Time-varying response of Treasury yields to monetary policy shocks: Evidence from the Tunisian bond market

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Abstract

This paper examines the Treasury bond yields response to monetary policy shocks in Tunisia under a heterogeneous economic environment. Using a traditional fixed coefficient model, we first estimate the impact of monetary policy changes on the term structure of interest rates for the whole period from January 2006 to December 2016. We then study the stability of this relationship by distinguishing two sub-periods around the revolution of January 2011. To investigate how the relationship between the monetary policy and the Treasury yield curve evolves over time, we estimate a time-varying parameter model. The results show that the impact of monetary policy is more pronounced at the short end of the yield curve relative to the longer end. Further, this impact declined significantly across all maturities following the revolution and exhibits wide time variation. This evidence supports the negative influence of high levels of uncertainty on monetary policy effectiveness and highlights the desirability of more active monetary policy especially in turbulent environment.

JEL classification: E43 ; E52; E58

Key words: Treasury yield curve, Monetary policy, Time-varying parameter model, Uncertainty

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1. Introduction

Assessing the effect of monetary policy on the term structure of interest rates is a key challenge, and the subject of an intense debate among policymakers and academics. It has attracted great attention in the literature especially in the aftermath of the recent financial crisis. In many countries, steering the short end of the yield curve is the operational target of monetary policy implementation. This, in turn, can affect long-term interest rates via the expectation hypothesis of the term structure of interest rates. Monetary authority can most control short-term interest rates as they supply reserves to the banking system and can estimate the demand for overnight funds which are largely driven by reserve requirements and changes in autonomous factors of liquidity. Meanwhile, the aggregate demand in an economy depends primarily on long-term interest rates which represent part of the cost of borrowing for households and the cost of capital for firms.

As suggested by Benito et al. (2007), the uncollateralized overnight rate in the interbank market is crucial for signaling monetary policy stance, marking the first step of the monetary policy transmission process and allows central banks to influence the behavior of longer term interest rates. In the same vein, Bernanke and Blinder (1992), Estrella and Hardouvelis (1991), Mishkin (1990), among others, argue that monetary policy is a major factor in explaining the term structure of interest rates[1]. Monetary policy actions such as policy rate changes often contain new information relevant to financial markets. In addition to the overnight rate, the central bank can affect long-term rates by modifying expectations of future short-term rates. The dynamics of interest rates across the maturity spectrum depend also on various underlying factors such as prospects of economic growth, expectations regarding inflation and monetary policy as well as risk preferences. Interest rates are subject to constant up and down-movements as market participants receive new information about these factors.

In the early nineties, several central banks intervened on long-term bond markets (the Fed, the Bundesbank, some Latin American central banks…). In contrast, over the past 20 years, intervening at the short end of the yield curve in order to influence long-term rates and aggregate demand has become the general practice. The severity of the financial crisis of 2008 led many central banks in advanced economies to cut their policy rates to near zero in order to alleviate financial market distress, boost output and stabilize inflation. In such a situation, major central banks resorted to unconventional monetary policy tools such as large-scale asset purchases (quantitative easing) directly aimed at targeting longer-term rates, communication regarding the future path of the policy rate (forward guidance), and recently negative interest rates. Unconventional tools may be seen as a substitute for conventional monetary policy when policy rates are close to the zero lower bound. Bayoumi et al. (2014) conjecture that central banks would be less constrained by hitting the zero lower bound if unconventional monetary policy tools were as effective as the short-term policy rate. Santor and Suchanek (2016) state that the unconventional is increasingly becoming conventional, and unconventional monetary policies have established themselves as part of any modern central bank's tool kit. As advocated by Pain et al. (2014), monetary policy actions undertaken were largely successful in coping with financial market distress, but their effects on inflation and growth were limited. Bloom (2014) noticed that the effectiveness of monetary policy may vary with respect to the degree of uncertainty throughout a financial crisis.

[1] Since 1930, Keynes conjectured that 'the influence of the short-term rate of interest on the long-term rate is much greater than anyone …would have expected...', Keynes (1930, 353).

Given the importance of monetary policy transmission to the real economy, an interesting question is to what extent could the central bank impact interest rates across the maturity spectrum. Thus, the question addressed in this study is about the effectiveness of monetary policy in controlling the dynamics of the yield curve, especially long-term interest rates which are crucial in determining saving, investment and economic behavior.

This paper examines the relationship between monetary policy rate changes and Treasury bond yields in Tunisia under heterogeneous economic environment. It provides two main contributions. Firstly, we extend the empirical literature on the relationship between conventional monetary policy and the term structure of interest rate for an emerging country in context of transition and under high levels of uncertainty. Secondly, we investigate the stability of this relationship by distinguishing two episodes around the revolution of January 2011, and also by estimating a state-space model to test for time-varying behavior and examine the influence of increased economic uncertainty on monetary policy effectiveness.

The reminder of the paper is organized as follows. Section 2 presents a literature review on effects of monetary policy on the yield curve. Section 3 provides an overview of the monetary policy and the Government bond market in Tunisia. Section 4 describes data and methodology. Section 5 discusses the empirical results. Section 6 concludes the paper.

2. Literature review

The most commonly used framework to understand how the yield curve responds to monetary policy actions is the term structure of interest rates[2].

2.1 Theories of term structure of interest rates

According to Cox, Ingersoll and Ross (1985), there are mainly four theories with respect to the term structure of interest rates: the expectation hypothesis, the liquidity preference theory, the market segmentation theory and the preferred habitat theory.

Introduced by Fisher (1896) more than a century ago, the expectation hypothesis postulates that the interest rate on a long-term bond will equal an average of the short-term interest rates that people expect to prevail over the life of the long-term bond. This approach is based on the key assumption that investors regard bonds of different maturities to be perfect substitutes. Under the expectation hypothesis, since interest rates at all maturities depend on today’s short-term rate, they tend to move together, rising when it rises and falling when it falls. Moreover, the yield curve can slope up or down depending on the expectation of short-term interest rates in the future.

In contrast to that, the liquidity preference theory, advanced by Hicks (1939), states that investors prefer short-term bonds to long-term bonds. This theory is based on the assumption that bonds of different maturities are substitutes but not perfect substitutes. Yields on long-term bonds are greater than the expected return from rolling-over short-term bonds in order to compensate investors in long-term bonds for bearing interest rate risk. Therefore, investors require a term or liquidity premium in order to be induced to invest in bonds with longer maturities. The interest rate on a long-term bond will equal the average of short-term interest rates expected to occur over the life of the long-term bond plus a liquidity premium that responds to supply and demand conditions for that bond. The liquidity premium is assumed to be positive and increasing with maturity. This could result in an upward sloping term structure

[2] The relationship among the yields on default-free securities that differ only in their term to maturity is referred to in the literature as the term structure of interest rates. This relationship is more popularly known as the shape of the yield curve (Burton G. Malkiel, 1962).

even if the market does not anticipate an increase in interest rates. Under the liquidity preference theory, the yield curve slopes down only when short-term interest rates are expected to fall sharply. This implies that yield curves are more likely to have an upward slope.

