating rate between the periods t_{i-1} and t_i.

Since the floating rate is not observable at the beginning of the contracts, by using cash flows of floating rate bonds, the value of the swap at time t_0 can be written as:

$$NL(t_{i-1}, t_i)\tau = N\{D(t_0, t_{i-1}) - D(t_0, t_i)\} \tag{4}$$

The sum of all floating cash flow values can be shown as

$$B_{t_0,flt} = \sum_{i=1}^{m} N\{D(t_0,t_{i-1}) - D(t_0,t_i)\} + ND(t_0,t_m) \quad (5)$$

Immediately after the payment, the floating rate bond is worth the notional principal. At the beginning of the contract and the coupon dates, the value of the floating bond is equal to its par value. According to equation (1), at time t_0 , the value of the swap that receives the fixed pay floating value is equal to the value of the fixed rate coupon minus the value of the floating rate bond. We get the following equation when we put the fixed and floating rate bond values in the first equation.

$$V_{t_0,swap} = \sum_{i=1}^{m} N\tau cD(t_0,t_i) + ND(t_0,t_m) - (\sum_{i=1}^{m} N\{D(t_0,t_{i-1}) - D(t_0,t_i)\} + ND(t_0,t_m)) \quad (6)$$

As we know, the value of the swap is equal to zero at the initiation of the contract. By solving the equation, the fixed rate of the swap formula is

$$c = \frac{1}{\tau}\frac{1 - D(t_0,t_m)}{\sum_{i=1}^{m} D(t_0,t_i)} \quad (7)$$

The swap rate *is* a function of the yield curve up to the swap's maturity and it represents par-rates rather than zero coupon rates. Calculating zero coupon rates is crucial to interpreting the effects of changes in swap rates.

5.2. FX Swap and Coupon Structure

A cross-currency swap is a financial derivative contract between two counterparties that allows the parties to convert assets or liabilities in one currency into another currency for the exchange of interest payments based on a notional principal amount, within predetermined periods. A similar methodology used in constructing the OIS yield curve is also used in constructing the FX swap yield curve[1].

[1] For further information about FX swap curve construction, see Küçüksaraç at el. [21]

Consider a swap transaction in which floating rate payments in foreign currency are exchanged for fixed rate payments in domestic currency. The short position in the foreign currency floating rate bond and the long position in the local currency fixed rate coupon bond is equal to the receive fixed, pay floating swap at time t_0.

To compose this kind of cash flow, take a short position in foreign currency floating rate coupon bond and a long position in domestic currency fixed rate coupon bond.

$$V_{t_0,swap} = B_{t_0,fix} - B_{t_0,flt} S_{t_0} \tag{8}$$

If 1 unit of foreign currency is equal to S_{t_0} units of domestic currency, then the value of the short position in floating rate bond in foreign currency can be shown by $B_{t_0,flt} S_{t_0}$. The only difference between equation (1) and equation (8) is S_{t_0}. With a similar methodology used in the IRS swap curve construction, bond values can be found as follows:

$$B_{t_0,fix} = \sum_{i=1}^{m} S_{t_0} N \tau c D(t_0, t_i) + S_{t_0} N D(t_0, t_m) \tag{9}$$

$$B_{t_0,flt} = \sum_{i=1}^{m} N L(t_{i-1}, t_i) \tau D^f(t_0, t_i) + N D^f(t_0, t_m) \tag{10}$$

In these formulas, the notional amount of foreign currency bonds is denoted by N. Discount functions for the foreign currency and local currency are denoted by $D^f(t_0, t_i)$ and $D(t_0, t_i)$ respectively. $L(t_{i-1}, t_i)$ represents the floating rate between the periods t_{i-1} *and* t_i. Coupon payments in terms of years is denoted by τ and the currency swap rate is represented by c.

The value of floating cash flows can be formulated as:

$$B_{t_0,flt} = \sum_{i=1}^{m} N\{D^f(t_0, t_{i-1}) - D^f(t_0, t_i)\} + N D^f(t_0, t_m) \tag{11}$$

As mentioned earlier, at the initiation of the swap, the value of the floating leg is equal to the par value. So, at time t_0, the value of a currency swap can be expressed with the following formula.

$$V_{t_0,swap} = \sum_{i=1}^{m} S_{t_0} N\tau c D(t_0, t_i) + S_{t_0} N D(t_0, t_m) - \sum_{i=1}^{m} S_{t_0} N\{D^f(t_0, t_{i-1}) - D^f(t_0, t_i)\} - S_{t_0} N D^f(t_0, t_m) \quad (12)$$

Since the currency swap's value is zero at the initiation of the contract, the fixed rate in the currency swap is obtained as:

$$c = \frac{1}{\tau} \frac{1 - D(t_0, t_m)}{\sum_{i=1}^{m} D(t_0, t_i)} \quad (13)$$

Currency swap rates are par rates, so we need to calculate zero coupon rates with Nelson and Siegel [27] methodology.

5.3. Treasury Yields

In the bond market, very different returns correspond to different maturities. An understanding of the maturity structure is required to examine how bond yields tend to behave over varying maturities and over time.

It is generally accepted in the literature that typically three factors or principal components appear to be sufficient to explain nearly all the variations in the yield curve. Before the zero-coupon yield curve is created, bond pricing should be understood.

$$P_t(m) = \exp(-m * r_t(m)) \quad (14)$$

$$r_t(m) = -\frac{1}{m} * \ln(P_t(m)) \quad (15)$$

$P_t(m)$ is a zero-coupon bond price at time t with m years of maturity and $r_t(m)$ denotes a continuously compounded zero-coupon rate of a bond with price $P_t(m)$. In other words, we assume that $P_t(m)$ is a price of a m-period discount bond, which means the par value can be received after m periods.

These expressions and equations imply that the discount curve and the yield curve are fundamentally related. Inevitably, the forward rate curve obtained from the yield curve is also related to the discount function. The forward rate curve can be formulated as:

$$f_t(m) = \frac{P_t(m)'}{P_t(m)} \tag{16}$$

$P_t(m)'$ is the first derivative of a zero-coupon bond price at time t. So, the relation between yield curve and forward rate curve can be defined as

$$r_t(m) = \frac{1}{m}\int_0^m f_u\,(u,0)\,du \tag{17}$$

This equation shows that the average of the equally weighted forward rates is equal to the zero-coupon yield. Thus, the basic relationship between yield curve, discount curve and forward rate curve is shown. In this study, zero-coupon bond price $P_t(m)$, continuously compounded zero-coupon rate $r_t(m)$ and forward rate $f_t(m)$ will be used to calculate the implied policy rates.

The implied rates of bond market, FX swap and OIS contracts are employed to extract expectations about monetary policy rate expectations. Since the methodology requires estimating implicit rates at any maturities, the yield curve through the Nelson and Siegel [27] model is estimated for all markets.

5.4. Zero Coupon Yield Curve Construction and Implied Rate Estimation

The implied rates of the bond market, FX swap, and OIS contracts are used to extract expectations about monetary policy rate expectations. Central banks and financial market practitioners frequently use the Nelson and Siegel [27] method for yield curve fitting (BIS [9]).

Since the methodology requires estimating implicit rates at any maturities, the yield curve through the Nelson and Siegel [27] model is estimated for all markets.

Nelson and Siegel [27] model assumes that the following functional form can describe zero rates:

$$r(m,\beta,\tau_{NS}) = \beta_0 + \beta_1 \left(\frac{1-e^{-\frac{m}{\tau_{NS}}}}{-\frac{m}{\tau_{NS}}} \right) + \beta_2 \left(\frac{1-e^{-\frac{m}{\tau_{NS}}}}{-\frac{m}{\tau_{NS}}} - e^{-\frac{m}{\tau_{NS}}} \right) \tag{18}$$

where $r(m,\beta,\tau_{NS})$ denotes the zero rate for time to maturity m and, $\{\beta_0, \beta_1, \beta_2, \tau_{NS}\}$ is the parameter set to be estimated. $\beta_0, \beta_1, \beta_2$ are level, slope and curvature factors, respectively. The coefficient τ_{NS} is the shape parameter which determines the maximum or minimum of the curvature factor.

