Monetary and Fiscal Policy Interactions in Turkey:
A Markov Switching Approach

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March 20, 2013

Abstract

Until recently, Turkey’s economy was characterized by high inflation, undisciplined public finance management and a fragile banking system and experienced multiple economic crises. After the economy was hit by another crisis in 2001, the central bank became independent, adopted Inflation Targeting as the monetary policy framework and implemented reforms to adopt a more stringent fiscal policy. Inflation rates decreased to single digit levels within three years after the independence of the central bank. This paper analyzes the end of the high inflation period in the context of monetary and fiscal policy interactions within a rational expectations model in which policy rules are allowed to switch between “active” and “passive” regimes. It is shown that after 2001 monetary policy experienced a switch to an “active” regime whereas fiscal policy experienced a switch to a “passive” regime - the conditions necessary for monetary policy to stabilize prices by preventing deficit shocks from affecting inflation.

JEL Classification: C59, E50, E58, E62, E63
Keywords: monetary and fiscal policy interactions, time-varying policy rules, Markov switching estimation, rational expectations models.

*I thank Professors Victor J. Valcarcel, Ronald Gilbert, Masha Rahnama and especially Salem Abo-Zaid for helpful comments. All remaining errors are mine. Correspondence: Department of Economics, Texas Tech University, TX. Email: semih.cekin@ttu.edu
1 Introduction

It has become widely accepted that an analysis of high inflation dynamics that neglects the possible role of fiscal policy can lead to inconclusive findings. As analyzed by Sargent (1982) and Sargent et al. (2009), an economy that suffers from an undisciplined fiscal sector can easily find itself in a situation where the role of the monetary authority is to accommodate the needs of fiscal authorities.

Similar to many other emerging economies during the 1990 decade, the Turkish economy was plagued by an undisciplined public finance management, a fragile banking sector, financial crises and perhaps most importantly by a non-independent central bank. The crisis year of 2001 constitutes a turning point as the central bank became formally independent, structural reforms were implemented to introduce a more stringent public finance management and prudential measures were introduced to strengthen the financial sector. Almost immediately after the central bank became independent and structural reforms were implemented, rates and volatilities of inflation and interest decreased to historically low levels.

This work seeks out to explain this success by modeling monetary and fiscal policy interactions in Turkey within the context of a rational expectations model in the spirit of Leeper (1991). Within this model simple Markov switching policy rules are used for the periods before and after the central bank became independent.

The model employed in this work extends Leepers (1991) original model in several directions: I impose a partial adjustment mechanism for the monetary policy rule and allow for a wider array of exogenous variables for the fiscal and monetary policy rules. The assumption of non-linear Markov switching policy rules also constitutes an extension that allows for richer analyses compared to linear specifications for the policy rules. In this process, stability and uniqueness conditions are provided for this new system that incorporates interest rate inertia.

There are several important findings: It is confirmed that it was a change in the interaction of monetary and fiscal policies that helped stabilize inflation successfully. It is shown that before 2001, a combination of passive monetary policy (MP) and active fiscal policy (FA) was mainly prevalent\(^1\) whereas after 2001, the interaction can be characterized by a combination of

\(^1\)The definitions of “active” and “passive” regimes follow Leeper (1991): monetary policy is active if the Taylor principle is satisfied and passive otherwise. Government policy is passive (or Ricardian) if taxes are increased enough in response to increasing debt-output ratio to cover interest payments and active (or non-Ricardian)
active monetary policy (MA) and passive fiscal policy (FP). I also provide the conditions for the existence and uniqueness of a solution for these combinations of MA/FP and MP/FA. It is shown that a combination of MA/FP corresponds to the case where inflation and interest rates are insulated from fiscal shocks and monetary policy is free to stabilize prices whereas a combination of MP/FA corresponds to the case where inflation and the interest rate are affected by fiscal shocks. These results have the important implication that in order to decrease inflation rates successfully, independency of central banks have to be accompanied by a disciplined fiscal sector.

This work is broadly connected to the literature of monetary and fiscal policy Interactions and it is specifically related to the subbranch of this literature that came to be known as the Fiscal Theory of the Price Level (FTPL). The literature on the subject of monetary and fiscal policy interactions goes back to the work of Sargent and Wallace’s (1981) ’Unpleasant Monetarist Arithmetic’. In this work, the authors postulate - under several assumptions - that the implementation of tight monetary policy can have counterintuitive results if the government is dependent on seigniorage as a revenue source and there is no adjustment of the budget surplus after seigniorage revenue falls. In this case, the price level is the only variable that can adjust to satisfy the government budget constraint and inflation is the result. Hence, a ’dominant’ fiscal authority can set the path for the inflation rate and inflation is not always and everywhere a monetary phenomenon as Friedman and Schwartz (1963) postulated two decades before. These findings are based on the “game of chicken” situation described in their paper in which neither the fiscal nor the monetary authority sees itself obligated to satisfying the present value budget constraint (PVBC) that the government faces. If, in this case, it is the monetary authority that is dominant, the fiscal authority will adjust the tax rate to satisfy the PVBC. If however it is the fiscal authority that dominates the situation described, it is the monetary authority that has to adjust seigniorage revenues to satisfy the PVBC that lies at the heart of SW’s argument. Specifically, the PVBC is described in its most simple form as

\[
\frac{B_t}{P_t} = b_t = PV(Seigniorage) + PV(GovernmentRevenue)
\]

where \(b_t\) is real government debt and \(PV(Seigniorage)\) is the present value of government revenues from seigniorage and \(PV(Government Revenue)\) is the present value of government otherwise.
revenues coming from tax revenues. As outlined above, the implication of this equation is that if the government is dominant and does not see itself obligated to satisfying the PVBC, the central bank has to adjust seigniorage revenues. If on the other hand, it is the central bank that dominates the situation, the government has to adjust government revenues upon changes in the seigniorage revenue to satisfy the PVBC.

The present work is also connected to arguably the most famous and probably controversial line of work that seeks a way out of Sargent and Wallace’s policy coordination problem. This theory - called the FTPL - was developed and put forward by Leeper (1991), Woodford (1994, 1995, 1996, 1998), Sims (1994, 1997), and Cochrane (1998, 2001, 2005) and shows how the price level reacts to changes of fiscal variables in a non-Ricardian environment. A Ricardian policy is defined as a situation in which the primary surplus responds positively to increasing levels of debt to satisfy the intertemporal budget constraint of the government. It is non-Ricardian for the opposite case. One of the crucial differences between the FTPL and Sargent and Wallace’s model is that for the former, the PVBC is assumed to be an equilibrium condition and not a binding constraint.

Arguably the first author who sought out to establish stability and uniqueness conditions within a rational expectations model characterizing the interaction of monetary and fiscal policies was Leeper (1991). Postulating simple rules for these policies, his work aimed at finding the set of reaction coefficients (interest rate on current inflation for the case of monetary policy and the reaction of tax rates in response to changes in real government debt for the case of the fiscal rule) that result in unique, locally stable solutions. Dubbing certain values of the response coefficients as “active” and “passive”, he argues that there exists a unique and locally stable solution only if there is a combination of either active monetary policy (MA) and passive fiscal policy (FP) or passive monetary policy (MP) and active fiscal policy (FA).

Taking the modeling one step further, Davig and Leeper (2006b, 2009) characterized the interaction problem using stochastically switching policy regimes for the period of post-WWII in the US. The estimates of policy reaction coefficients which obey Markov switching processes can again take the combinations described in Leeper (1991) - i.e. monetary active/fiscal passive (MA/FP), monetary passive/fiscal active (MP/FA), monetary passive/fiscal passive (MP/FP)

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2The term active goes back to Samuelson (1967)
or monetary active/fiscal passive (MA/FP). In order to test the plausibility of their estimated switching processes, they embed them into a DSGE model calibrated to U.S. data. Their findings confirm the idea that U.S. monetary and fiscal policies have fluctuated among active and passive rules.

There exists a broad literature that provided explanations on the persistent high inflation in Turkey for the pre-2001 period. Some studies that put forward explanations based on monetary fiscal interactions include but are not limited to, Yeldan (1993) - who employs a computable general equilibrium model, Insel (1995) - who employs a cointegration approach, Metin (1995, 1998) - who employs a multivariate cointegration approach, Akcay et al. (1997) - who employ a VAR and VECM approach. Recent analyses of monetary and fiscal policy interactions in Turkey include Aktas et al. (2010) where an extended Kalman filter is employed and Cebi (2011) who employs a New Keynesian DSGE model.

The current work adds to the literature by using Markov switching rules in the context of a rational expectations model on Turkey and by analyzing whether the conditions were present for monetary policy to stabilize prices without the effect of fiscal shocks for the pre- and post-2001 period. The remaining part of the paper is organized as follows: Section 2 provides a brief history of monetary and fiscal policy interactions, section 3 introduces the policy rule specifications to be estimated and discusses the results, section 4 demonstrates in a rational expectations model explicitly how policies interact and under which conditions a solution exists and finally, section 5 concludes.