Third, the market segmentation theory, advanced by Culberston (1957), asserts that the market for different maturity bonds is completely separate and segmented. The same arguments are used by Modigliani and Stuch (1966) in their preferred habitat theory. They argue that investors should be distinguished based on their institutional and business characteristics. For example, insurance companies prefer investing in long-term bonds whereas commercial banks are interested to hold short-term bonds. This implies that the yield of a bond with a given maturity is determined by the supply and demand in that segment with no effect from the market conditions in other segments. There is no reason for term premiums to be positive or increasing functions of maturity. Therefore, the term structure of interest rates can take any form (Gibson et al., 2010).

Using various techniques and data sets, Shiller (1979), Jones and Roley (1983), Campbell and Shiller (1991), Bekaert and Hodrick (2001), Sarno, Thornton and Valente (2007), among others, reject the expectation theory of the term structure. Campbell and Shiller (1991) explained the failure of the expectation theory by time-varying risk premium. Mankiw and Miron (1986) attribute the rejection of the expectation theory to the influence of monetary policy. When monetary policy actions are mostly predictable, a change in the target rate may have a small effect on long-term rates. However, some studies document opposite findings. Dale (1993), Roley and Sellon (1995), Mehra (1996), Buttiglione et al. (1997), find a positive relationship between short-term rates and long-term rates as predicted by the expectation theory. Romer and Romer (2000) conjecture that this positive relationship is inconsistent with monetary policy theory since a policy tightening should reduce inflation and consequently long-term rates. On the other hand, Ellingsen and Soderstrom (2001) construct a structural model to explain the behavior of the term structure of interest rates taking into account supply and demand shocks as well as monetary policy shock. They demonstrate that after an endogenous shock (supply and demand shocks), interest rates of all maturities move in the same direction of the policy innovation. But, after an exogenous policy shock (monetary policy shock), short and long rates should move in the opposite direction.

An important channel in the transmission of monetary policy is the relationship between the short-term policy rate and long-term interest rates. Long-term rates are essential for the transmission of monetary policy, since they represent part of the cost of borrowing for consumers and the cost of capital for businesses (Dorich, Mendes and Zhang, 2011). Long-term yields reflect the expected future path of short-term interest rates and a time-varying term premium (Gürkaynak and Wright, 2012). Many studies have linked this premium to uncertainty about future inflation and to financial market segmentation driven by differences in preferences over alternative assets (Rudebusch and Swanson, 2008; Vayanos and Vila, 2009; Wright, 2011).

2.2 Literature related to the monetary policy effect on the yield curve

The effect of changes in the target rate on the term structure of interest rates has been the focus of a large strand of literature. In the US, Cook and Hahn (1989) document large and significant responses of bond rates to Federal funds rate changes during the 1970s. Roley and Sellon (1995) point out that the impact of the Federal funds rate on long-term rates varies significantly over time. Dale and Haldane (1993) show that monetary policy actions of the Bank of England have a significant effect on the short-term rate while long- term rates are less affected. Kuttner (2001) suggests distinguishing between anticipated and unanticipated changes in the key rate. He finds significant impact of unanticipated policy changes on the long-end of the yield curve from 1989 to 2000. The unanticipated component could be obtained from derivative prices (Kuttner, 2001), survey expectations (Ehrmann and Fratzscher, 2003) or jumps in short-term interest rates (Winkelmann, 2013). Thornton (2004) explores how the actions of the Bank of Japan get translated along the term structure of interest rates. He shows that the expectation hypothesis holds only at the short end of the maturity spectrum.

However, as noted by Kuttner (2001), simple regressions of market interest rates on the policy rate can be misleading given the increasing ability of financial markets to forecast policy rate changes. Swanson (2004) attributes this finding to the improvement of monetary policy transparency in 1990s. In the same vein, using the target federal funds rate and the 10-year Treasury bond yield, Wu (2005) finds that changes in long-term rates Granger-cause changes in the target rate during the 1990s, but not vice versa. He concluded that changes in the monetary policy stance are more predictable in the 1990s than the 1970s. Instead of using a single regression to study the responses of the long end of the yield curve to monetary policy changes, another strand of empirical studies employs impulse response function from a VAR model (Edelberg and Marshall, 1996; Evans and Marshall, 1998; Christiano et al., 1999).

The ability of a central bank to operate at longer horizons other than the very short-term has recently attracted substantial interest from both academics and practitioners. According to Carlstrom et al. (2014), the zero lower bound constraint has renewed the debate on whether monetary policy should go back to targeting directly long-term rates. On the one hand, Adão Correia and Teles (2010) as well as Magill and Quinzii (2012), show that a central bank can independently target short and long nominal interest rates, possibly the whole term structure of nominal interest rates. Monetary policy is thus able to implement a unique equilibrium regardless of whether prices are flexible or sticky. On the other hand, Eggertsson and Woodford (2003) as well as Woodford (2005) rejected the possibility of using long-term interest rate as operational target for monetary policy.

With the zero lower bound constraint, central banks faced the challenge of how to further ease the stance of monetary policy as the economic outlook deteriorated in the aftermath of the recent global financial crisis. In response, major central banks have implemented large-scale asset purchase programs. As argued by Gagnon et al. (2011), these programs led to sizeable reductions in long-term interest rates. These reductions primarily reflect lower risk premiums rather than lower expectations of future short-term rates. Bayoumi et al. (2014) address the question of using unconventional monetary policy as substitute to conventional tools in normal times. The authors suggest that targeting long-term rates directly may be desirable given that they are more relevant for spending decisions.

Both in advanced and emerging economies, financial distortions are not only present in crisis times or when the economy hits the zero lower bound. It may then be desirable to act on different asset classes or points of the yield curve. Chen et al. (2014) investigate the channels through which asset purchases by central banks can affect real activity. First, through the portfolio balance channel pioneered by Tobin (1958; 1969), purchases of long-term securities can lower the long end of the yield curve and induce investors to buy assets with greater duration or higher credit risk. In the second, the signaling channel, purchases of long-term securities can lower the expected future path of short-term rates and reduce longer-term yields. If it is perceived as credible by market participants, this commitment can also reduce uncertainty and thus drive down risk premiums. Third, through the interest rate channel, if nominal prices and wages are slow to adjust, reducing long-term yields and subsequently real interest rates encourages spending by firms and households. According to Amstad and Martin (2011), longer-term money market rates are more challenging to target directly, because supply and demand for such funds are determined by market participants. Another problem with targeting long-term rates is the risk of fiscal dominance. Woodford (2016) argues that outright portfolios can provide monetary accommodation with less risk to financial stability than conventional interest rate policies. This is because outright portfolios with duration, credit and liquidity risk reduce risk premiums, and thereby dampen incentives for financial intermediaries to excessively take such risks.