To better understand how yield curve parameters are derived, it is necessary to show that the theoretical price of bond can be calculated from future cash flows. Theoretical price P^{fitted} of bond number i at time t is the sum of the discounted values of its future cash flows. When the j-th payment of the i-th bond occurs at time t, it is denoted by $CF^i_{t_j}$. Theoretical price can be shown as,

$$P_t^{i,fitted}(m) = \sum_{j=1}^{K} CF^i_{t_j} \, e^{-r_t^{i,fitted} * (t_j - t)} \tag{19}$$

Finally, an ordinary least squares fitting procedure is applied to minimize the sum of squared differences of theoretical prices from actual prices to obtain Nelson Siegel parameters. In this regard, these parameters are estimated by minimizing the difference between the actual price and fitted price by the inverse of the Macaulay duration of bonds (the fixed leg of the swap contract). The minimization formula can be defined as

$$min_{\beta} \sum_{j=1}^{K} \left(\frac{P_t^i - P_t^{i,fitted}}{D_t^i} \right)^2 \tag{20}$$

where K denotes the number of number of bonds traded (number of quoted swap rates), D_t^i stands for the Macaulay duration, P_t^i denotes the par value.

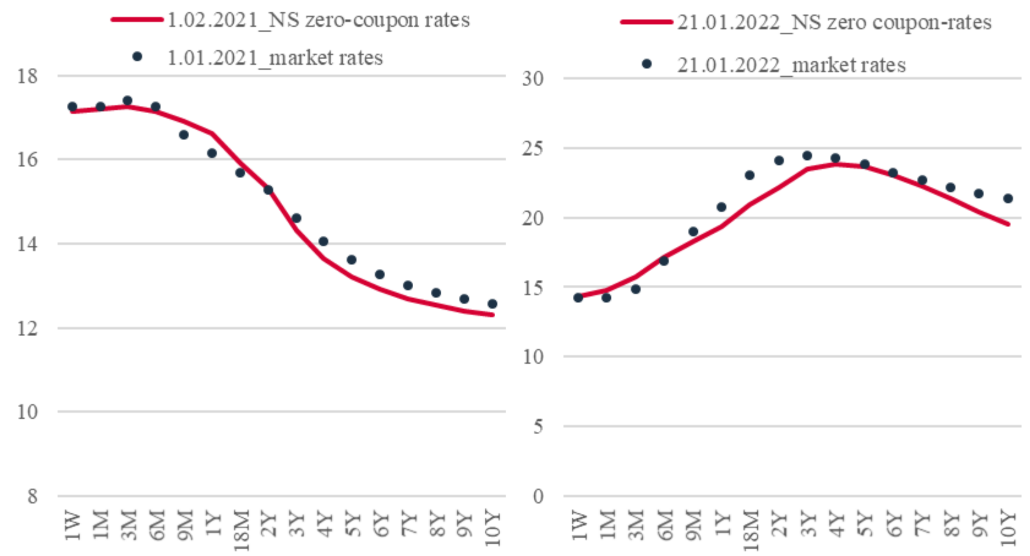

Figure 5.1: Türkiye OIS Fitted Curve and Quoted Yields

Figure 5.1 shows the quoted OIS rates and NS fitted yields for randomly selected dates. Although there are some differences, the fitted and quoted OIS rates are close to each other.

Factors calculated from Nelson and Siegel [27] method are used to calculate zero coupon rates. A well-fitting model also contributes to calculating implied forward interest rates and thus forming risk-free interest rate expectations. Thus, the predictive power of the implied interest inferred from the OIS yield curve is positively affected.

The factors obtained from the yield curves come to the fore not only in the finance literature but also in the explanation of macroeconomic variables. The inclusion of macroeconomic variables in yield curve models helps illuminate the main determinants of interest rates (Diebold et al. [10]).

In their study for the USA, Diebold et al. [10] determines three factors from bond yields and relates them to variables such as inflation rate, real activity levels, and monetary policy instruments' variables. When the correlations between factors and variables are examined, inflation rate and level factor, real activity level, and slope factor are highly correlated (Diebold et al. [10])

In this thesis, Nelson and Siegel [27] parameters are estimated using government bonds, FX swaps, and OIS data. The next step is calculating the instantaneous forward rates $f(m, \beta, \tau_{NS})$ at the policy meeting dates for all government bonds, FX swaps, and OIS markets.

$$f(m, \beta, \tau_{NS}) = \beta_0 + \left(\beta_1 + \beta_2 \frac{m}{\tau_{NS}}\right) \left(e^{-\frac{m}{\tau_{NS}}}\right) \tag{21}$$

Implied policy rates from the yield curves are estimated through NS parameters. The next step is to test whether these markets reflect policy rate expectations 1 day, 1 week, 1 month, and 3 months before each policy meeting date.

5.5. Predictive Powers of Implied Rates

It is tested whether the implied forward rates from all three markets are good predictors of monetary policy. In this regard, the changes in the monetary policy rates are regressed on the difference between the instantaneous forward rates and policy rates. In order to solve the unit root problem in interest rates and to measure the predictive power of implied policy rates, the standard equation of the previous articles is applied. (Gürkaynak et al. [16])

$$\left(r_{(t+m)} - r_{(t)}\right) = \alpha_0 + \alpha_1\left(f_{t,t+m} - r_{(t)}\right) + \varepsilon_t \tag{22}$$

where $r_{(t+m)}$ is monetary policy rate on period $t + m$ and $f_{t,t+m}$ is instantaneous forward rate on period “t” for following “m” periods. If α_1 is found to be statistically significant and positive, then instantaneous forward rates are thought to have a representative power in extracting monetary policy rate expectations.

CHAPTER 6

EMPIRICAL FINDINGS AND DISCUSSION

6.1. FX Swap Implied Yields

FX swap contracts are frequently used by investors and real sector representatives with assets and liabilities in different currencies in international trade to manage foreign exchange liquidity and carry trade investments. FX swap products are derivative instruments that convert local currency assets and liabilities into foreign currency assets and liabilities.

Real sector companies and the banking sector in Türkiye widely use FX swap products. The counterparty to these contracts is usually non-residents who want to invest in assets in Türkiye and needs assets in Turkish Lira. Transactions in the FX swap market monitored by institutions that take care of financial stability in Türkiye, and regulations are made for the FX swap market from time to time.

The Banking Regulation and Supervision Agency (BRSA) imposed some limitations in September 2018. BRSA restricts the currency swaps with foreign counterparties in which banks pay TL and receive FX, and similar regulations are imposed to restrict currency swap transactions further.

Table 6.1: The BRSA Regulations About FX Swap Market

Announcement Date	**Regulation**
13 August 2018	The BRSA limited the notional principle amount of currency swaps and other similar products (spot + forward FX transactions) that banks carry out with foreign counterparties to pay FX and receive TL at maturity to 50% of the bank's regulatory capital.

15 August 2018	The BRSA reduced the notional principle amount of currency swaps and other similar products (spot + forward FX transactions) that banks carry out with foreign counterparties to pay FX and receive TL at maturity from 50% to 25% of the bank's regulatory capital.
9 February 2020	The BRSA reduced the notional principle amount of currency swaps and other similar products (spot + forward FX transactions) that banks carry out with foreign counterparties to pay FX and receive TL at maturity from 25% to 10% of the bank's regulatory capital.

The BRSA limited banks' derivative transactions with non-residents to the upper limit of the bank's regulatory capital, for derivative transactions that receive TL at maturity and to derivative transactions that pay TL at maturity. The upper limits have been differentiated for maturities of up to 7 days, 30 days and 1 year for derivative transactions that pay TL and receive FX in exchange at maturity. (See table 6.2)

Table 6.2: The BRSA Upper Limits for Different Transactions Type

Transaction	12 April 2020	25 Sept. 2020	11 Nov. 2020
Receiving TL paying FX at maturity	1%	10%	10%
Paying TL receiving FX at maturiy			
-up to 7 days	1%	2%	5%
-up to 30 days	2%	5%	10%
-up to 1 year	10%	20%	30%

The implied policy rate obtained from FX swap market and the bond yield curve offer the opportunity to make comparisons for the period when the OIS market was not active. Pre- and post-regulation comparisons in the FX swap market help us make inferences about the information value of market instruments under free or restrictive market conditions.