2 History of Monetary Policy and its Interactions with Fiscal Policy in Turkey

The high inflation period started with the mid 1950’s and - with the exception of 1960-1971 - until 2004, inflation has always been at least at two digit rates. Average annual inflation rates reached about 20% in the second half of the 1950 decade, about 25% in the 1970 decade, about 50% in the 1980 decade and close to 80% in the 1990 decade. The emergence of inflation during the decades between 1950-1990 is mainly attributable to monetization of high budget deficits as

3According to the characterization in Leeper (1991), the combination MP/FP leads to sunspot equilibria whereas MA/FA regimes lead to explosive paths.
a result of inefficiently running State Economic Enterprises (SEEs), exchange rate devaluations and inflation inertia (see Krueger 1995, A. Kibritcioglu 2002). For the period of interest in this work - pre- and post-2001 - inflation levels can be categorized into two periods: the pre-2001 period with high rates and high volatility and the post-2001 period with relatively low rates and low volatility. Figure 1 depicts growth rates of M1 series and of gross public debt for the period of 1990-2012 for Turkey.

Figure 1: M1 vs. Public Debt

Sources: CBRT and Treasury

A visual inspection of this figure gives us hints on possible monetization of gross public debt for the pre-2001 period in Turkey. One can see that there is a high correlation between the two series which indicates - as the authors mentioned above postulate - a possible monetization of deficits and gross public debt.\footnote{One should note that the hike at the end of 2005 is due to a new definition of M1 which includes foreign denominated time deposits.}  

The Turkish economy in the 1990 decade was characterized by high inflation, a fragile banking...
sector, high budget deficits and general macroeconomic instability. Exhibiting already high numbers, the inflation rate hiked following the 1994 financial crisis and to tackle the inflation problem, Turkey started a stabilization program which became a stand-by agreement with the IMF. The major aim of this program was to stabilize public finances by increasing government revenues, decreasing spending and by introducing privatization reforms. These reforms however were halted by the political authority due to elections in 1995. Because of the lack of political will to tackle the inflation problem, inflation rates remained in the upper double digit levels. In 1998, another stand-by agreement was signed to solve this ongoing inflation problem but this program was again abandoned after the economy was hit by the devastating effects of the Russian financial crisis in 1998 and the 1999 earthquake. The early part of the year 2000 saw an initial recovery from the volatile period of the 1990 decade with increases in real GDP and decreases in inflation rates but at the end of 2000, in November, a small scale financial crisis hit the economy. This crisis was the result of fragility in the banking sector that came as a consequence of banks having portfolio losses and having problems with liquidity and finally the bankruptcy of a bank. The deterioration of confidence in the banking sector lead to massive outflows of capital which lead to interest rate hikes, stock market declines and depletion of central bank reserves.

IT was adopted after a severe financial crisis in February 2001 which emerged after the previously adapted fixed exchange rate regime had to be abandoned. The program of the IMF that was adopted at the end of 1999 aimed at disinflation based on exchange rates and monetary control by setting upper bounds on domestic asset positions. The commitment of the central bank of the Republic of Turkey (CBRT) foresaw a policy of no offset so that changes in the monetary base would be reflected in the net foreign assets. The next part of the program was the implementation of a flexible exchange rate system that was planned to start in summer 2007. Facing problems with the realization of structural reforms and the lack of confidence in the CBRT with regard to the commitment to the program, inflation expectations and the demand of investors and domestic banks for foreign exchange increased. The CBRT was no longer able to defend its parity because of the depletion of foreign reserves and the currency was allowed to float in February 2001.

Three years after the adaptation of IT (2004), (annual) inflation rates decreased to one digit

$^5$Parity = $1+€0.77$
levels - a situation unprecedented since the early 1970’s. Turkey’s case is particularly interesting since in April 2001, the CBRT was given formal independence with legislation. It was anchored in Central Bank Law that the CBRT is independent in choosing a monetary policy framework and is independent from other institutions in conducting monetary policy. It was also anchored that the primary objective of the CBRT is to achieve and maintain price stability. Figure 1 displays the movement of annualized inflation rates since 1975.

Figure 2: CPI Inflation in Turkey

The history of monetary and fiscal policy interactions in Turkey starts with the onset of World War II. According to its own accounts, the CBRT had relative independence in the conduct of monetary policy until the 1940’s. With the start of WWII, the adverse effects of the war necessitated the implementation of policies to offset the increasing public finance deficit. In the decades following the war, arguably the most significant change pertaining to the above mentioned interaction was established in 1970 with The Law on the Central Bank of the Republic of Turkey No. 1211. This law established the objectives of the central bank and brought significant changes to the legal status, organizational structure, duties and powers of the Bank. To limit fiscal dominance, the upper limit for short term advances to the Treasury was set at 15 percent.
This restriction was however eased by the newly formed government in 1993 and the accumulated debt owed to the central bank by the Treasury was canceled. As Celasun (1998) explains, the easing of the upper limit had the consequence that through an ‘annexed budget’ additional advances from the central bank were provided and within the first three weeks of 1994, more than half of the legal limit of short term advances were used up. These and other factors lead to the 1994 crisis where Turkey saw a 6% contraction of its economy.

Having experienced the results of an undisciplined fiscal sector, an amendment was added to the Central Bank Law, limiting the ability of the Treasury to use central bank funds. It was however not until 1997 that the use of short term advances was abolished - the Treasury and central bank agreed that from 1998 on there will be no short term advances from the central bank. Although policy makers tried to control fiscal spending, the effects of the Russian crisis in 1998, the election in 1999 and the devastating earthquake in the same year had the result of continuing high inflation rates for the rest of the decade. Turkey entered into a stand-by agreement with the IMF at the end of 1999 which was a disinflation program that saw to implement stringent fiscal policies and a wide array of structural reforms. Although the economy started recovering in the first half of the year 2000, a small scale banking crisis and a political crisis in the beginning of 2001 gave way to a deep crisis. It was after this crisis that the central bank gained formal independence and it was amended in the Central Bank Law that “the Bank shall not grant credit or advance to the Treasury and to the public sector. Nor shall it buy such institutions’ debt instruments in the primary markets”. This constituted a landmark for the interaction between the aforementioned policies and inflation rates fell to single digit levels shortly afterwards. Table 1 reports several key indicators for the public sector for the pre- and post-2001 period.

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Table 1: Key indicators for the Public Sector before and after 2001

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<td>Public Debt/GDP in %</td>
<td>62.4</td>
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<td>Domestic Debt/GDP in %</td>
<td>20.7</td>
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<td>External Debt/GDP in %</td>
<td>41.8</td>
<td>32.1</td>
<td>29.3</td>
<td>27.7</td>
<td>17.8</td>
<td>22.0</td>
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<td>PSBR/GDP in %</td>
<td>4.6</td>
<td>3.7</td>
<td>6.5</td>
<td>5.8</td>
<td>7.1</td>
<td>11.6</td>
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<td>Primary Surplus/GDP in %</td>
<td>3.8</td>
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<td>1.8</td>
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<tr>
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<td>Domestic Debt/GDP in %</td>
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<td>External Debt/GDP in %</td>
<td>26.7</td>
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<td>PSBR/GDP in %</td>
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<td>Primary Surplus/GDP in %</td>
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<td>3.1</td>
<td>1.6</td>
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Sources: Treasury, State Planning Organization and author’s own calculations

The evolution of the numbers is revealing about a possible change in public finance management. One can see that for the period before 2001, public finance variables either remained relatively steady or saw a deterioration. After reaching a peak in deterioration in 2001, for a period of almost seven years after 2001, all key variables saw an improvement: public sector debt as a ratio to GDP declined along with Public Sector Borrowing Requirements (PSBR) whereas primary surplus reached high numbers that lasted until the effects of the Great Recession in 2008 took effect. In fact, one of the reasons that the rating agency Fitch mentioned for its 2012 upgrading of Turkey’s investment grade after 18 years was the moderate and declining government debt burden. Understanding that the independence of the central bank was accompanied with a more stringent public finance management raises the natural question of whether this change in the interaction of both policies played a role in ending the high inflation period that lasted for more than three decades. The next section will introduce the policy rule specifications to be estimated.
3 Policy Rule Specifications

3.1 Monetary Policy

The use of simple policy rules for the characterization of monetary policy is a common practice. Amongst these rules, arguably the most famous and widely used is the Taylor rule which was named after its proponent John B. Taylor (1993). Over the years, the Taylor rule has been acclaimed and criticized by researchers to an almost equal extent. The most simple form of this rule suggested by Taylor’s original paper postulates a reaction function for the short term policy instrument of the central bank where the rule reacts to deviations of inflation from its targeted value and to deviations of real output from its potential level. In his original essay, Taylor did not econometrically estimate the coefficients but made suggestions on the magnitudes instead. According to him, setting the equilibrium real interest rate and the inflation target to 2 percent and assigning the value 0.5 for the reaction coefficients on inflation gap and output gap respectively is a close enough approximation of the actual behavior of the Federal Reserve. Taylor does however also point out that his rule is not necessarily meant to be a fixed setting for policy instruments or a mechanical formula.

In this section, a policy rule of the following form will be estimated:

\[ i_t^* = r_t^* + \phi_\pi (\pi_t - \pi_t^*) + \phi_y y_t + \phi_e \Delta e_t, \]  

(1)

where

- \( i_t^* \) is the targeted short term nominal interest rate,
- \( \pi_t \) is the CPI inflation rate at time \( t \),
- \( \pi_t^* \) is targeted inflation at each state,
- \( \Delta e_t \) is the first difference of log exchange rates
- \( y_t \) is the output gap,
- \( \phi_\pi \) is the reaction coefficient of short term interest rates on the inflation gap,
- \( \phi_y \) is the reaction coefficient of short term interest rates on output gap,
- \( \phi_e \) is the reaction coefficient of short term interest rates on exchange rates,
- \( r_t^* \) is the nominal interest rate when output gap and inflation gap are zero.