Furthermore, Berument and Froyen (2006) show that long-term interest rates responses to Fed's policy innovations change with changes in the monetary policy regime. Evidence of regime shifts is also found in Ang et al. (2011), Bae et al. (2012), Beckworth et al. (2012), Cogley (2005). Marfatia (2015) scrutinizes the impact of US monetary policy on yield curve using a flexible time-varying parameter framework. He finds wide time variations in the response of bond yields across all maturities to the Fed's policy surprises in presence of uncertainty which supports that higher level of financial market and economic uncertainty is associated with lower impact of the Fed on interest rates across the maturity spectrum.

3. Overview on the monetary policy and the domestic bond market in Tunisia

3.1 Implementation of monetary policy in Tunisia

According to Bindseil (2004), most central banks try to steer a short-term market rate, most commonly the overnight rate on interbank loans. This is done directly by deciding on a target for the overnight rate or indirectly as the standing facilities rates are linked to the policy rate by setting a corridor for interest rates.

The Law No.2016-35 related to the statute of the Central Bank of Tunisia (CBT) clearly states that the primary objective of the Central bank is to maintain price stability. To achieve its price stability objective, the CBT adjusts the level of its policy rate, which has a direct influence, through the monetary policy transmission mechanisms, on the financing conditions for all economic agents and, consequently, on price stability and growth.

The operational framework for the implementation of monetary policy is designed to steer the interbank overnight interest rate to levels close to the CBT's policy rate. Indeed, the overnight rate has a direct influence on the average monthly money market rate, which is a reference rate widely used by the Tunisian banking system. Hence, the operational framework has an important role in assuring that the CBT can reach its goal of preserving price stability.

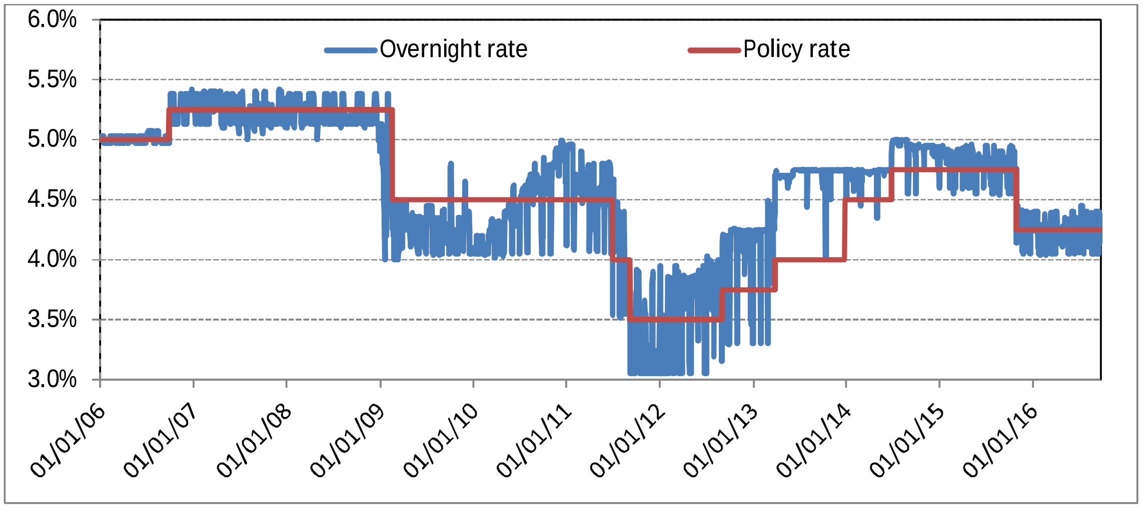
The Central Bank Law has provided a wide range of instruments for monetary policy implementation. At present, the operational framework for the implementation of monetary policy relies basically on open market instruments conducted at the central bank discretion, two standing facilities available at counterparties' initiative and a system of reserve requirement[3].

In terms of stabilizing the interbank overnight rate, the CBT's operational framework has worked reasonably well both in normal and turbulent times. As shown by Figure 1, the central bank achieved close control over the overnight rate during the period from 2006 to 2016. We begin from 2006 because the monetary policy has started to target short term rates from this

[3] To meet the banking system's refinancing needs, the CBT engages in various open market operations. The principal liquidity injection tool is the main refinancing operations. The longer-term refinancing operations are an additional tool to supply liquidity to eligible counterparties for longer durations. The CBT can also perform fine-tuning and structural operations. Banks are allowed to deposit liquidity overnight at a deposit rate corresponding to the policy rate minus a margin and to borrow liquidity against eligible collateral at a lending rate corresponding to the policy rate plus a margin. The rates applicable to these two permanent facilities form a corridor that limits fluctuations in the money market interest rates and thus keeps the latter rates at levels close to the policy rate. Finally, the CBT makes it mandatory for Tunisian banks to maintain a minimum ratio of required reserves which increases the banking system's demand for central bank money. As it must be met on average over a reserve maintenance period, a calendar month, the reserve requirement represent an instrument to smooth the day-to-day liquidity fluctuations and so induce greater stability in the money market interest rates.

date instead of targeting base money in the past. For the whole period, the spread between the target rate and the policy rate has an average and a standard deviation of 6 and 31 basis points, respectively. The Central Bank of Tunisia changed its policy rate nine times during the period considered of which four cuts and five increases: (i) a 75 basis point cut on September 2006 followed by three 50 basis point cuts respectively in June 2011, September 2011 and October 2015 (ii) four 25 basis point increases respectively in August 2012, March 2013 and June 2014, and a 50 basis point rise in December 2013.

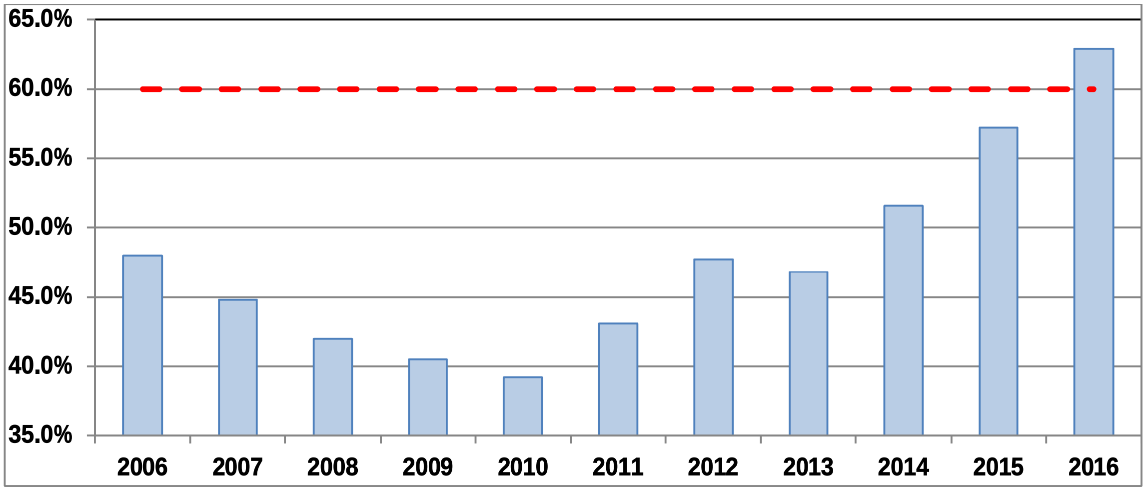
Figure 1. Evolution of the interbank overnight rate vs. the policy rate