Table 6.3 reports the descriptive statistics of FX swap implied yields before the meeting dates. The sample period is from January 2011 to February 2022.

Table 6.3: Descriptive Statistics for the FX Implied Yields

	1 day	1 week	1 month	3 months
Mean	11,28	10,50	11,56	11,27
Standard Error	0,46	0,48	0,59	0,48
Median	10,27	9,02	10,10	10,22
Standard Deviation	5,22	5,38	6,59	5,33
Sample Variance	27,22	28,91	43,47	28,40
Kurtosis	0,22	0,07	12,21	1,33
Skewness	0,96	0,95	2,69	1,24
Range	21,24	20,72	49,27	23,86
Minimum	3,51	3,47	3,86	3,67
Maximum	24,75	24,19	53,12	27,52
Observations	126	126	125	124

Table 6.3 indicates that standard deviation of 1-month FX implied rates is high and 1-month FX implied rates sample have significant outliers. Other maturities have similar standard deviations and distributions.

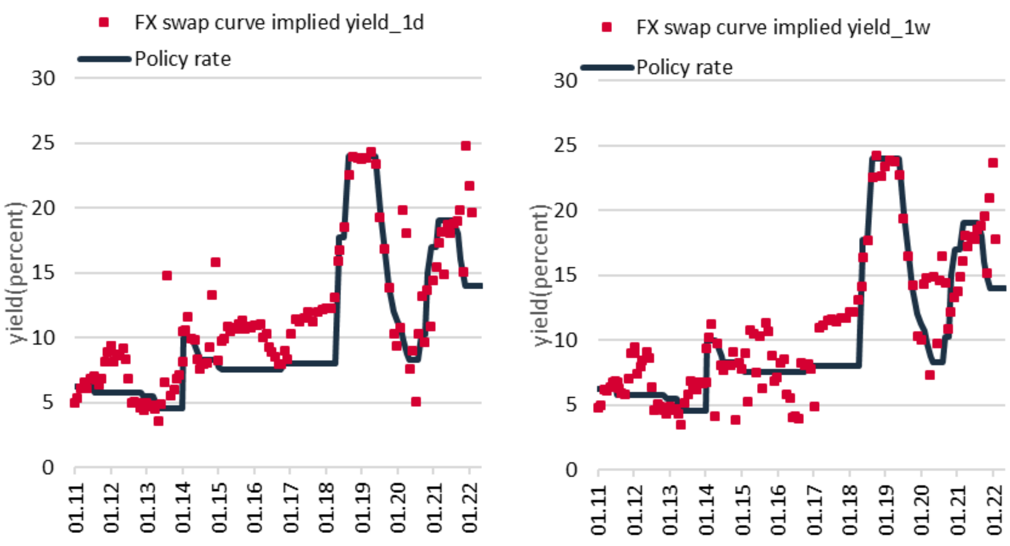

Figure 6.1: FX Swap Implied Yields (1-day, 1-week) and Policy Rate

The sample period is from January 2011 to February 2022. See the text for details.

Figure 6.1 plots the estimated forward implied yields 1-day and 1-week before policy meetings. Short-term implied interest rates derived from the FX swap yield curve are generally far from estimating monetary policy rates. There are various reasons why implied interest rates may deviate from the benchmark rate. The interest rate corridor and liquidity management (determining the funding composition daily), the CBRT's late liquidity window application and preference for monetary tightening without increasing the policy rate have led to deviations in short-term interest rates.

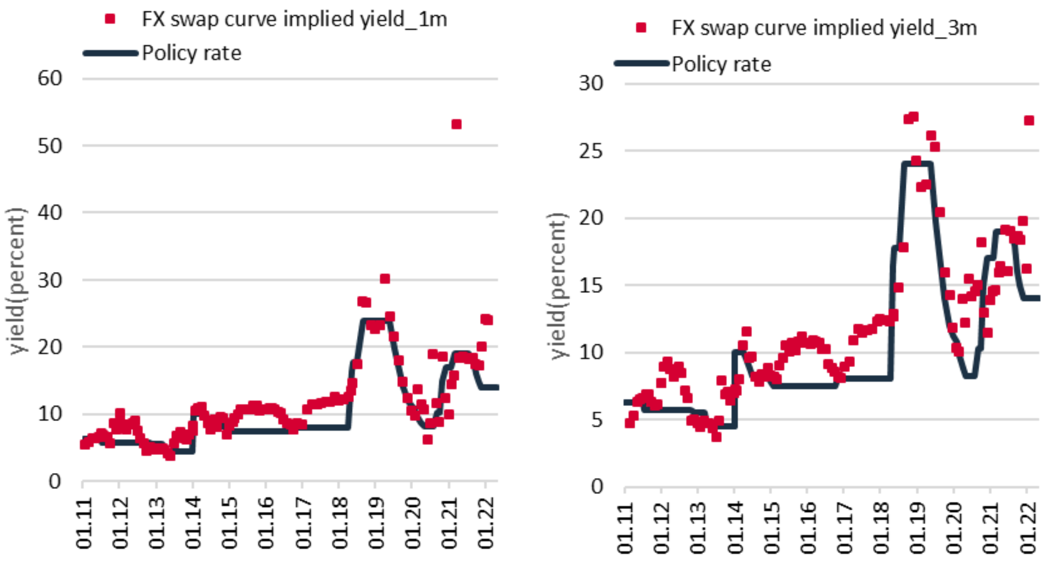

Figure 6.2: FX Swap Implied Yields (1-month, 3-month) and Policy Rate. The sample period is from January 2011 to February 2022. See text for details.

Figure 6.2 plots the estimated 1-month and 3-month forward implied yields and the policy rates. The figure shows the policy rate path is well priced, especially one month and three months before the meeting date. It is striking that the monetary policy tightening period of 2018 is well-estimated, with the forward implied interest rates obtained from the currency swap yield curve the day before the meeting and one week before the meeting date.

After the FX swap restrictions (see Table 6.1, Table 6.2) at the end of 2018, volatility increased in the FX swap market, especially in short-term contract rates. Due to the additional regulations made during the pandemic period and the liquidity squeeze in the FX swap market, serious deviations were seen in some periods in the implied yields obtained from the yield curve.

Since the regulations decrease the transaction volume in the FX swap market, it has become essential to examine the regression for different sample periods while examining the estimation power of the FX swap implied returns. Therefore, when making model estimations, January 2011-February 2022 refers to the entire sampling period, January 2011-September 2018 refers to the period without restrictions, and the September 2018-February 2022 period indicates the sampling period with restrictions.

Table 6.4: Predictive Power of FX Swap Rates (1 day, 1 week). Coefficients α(0) and α(1) from the regression $\left(r_{(t+m)} - r_{(t)}\right) = \alpha_0 + \alpha_1\left(f_{t,t+m} - r_{(,t)}\right) + \varepsilon_t$ estimated via least squares. T-statistics in parentheses and prob. in square brackets; (*), (**) and (***) denote significance at 10%, 5% and 1% levels, respectively.

	1 day			1 week		
	Full Sample	Before BRSA Swap Restrictions	After BRSA Swap Restrictions	Full Sample	Before BRSA Swap Restrictions	After BRSA Swap Restrictions
α(0)	-0.196885	-0.262562	-0.378150	-0.102278	0.044565	-0.42105
(t-stat)	(-0.761452)	(-0.537875)	(-0.820133)	(-0.400467)	(0.100043)	(-0.980121)
[prob.]	[0.4479]	[0.5921]	[0.4180]	[0.6895]	[0.9206]	[0.3342]
α(1)	0.141952***	0.242609***	0.09215	0.148381***	0.213061***	0.10164
(t-stat)	(3.894699	(4.829509)	(1.368796)	(2.995456)	(2.647362)	(0.951810)
[prob.]	[0.0002]	[0.0000]	[0.1803]	[0.0033]	[0.0097]	[0.3481]
R squared	0.2338	0.3418	0.3246	0.2372	0.3067	0.326971
Observations	128	89	39	128	89	39

The results for 1-day and 1-week regressions implied that, in the full sample period and before the BRSA regulation period, FX swap implied yields have predictive power on policy rate changes and are statistically significant. Although the number of observations is limited, the effect of FX swap implied yields 1 day ahead decreases and becomes statistically insignificant after the currency swap arrangement. The statistical robustness checks for the models are provided in the appendix[2].