Some researchers claim that a rule of the above form describes actual policy making only
incompletely. Goodfriend (1991), Clarida et al. (1998, 2000) and Woodford (1999) argue that instead, central banks set interest rates following a partial adjustment mechanism of the following form:

$$i_t = (1 - \rho_1 - \rho_2) i_t^* + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \nu_t^i. \quad (2)$$

where

$$\rho_i \in [0, 1]$$

is the smoothing parameter or degree of policy inertia, 

$$\nu_t^i$$

is an i.i.d. random exogenous Gaussian shock to $$i_t$$.

Explanations put forward in the literature for the partial adjustment behavior include avoiding a loss of credibility in markets from sudden changes in policy and disruptions of capital markets. Cebi (2011) finds that this type of smoothing mechanism can be justified for the case of Turkey estimating a significant coefficient for the smoothing coefficient in a New Keynesian DSGE setup. Adopting this mechanism, combining equations (1) and (2) and rearranging terms results in the following equation:

$$i_t = (1 - \rho_1 - \rho_2) [r^* + \phi_\pi (\pi_t - \pi^*) + \phi_y y_t + \phi_e \Delta e_t] + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \nu_t^i. \quad (3)$$

With a slight rearrangement of terms, we end up with the following equation to estimate:

$$i_t = a + (1 - \rho_1 - \rho_2) [\phi_\pi \pi_t + \phi_y y_t + \phi_e \Delta e_t] + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \nu_t^i, \quad (4)$$

with

$$a = (1 - \rho_1 - \rho_2)[r^* - \phi_\pi \pi^*].$$

This type of formulation is convenient since it allows us to avoid making assumptions about the equilibrium rate of real interest rate or the inflation target. Instead, they will be isolated and estimated as a constant. A drawback of this approach may be that in reality, inflation targets vary which the model does not take into account explicitly.

### 3.1.1 Exchange Rates

As argued by Ball (1999) and Svensson (2000), traditional Taylor rules will obtain suboptimal results for small open economies unless modified to include exchange rates. Ball (1999) justifies this argument by showing that there is a channel through which domestic inflation is affected by exchange rates separable from domestic demand and supply shocks. The possibility
of intertemporal and intratemporal trade for the purpose of consumption smoothing is more available for open economies than it is for their closed counterparts. In addition to this, foreign shocks, such as terms of trade shocks, which are more relevant for open economies, can influence and induce domestic business cycle fluctuations. This in return may lead monetary authorities to take into account international variables explicitly. In order to assess the validity of this argument, Lubik and Schorfheide (2007) analyzed the behavior of central banks by asking the question of whether central banks react to exchange rates. Their analysis, which focuses on Australia, Canada, New Zealand and the UK suggests that the central banks of Canada and the UK do indeed respond to the nominal exchange rate. Following these authors and Kam et al. (2009) who confirm the findings of Lubik and Schorfheide (2007), the inclusion of nominal exchange rates is perceived to be appropriate for the case of Turkey.

### 3.1.2 Markov Switching Framework

The emergence of Markov Switching models is largely related to the natural need to model time series that exhibit breaks or shifts in their means. Financial time series, National Account statistics and monetary policy variables are only a small number of popular time series that potentially fit into this category. The dramatic changes to monetary policy variables in Turkey potentially necessitate the use of non-linear time series modeling and Markov Switching frameworks are natural candidates for this purpose.

A Markov Chain is defined as a process which satisfies the following condition:

\[ P\{S_{t+1} = j \mid S_t = i_t, S_{t-1} = i_{t-1}, S_1 = i_1, S_0 = i_0\} = P\{S_{t+1} = j \mid S_t = i_t\} = p_{ij}. \]

This condition defines the Markov chain as a process \( \{S_t, t = 0, 1, \ldots\} \) that takes a finite number of integer values denoted by \( i, j \). Furthermore, the conditional distribution of any future state \( S_{t+1} \) is independent of the past states and only dependent on the present state given the past states \( S_0, S_1, \ldots, S_{t-1} \) and the present state \( S_t \). \( p_{ij} \) is called the transition probability from \( i \) to \( j \) and is defined as the probability that when the preceding state is \( i \), the next state will be \( j \). Assuming there are \( N \) states, the matrix that summarizes all transitions - the transition matrix - can be expressed as:
\[ P = \begin{bmatrix}
    p_{11} & p_{12} & \cdots & p_{1N} \\
    p_{21} & p_{22} & \cdots & p_{2N} \\
    \vdots & \vdots & \ddots & \vdots \\
    p_{N1} & p_{N2} & \cdots & p_{NN}
\end{bmatrix} \]

In addition, the following is satisfied for all probabilities:

\[ \sum_{j=1}^{N} p_{ij} = 1, \quad \text{and} \quad p_{ij} \geq 0 \quad \text{for} \quad i = 1, 2, \ldots, N. \]

Standard references for the technical details of Markov Switching models are Hamilton (1989, 1990 and 1994). The estimation of Markov chain regime switching models is achieved by a process called filtering. This process takes conditional probabilities of current states as input, passes these through the transition probability matrix and produces the conditional probabilities of future states as output. The estimates of parameters are then obtained after calculating the conditional likelihood function.

Markov Switching (MS) models were introduced to Econometrics by the work of Goldfeld and Quant (1973) and popularized by Hamilton (1989). The use of MS frameworks for the modeling of monetary policy has applications for the case of U.S. such as Sims and Zha (2006) and Davig and Leeper (2005, 2009), for the case of Switzerland - Perruchoud (2009) and for the case of Brazil - Lima et al. (2007). There is a relatively small number of applications of Markov switching models to Turkey. These works mainly focus on the modeling of business cycles as with Tastan and Yildirim (2008) and Ozun and Turk (2009). An application that is close to the present work is Chen (2004) but his work focuses on the relation between nominal interest rates and exchange rates whereas the present work seeks to model monetary policy behavior. Hence, to my knowledge, this work is the first application of Markov Switching Regimes on the modeling of Turkish monetary policy.

Taking the formulation in (4), the following Markov Switching Taylor rule is considered:

\[ i_t = a_{S_t} + (1 - \rho_{1,S_t} - \rho_{2,S_t}) [\phi_{\pi,S_t} \pi_t + \phi_{y,S_t} y_t + \phi_{e,S_t} \Delta e_t] + \rho_{1,S_t} i_{t-1} + \rho_{2,S_t} i_{t-2} + \nu_{t,S_t}, \quad (5) \]
where
\[ a_{S_t} = (1 - \rho_{1,S_t} - \rho_{2,S_t})[r^* - \phi_{\pi,S_t} \pi^*], \]
\[ S_t \in 1, 2, \ldots, T \] is the prevailing regime at time \( t \),
\[ \nu_{t,S_t} \sim N(0, \sigma_{\nu_{t,S_t}}^2) \] is an i.i.d. random exogenous Gaussian shock to \( i_t \) whose variance is also switching.

As Hamilton (1994) explains, a likelihood-ratio hypothesis is not testable for the selection of the number of regimes since one of the regularity conditions fails to hold \(^6\). Hence, the number of regimes and lags in the above specified version of the model were selected mainly due to Akaike Information Criterion (AIC) suggestions. AIC suggests that a model with four regimes and two lags for the interest rate results in a better model fit. However, in order to assess its plausibility and utilize its implications, a two regime specification will also be estimated. Following Sims and Zha (2006), who argue that a heteroscedastic error term is essential in fitting time series, the variance also is allowed to switch between states. Allowing the variance to switch also enables us to understand whether there has been a significant reduction in the volatility of interest rates - a desirable characteristic of monetary policy making.

### 3.2 Fiscal Policy


Especially since the recent Euro crisis, the importance of fiscal considerations have once more become apparent. Fiscal rules have been implemented by political authorities for many years by many countries. There is however a wide dispersion on how these rules are implemented. As explained by Wyplosz (2012) they can take the form of rules that set upper limits on debt levels, government spending and the balanced budget or impose lower limits on tax revenues or combine some of these features. These rules mainly have the goal to achieve fiscal discipline and

\(^6\) In order to have an asymptotic \( \chi^2 \) distribution for the likelihood ratio test, the information matrix has to be nonsingular.
are in some cases (e.g. Argentina, Brazil, Columbia or Ecuador) associated with sanctions for failing proper implementation. According to the IMF (2009) there were by 2009 80 countries globally that implement some type of national or supranational fiscal rule.

In this section, two specifications will be estimated. The first specification considers an extension of the original fiscal rule of Leeper (1991) which is also considered in Davig and Leeper (2006b). Here the tax-output ratio is regressed on government spending, the output gap and lagged debt. According to this specification government policy is passive (or Ricardian) if taxes are increased enough in response to increasing debt-output ratio to cover interest payments and active (or non-Ricardian) otherwise.