3.2 The domestic bond market in Tunisia

Over the past 10 years, Tunisian public debt path has reflected prudent fiscal management since the ratio of public debt-to-GDP has never exceeded the fiscal sustainability guideline of 60%, as shown by Figure 2. However, two notable episodes in the evolution of Tunisian's public debt should be distinguished. During the pre-revolution episode 2006-2010, huge efforts were made to reduce the public debt level and achieve fiscal consolidation. Coupled with the strengthening economy, this consolidation led to a continuous decline in the ratio of public debt-to-GDP. The deterioration of the economic activity since the revolution necessitated a fiscal expansion in Tunisia. Besides running sizable budget deficits during the past six fiscal years (2011-2016), the government also engaged itself in borrowing to mobilize local and foreign currency funds.

Figure 2. General government net debt (% GDP)



Source: IMF, World Economic Outlook Database, October 2017

As depicted in Figure 2, the general government gross debt was on a declining trend from 2006 to 2010, bottoming out at 39.2% of GDP in 2010. Then, there was a sharp rise in public debt to a peak of 62.9% of GDP in 2016, as a result of increasing public spending and the sluggish economy during the post-revolution period 2011-2016.

Table 1. Tunisia's key economic indicators

Key economic indicators	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GDP, constant prices (% change)	5.7	6.3	4.5	3.1	2.6	-1.9	3.9	2.4	2.3	1.1	1.0
Inflation rate, average consumer prices (% change)	3.2	3.0	4.3	3.7	3.3	3.5	5.1	5.8	4.9	4.9	3.7
General government structural balance (% of potential GDP)	-2.7	-3.3	-1.8	-3.9	-3.0	-4.3	-5.7	-6.4	-4.5	-4.6	-5.5
General government gross debt (% of GDP)	48.0	44.8	42.0	40.5	39.2	43.1	47.7	46.8	51.6	57.2	62.9
Current account deficit (% GDP)	-1.8	-2.4	-3.8	-2.8	-4.8	-7.4	-8.3	-8.4	-9.1	-8.9	-9.0

Source: IMF, World Economic Outlook Database, October 2017

The Government and the Central Bank of Tunisia have made continuous efforts to strengthen and deepen the domestic bond market. As a result, the local bond market has grown in terms of size, depth and liquidity in the last decade. The government's total gross loan debt, which comprises domestic and foreign government debt, increased from 22.2 billion of Tunisian dinar[4] in 2006 to 53.5 billion of Tunisian dinars in 2016. Domestic government debt accounted for 38.5% of total gross debt of the national government in 2016.

The issuance of securities by the Treasury in the primary market is based on an auction system inspired by the French experience, which, in turn, refers largely to the US model. The Treasury issues two kinds of securities: T-bills for tenors less than one year (at present for 3, 6 and 12 months) and T-bonds for maturities beyond one year (currently ranging from one to 15 years)[5]. While auctions for T-bills are yield based, those for T-bonds are price based. These two types of securities have the same face value of one thousand Tunisian dinars.

Most primary dealers in government securities called SVT belong to banks. As central securities depository for Tunisian capital markets (CSD), 'Tunisie Clearing' is in charge of the settlement

[4] 1 USD = 2.3036 TND on December 30, 2016

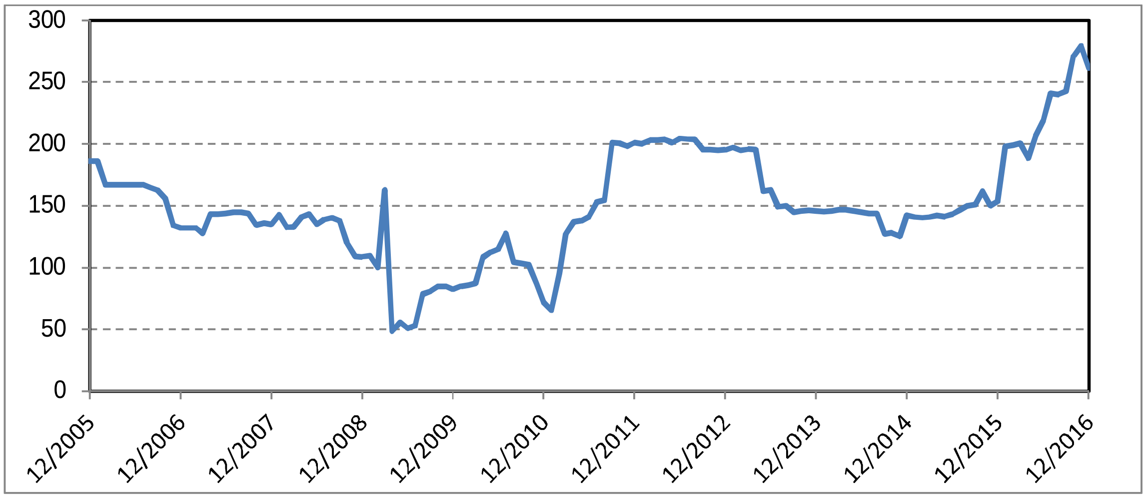
[5] T-bills accounted only for 1% of the total stock of domestic public debt at end December 2016.

of all Government bills and bonds. Cash payment is processed by the Central Bank of Tunisia through the real time gross settlement system (RTGS).

In December 2016, the outstanding amount of all types of securities issued by the Treasury reached 12.5 billion of Tunisian dinars against 6.1 billion of Tunisian dinars in December 2006. The average maturity was around 5 years at end December 2016. The total value of transactions in the secondary market amounted to 3.3 billion of Tunisian dinars in 2016 compared to 0.3 billion of Tunisian dinars in 2006.

As shown by Figure 3, the slope of the yield curve is positive throughout the entire period 2006-2016. The spreads 10-year minus 1-year bond widened from 49 basis points in April 2009 to 279 basis points in November 2016, given the notable increase in the supply of government bonds.

Figure 3. Spreads between 10-year and 1-year Treasury yields



4. Data and methodology

4.1 Data

This study employs market interest rates across the nominal yield curve sampled monthly from January 2006 to December 2016. Since overnight interest rates data are daily based, we take simple average to transform series into monthly frequency. For Treasury bonds, we use end-of-month yields. Thus, the final sample contains 132 observations. We choose monthly frequency to mitigate the problem of missing data given the low level of liquidity of the Tunisian bond market.