Table 6.5: Predictive Power of FX Swap Rates (1-month, 3 month). Coefficients α(0) and α(1) from the regression $\left(r_{(t+m)} - r_{(t)}\right) = \alpha_0 + \alpha_1\left(f_{t,t+m} - r_{(,t)}\right) + \varepsilon_t$ estimated via least squares. T-statistics in parentheses and prob. in square brackets; (*), (**) and (***) denote significance at 10%, 5% and 1% levels, respectively.

	1 month			3 month		
	Full Sample	Before BRSA Swap Restrictions	After BRSA Swap Restrictions	Full Sample	Before BRSA Swap Restrictions	After BRSA Swap Restrictions
α(0)	-0.0280377	-0.396452	-0.496350	-0.015512	-0.145945	-0.246023
(t-stat)	(-1.044576)	(-0.836150)	(-1.215886)	(-0.044723)	(-0.162996)	(-0.473078)
[prob.]	[0.2983]	[0.4055]	[0.2327]	[0.9644]	[0.8709]	[0.6393]
α(1)	0.199388***	0.351985**	0.144578**	0.045369	0.26577	0.000585
(t-stat)	(5.434559)	(2.414935)	(2.604087)	(0.541294)	(1.102735)	(0.003507)
[prob.]	[0.0000]	[0.0179]	[0.0137]	[0.5893]	[0.2734]	[0.9972]
R squared	0.27703	0.31534	0.41495	0.283523	0.22430	0.27562
Observations	128	89	39	127	88	39

The 1-month implied return on currency swap estimates a small fraction of the change in monetary policy rates considering the entire sample period. The pre-constraint sample period regression results imply that the coefficient gets more prominent and is statistically significant. On the other hand, when the regulations are imposed, the predictive power decreases.

The 3-month implied interest rates obtained from the FX swap yield curve statistically insignificant for the full sample, pre and post regulation periods.

6.2. Treasury Bond Implied Yields

The information set of the treasury yield curves' term structure gives valuable information about economic agents' future expectations. The short-term treasury bills (T-bonds) used in generating the yield curve may not have a liquid secondary market volume. Therefore, it may not provide reliable information about future interest rates. However, when the information set of yield curves at different

[2] For brevity, I do not include other windows’ robustness checks. Please check appendix for 1-month estimations.

maturities is evaluated, bond pricing is closely related to policy interest expectations.

The treasury bond yield curve stands out as a vital instrument for comparing the forecast content of various financial market instruments. Because the treasury bond data set covers an extended period, it allows one to compare the information set of term structure with other yield curves.

Table 6.6: Descriptive Statistics for Treasury Implied Yields. This table reports the descriptive statistics of Treasury implied yields before the meeting dates. The sample period is from January 2011 to July 2022.

	1 day	1 week	1 month	3 months
Mean	10,51	10,60	10,47	10,54
Standard Error	0,35	0,35	0,38	0,36
Median	9,56	9,47	9,12	9,48
Standard Deviation	3,95	4,00	4,27	4,03
Sample Variance	15,61	16,00	18,27	16,25
Kurtosis	0,34	0,26	1,41	0,82
Skewness	0,92	0,92	1,33	1,16
Range	18,50	18,45	20,72	19,51
Minimum	3,86	3,95	4,72	3,97
Maximum	22,37	22,39	25,44	23,48
Observations	129	129	128	127

Descriptive statistics of treasury implied rates show that 1-day and 1-week rates show negative skewness and 1-month and 3-month rates show positive skewness. All rates have similar standard errors.

The treasury bond yield curve provides valuable information in reflecting monetary policy expectations, especially considering the high correlation of returns at the short end of the yield curve with monetary policy rates. The forward implied interest for any maturity can be calculated using the yield curve factors. Easy calculation of any forward point instantaneous rate provides an opportunity to obtain a healthier forecasting path than individual financial instruments whose liquidity may reduce on some days or even not quoted.

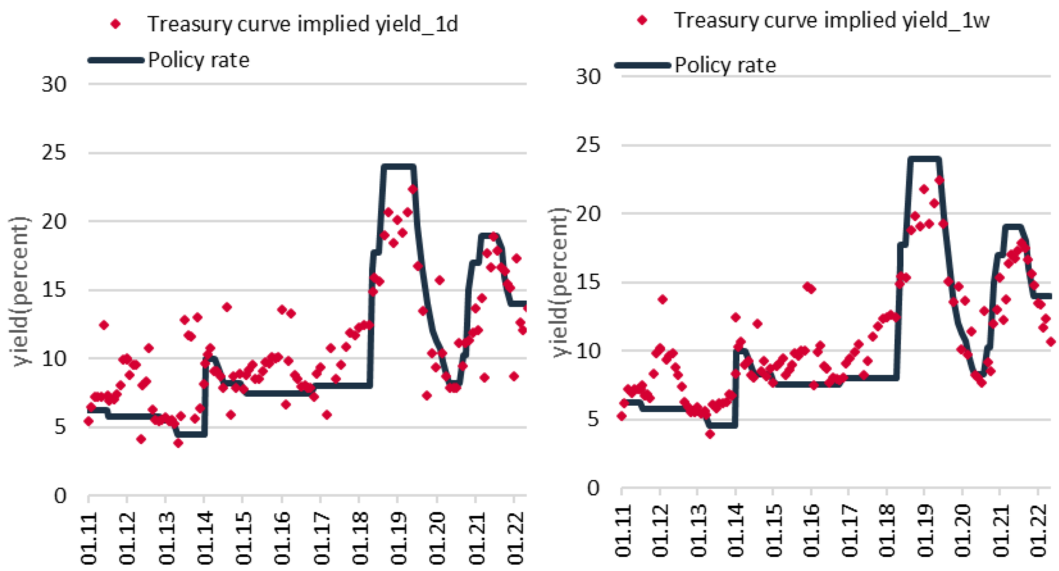

Figure 6.3: Treasury Curve Implied Yields (1-day, 1-week) and Policy Rate. The sample period is from January 2011 to July 2022. See text for details.

Figure 6.3 plots the 1-day and 1-week implied interest rates obtained from the bond yield curve. 1-day implied bond yields predict a more dispersed forecasting path than 1-week maturity. This result may be due to the low liquidity of short-term bonds traded in the market. In addition, bond investors may act on the principle of waiting until maturity in short-term bonds.

Investor decisions and illiquidity of short maturity bonds restrict short-term bond price data traded in the market. Illiquidity on some days may result in high error terms between fitted and actual yields. 1-week implied rates give more consistent results than 1-day implied rates in estimating policy rates.

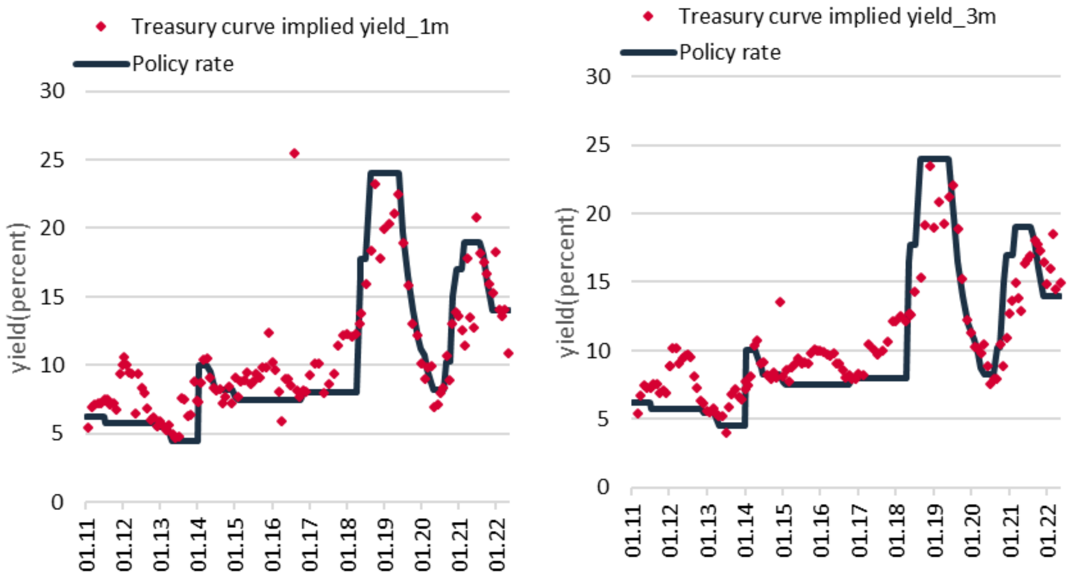

Figure 6.4: Treasury Curve Implied Yields (1-month, 3-month) and Policy Rate. The sample period is from January 2011 to July 2022. See text for details.