The second specification follows Bohn (1998) who modeled the behavior of U.S. public deficits for the post-WWI period relating primary surplus to lagged debt and other variables. Bohn used this specification to analyze whether U.S. Fiscal policy historically acted in a Ricardian or non-Ricardian fashion. According to his analysis, post-WWI fiscal policy is characterized by a Ricardian policy and hence, there is a strong enough positive response by the primary surplus to satisfy the government constraint. It is appealing to use Bohns specification to analyze fiscal policy in Turkey for the period between 1994 and 2012 and understand whether fiscal policy was Ricardian in nature or not. It is appealing because it is important to understand whether the fiscal authority has become more disciplined, i.e. more reactive/responsive to increases in public debt by adjusting revenues and/or spending to generate primary surplus after 2001. Considering the primary surplus response as an indicator is meaningful for this purpose since increases in the primary budget surplus cause the stock of debt to decrease and hence allow the fiscal authority to pay off part of the debt. This is also in line with the IMF which uses the primary surplus as an indicator for fiscal effort (IMF 1994). This specification and its results are independent of the rational expectations model used in section 4 and serve as a robustness check for the first fiscal rule considered.
3.2.1 Extended Fiscal Rule of Leeper (1991)

As mentioned above, the first specification used in this section extends the original specification of Leeper (1991) by including an output gap and a government spending term and by allowing the rule to switch between regimes. It takes the following form:

\[
\tau_t = \gamma_0 S_t + \gamma_b b_{t-1} + \gamma_y y_t + \gamma_g g_t + \nu_{t,S_t},
\]

where \(\tau_t\) represents tax revenues after transfers for the central government, \(b_{t-1}\) lagged public debt, \(y_t\) the deviation of real output from its potential level (output gap) and \(g_t\) government spending. All variables are expressed as ratios to current GDP. The model allows for two states and four states, respectively. \(S_t\) is the prevailing regime and follows a Markov chain with a transition matrix for the two and four states, respectively. \(\nu_{t,S_t} \sim N(0,\sigma_{\nu_{t,S_t}}^2)\) is an i.i.d. random exogenous Gaussian shock to \(\tau_t\) whose variance is also switching.

A specification of the type as described in eq.(6) is convenient because its implications regarding the uniqueness of the rational expectation model will be used in this work and because it is perceived to capture the main channels for fiscal policy behavior. The definitions of active and passive regimes follow Leeper (1991) who calls a regime passive when there is a strong enough response of the tax-output ratio in response to an increase in lagged debt whereas an active regime is defined as the case where there is not a response that is enough to cover interest payments on lagged debt. Specifically, an active regime fiscal regime is present whenever \(|\beta^{-1} - \gamma| > 1\) whereas a passive fiscal regime is present whenever \(|\beta^{-1} - \gamma| < 1\). The Akaike Information Criterion (AIC) suggests that a four regime specification results in the best model fit. Therefore, a four regime specification is also estimated. The results on the estimation of Eq. (6) with two and four regimes respectively are reported in tables 4 and 5.

3.2.2 Extended Fiscal Rule of Bohn (1998)

The second specification in this section takes following form:

\[
PS_t = \theta_0 + \theta_b b_{t-1} + \theta_G GVAR_t + \theta_Y YVAR_t + \delta_t.
\]

In the original specification of Bohn (1998), \(b_{t-1}\) is lagged public debt, \(GVAR_t\) the temporary deviation of government expenditures from its trend level as a ratio to GDP and \(YVAR_t\) is a measure of business cycle fluctuations defined by the deviation of unemployment rate from its
natural level multiplied by the trend level of government expenditures as a ratio of GDP. The specification utilized in this subsection deviates from Bohns original strategy in that it allows for an autoregressive term, defines $YVAR_t$ using the output gap and utilizes a Markov Switching methodology in contrast to a linear specification. Both $GVAR_t$ and $YVAR_t$ are measured using the Hodrick-Prescott filter. The inclusion of these changes results in the following specification to be estimated:

$$PS_t = \theta_{0,S_t} + \theta_{PS,S_t} PS_{t-1} + \theta_{b,S_t} b_{t-1} + \theta_{G,S_t} GVAR_t + \theta_{Y,S_t} YVAR_t + \delta_{t,S_t}.$$  

(8)

The sample period covers 1994 Q1 to 2012 Q1 and results are reported in Table 6.

3.3 Data

For the estimation of Eq. (5), the data used has quarterly frequency and covers the interval of 1988:Q2 through 2012:Q1. For the short term policy rate of the CBRT, the overnight interbank borrowing is used. Output gap was retrieved by applying the Hodrick-Prescott filter on real GDP series that was taken from the International Financial Statistics (IFS) database of the IMF. Finally, the annualized CPI series and nominal exchange rates were taken from IMFs International Financial Statistics (IFS) database.

For the estimation of equations (6) and (8), data was used that has quarterly frequency and covers the period between 1994:Q1 and 2012:Q1. Central government data for net tax revenues after transfers and government spending was retrieved from the General Directorate of Public Accounts of the Ministry of Finance. Data on public debt comes from both the Ministry of Finance and the Central Bank of Republic Turkey’s statistical database. Appendix A.2 gives more detail on the characteristics of the data. An important note here is that unit root tests cannot reject the existence of a unit root for the CPI series. This is perceived to be due to the low power of unit root tests as the same tests cannot reject the hypothesis of stationarity for the highly correlated overnight interest rate series.
### 3.4 Results

#### 3.4.1 Estimation Results for the Monetary Policy Rule

Table 2: Two Regime Markov Switching Model for Eq. (5)

<table>
<thead>
<tr>
<th>Parameter/Regime</th>
<th>Regime 1</th>
<th>Regime 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>0.04***</td>
<td>0.39**</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>0.86***</td>
<td>−0.14</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.32)</td>
</tr>
<tr>
<td>$\phi_y$</td>
<td>0.08</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>$\phi_e$</td>
<td>−0.20</td>
<td>3.38***</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>0.35***</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>$\rho_2$</td>
<td>0.14</td>
<td>−0.04</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Std. Deviation (×10^{-2})</td>
<td>3.81***</td>
<td>24.44***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>AIC</td>
<td></td>
<td>−1.67</td>
</tr>
<tr>
<td>Log-Likelihood</td>
<td></td>
<td>93.5</td>
</tr>
</tbody>
</table>

*a (*) (**) (***) denote significance at 1%, 5%, 10%, respectively.

b ML-Estimation: EM Filter.
Figure 3: Regime 1 Probabilities ($\phi_\pi = 0.86$)

Figure 4: Regime 2 Probabilities ($\phi_\pi = -0.14$)
Figure 5: Actual vs. Fitted series
Table 3: Four Regime Markov Switching Model for Eq. (5)

<table>
<thead>
<tr>
<th>Parameter/Regime</th>
<th>Regime 1</th>
<th>Regime 2</th>
<th>Regime 3</th>
<th>Regime 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>0.05</td>
<td>0.16***</td>
<td>−0.005</td>
<td>−6.11***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.04)</td>
<td>(0.004)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\phi_x$</td>
<td>0.45***</td>
<td>0.62***</td>
<td>1.12***</td>
<td>1.92***</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.06)</td>
<td>(0.24)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\phi_y$</td>
<td>−0.18</td>
<td>0.03</td>
<td>1.04***</td>
<td>−1.71***</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.1)</td>
<td>(0.2)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\phi_e$</td>
<td>0.12*</td>
<td>0.12</td>
<td>0.03</td>
<td>8.04***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.18)</td>
<td>(0.19)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>−0.03</td>
<td>0.27***</td>
<td>0.66***</td>
<td>2.00***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\rho_2$</td>
<td>0.23**</td>
<td>−0.04*</td>
<td>0.21***</td>
<td>−7.63***</td>
</tr>
<tr>
<td></td>
<td>(0.1)</td>
<td>(0.02)</td>
<td>(0.04)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

| Std. Deviation ($\times 10^{-2}$) | 4.39*** | 5.39*** | 1.36*** | 0.00 |
|                                   | (0.01)  | (0.007) | (0.002) | (0.00) |

| AIC                             | −3.79   |
| Log-Likelihood                  | 214.19  |

$^a$ (*), (**) and (***) denote significance at 1%, 5%, and 10%, respectively;

$^b$ ML-Estimation: EM Filter
Figure 6: Regime 1 Probabilities ($\phi_\pi = 0.45$)

Figure 7: Regime 2 Probabilities ($\phi_\pi = 0.62$)
Figure 8: Regime 3 Probabilities ($\phi_{\pi} = 1.12$)

Figure 9: Regime 4 Probabilities ($\phi_{\pi} = 1.92$)
The estimation results for the two regime and four regime specifications give a slightly different account of monetary history of Turkey in the last two decades. Although the two regime specification is able to capture two distinct regimes with a relatively weak and a relatively strong response coefficient, the regime with a strong response (Regime 1) does not satisfy the Taylor’s principle with a coefficient of 0.86. As mentioned above, this is perceived to be a result of an aggregation of distinct regimes. In contrast to the two regime specification, the four regime specification is able to capture two distinct regimes with different implications. There are broadly two periods - namely the period in which the Taylor principle is not satisfied (i.e. monetary policy is destabilizing with $\phi_\pi < 1$) and the period in which it is satisfied (i.e. monetary policy is stabilizing with $\phi_\pi > 1$).