The dataset used includes overnight interest rates as well as Treasury yields for various maturities in order to cover almost the entire spectrum of term structure. We particularly use the 1-year, 2-years, 4 years, 5-years, 7-years, and 10-years Treasury yields. We focus on all these maturities because different long-term rates may have different dynamics. Overnight rates were obtained from the Central Bank of Tunisia database whilst Treasury yields were collected from the Tunisian Financial Market Board website (www.cmf.org.tn).

Table 2 reports summary statistics for various interest rates used in this study.

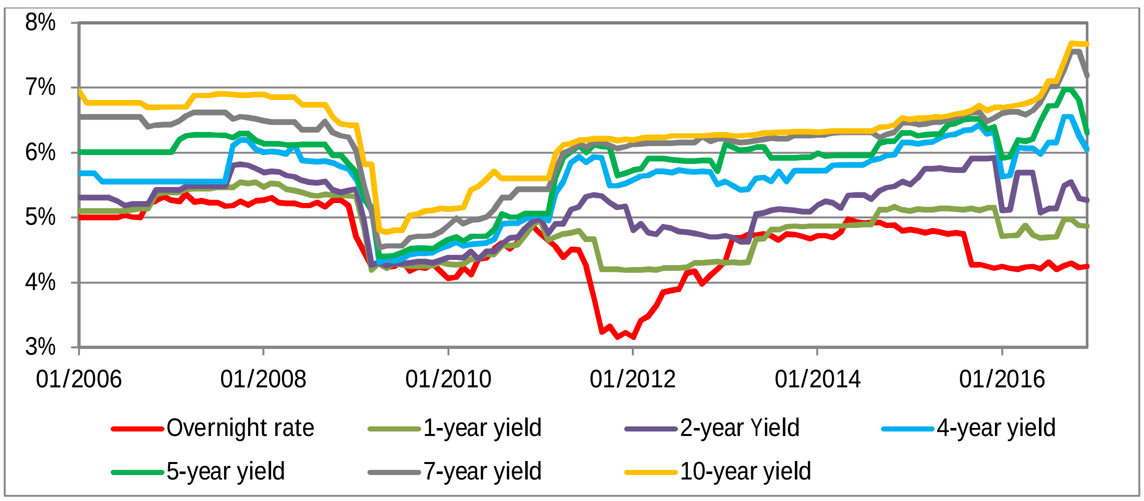
Table 2. Summary statistics of interest rates

Maturity	Mean	Median	Maximum	Minimum	Std. Dev.	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Overnight	4.593	4.700	5.360	3.160	0.518	0.97	0.26
1-year	4.841	4.869	5.546	4.192	0.429	0.96	0.39
2-year	5.162	5.221	5.915	4.260	0.450	0.94	0.32
4-year	5.612	5.701	6.557	4.313	0.528	0.95	0.36
5-year	5.856	6.013	6.972	4.406	0.587	0.97	0.43
7-year	6.148	6.293	7.558	4.543	0.628	0.97	0.42
10-year	6.339	6.334	7.686	4.781	0.593	0.95	0.37

We observe wide variation in most interest rates given the comprehensive coverage of the study from 2006 to 2016. In addition, all yields are highly persistent for all maturities, with average first order autocorrelation greater than 0.94.

Indeed, yields across maturities tend to co-move as revealed by Figure 4. The overnight rate is closely linked to the 1-year bill rate while the connection to other rates appears to be weaker. For example, short-term rates declined in response to the cut of the policy in late 2015 rate while long-term rates rose[6]. This could reflect either revision in expectation about economic growth or perception by market participants that the easing is temporary. The behavior of interest rates in late 2015 and 2016 is in line with the explanation that market participants believe that the current stance is temporary and likely to be reversed in the future[7]. This tells us that long rates don't move systematically in the same direction as short rates.

Figure 4. Market interest rates for various maturities



To further strengthen this inference, we compute the correlation coefficient between yields of different maturities. The results presented in Table 3 show strong positive correlations for bonds with close maturities. Correlation becomes weaker as the gap between maturities widens. This is consistent with the expectation hypothesis which provides the theoretical link between short-term and long-term interest rates.

[6] Alan Greenspan described this behavior as a "conundrum". In fact, when the Fed increased its policy rate in an attempt to slow growth and reduce inflationary pressures during the 2004-05, long-term interest rates remained stable. Many studies suggest that the term-structure risk premium was falling at the time, helping to offset the impact of the Fed's actions on long-term interest rates.

[7] The CBT raised its key rate twice during the first half of 2017 by 50 and 25 basis points, respectively in April and May 2017.

Table 3. Correlation coefficients between Treasury yields

Maturities	Overnight	1 year	2 years	4 years	5 years	7 years	10 years
Overnight	1	0.828	0.462	0.197	0.256	0.281	0.364
1-year	0.828	1	0.826	0.552	0.568	0.584	0.660
2-year	0.462	0.826	1	0.858	0.818	0.796	0.806
4-year	0.198	0.552	0.857	1	0.950	0.908	0.870
5-year	0.259	0.569	0.818	0.950	1	0.970	0.937
7-year	0.281	0.584	0.796	0.908	0.970	1	0.977
10-year	0.360	0.656	0.806	0.870	0.937	0.977	1

4.2 Methodology

4.2.1 The fixed coefficient model

To test the responses of short and long-term rates to monetary policy actions, we estimate the following model by ordinary least squares (OLS) for the whole period from January 2006 to December 2016.

$$\Delta R_{i,t} = c + \alpha_0 \Delta R_{m,t} + \alpha_1 \Delta R_{m,t-1} + \alpha_2 \Delta R_{m,t+1} + \beta \Delta R_{i,t-1} + u_t \quad (1)$$

where Δ is the difference operator, $R_{i,t}$ refers to yields for maturity i, $R_{m,t}$ stands for the monetary policy instrument (the overnight rate), α is the i-th maturity Treasury yields' response to changes in the monetary policy instrument, u_t is the error term. Maturities considered in this work are: 1 year, 2 years, 4 years, 5 years, 7 years and 10 years. The lagged difference of the monetary policy instrument is introduced to capture any anticipation of monetary policy action. The lagged dependent variable aims to address any residual autocorrelation. The lead was included to allow for any possible contemporaneous reactions that would otherwise not be captured by the data[8].

Although we focus primarily on the response of the yield curve to observed changes in the central bank's interest rate, our analysis bears equally on yield curve movements on days when there are no policy changes. On these days movements are driven by expectations of the central bank's future reaction to the economic developments.

Similar versions of equation (1) were extensively used in empirical literature addressing the question of the effects of monetary policy actions on the yield curve (Thornton, 1998; Haladane and Read, 2000; Drakos, 2001; Anderson et al., 2006; Kaketis and Sarantis, 2006; Fama, 2013). As pointed out by Drakos (2001), equation (1) assumes a stationary relationship between the contemporaneous variations in nominal rates explained as an affine function of contemporaneous and lagged (lead) variations in the monetary policy instrument (the overnight rate). It is important to test for unit roots in order to avoid spurious regressions. The results of the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests show that the variables in level are non-stationary while in first difference they are stationary[9].