As the asset ratio[3] increases the demand for bonds, one of the measures taken during the pandemic to increase economic activity, bond interests decrease. In addition, ongoing asset purchases by the Central Bank also suppress the treasury yield curve downwards. However, since no apparent regulations or restrictions affect the market structure and liquidity, such as FX swap regulations, the sampling period is not divided into subperiods.

Figure 6.4 and Table 6.7 indicate that 1-month implied interest rates follow a more consistent path, and monetary policy forecasts follow a close course even if implied rates change from meeting to meeting. According to economic data and monetary policy expectations, this may indicate that investors have updated their bond positions one month or more before.

[3] $\text{Asset Ratio} = \frac{\text{Loans} + (\text{Securities x } 0.75) + (\text{CBRT Swaps x } 0.5)}{\text{TRY Deposit} + (\text{FX Deposit x } 1.75*)}$

Table 6.7: Predictive Power of Treasury Curve Implied Yields. Coefficients α(0) and α(1) from the regression $\left(r_{(t+m)} - r_{(t)}\right) = \alpha_0 + \alpha_1\left(f_{t,t+m} - r_{(,t)}\right) + \varepsilon_t$ estimated via least squares. T-statistics in parentheses and prob. in square brackets; (*), (**) and (***) denote significance at 10%, 5% and 1% levels, respectively. The statistical robustness checks for the models are provided in the appendix.

	1 day	1 week	1 month	3 month
α(0)	-0.01752	-0.018816	-0.060336	-0.015618
(t-stat)	(-0.055303)	(-0.067309)	(-0.196371)	(-0.050364)
[prob.]	[0.9560]	[0.9464]	[0.8446]	[0.9599]
α(1)	0.129113**	0.150382**	0.228308***	0.131496
(t-stat)	(2.44197)	(2.570721)	(3.769046)	(1.448938)
[prob.]	[0.0159]	[0.0114]	[0.0003]	[0.1499]
R squared	0.231571	0.226594	0.257116	0.178115
Observations	128	128	128	127

Table 6.7 summarizes the predictive power of the treasury curve implied yields over the entire sample. The implied yields of short-term horizons are statistically significant in explaining the policy rate path, but they can explain only a small part of policy rate change.

It is noteworthy that the one-month implied returns are more successful than other maturities in predicting the policy rate path. The model indicates that approximately 20 basis points of the 100-basis point interest rate change can be estimated using one-month implied interest rates.

In this case, the unique dynamics of the bond market are effective. The low trading volume of the bonds at the short end of the Turkish bond curve reveals the importance of the information content of the yield curve.

Even if short-term bonds do not trade on some days, short-term implied returns calculated with the help of yield curve factors. Bond investors' expectations regarding their monetary policy stances were made earlier rather than closer to the meeting dates. Therefore, shorter-term implied returns might be less potent than one-month implied returns in predicting the policy path. 3-month implied interest rates obtained from the treasury yield curve statistically insignificant.

6.3. OIS Curve Implied Yields

As stated in the literature section, the OIS curve is seen by market participants as a good representative of the risk-free yield curve (Joyce et al. [19]). In a study of advanced economies, OIS rates provide broadly accurate measures of policy rate expectations up to a maturity of approximately 2 years. (Lloyd [24]).

The regulation of national benchmark ratios and the activation of these markets following the LIBOR scandal by some countries, including Türkiye, created a new empirical data set for analyzing monetary policy expectations.

Table 6.8: Descriptive Statistics for OIS Implied Yields Model Variables. This table reports the descriptive statistics of OIS implied yields before the meeting dates. The sample period is from December 2019 to July 2022.

	1 day	1 week	1 month
Mean	14,07	14,02	14,18
Standard Error	0,64	0,60	0,63
Median	13,57	13,59	14,71
Standard Deviation	3,60	3,41	3,59
Sample Variance	12,97	11,63	12,86
Kurtosis	-1,12	-0,99	-1,06
Skewness	-0,11	-0,13	-0,35
Range	11,14	10,85	11,07
Minimum	7,97	7,97	8,08
Maximum	19,10	18,82	19,15
Observations	31	31	31

OIS yield curve data used in this study starts at the end of October 2019. The analysis used in the study includes calculating implied returns on different horizons before the monetary policy meetings, and the sampling period covers 31 meeting dates between December 2019 and July 2022. On the other hand, due to the interruption in LIBOR data, the FX swap sample covers 27 meeting dates as it expires in February 2022.

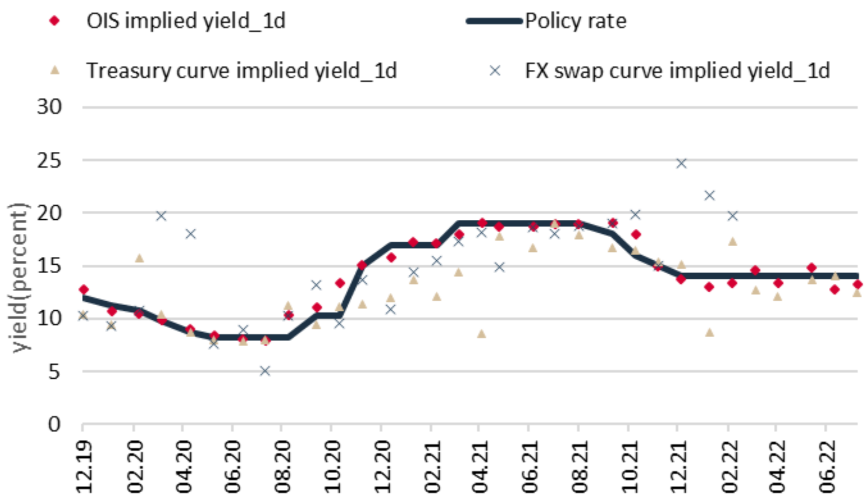

Figure 6.5: OIS, FX Swap and Treasury Implied Yields (1-day) See text for details. The sample period is from December 2019 to July 2022. See text for details.

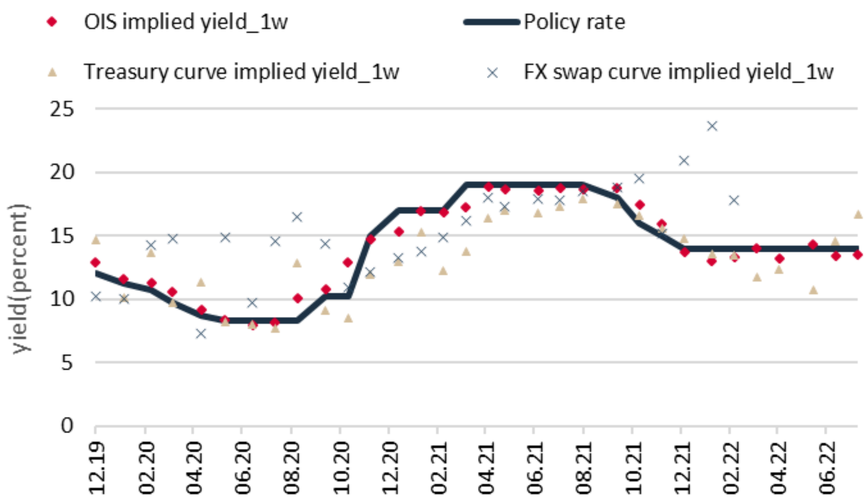

Figure 6.6: OIS, FX Swap and Treasury Implied Yields (1-week). The sample period is from December 2019 to July 2022. See text for details.