As one can see for both the two and four regime specifications, prior to 2001, there have been periods where both regimes were prevalent. For the period after 2001 however, it can clearly be seen that only a stabilizing regime is in place. For the four regime specification, the two regimes that correspond to a passive or non-stabilizing monetary policy - regimes one and two - are mostly prevalent during the period prior to 2001. As described in the introduction and outlined by Celasun (2002) this period is characterized by undisciplined public spending, dependency on
short term foreign capital inflows and a fragile financial system. It is also the period in which the CBRT did not have formal independence.

Accordingly, the reaction coefficient on inflation is characterized by a coefficient that does not satisfy the Taylor principle (with 0.45 and 0.62 in the four regime specification). At the same time, the pre-2001 period involves intervals in which the coefficient exhibits the highest reaction out of the estimated parameters. This seemingly contradictory finding is explained by the fact that Turkey experienced foreign shocks (such as the Asian crisis in 1997 and the Russian crisis of 1998) and currency crises during this period that necessitated substantial increases in the interest rate. The prevalence of Regime 4 for the period between March 1994 - July 1995 is a result of the 1994 crisis which resulted from fiscal imbalances and an outflow of foreign capital (DPT 1997). The prevalence of Regime 4 for the period between June 1997 and August 1998 is attributable to the Russian and Asian crises which had the effect of capital outflow for Turkey. The last period in which Regime 4 prevailed falls into the period between January 2000 and March 2001 where the 2001 crisis occurred. The fact that almost the entire period after September 2001 is characterized by Regime 2 confirms the idea that the formal independence of the CBRT materialized itself into an “active” monetary policy. A closer look at the standard deviation in the prevailing regimes also reveals important information regarding the volatility of interest rates. As one would suspect, the regime that captures the crisis periods - Regime 4 - also exhibits the highest volatility. This regime is followed by the two regimes that correspond to a non-stabilizing monetary policy - Regime 1 and Regime 2. The lowest volatility is exhibited by Regime 3 which is also the regime that corresponds to a stabilizing monetary policy and successful decrease in the inflation and interest rate.

3.4.2 Estimation Results for the Fiscal Policy Rules

After observing that monetary policy did experience a change after 2001, results on the estimations of fiscal policy rules are reported. The following table reports the Markov switching regime estimations for the extended fiscal policy rule of Leeper (1991) that relates tax revenues to lagged public debt and other variables.
The results in Table 4 are illustrative since the passive regime is characterized by a significant positive response of the tax/output ratio to an increase in lagged public debt. The active regime is characterized by a positive response, too, but this coefficient is small implying that the government’s response is not greater than most estimates for the real interest rate for the pre-2001 period. Hence, as one would expect from an active regime, there is not a strong enough increase or decrease of the tax/output ratio to changes in lagged public debt. As one can see from the output gap response coefficient, taxes rise systematically with the output gap. But both with the output gap coefficient and the government spending coefficient, significance is given only for the passive regime on the 10% level. Figures 11 and 12 show the regime probabilities for the two regime specification for Eq. (6) of being in an active and passive regime, respectively. It is interesting to see that although there is a switch to a passive fiscal regime in the critical period right after 2001, this switch does not last for a very long period of time.
Figure 11: Passive Regime Probabilities ($\gamma_b = 0.13$)

Figure 12: Active Regime Probabilities ($\gamma_b = 0.05$)
Figure 13: Actual vs. Fitted series

Table 5: Four Regime Markov Switching Model for Eq. (6)

<table>
<thead>
<tr>
<th>Parameter/Regime</th>
<th>Regime 1</th>
<th>Regime 2</th>
<th>Regime 3</th>
<th>Regime 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_0$ (Constant)</td>
<td>0.04***</td>
<td>0.07***</td>
<td>0.07</td>
<td>0.06***</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>$\gamma_b$</td>
<td>0.10***</td>
<td>0.05***</td>
<td>0.04***</td>
<td>0.05**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.001)</td>
<td>(0.004)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>$\gamma_y$</td>
<td>0.02*</td>
<td>0.002</td>
<td>0.01**</td>
<td>-0.08</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>$\gamma_g$</td>
<td>-0.03***</td>
<td>-0.004</td>
<td>0.08***</td>
<td>0.16***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.06)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Std. Deviation ($\times10^{-2}$)</td>
<td>0.63***</td>
<td>0.2***</td>
<td>0.16***</td>
<td>0.89***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0003)</td>
<td>(0.0002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>AIC</td>
<td></td>
<td></td>
<td>-5.63</td>
<td></td>
</tr>
<tr>
<td>Log-Likelihood</td>
<td></td>
<td></td>
<td>225.11</td>
<td></td>
</tr>
</tbody>
</table>

(*), (**) and (***) denote significance at 1%, 5%, and 10%, respectively.
Table 5 gives the estimation results on the four regime specification for eq. (6) that - according to AIC - results in a better model fit.

The four regime specification is also illustrative and finds a strong lagged debt reaction coefficient in regime 1 that - as can be seen in Figure 14 - seems to appear significantly after 2001 for the first time. The response coefficients again imply that in the passive regime the government was responsive enough to increases in public debt to cover the real interest rate. The duration of this regime also appears to be longer in the four regime specification. It is also interesting to see that a significant prevalence of the remaining regimes occurs only for the pre-2001 period. The only exception is the prevalence of regime 4 after 2005 - a period in which interest rates decreased to significantly lower levels compared to the beginning of the decade. Similar to the three equation specification, all significant response coefficients on output gap and government spending are positive.

Figure 14: Regime 1 Probabilities ($\gamma_b = 0.10$)
Figure 15: Regime 2 Probabilities ($\gamma_b = 0.05$)

Figure 16: Regime 3 Probabilities ($\gamma_b = 0.04$)
The following table reports estimation results for eq. (8) which regresses the primary surplus
on the variables lagged public debt, the deviation of government spending from its natural level and the output gap. As expected, two distinct regimes are estimated where the first regime has an estimated coefficient that is negative and only significant on the 10% level. This regime corresponds to a non-Ricardian regime, since the government does not react positively to increases of public debt. In contrast to this, the second regime has an estimated response coefficient of 0.25 and this corresponds to a strong positive response to increases in public debt. Correspondingly, the regime is the Ricardian regime in which the government displays a fiscally disciplined behavior. This result supports the estimation results of eq. (6) which also implied that after 2001 the fiscal authority became more disciplined.

Table 6: Two Regime Markov Switching Model for Eq. (8)

<table>
<thead>
<tr>
<th>Parameter/Regime</th>
<th>Regime 1 (non-Ricardian)</th>
<th>Regime 2 (Ricardian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_0$ (Constant)</td>
<td>$-0.01^{***}$</td>
<td>$0.055^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>$\theta_b$</td>
<td>$-0.09^*$</td>
<td>$0.25^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>$\theta_{PS}$</td>
<td>$0.28^{***}$</td>
<td>$-0.34^*$</td>
</tr>
<tr>
<td></td>
<td>(0.1)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>$\theta_G$</td>
<td>$-0.81^{***}$</td>
<td>$-0.86^{**}$</td>
</tr>
<tr>
<td></td>
<td>(0.1)</td>
<td>(0.39)</td>
</tr>
<tr>
<td>$\theta_Y$</td>
<td>0.03</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Std. Deviation ($\times 10^{-2}$)</td>
<td>1.28^{***}</td>
<td>2.66^{***}</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>AIC</td>
<td>-4.32</td>
<td></td>
</tr>
<tr>
<td>Log-Likelihood</td>
<td>162.90</td>
<td></td>
</tr>
</tbody>
</table>

(*), (**), and (***) denote significance at 1%, 5%, and 10%, respectively.

Figures 19 and 20 plot the probabilities of being in a Ricardian and non-Ricardian regime respectively. Figure 21 plots actual vs. fitted series of primary surplus to GDP ratio. As can be seen clearly by Figure 20, there is a switch to a Ricardian regime around 2000 whereas
before that period, government policy can mainly be characterized as non-Ricardian. Hence the results reinforce the claim of the results of the first specification that fiscal policy became more disciplined and reacted strong enough to stabilize the government budget after 2001 whereas before 2001, fiscal policy was not responsive to increases in public debt. As one would expect, the coefficient on the temporary deviation of government expenditures from its trend level exhibits a negative number. Hence, primary surplus is decreased whenever government expenditures deviate positively from the trend level. Again, as expected, the coefficient on the output gap is positive implying that a positive output gap implies increases in the primary surplus whereas with a negative output gap the opposite is the case. This coefficient however is insignificant for the Non-Ricardian regime and significant for the Ricardian regime only at the 10% level.

Figure 19: Non-Ricardian Regime Probabilities ($\theta_b = -0.09$)
Figure 20: Ricardian Regime Probabilities ($\theta_b = 0.25$)

Figure 21: Actual vs. Fitted series
4 Monetary and Fiscal Policy Interactions in a Simplified Rational Expectations Model

The previous sections estimated monetary and fiscal policy rules without explicitly demonstrating how these policies interact. The purpose of the following section is to demonstrate this explicit interaction within a rational expectations model and provide conditions for the stability of the resulting system. For this purpose, the original model of Leeper (1991) is extended in several directions: in contrast to the monetary policy rule that Leeper utilized in his model, a partial adjustment mechanism for the monetary policy rule is imposed and a wider array of exogenous variables for the fiscal and monetary policy rules are allowed for. The assumption of non-linear Markov switching policy rules is not explicitly included in this section although the results and implications of the Markov switching estimation results are utilized in the stability analysis of the system.