[8] For instance, when a policy move is announced on Friday afternoon, with markets still open, but officially recorded on the following Monday (See Buttiglione et al.; 1997).

[9] While ADF test assumes that errors are statistically independent and have a constant variance, PP test controls serial correlation when testing stationarity. Results of these tests on level and first difference are available upon request.

The deterioration of all economic indicators since 2011 and the sharp increase of financial risks and economic uncertainty may induce a break in the relationship between monetary policy shocks and the yield curve. After analyzing this relationship for the whole period, we focus on two distinct periods around the revolution of January 2011.

4.2.2 The time-varying parameter model

We also consider a time-varying parameter model (TVP) to investigate how the relationship between the monetary policy actions and the Treasury yields evolves over time. To this end, we use a state-space model as suggested by Stock and Watson (2002), Boivin (2006), Fama (2013), Marfatia (2015), among others. This alternative approach is based on a time-varying parameter framework which provides a more flexible way to model the dynamic impact of the Tunisian monetary policy shocks on Treasury bond yields.

The state-space model is defined by two equations. Firstly, a measurement equation describes the link between the observable variables (data) and the unobserved state vector (time-varying coefficients). The measurement equation of our state-space model shows the unobserved time-varying response of yields on Treasury bonds to a change in the overnight rate.

Similar to Marfatia (2015), the measurement equation and its state-space representation are specified as follows:

$$\Delta R_t = X_t \theta_t + e_t \qquad \text{where } e_t \sim N(0, \sigma_e) \tag{2}$$

$$\Delta R_t = \begin{bmatrix} c & \Delta R_m & \Delta R_{m,t-1} \end{bmatrix} \begin{bmatrix} \alpha_{ct} \\ \alpha_{0t} \\ \alpha_{1t} \end{bmatrix} + e_t \tag{3}$$

where Δ is the difference operator, R_t refers to yields on Treasury bonds, X_t is a vector of exogenous variables which includes a constant (c) and overnight rate changes (ΔR_m), θ_t is a vector capturing unobserved time-varying parameters (α_{ct}, α_{0t} and α_{1t}) of the model. The parameters of interest are α_{0t} and α_{1t} which capture the time-varying impact responses of Treasury bond yields to monetary policy. The sign of this coefficient is expected to be positive in accordance with the term structure of interest rates.

Secondly, a state or transition equation defines the dynamics of the unobserved state vector. Following pioneering work of Cooley and Prescott (1976), the transition equation of the state-space system is modeled as a driftless random walk process. This allows for the impact of the policy to evolve gradually over time and is also consistent with the persistent interest rate process. The transition equation and its state-space form are then represented as follows:

$$\theta_t = F\theta_{t-1} + v_t \qquad \text{where } v_t \sim N(0,Q) \tag{4}$$

$$\begin{bmatrix} \alpha_{ct} \\ \alpha_{0t} \\ \alpha_{1t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha_{ct-1} \\ \alpha_{0t-1} \\ \alpha_{1t-1} \end{bmatrix} + \begin{bmatrix} v_{ct} \\ v_{0t} \\ v_{1t} \end{bmatrix} \tag{5}$$

where Q is the variance-covariance matrix of the disturbances terms v_{ct}, v_{0t} and v_{1t} which are assumed to be uncorrelated. The Kalman filter is applied to the above state-space model and the parameters are estimated using maximum likelihood.

5. Empirical results

5.1 Estimation of the fixed coefficient model

5.1.1 Results for the whole period (2006-2016)

The OLS estimation results of equation (1) are presented in Table 4. In particular, the Durbin-Watson statistics indicate the absence of first-order serial correlation. The contemporaneous impact of monetary policy changes on Treasury yields is statistically significant only for the short end of the yield curve, 1-year T-bill. While lagged changes of monetary policy have a significant impact on the 1-year, 7-year, and 10-year Treasury yields, the lead of the policy instrument is not significant in any case. The total impact of monetary policy changes $(\alpha_0 + \alpha_1 + \alpha_2)$ for 1-year T-bill yield is 0.48, which is two times stronger than 0.22 for the 10-year T-bond yield, which is in line with the expectation theory. For medium-term maturities, monetary policy does not exert any significant impact on Treasury yields.

Table 4. Estimating the effect of monetary policy actions on Treasury yields

Maturity	c	α_0	α_1	α_2	$\alpha_0 + \alpha_1 + \alpha_2$	β	Adj. R^2	DW	Chow test
1-year	1.07E-05	0.226***	0.323***	-0.061	0.488	-0.0001	0.205	2.00	3.379***
	(0.117)	(3.080)	(4.234)	(-0.841)		(-0.001)			
2-year	7.10E-06	0.100	0.180	-0.122	0.158	0.051	0.005	2.00	2.329**
	(0.048)	(0.811)	(1.286)	(-1.385)		(0.575)			
4-year	5.28E-05	-0.042	0.179	0.093	0.230	0.061	0.002	2.02	1.595
	(0.385)	(-0.382)	(1.639)	(0.850)		(0.684)			
5-year	6.18E-05	0.007	0.103	0.114	0.224	0.164*	0.025	2.07	3.283***
	(0.510)	(0.075)	(1.071)	(1.185)		(1.853)			
7-year	5.23E-05	-0.036	0.186***	0.048	0.198	0.468***	0.264	2.15	6.978***
	(0.633)	(-0.538)	(2.825)	(0.737)		(6.136)			
10-year	7.58E-05	-0.098	0.235***	0.086	0.223	0.118	0.048	2.10	9.203***
	(0.633)	(-1.088)	(2.660)	(0.975)		(1.372)			

Notes: t-statistics in parentheses. The numbers in Chow test column report the F-statistics for the null hypothesis that no structural break is present. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent levels, respectively.

Thus, the pass through of monetary policy shocks is more pronounced at the short end of the yield curve relative to the longer end in Tunisia. This evidence is in accordance with findings reported in the literature for both advanced and emerging markets. For instance, the estimated responses of short-term market rates to Fed's policy shocks range between 56 and 81 basis points while the long-term interest rates from insignificant responses to 32 basis points (Jorda and Demirlap, 2004; Poole et al., 2002; Swiston, 2007). Total responses of 0.07 and 0.02 respectively for 1-year and for 10-year bond yields are reported by Drakos (2001) for Greece.

5.1.2 Results for the two periods pre- and post-2011: The revolution's effect

In order to investigate whether the Tunisian revolution has changed the relationship between the monetary policy stance and the yield curve, we split the full sample period into two sub-periods, pre- and post-January 2011. This periodization is supported by the Chow structural stability test (Chow, 1960) which accepts 2011 as a structural break point in the relation between monetary policy shocks and interest rates. The results are presented in panel A and panel B of Table 5.