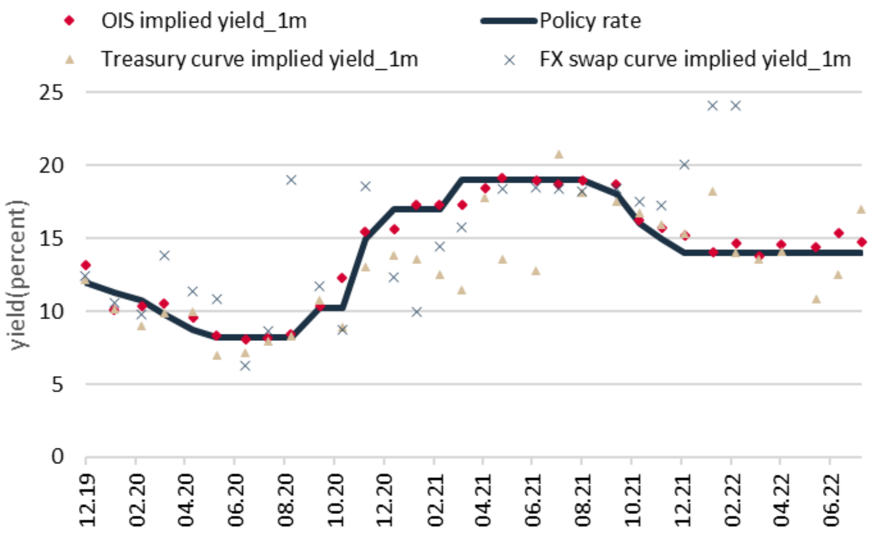

Figure 6.7: OIS, FX Swap and Treasury Implied Yields (1-month). The sample period is from December 2019 to July 2022. See text for details.

Figure 6.5, Figure 6.6 and Figure 6.7 show the policy rate and the implied interest calculated from all three yield curves. Notably, the implied returns of the TLREF-indexed OIS yield curve priced the monetary policy stance better than other market implied rates.

Monetary policy tightening period of 2020 is well-estimated, with the forward implied interest rates obtained from the OIS yield curve the day before the meeting and one week before the meeting date. After the FX swap restrictions at the end of 2018, volatility increased in the FX swap market, especially in short-term contract rates. Due to the additional regulations made during the pandemic period and the liquidity squeeze in the FX swap market, serious deviations seen in some periods in the implied yields obtained from the yield curve.

Although the sample set is limited, it is essential to test the predictive power to provide information about the future use of the interest rates implied by the OIS market.

Considering that the predictive power of the FX swap market and the bond market's monetary policy stance have weakened recently, the importance of analyzing the OIS market increases.

Table 6.9: Correlation Matrix for Model Variables. This table shows correlations among policy rate and implied yields. The sample period is from December 2019 to July 2022

	P. rate	*OIS_1 d*	*OIS_1 w*	*OIS_1 m*	*B_1 d*	*B_1 w*	*B_1 m*	*FX_1 d*	*FX_1 w*	*FX_1 m*
Policy rate	1,00									
OIS_1d	0,97	1,00								
OIS_1w	0,97	0,99	1,00							
OIS_1m	0,98	0,97	0,97	1,00						
Bond_1d	0,67	0,68	0,71	0,71	1,00					
Bond_1w	0,79	0,78	0,81	0,82	0,74	1,00				
Bond _1m	0,76	0,74	0,75	0,79	0,54	0,80	1,00			
FX swap_1d	0,55	0,53	0,53	0,60	0,49	0,61	0,70	1,00		
FX swap_1w	0,51	0,50	0,49	0,52	0,48	0,57	0,65	0,64	1,00	
FX swap_1m	0,48	0,48	0,48	0,48	0,10	0,50	0,58	0,50	0,54	1,00

The correlation matrix shows that the OIS implied yields have the highest relationship with the policy rates. FX swap implied yields have a low correlation among other financial instruments and the policy rate.

Table 6.10: Predictive Power of OIS, FX Swap and Treasury Implied Yields. Coefficients α(0) and α(1) from the regression $\left(r_{(\ t+m)} - r_{(t)}\right) = \alpha_0 + \ \alpha_1\left(\ f_{t,t+m} - r_{(,t)}\right) + \varepsilon_t$ estimated via least squares. T-statistics in parentheses and prob. in square brackets; (*), (**) and (***) denotes significance at 10%, 5% and 1% levels, respectively. (Sample period between December 2019- July 2022)

	1 day			1 week			1 month		
	OIS	Treasury	FX Swap	OIS	Treasury	FX Swap	OIS	Treasury	FX Swap
α(0)	-0.121212	0.051104	0.002354	-0.072818	-0.014888	-0.293684	-0.138021	0.008933	-0.408525
(t-stat)	(-0.768889)	-0.08206	(0.275834)	(-0.444419)	(-0.022452)	(-0.576518)	(-1.001291)	(0.018241)	(-0.748301)
[prob.]	[0.4484]	[0.9352]	[0.9933]	[0.6602]	[0.9823]	[0.5694]	[0.3253]	[0.9856]	[0.4613]
α(1)	0.700759***	0.109694	-0.002471	0.776110***	0.090926	0.063096	0.853419***	0.152975	0.0132580**
(t-stat)	(6.184130)	(0.960574)	(0.066833)	(5.721865)	(0.526676)	(0.479199)	(7.667049)	(1.361651)	(2.370053)
[prob.]	[0.0000]	[0.3460]	[0.9708]	[0.0000]	[0.6031]	[0.6360]	[0.0000]	[0.1855]	[0.0258]
R squared	0.577317	0.259265	0.000055	0.539017	0.224569	0.228083	0.677359	0.273653	0.343031
SSR	20.55297	40.49852	42.44627	22.41531	42.39546	42.2033	15.68844	39.71185	35.91869
AIC	2.591939	3.498772	3.546585	2.679757	3.545355	3.530872	2.322937	3.480968	3.387879
Observations	31	31	27	31	31	27	31	31	27

The results indicate that especially following the swap market restrictions by BRSA and the government debt security market dysfunction in constituting a benchmark for the monetary policy outlook in Türkiye, the introduction of TLREF instruments establish as a sole indicator to represent future monetary policy decisions by CBRT.

The findings above highlight that in all estimation windows OIS instruments are robust to indicate the policy decision and provide estimations with lower information criteria values.

The forecast success of OIS, FX swap, and bond implied interest rates for the period of December 2019-July 2022 is shown in the table. The interest rates implied by the TLREF indexed OIS yield curve are statistically significant at all maturities. Implied returns of OIS estimated about 75 bp of the 100 bp change in policy rates. Again, the sample R-square data also indicates a high predictive power. The sum of square residuals is lower and Akaike info criterion (AIC) lower for OIS models. On the other hand, implied interest rates of bonds and FX swaps, which are not statistically significant, are insufficient to explain the policy rate.

The results confirm the success of the OIS implied returns in predicting the policy stance. Lloyd [24] showed in his study for advanced economies that OIS rates provide broadly accurate measures of rate expectations up to a maturity of about 2 years. The short-term findings show that the implied interest rates obtained from the OIS yield curve in Türkiye give accurate signals regarding monetary policy expectations.

Another aspect where monetary policy decision-makers can benefit from OIS yield curves is that it becomes easier to monitor the change in expectations for future meetings. The existence of a market-based financial instrument that accurately reflects expectations after changes in communication policy or surprise data is vital for both decision-makers and investors.

CONCLUSION

There exists an extant literature on measuring monetary policy expectations using fixed income securities, especially for the developed economies, but the predictive power of the financial instruments on developing economies is less investigated. The deepening of derivatives' markets such as OIS, from overnight maturities to longer spans, provides a path for researchers for comparative cross-country analysis. Thus, research constitutes as one of the first studies that focus on the indicative role of derivative markets in deriving monetary policy expectations for a developing economy.

This study investigates the monetary policy predictive power of OIS, FX swap, and Treasury yield curves in Türkiye. The zero-coupon yield curve fitted using the data of bonds, FX swaps, and OIS of different maturities. After measuring the yield curve factors for all three markets, the forward implied interest calculated according to the remaining duration to the meeting date.