The economy in this setup is populated by a representative consumer who lives infinitely and derives utility from consumption and real balance holdings. Correspondingly, the consumer chooses consumption, real balances and real bond holdings \((c_t, m_t, b_t)\) to maximize

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log(c_t) + \log(m_t) \right],
\]

subject to

\[
c_t + m_t + b_t + \tau_t = \hat{y} + m_{t-1} \frac{1}{\pi_t} + i_{t-1} b_{t-1} \frac{1}{\pi_t}, \tag{9}
\]

where \(\beta \in (0,1)\) is the discount factor, \(\hat{y}\) is endowment of the consumer, \(R_t\) is the nominal interest rate earned from bond holdings and \(\tau_t\) are units of the consumption good paid in direct taxes. It should further be noted that small letters correspond to real variables (i.e. \(b_t = B_t/p_t, m_t = M_t/p_t\) etc.) and that \(\pi_t = p_t/p_{t-1}\). Solving for the first order conditions of this maximization problem and rearranging result in the budget constraint along with the Fisher and money demand equations:

\[
\frac{1}{i_t} = \beta E_t \left\{ \frac{1}{\pi_{t+1}} \right\}, \tag{10}
\]

\[
m_t = c \frac{i_t}{i_t - 1}. \tag{11}
\]
The government faces the following aggregate resource constraint:

\[ b_t + m_t + \tau_t = g_t + m_{t-1} \frac{1}{\pi_t} + i_{t-1} b_{t-1} \frac{1}{\pi_t}, \tag{12} \]

which states that it uses revenues from seigniorage, taxes and debt issuing to finance the level of purchases.

The modeling of monetary policy follows the extended Taylor rule that was introduced in section 3.1 which allows for a second order partial adjustment mechanism similar to Clarida et al. (1998):

\[ i_t = a + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \phi_\pi \pi_t + \phi_y y_t + \phi_e \Delta e_t + \nu_t^i, \tag{13} \]

where

\[ a = (1 - \rho_1 - \rho_2) [r^* - \phi_\pi \pi^*], \]
\[ \phi_\pi = (1 - \rho_1 - \rho_2) \phi_\pi, \]
\[ \phi_y = (1 - \rho_1 - \rho_2) \phi_y, \]
\[ \phi_e = (1 - \rho_1 - \rho_2) \phi_e, \]

and

\[ y_t = \xi_1 y_{t-1} + \epsilon_{1t}, \quad |\xi_1| \leq 1, \quad \epsilon_{1t} \sim N(0, \sigma_y^2), \]
\[ \Delta e_t = \xi_2 \Delta e_{t-1} + \epsilon_{2t}, \quad |\xi_2| \leq 1, \quad \epsilon_{2t} \sim N(0, \sigma_e^2), \]
\[ \nu_t^i = \xi_3 \nu_{t-1}^i + \epsilon_{3t}, \quad |\xi_3| \leq 1, \quad \epsilon_{3t} \sim N(0, \sigma_{\nu_i}^2). \]

Fiscal policy behavior takes the form of the tax rule in section 3.2.1 where the ratio of taxes to output responds to government debt, the output gap and government spending:

\[ \tau_t = \gamma_0 + \gamma_b b_{t-1} + \gamma_y y_t + \gamma_g g_t + \nu_t^\tau, \tag{14} \]

where

\[ g_t = \xi_4 g_{t-1} + \epsilon_{4t}, \quad |\xi_4| \leq 1, \quad \epsilon_{4t} \sim N(0, \sigma_g^2), \]
\[ \nu_t^\tau = \xi_5 \nu_{t-1}^\tau + \epsilon_{5t}, \quad |\xi_5| \leq 1, \quad \epsilon_{5t} \sim N(0, \sigma_{\nu_\tau}^2). \]

It is assumed that the innovations to the policy shock are serially uncorrelated.
4.1 Linearized System and Stability Analysis

In order to obtain a system, I will first reduce this model to a recursive system in the nominal interest rate and real debt. Variables with a tilde correspond to deviations of the respective variables from their steady-state values. To do this, linearize the Fisher equation (10) and the monetary policy rule (13) to obtain

\[ \tilde{i}_t = \frac{1}{\beta} E_t \{ \tilde{\pi}_{t+1} \}, \]  
(15)

\[ \tilde{i}_t = \rho_1 \tilde{i}_{t-1} + \rho_2 \tilde{i}_{t-2} + \tilde{\phi}_\pi \tilde{\pi}_t + \tilde{\phi}_y y_t + \tilde{\phi}_e \Delta e_t + \nu_t^i. \]  
(16)

Combine these two equations and take expectations at time \( t \) to get

\[ E_t \{ \tilde{i}_{t+1} \} = (\beta \tilde{\phi}_\pi + \rho_1) \tilde{i}_t + \rho_2 \tilde{i}_{t-1} + \xi_3 \nu_t^i + z_t, \]  
(17)

where

\[ z_t = \tilde{\phi}_y \xi_1 y_t + \tilde{\phi}_e \xi_2 \Delta e_t. \]

Substitute equations (11), (14), and (16) into the government budget constraint (12) and linearize to obtain the following

\[ \tilde{b}_{t+1} = (\beta^{-1} - \gamma_b) \tilde{b}_t + \varphi_1 \tilde{i}_{t+1} + \varphi_2 \tilde{i}_t + \varphi_3 \tilde{i}_{t-1} + \varphi_4 \nu_{t+1}^i - \nu_t^i + \tilde{z}_{t+1}, \]  
(18)

where

\[ \varphi_1 = \frac{c}{(i-1)^2} - \frac{1}{\beta \pi \phi_\pi} \left[ b + \frac{c}{i-1} \right], \quad \varphi_3 = \frac{\rho_2}{\beta \pi \phi_\pi} \left[ b + \frac{c}{i-1} \right], \]
\[ \varphi_2 = \frac{1}{\pi} \left[ b - \frac{c}{(i-1)^2} \right] + \frac{\rho_1}{\beta \pi \phi_\pi} \left[ b + \frac{c}{i-1} \right], \quad \varphi_4 = \frac{1}{\beta \pi \phi_\pi} \left[ b + \frac{c}{i-1} \right], \]

and

\[ \tilde{z}_{t+1} = [\tilde{\phi}_y \varphi_4 - \gamma_y] y_{t+1} + \tilde{\phi}_e \varphi_4 \Delta e_{t+1} - (\gamma_g - 1) g_{t+1}. \]

The system of equations (17)-(18) in real debt and nominal interest rate can be written in matrix notation with the following eigenvalues (see Appendix for details):

\[ \lambda_1 = (\beta^{-1} - \gamma_b), \]  
(19)

\[ \lambda_{2,3} = \frac{(\beta \tilde{\phi}_\pi + \rho_1) \pm \sqrt{(\beta \tilde{\phi}_\pi + \rho_1)^2 + 4 \rho_2}}{2}. \]  
(20)

According to Sims (2002), this system is stable only if the absolute value of two of these three eigenvalues are less than one and the absolute value of the other one is greater than one. Next, I consider the cases in which this condition is satisfied.
4.1.1 Active Monetary and Passive Fiscal Policies

In the regime combination of MA/FP, stability is given in the following cases

\[ |\lambda_1| < 1, \text{ and } |\lambda_2| > 1, \text{ and } |\lambda_3| < 1, \]

or

\[ |\lambda_1| < 1, \text{ and } |\lambda_2| < 1, \text{ and } |\lambda_3| > 1. \]

In this case, without loss of generality, one can assume that \( \lambda_2 > 1 \) and \( \lambda_3 < 1 \). Then the solution for the interest rate comes from the forward solution of (17) using the lag operator

\[(L^{-1} - \lambda_2)(L^{-1} - \lambda_3)\tilde{i}_t = \xi_3 \nu_t + z_t,\]

which yields

\[\tilde{i}_t = \lambda_3 \tilde{i}_{t-1} - \sum_{j=0}^{\infty} \lambda_2^{-j-1} E_t \{ \xi_3 \nu_{t+j} + z_{t+j} \}. \quad (21)\]

Substituting this solution into the linearized monetary policy rule (16) gives the solution for the inflation rate \( \tilde{\pi}_t \), which is independent of fiscal policy shocks: it is entirely dependent on the parameters of the monetary policy rule.

The solution of real debt \( \tilde{b}_t \) comes from solving (18) backward (since \( \lambda_1 < 1 \)):

\[\tilde{b}_t = \sum_{j=0}^{t} (\beta^{-1} - \gamma_b)^{j-1} [\varphi_1 \tilde{i}_{t-j} + \varphi_2 \tilde{i}_{t-1-j} + \varphi_3 \tilde{i}_{t-2-j} + \varphi_4 \nu_{t-j} - \nu^\tau_{t-j} + \bar{z}_{t-j}] + (\beta^{-1} - \gamma_b)^{t-p} \tilde{b}. \quad (22)\]

Substituting the solution (21) of the interest rate into the equation above will provide the solution of the real debt.