Table 5. Estimating the impact of monetary policy changes on Treasury yields pre- and post-2011

Maturity	c	α_0	α_1	α_2	$\alpha_0 + \alpha_1 + \alpha_2$	β	Adj. R^2	DW
Panel A : Pre-2011 (January 2006-December 2010)								
1-year	-7.59E-06	0.349***	0.661***	-0.068	0.942	0.011	0.538	2.67
	(-0.067)	(3.359)	(5.771)	(-0.659)		(0.112)		
2-year	-2.65E-05	0.183	0.581***	0.023	0.787	0.130	0.292	2.23
	(-0.157)	(1.170)	(3.613)	(0.151)		(1.083)		
4-year	-8.32E-05	0.087	0.505***	0.162	0.754	0.043	0.122	2.15
	(-0.431)	(0.481)	(2.790)	(0.918)		(0.339)		
5-year	-0.10E-03	0.044	0.525***	0.197	0.766	0.199*	0.330	2.32
	(-0.755)	(0.341)	(4.084)	(1.579)		(1.736)		
7-year	-9.29E-05	0.038	0.579***	0.203*	0.820	0.364***	0.517	2.38
	(-0.757)	(0.333)	(4.980)	(1.822)		(3.678)		
10-year	-0.14E-03	-0.237	0.813***	0.328*	0.904	0.074	0.308	2.34
	(-0.775)	(-1.307)	(4.663)	(1.915)		(0.648)		
Panel B : Post-2011 (January 2011-December 2016)								
1-year	2.69E-05	0.171*	0.180*	-0.050	0.301	-0.101	0.068	2.01
	(0.209)	(1.795)	(1.874)	(-0.536)		(-0.847)		
2-year	4.41E-05	0.061	-0.022	-0.202	-0.163	-0.049	-0.031	1.99
	(0.203)	(0.376)	(-0.142)	(-1.282)		(-0.398)		
4-year	0.17E-03	-0.078	0.019	0.051	-0.008	-0.003	-0.054	1.94
	(0.904)	(-0.559)	(0.139)	(0.369)		(-0.024)		
5-year	2.29E-03	0.019	-0.108	0.065	-0.024	0.054	-0.043	1.93
	(1.262)	(0.145)	(-0.836)	(0.500)		(0.437)		
7-year	0.20E-03**	-0.032	-0.004	-0.034	-0.070	0.308**	0.053	1.96
	(2.076)	(-0.476)	(-0.060)	(-0.520)		(2.633)		
10-year	0.20E-03**	0.042	-0.061	-0.067	-0.086	0.270**	0.046	1.98
	(2.263)	(0.668)	(-1.001)	(-1.081)		(2.292)		

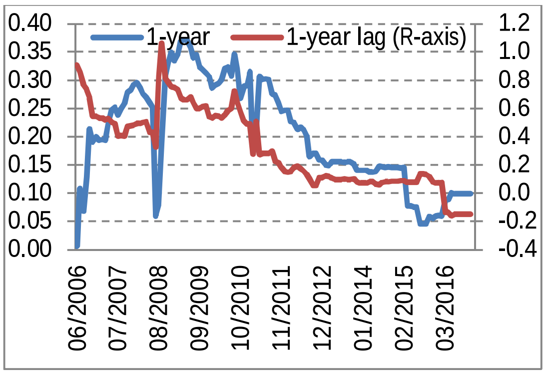
Notes: t-statistics in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent levels, respectively.

The response coefficients show significant variations across all maturities between pre- and post-2011 periods. For panel A, the Treasury yields responses to monetary policy shocks are statistically significant for all maturities, albeit higher for 1-year T-bill and 10-year T-bond. Unlike advanced financial markets, the monetary policy impact does not exhibit a monotonically decreasing pattern for the pre-revolution period. In fact, Treasury yields responses exhibit decreasing pattern for maturities less than 4 years but move back up from 5 years. This behavior supports the segmented nature of the monetary policy impact across maturities with a clear market preference for two benchmarks, 1-year and 10-year. Indeed, the impact of monetary policy actions on the entire yield curve has sharply declined after 2011. It became insignificant across all maturities longer than one year. Overall, results show that following 2011 revolution, the impact of the monetary policy actions has decreased considerably on both short-term and long-term rates. In addition to the negative influence of the increased economic uncertainty, such behavior could be attributed to other factors such as inflation expectations, transparency of the monetary policy, position in the business cycle, and financial market dysfunctioning (Romer and Romer, 2000; Ellingsen and Söderström, 2001; Marfatia, 2015).

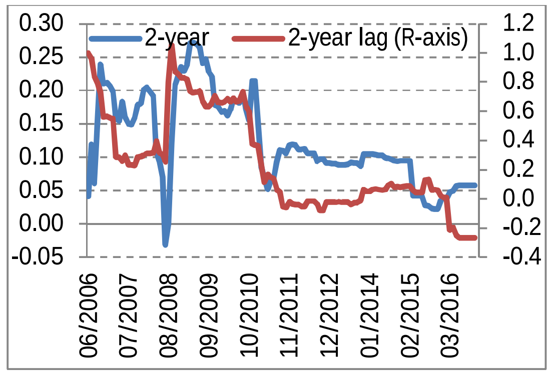
5.2 The time-varying responses of Treasury yields

Figure 5 presents the TVP estimates of different bond maturities. Each plot reflects both the contemporaneous as well as lagged effects of monetary policy changes on 1-year, 2-year, 4-year, 5-year, 7-year, and 10-year Treasury yields. Evidence clearly suggests that there is significant time variation in the impact of monetary policy actions on the entire term structure of interest rates. These results support the above preliminary evidence of significant structural break in the effects of monetary policy.

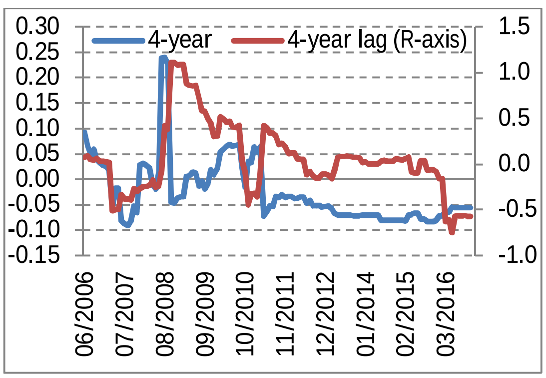
Figure 5. Time-varying parameter (TVP) estimates showing contemporaneous and lagged effects on different bond maturities