The results show that the success of market-based instruments in reflecting policy expectations has changed over time. The restrictions on the FX swap market disrupt the functioning of FX swap contracts and reduce the policy forecasting success of implied interest rates.

Forward implied rates obtained from the bond market yield curve are valuable tools in estimating policy rates. It is noteworthy that the one-month implied returns are more successful in estimating the policy rate path than the shorter maturities. Regarding the monetary policy stance expectations, investors change their bond positioning earlier than one-day or one-week before the meeting dates. Therefore, one-month implied yields outperform other implied yields in estimating the policy path.

Estimation results prove that OIS implied yields have high explanatory power on monetary policy stance. Although the number of observations is limited, initial results suggest that TLREF indexed OIS yield curve has high explanatory power on policy rates.

The results suggest that the predictability of future monetary policy decisions weakens as the CBRT extends the policy dimensions to the unconventional policies. The use of unconventional monetary policy results in the sharp reduction of indicative power of bond and FX swap markets, while TLREF is found to be consistently robust in providing insights for the monetary policy decision. Therefore, the findings support using TLREF as a sole predictor of monetary policy decisions in Türkiye.

As to my knowledge, this study is the first to infer the monetary policy expectations using the TL denominated yield curves including bond, FX swap and TLREF markets. Therefore, the results have the potential to provide insights to the investors and policy makers in analyzing the market expectations on monetary policy.

The main weakness of this study is using a restricted dataset since TLREF is only became available in the last quarter of 2019. Therefore, as the date piles up there is a deeper avenue for future studies. For further research, monetary policy stance would be tested for longer maturities as OIS market expands. TLREF constitutes a reliable indicator for measuring monetary policy expectations and the surprises and paves the way to analyze the effects of monetary policy surprises on the financial markets. In addition, OIS term structure could be used to infer monetary policy stance and decision timing in Türkiye as the market becomes more liquid and actively used by the financial market agents.

REFERENCES

[1] Akçelik, Fatih, and Anıl Talaslı, 2020, Market-based monetary policy expectations for Türkiye, Central Bank Review 20.1, (2020): 9-19

[2] Alp, H., Kara, H., Keleş, G., Gürkaynak, R., and Orak, M., 2010, Türkiye'de piyasa göstergelerinden para politikası beklentilerinin ölçülmesi, İktisat İşletme ve Finans, 25(295), 21-45.

[3] Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R., and Ragusa, G. 2019, Measuring euro area monetary policy, Journal of Monetary Economics, 108, 162-179.

[4] Bomfim, Antulio N, 2003, Monetary policy and the yield curve. Available at SSRN 410763.

[5] Cheng, M., S. L. Dorji, and C. Lantz. A guide to the front-end and basis swap markets. Basis points, Credit Suisse, Fixed Income Research.

[6] Christensen, Jens HE, and Glenn D. Rudebusch,2012, The response of interest rates to US and UK quantitative easing, The Economic Journal 122.564 (2012): F385-F414.

[7] Cieslak, Anna, and Annette Vissing-Jorgensen, 2021, The economics of the Fed put, The Review of Financial Studies 34.9, 4045-4089.

[8] Cochrane, John H., and Monika Piazzesi, 2002, The fed and interest rates-a high-frequency identification, American economic review 92.2, 90-95.

[9] Curves, BIS Zero-Coupon Yield, 2005, Technical Documentation. BIS papers 25.

[10] Diebold, Francis X., Glenn D. Rudebusch, and S. Boragan Aruoba, 2006, The macroeconomy and the yield curve: a dynamic latent factor approach. Journal of econometrics 131.1-2, 309-338.

[11] Edelberg, Wendy, and David Marshall,1996, Monetary policy shocks and long-term interest rates, Economic Perspectives-Federal Reserve Bank of Chicago 20, 2-17.

[12] Ellingsen, T., and U. Söderström, 1999, Monetary Policy and Market Interest Rates, Working Paper in Economics and Finance No. 242, Stockholm: Stockholm School of Economics.

[13] Evans, Charles L., and David A. Marshall, 1998, Monetary policy and the term structure of nominal interest rates: evidence and theory, Carnegie-Rochester Conference Series on Public Policy, Vol. 49., North-Holland.

[14] Faust, Jon, Eric T. Swanson, and Jonathan H. Wright, 2004, Identifying VARs based on high frequency futures data, Journal of Monetary Economics 51.6, 1107-1131.

[15] Gürkaynak, Refet S., Brian P. Sack, and Eric T. Swanson, 2004, Do actions speak louder than words? The response of asset prices to monetary policy actions and statements, International Journal of Central Banking, 1,1.

[16] Gürkaynak, Refet S., Brian P. Sack, and Eric T. Swanson, 2007, Market-based measures of monetary policy expectations, Journal of Business & Economic Statistics 25.2, 201-212.

[17] Gürkaynak, Refet S., Brian Sack, and Jonathan H. Wright, 2007, The US Treasury yield curve: 1961 to the present, Journal of monetary Economics 54.8, 2291-2304.

[18] Hoffmann, Andreas, 2013, Did the Fed and ECB react asymmetrically with respect to asset market developments?, Journal of Policy Modeling 35.2, 197-211.

[19] Joyce, Michael, Matthew Tong, and Robert Woods, 2011, The United Kingdom's quantitative easing policy: design, operation and impact, Bank of England Quarterly Bulletin .

[20] Krueger, Joel T., and Kenneth N. Kuttner, 1996, The Fed funds futures rate as a predictor of Federal Reserve policy, Journal of Futures Markets 16.8, 865-879.

[21] Kucuksarac, Doruk, Abdullah Kazdal, and Ibrahim Ethem Guney, Estimation of currency swap yield curve, 2018, No. 1803. Research and Monetary Policy Department, Central Bank of the Republic of Türkiye.

[22] Kuttner, Kenneth N., 2001, Monetary policy surprises and interest rates: Evidence from the Fed funds futures market., Journal of monetary economics 47.3, 523-544.

[23] Lloyd, Simon P. Estimating nominal interest rate expectations: Overnight indexed swaps and the term structure, 2020, Journal of Banking & Finance 119, 105915.

[24] Lloyd, Simon P.,2021, Overnight indexed swap-implied interest rate expectations, Finance Research Letters 38, 101430.

[25] Mehra, Yash P., 1996, Monetary policy and long-term interest rates, FRB Richmond Economic Quarterly 82.3, 27-49.

[26] Nakamura, Emi, and Jón Steinsson, 2018, High-frequency identification of monetary non-neutrality: the information effect, The Quarterly Journal of Economics 133.3, 1283-1330.

[27] Nelson, Charles R., and Andrew F. Siegel, 1987, Parsimonious modeling of yield curves, Journal of business, 473-489.

[28] Poole, William, and Robert H. Rasche, 2000, Perfecting the market's knowledge of monetary policy, Journal of Financial Services Research 18.2, 255-298.

[29] Rigobon, Roberto, and Brian Sack, 2003, Measuring the reaction of monetary policy to the stock market, The quarterly journal of Economics 118.2, 639-669.

[30] Rigobon, Roberto, and Brian Sack, 2004, The impact of monetary policy on asset prices, Journal of monetary economics 51.8, 1553-1575.

[31] Rudebusch, Glenn D., 1998, Do measures of monetary policy in a VAR make sense?., International economic review, 907-931.

[32] Steffensen, Sigurd Anders Muus, Maik Schmeling, and Andreas Schrimpf, 2021, Monetary policy expectation errors.,Danmarks Nationalbank Working Papers No. 175.

[33] Swanson, Eric T., 2021, Measuring the effects of federal reserve forward guidance and asset purchases on financial markets, Journal of Monetary Economics 118, 32-53.

[34] Tabb, Rebecca, and Joseph Grundfest, 2013, Alternatives to LIBOR, Capital Markets Law Journal 8.3, 229-260.

[35] Woodford, Michael, 2012, Methods of Policy Accommodation at the Interest-rate Lower Bound, Jackson Hole symposium, August, Federal Reserve Bank of Kansas City.

[36] Wang, Yaw-Huei, Aneel Keswani, and Stephen J. Taylor, 2006, The relationships between sentiment, returns and volatility, International Journal of Forecasting 22, 109–123.