4.1.2 Passive Monetary and Active Fiscal Policies

In the regime combination of MP/FA, stability is given in the following case only

\[ |\lambda_1| > 1, \text{ and } |\lambda_2| < 1, \text{ and } |\lambda_3| < 1. \]

For the solution of real debt, I take the expectation of the Eq. (18) and solve forward to obtain:

\[\tilde{b}_t = \sum_{j=0}^{\infty} (\beta^{-1} - \gamma_b)^{-j-1} E_t \{ \varphi_1 \tilde{i}_{t+j+1} + \varphi_2 \tilde{i}_{t+j} + \varphi_3 \tilde{i}_{t+j-1} + \varphi_4 \nu_{t+j+1} - \nu^\tau_{t+j+1} + \bar{z}_{t+j+1} \}. \quad (23)\]
The terms $E_t \{ \varphi_1 \tilde{\iota}_{t+j+1} + \varphi_2 \tilde{\iota}_{t+j} + \varphi_3 \tilde{\iota}_{t+j-1} \} - future values of the interest rate - can be evaluated using the difference equation (17) and real debt $\tilde{b}_t$ can be written in terms of $\tilde{\iota}_t$, $\tilde{\iota}_{t-1}$ and $\nu_t^f$, $\nu_t^r$, $z_t$, $\bar{z}_t$. Then the simultaneous solution of this result and the linearized budget constraint (18) will lead to solutions for real debt $\tilde{b}_t$ and nominal interest rate $\tilde{\iota}_t$, where the interest rate will be dependent on fiscal policy shocks. Therefore the solution of the inflation rate $\tilde{\pi}_t$ - which one can get by substituting the interest rate solution into the linearized monetary policy rule (16) - will also depend on fiscal shocks.

4.1.3 Discussion on Numerical Results

It is a trivial exercise to check that the estimated coefficients for the policy rules in section 3 satisfy the conditions required for the existence and uniqueness of a solution. In order to do this, the values of the eigenvalues are computed for the cases of MA/FP and MP/FA.\(^7\)

The following numbers are taken from table 3 for the monetary policy rule coefficients and from tables 4 and 5 for the fiscal policy rule coefficients. These combinations refer to cases of MA/FP and MP/FA regimes, respectively.

| Table 7: MA/FP Regime: | $|\lambda_1| < 1$, $|\lambda_2| > 1$, $|\lambda_3| < 1$ |
|------------------------|---------------------------------|
|                        | $\lambda_1$ | $\lambda_2$ | $\lambda_3$ |
| Table 3 (Regime 3) & Table 5 (Regime 1) | 0.95 | 1.01 | $-0.20$ |

| Table 8: MP/FA Regimes: | $|\lambda_1| > 1$, $|\lambda_2| < 1$, $|\lambda_3| < 1$ |
|------------------------|---------------------------------|
|                        | $\lambda_1$ | $\lambda_2$ | $\lambda_3$ |
| Table 3 (Regime 2) & Table 5 (Regime 2) | 1.02 | 0.58 | 0.53 |
| Table 3 (Regime 3) & Table 5 (Regime 3) | 1.02 | 0.53 | 0.09 |

\(^7\) Following Chadha and Nolan (2003) it is further assumed that the discount rate $\beta$ takes the value of 0.95. The results are however stable up to a value of $\beta = 0.9$.

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These results confirm numerically that a unique solution exists and the system described above is stable. The implication of these results is that they also confirm that the pre-2001 period was characterized by a regime that was not insulated against fiscal shocks (MP/FA) whereas the post-2001 period experienced a switch to a regime in which the interest and inflation rates are solely influenced by the shocks of the monetary policy rule (MA/FP). Hence, this is a numerical demonstration that the independence resulted in a more active policy making and that it was accompanied by a more disciplined fiscal policy making.

5 Conclusion

This work has characterized monetary and fiscal policies in Turkey with Markov Switching simple policy rules for the periods before and after 2001. The purpose of the analysis was to see whether these policies underwent a significant change and whether this change can be modeled without explicitly imposing when it happened. The starting point for the analysis was the observed decrease of the high inflation period in Turkey that lasted from the beginning of the 1970 decade into the beginning of the new millennium. Following the literature on monetary and fiscal policy interactions, it was suspected that it was a change in both policies that lead to this successful decrease. Consequently, both policies were analyzed with means of simple policy rules. For monetary policy, as suggested by the Taylor principle literature and shown in this work with the modified Taylor principle, the response coefficient on inflation did contribute to stability for the post-2001 period after the central bank gained independence and the short periods where Turkey experienced economic crises. The period prior to 2001 is characterized by a violation of the Taylor principle and correspondingly, monetary policy did not contribute to economic stability.

Having argued that it was a combination of monetary and fiscal policies that contributed to the high inflation period and the end of it, fiscal policy rules were estimated to model the behavior of the fiscal authority. For fiscal policy, the results confirm that there has been a switch from a non-Ricardian (active) policy to a Ricardian (passive) policy, but the two approaches mentioned in section 3.2 differ in the timing and the duration of this change. What is implied by both approaches is that after the crisis in 2001, there has been a period of several years in which fiscal policy was characterized by a passive regime. The important conclusion at this point is that central bank independence was accompanied with a more disciplined fiscal policy making.
geared towards stabilizing debt.

The simultaneous change that both policies experienced is important because of its implications on inflation dynamics. In the sense of Leeper (1991), a switch to an “active” regime for monetary policy and a switch to a “passive” regime for fiscal policy provide the necessary conditions for monetary policy to stabilize prices by preventing deficit shocks from affecting inflation. In the other case of a combination of a passive monetary and active fiscal policy regime, fiscal shocks can affect the path of inflation and the price level is not controlled by the actions of monetary policy.

To prove this point in a more formal setup, a simple model of a rational expectations economy was utilized in which the interaction of policies is explicitly modeled. By incorporating the specifications that were estimated in section 3, explicit solutions for the interest rate and real debt were provided. In the process of solving this model, stability and uniqueness conditions were also provided. Finally, using the estimated coefficients and utilizing the implications of the stability conditions of the rational expectations system, it was confirmed numerically that the economy experienced a switch after 2001 to a regime where a combination of MA/FP was prevalent whereas before that, a combination of MP/FA was prevalent.
6 References


A APPENDIX

A.1

This Appendix provides further details on the system introduced in section 4. The system (17)-(18) in real debt and nominal interest rate can be written in the following matrix form:

\[
\begin{bmatrix}
1 & -\varphi_1 & -\varphi_2 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
\bar{b}_{t+1} \\
\bar{i}_{t+1} \\
\bar{i}_t
\end{bmatrix}
= \begin{bmatrix}
\beta^{-1} - \gamma_b & 0 & \varphi_3 \\
0 & (\beta\bar{\phi}_\pi + \rho_1) & \rho_2 \\
0 & 1 & 0
\end{bmatrix}
\begin{bmatrix}
\bar{b}_t \\
\bar{i}_t \\
\bar{i}_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
\varphi_4 \nu_{t+1} - \nu_{t+1}^2 + \bar{z}_{t+1} \\
\xi_3 \nu_t + z_t \\
\eta_{t+1}
\end{bmatrix}
\] 

where \( \eta_t \) is the prediction error

\[
\eta_{t+1} = \bar{i}_{t+1} - E_t \{ \bar{i}_{t+1} \}.
\]

Let

\[
A = \begin{bmatrix}
1 & -\varphi_1 & -\varphi_2 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{bmatrix}
\quad \text{and} \quad
B = \begin{bmatrix}
(\beta^{-1} - \gamma_b) & 0 & \varphi_3 \\
0 & (\beta\bar{\phi}_\pi + \rho_1) & \rho_2 \\
0 & 1 & 0
\end{bmatrix},
\]

then the so called transition matrix becomes

\[
A^{-1}B = \begin{bmatrix}
(\beta^{-1} - \gamma_b) & \varphi_1 (\beta\bar{\phi}_\pi + \rho_1) + \varphi_2 \varphi_3 & \varphi_1 \rho_2 \\
0 & (\beta\bar{\phi}_\pi + \rho_1) & \rho_2 \\
0 & 1 & 0
\end{bmatrix}.
\]

Eigenvalues of the matrix \( A^{-1}B \) are

\[
\lambda_1 = (\beta^{-1} - \gamma_b),
\]

\[
\lambda_{2,3} = \frac{(\beta\bar{\phi}_\pi + \rho_1) \pm \sqrt{(\beta\bar{\phi}_\pi + \rho_1)^2 + 4\rho_2}}{2}.
\]

In order for this system to have a unique solution, one unstable root and two stable roots are necessary for a single forecast error \( \eta_{t+1} \). Specifically, uniqueness is given for the following cases:
As explained in section 4.1.3, these cases correspond to active fiscal, passive monetary regimes (MP/FA) and active monetary, passive fiscal regimes (MA/FP) respectively.
A.2

This appendix provides details on the characteristics of the data used for the estimations.