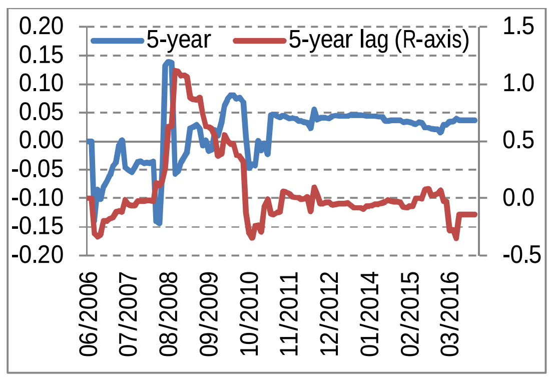
(a) TVP of 1-year yield and its lag



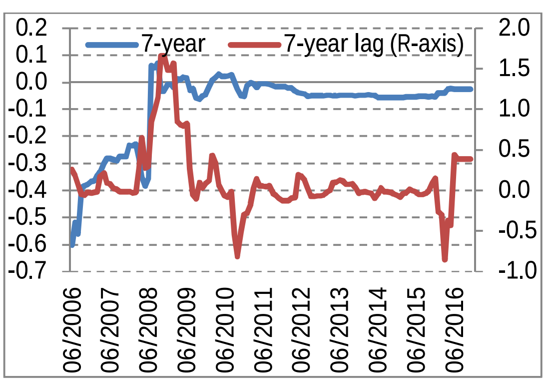
(b) TVP of 2-year yield and its lag



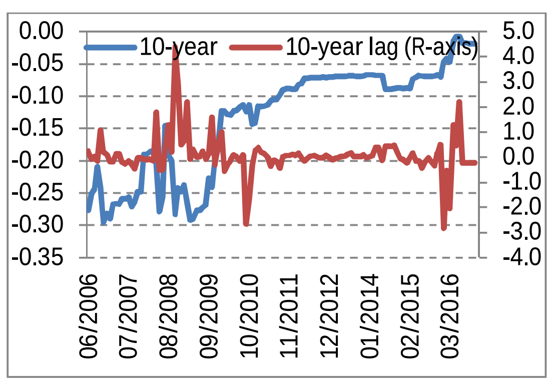
(c) TVP of 4-year yield and its lag



(d) TVP of 5-year yield and its lag



(e) TVP of 7-year yield and its lag



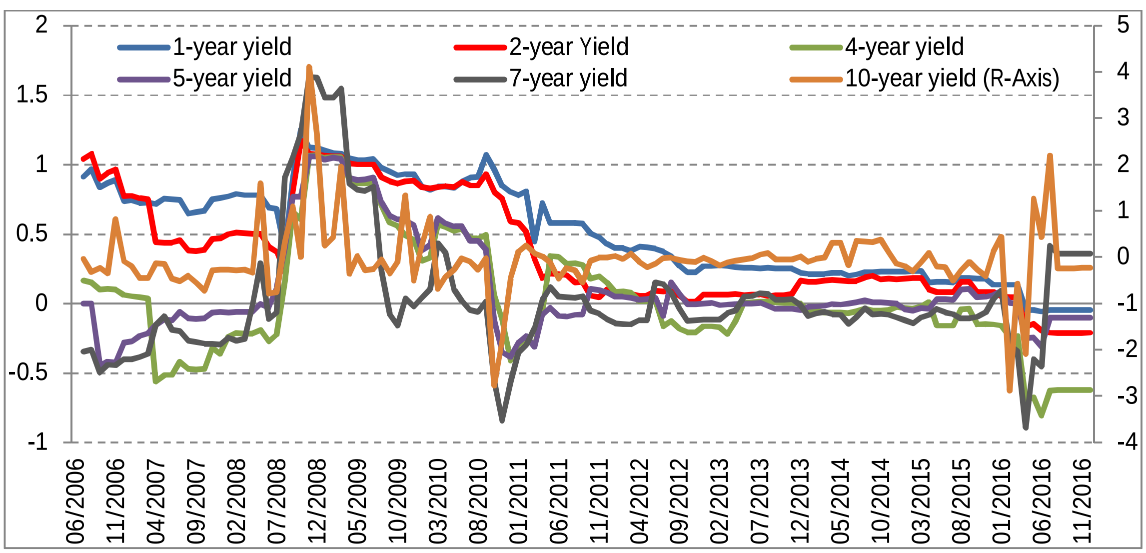
(f) TVP of 10-year yield and its lag

We also find that the impact is stronger on near term maturity as compared to the longer end of the maturity structure. This collaborates with the existing evidence (Marfatia, 2015) and the expectations theory of interest rate which suggest that the longer end of the yield curve is expected to have the least impact of a monetary policy action.

The TVP patterns presented in Figure 5 also suggest that the time variation in the impact of monetary policy is found to be present contemporaneously as well as in the lag. Furthermore, the lagged impact is stronger than contemporaneous impact of monetary policy action. One of the possible explanations to this could be the nature of financial system. In a relatively developing financial system, the realignment of interest rates across maturities happens with some delay. Such effects are revealed in the plots presented in Figure 5, where we find that the lagged coefficient is higher than the contemporaneous effects, though both reflect significant time variations.

To study the combined effects of monetary policy actions on each maturity, we also add the time-varying parameter estimates of the contemporaneous and lagged coefficient. These TVP estimates are plotted in Figure 6. Clearly, there is significant time variation in the combined effect of monetary policy actions. The pattern shows that in the pre-crisis period the impact of monetary policy was mainly positive for 1-year and 2-year maturity and negative for 4-, 5-, and 7-year maturities. But with the advent of the crisis, the impact on all the maturities spiked significantly. In fact, the effect was so pronounced that the monetary policy actions had one-to-one impact on the T-bills of all the maturities. The effects remained at elevated levels till 2011, after which the impact is found to slowly device across the term structure. Only recently in the 2016 period the longer end of maturity structure showed a spike.

Figure 6. Time-varying parameter estimates showing the combined effects on different bond maturities



6. Conclusions

In order to analyze the impact of monetary policy shocks on Treasury bond yields in Tunisia under a heterogeneous economic environment, we use a fixed coefficient approach as well as a time-varying parameter framework. Empirical results show that monetary policy actions do not exert significant impact on the entire spectrum of the yield curve. For the whole period 2006-2016, monetary policy is able to influence short-term and to lesser extent long-term Treasury yields, but not medium-term yields. This supports the existence of preferred maturities by markets participants. In a stable environment, before the revolution of 2011, the response of Treasury yields to monetary policy shocks is significant across all maturities. However, this response becomes insignificant for maturities more than one year for the post-revolution period marked by increasing external and fiscal imbalances, high level of economic uncertainty and political instability. The estimation of the time-varying parameter model shows wide time variation in the impact of monetary policy shocks on Treasury bond yields, albeit with more pronounced impact at the shorter end of the yield curve.

Our findings have important implications for policy makers. They highlight the desirability of more active monetary policy especially in turbulent environment. Thus, a more active role of the central bank to influence the yield curve mainly through Treasury bond purchases covering medium and long maturities may be warranted. Communication also needs to be reinforced to ensure predictability of the monetary policy stance. The aim of such initiatives is to improve the effectiveness of the monetary policy in influencing the entire term structure of interest rates and to provide greater support to the development of the domestic bond market. This latter depends significantly on the commitment of the government to issue securities regularly regardless the fiscal needs, to diversify the base of investors, and to promote a more liquid secondary market.

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