[37] Zhang, Wei, and Pengfei Wang, 2020, Investor attention and the pricing of cryptocurrency market, Evolutionary and Institutional Economics Review 17, 445–468.

APPENDIX

Table A.1: FX Swap 1 Month Equation's Correlogram of Residuals

Date: 08/15/23 Time: 15:31
Sample: 2/15/2011 5/26/2022
Q-statistic probabilities adjusted for 3 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.024	0.024	0.0742	
		2	0.031	0.031	0.2030	
		3	0.055	0.054	0.6102	
		4	0.083	0.080	1.5430	0.214
		5	0.038	0.032	1.7366	0.420
		6	0.063	0.055	2.2864	0.515
		7	-0.094	-0.108	3.5062	0.477
		8	-0.082	-0.095	4.4454	0.487
		9	-0.046	-0.052	4.7391	0.578
		10	-0.205	-0.208	10.690	0.153
		11	-0.078	-0.057	11.550	0.172
		12	-0.169	-0.151	15.643	0.075
		13	-0.072	-0.032	16.401	0.089
		14	-0.088	-0.046	17.542	0.093
		15	-0.030	-0.001	17.678	0.126
		16	-0.119	-0.077	19.800	0.100
		17	-0.058	-0.080	20.300	0.121
		18	-0.100	-0.131	21.816	0.113
		19	0.138	0.101	24.727	0.075
		20	-0.030	-0.097	24.869	0.098
		21	-0.047	-0.095	25.218	0.119
		22	0.065	-0.007	25.873	0.134
		23	0.041	-0.036	26.135	0.161
		24	0.167	0.114	30.593	0.081
		25	0.123	0.065	33.050	0.061
		26	0.011	-0.044	33.069	0.080
		27	-0.017	-0.073	33.117	0.102
		28	0.090	-0.048	34.474	0.098
		29	0.046	0.023	34.824	0.116
		30	0.019	-0.062	34.887	0.142
		31	-0.007	-0.014	34.896	0.173
		32	-0.015	-0.008	34.937	0.207
		33	0.011	0.015	34.960	0.244
		34	-0.051	-0.030	35.425	0.267
		35	-0.091	-0.049	36.904	0.252
		36	-0.002	0.036	36.905	0.293

*Probabilities may not be valid for this equation specification.

Table A.2: FX Swap 1 Month Equation's Heteroscedasticity Test Result

Heteroskedasticity Test: ARCH

F-statistic	0.034456	Prob. F(1,125)	0.8530
Obs*R-squared	0.034998	Prob. Chi-Square(1)	0.8516

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 08/15/23 Time: 15:31
Sample (adjusted): 3/23/2011 5/26/2022
Included observations: 127 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.321567	0.563603	2.344853	0.0206
RESID^2(-1)	-0.016598	0.089420	-0.185623	0.8530

R-squared	0.000276	Mean dependent var	1.300077
Adjusted R-squared	-0.007722	S.D. dependent var	6.192180
S.E. of regression	6.216043	Akaike info criterion	6.507767
Sum squared resid	4829.899	Schwarz criterion	6.552557
Log likelihood	-411.2432	Hannan-Quinn criter.	6.525965
F-statistic	0.034456	Durbin-Watson stat	2.000378
Prob(F-statistic)	0.853041		

Table A.3: Treasury 1 Month Equation's Correlogram of Residuals

Sample: 2/15/2011 5/26/2022
Q-statistic probabilities adjusted for 3 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.021	0.021	0.0569	
		2	0.016	0.015	0.0893	
		3	0.032	0.031	0.2240	
		4	0.055	0.053	0.6276	0.428
		5	0.014	0.011	0.6541	0.721
		6	0.052	0.049	1.0261	0.795
		7	-0.049	-0.055	1.3598	0.851
		8	-0.033	-0.036	1.5106	0.912
		9	-0.020	-0.022	1.5650	0.955
		10	-0.215	-0.219	8.1030	0.324
		11	-0.104	-0.096	9.6490	0.291
		12	-0.117	-0.117	11.615	0.236
		13	-0.060	-0.046	12.135	0.276
		14	-0.066	-0.040	12.762	0.309
		15	0.061	0.087	13.309	0.347
		16	-0.021	0.024	13.377	0.419
		17	-0.044	-0.040	13.670	0.475
		18	-0.080	-0.091	14.641	0.478
		19	0.066	0.042	15.307	0.502
		20	0.017	-0.045	15.352	0.570
		21	0.146	0.101	18.653	0.413
		22	0.046	0.002	18.991	0.457
		23	0.013	-0.021	19.019	0.521
		24	0.131	0.101	21.774	0.413
		25	0.113	0.109	23.820	0.357
		26	-0.034	-0.038	24.009	0.403
		27	-0.025	-0.055	24.110	0.455
		28	0.111	0.070	26.172	0.398
		29	-0.062	-0.072	26.821	0.419
		30	0.032	-0.000	26.996	0.464
		31	-0.026	0.028	27.109	0.512
		32	-0.082	-0.040	28.281	0.503
		33	-0.033	0.021	28.475	0.545
		34	-0.025	0.018	28.589	0.591
		35	-0.071	0.008	29.499	0.594
		36	-0.027	-0.026	29.628	0.636

*Probabilities may not be valid for this equation specification.

Table A.4: Treasury 1 Month Equation's Heteroscedasticity Test Result

Heteroskedasticity Test: ARCH

F-statistic	0.077992	Prob. F(1,125)	0.7805
Obs*R-squared	0.079191	Prob. Chi-Square(1)	0.7784

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 08/15/23 Time: 15:26
Sample (adjusted): 3/23/2011 5/26/2022
Included observations: 127 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.370145	0.560905	2.442738	0.0160
RESID^2(-1)	-0.024971	0.089414	-0.279271	0.7805

R-squared	0.000624	Mean dependent var	1.336772
Adjusted R-squared	-0.007371	S.D. dependent var	6.153325
S.E. of regression	6.175963	Akaike info criterion	6.494829
Sum squared resid	4767.814	Schwarz criterion	6.539620
Log likelihood	-410.4217	Hannan-Quinn criter.	6.513027
F-statistic	0.077992	Durbin-Watson stat	2.000985
Prob(F-statistic)	0.780498		

Table A.5: OIS 1 Month Equation's Correlogram of Residuals

Date: 08/15/23 Time: 15:43
Sample (adjusted): 12/12/2019 5/26/2022
Included observations: 30 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.040	0.040	0.0534	0.817
		2	-0.198	-0.200	1.3954	0.498
		3	0.241	0.270	3.4655	0.325
		4	0.189	0.125	4.7801	0.311
		5	-0.130	-0.060	5.4308	0.366
		6	-0.027	-0.019	5.4598	0.486
		7	0.031	-0.089	5.4992	0.599
		8	-0.174	-0.180	6.8132	0.557
		9	-0.353	-0.360	12.515	0.186
		10	0.139	0.152	13.442	0.200
		11	-0.062	-0.144	13.638	0.254
		12	-0.298	-0.041	18.381	0.105
		13	0.023	0.058	18.411	0.143
		14	0.157	0.069	19.893	0.134
		15	-0.160	-0.083	21.524	0.121
		16	-0.060	-0.059	21.771	0.151

Table A.6: OIS 1 Month Equation's Heteroscedasticity Test Result

Heteroskedasticity Test: ARCH

F-statistic	0.334644	Prob. F(1,27)	0.5677
Obs*R-squared	0.355032	Prob. Chi-Square(1)	0.5513

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 08/15/23 Time: 15:43
Sample (adjusted): 1/16/2020 5/26/2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.551736	0.194184	2.841309	0.0084
RESID^2(-1)	-0.109267	0.188885	-0.578484	0.5677

R-squared	0.012242	Mean dependent var	0.492772
Adjusted R-squared	-0.024341	S.D. dependent var	0.879425
S.E. of regression	0.890063	Akaike info criterion	2.671424
Sum squared resid	21.38974	Schwarz criterion	2.765720
Log likelihood	-36.73564	Hannan-Quinn criter.	2.700956
F-statistic	0.334644	Durbin-Watson stat	2.022302
Prob(F-statistic)	0.567732		