A.2.1 Summary Statistics

Table 9: Summary statistics for monetary policy variables

<table>
<thead>
<tr>
<th></th>
<th>$i_t$</th>
<th>$\pi_t$</th>
<th>$y_t$</th>
<th>$\Delta e_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.51</td>
<td>0.49</td>
<td>-0.001</td>
<td>0.09</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.40</td>
<td>0.33</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.51</td>
<td>0.06</td>
<td>0.32</td>
<td>2.62</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>14.59</td>
<td>1.90</td>
<td>2.50</td>
<td>16.46</td>
</tr>
<tr>
<td># Obs.</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

Table 10: Summary statistics for (quarterly) fiscal policy variables

<table>
<thead>
<tr>
<th></th>
<th>$\tau_t$</th>
<th>$b_{t-1}$</th>
<th>$g_t$</th>
<th>$y_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.09</td>
<td>0.47</td>
<td>0.17</td>
<td>-0.001</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.02</td>
<td>0.11</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.09</td>
<td>0.38</td>
<td>0.43</td>
<td>0.11</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.30</td>
<td>2.25</td>
<td>3.05</td>
<td>2.41</td>
</tr>
<tr>
<td># Obs.</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>
Table 11: Summary statistics for (quarterly) fiscal policy variables of Bohn’s specification

<table>
<thead>
<tr>
<th></th>
<th>PST</th>
<th>$b_{t-1}$</th>
<th>YVAR$_t$</th>
<th>GVAR$_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.009</td>
<td>0.47</td>
<td>0.0007</td>
<td>-0.001</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.04</td>
<td>0.11</td>
<td>0.13</td>
<td>0.02</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.46</td>
<td>0.41</td>
<td>-0.30</td>
<td>0.64</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.52</td>
<td>2.26</td>
<td>4.03</td>
<td>3.52</td>
</tr>
<tr>
<td># Obs.</td>
<td>71</td>
<td>71</td>
<td>71</td>
<td>71</td>
</tr>
</tbody>
</table>

A.2.2 Unit Root Tests

Table 12: Unit root tests for monetary policy variables

<table>
<thead>
<tr>
<th>Test/Variable</th>
<th>ADF-test$^a$</th>
<th>PP-test$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_t$</td>
<td>-2.40</td>
<td>-5.61***</td>
</tr>
<tr>
<td>$\pi_t$</td>
<td>-0.33</td>
<td>-1.01</td>
</tr>
<tr>
<td>$y_t$</td>
<td>-3.64***</td>
<td>-10.98***</td>
</tr>
<tr>
<td>$\Delta e_t$</td>
<td>-6.42***</td>
<td>-6.47***</td>
</tr>
</tbody>
</table>

(*), (**), and (*** denote significance at 1%, 5%, and 10%, respectively;

### Table 13: Unit root tests for fiscal policy variables

<table>
<thead>
<tr>
<th>Test/Variable</th>
<th>ADF-Test(^a)</th>
<th>PP-Test(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\tau_t)</td>
<td>-6.10(^{**})</td>
<td>-6.20(^{**})</td>
</tr>
<tr>
<td>(b_{t-1})</td>
<td>-2.68(^*)</td>
<td>-3.18(^{**})</td>
</tr>
<tr>
<td>(y_t)</td>
<td>-3.63(^{***})</td>
<td>-9.10(^{***})</td>
</tr>
<tr>
<td>(g_t)</td>
<td>-3.75(^{***})</td>
<td>-6.56(^{***})</td>
</tr>
</tbody>
</table>

\(^*\),\(^{**}\) and \(^{***}\) denote significance at 1%, 5%, and 10%, respectively;
\(^a\) MacKinnon (1996) one-sided p-values.

### Table 14: Unit root tests for fiscal policy variables of Bohn’s specification

<table>
<thead>
<tr>
<th>Test/Variable</th>
<th>ADF-Test(^a)</th>
<th>PP-Test(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PS_t)</td>
<td>-6.74(^{***})</td>
<td>-6.74(^{***})</td>
</tr>
<tr>
<td>(b_{t-1})</td>
<td>-2.50</td>
<td>-3.17(^{**})</td>
</tr>
<tr>
<td>(YVAR_t)</td>
<td>-3.37(^{**})</td>
<td>-7.28(^{***})</td>
</tr>
<tr>
<td>(GVAR_t)</td>
<td>-8.01(^{***})</td>
<td>-24.92(^{***})</td>
</tr>
</tbody>
</table>

\(^*\),\(^{**}\) and \(^{***}\) denote significance at 1%, 5%, and 10%, respectively;
\(^a\) MacKinnon (1996) one-sided p-values.
### A.2.3 Cointegration Test

Table 15: Unrestricted cointegration rank test (maximum eigenvalue test) for monetary policy variables ($i_t$, $\pi_t$, $y_t$, $\Delta e_t$)

<table>
<thead>
<tr>
<th>Hypothesized # of Cointeg. eq’s</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>0.05</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.48</td>
<td>124.52</td>
<td>47.86</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 1*</td>
<td>0.31</td>
<td>64.31</td>
<td>29.80</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 2*</td>
<td>0.27</td>
<td>30.02</td>
<td>15.49</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.02</td>
<td>1.17</td>
<td>3.84</td>
<td>0.2792</td>
</tr>
</tbody>
</table>

(*') denotes rejection of the hypothesis at the 0.05 level;


---

Table 16: Unrestricted cointegration rank test (maximum eigenvalue test) for fiscal policy variables ($\pi_t$, $b_{t-1}$, $y_t$, $g_t$)

<table>
<thead>
<tr>
<th>Hypothesized # of Cointeg. eq’s</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>0.05</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.39</td>
<td>67.75</td>
<td>47.86</td>
<td>0.0003</td>
</tr>
<tr>
<td>At most 1*</td>
<td>0.24</td>
<td>35.11</td>
<td>29.80</td>
<td>0.0111</td>
</tr>
<tr>
<td>At most 2*</td>
<td>0.19</td>
<td>16.93</td>
<td>15.49</td>
<td>0.0302</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.04</td>
<td>2.85</td>
<td>3.84</td>
<td>0.0915</td>
</tr>
</tbody>
</table>

(*') denotes rejection of the hypothesis at the 0.05 level;

Table 17: Unrestricted cointegration rank test (maximum eigenvalue test) for fiscal policy variables ($PS_t$, $b_{t-1}$, $YVAR_t$, $GVAR_t$)

<table>
<thead>
<tr>
<th>Hypothesized # of Cointeg. eq’s</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>0.05 Critical Value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.78</td>
<td>139.56</td>
<td>47.86</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 1*</td>
<td>0.31</td>
<td>37.84</td>
<td>29.80</td>
<td>0.0048</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.13</td>
<td>12.57</td>
<td>15.49</td>
<td>0.1317</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.04</td>
<td>2.95</td>
<td>3.84</td>
<td>0.0861</td>
</tr>
</tbody>
</table>

(*) denotes rejection of the hypothesis at the 0.05 level;

A.3

This appendix provides further details on the Expectation-Maximization (EM) algorithm, developed by Dempster, Laird and Rubin (1977), that was used for the estimation of the Markov Switching Model in the preceding chapters. The exposition along with the notation closely follows Bilmes (1998).

The starting point for the EM-algorithm is the maximum-likelihood estimation problem. Consider

\[ p(\mathcal{X}|\Theta) = \prod_{i=1}^{N} p(x_i|\Theta) = \mathcal{L}(\Theta|\mathcal{X}) \]

where \( p(\mathcal{X}|\Theta) \) is the sample density, \( \Theta \) a set of parameters, \( N \) the size of the data set, \( \mathcal{X} = \{x_1,...,x_N\} \) the data vectors and \( \mathcal{L}(\Theta|\mathcal{X}) \) the likelihood of the parameters of the data. The goal of the maximum likelihood problem is to find the \( \Theta \) that maximizes the likelihood function \( \mathcal{L} \). For most cases however, the log of the likelihood function is maximized and set to zero for analytical easiness to solve for the mean \( \mu \) and variance \( \sigma^2 \).

The EM algorithm was developed for the cases in which this log-likelihood is not readily available. One such case is when the data set is incomplete, i.e. there are missing values, and/or when some parameters are hidden. The application of the EM algorithm in this work follows the hidden states assumption which assumes that the states (or regimes) are unobservable, i.e. hidden to the econometrician. Assuming that the data \( \mathcal{X} \) is the incomplete but observed data and it is generated by some distribution, the complete data is denoted \( \mathcal{Z} = (\mathcal{X}, \mathcal{Y}) \). Correspondingly, \( \mathcal{L}(\Theta|\mathcal{X}) \) is the incomplete data likelihood whereas \( \mathcal{L}(\Theta|\mathcal{Z}) = \mathcal{L}(\Theta|\mathcal{X}, \mathcal{Y}) = p(\mathcal{X}, \mathcal{Y}|\Theta) \) is the complete data likelihood.

As the name suggests, the EM-algorithm involves two steps: the Expectation step and the Maximization step. The first step involves finding the expectation of \( p(\mathcal{X}, \mathcal{Y}|\Theta) \), i.e. the complete data log likelihood with respect to \( \mathcal{Y} \), i.e the unknown data and current parameter estimates \( \Theta^{(i-1)} \). Specifically, the following is considered:

\[ Q(\Theta, \Theta^{(i-1)}) = E[\log p(\mathcal{X}, \mathcal{Y}|\Theta)|\mathcal{X}, \Theta^{i-1}] \]

where \( \Theta^{(i-1)} \) are estimates of current parameters that are used for the evaluation of the expectation. In addition to these, \( \Theta \) denotes the new parameters to be optimized to increase
the value of $Q$.

The second step of the EM-algorithm, namely the maximization step involves the maximization of the expectation that was computed in the expectation step. Specifically,

$$\Theta^{(i)} = \arg \max_{\Theta} Q(\Theta, \Theta^{(i-1)})$$

is maximized. These two steps are repeated if necessary and the following iterations increase the log-likelihood.