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Monetary Policy Reaction Functions in Iran: An Extended Kalman Filter Approach

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Abstract

Estimates of instrumental rules can be utilized to describe central bank's behavior and monetary policy stance. In the last decade, considerable attention has been given to time-varying parameter (TVP) specification of monetary policy rules. Constant-parameter reaction functions likely ignore the impact of model uncertainty, shifting preferences and nonlinearities of policymaker's choices. This paper examines the evolution of monetary policy reaction function in Iran via estimating a time-varying parameter (TVP) specification in the 1990:2-2014:4 period. We try to find out whether there is a significant time variation in coefficient of CBI (the Central Bank of Iran) reaction function. The main findings are threefold. First, monetary policy rules changed over time, hence making relevant the application of a time-varying estimation framework. Second, the monetary instrument smoothing parameter is much lower than typically reported by previous time-invariant estimates of policy rules. Third, CBI does not systematically follow instrumental rule to fight inflation. During the whole sample, there is no quarter in which the inflation gap coefficient is negative and significant; therefore, monetary policy has not counteracted inflationary pressures.

Key words: *Monetary policy, Instrumental rule, monetary policy reaction function, Time varying coefficient, Extended Kalman filter.*

JEL Classification: *E4, E5.*

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1. Introduction

Estimates of instrumental rules can be utilized to describe central bank's behavior and monetary policy stance. Empirical estimates of monetary policy reaction functions have been an active area since the early 1990s. The continued interest in empirical policy rules primarily stems from the ability of Taylor (1993) type rules to track real data in a number of countries, initially in the developed economies.

There have been a few empirical studies in the area of identifying monetary policy reaction function in Iran. Khatayi and Seyfipour (2006) estimated linear hybrid rule in which the growth rate of money supply is considered as a monetary policy instrument. In addition to inflation and output gap, government consumption expenditure and oil revenues are considered in this rule. They concluded that monetary policy in Iran is mostly affected by oil revenues and government expenditure and target variables –inflation and output gap- do not have an important role in determining the growth rate of monetary aggregate. Jalali-Naini and Hematy (2013) also provided linear and non-linear estimates for various instrumental rules for Iran. Based on their results, linear estimates show that monetary policy in Iran tends to accommodate rather than counteract inflationary pressures. The estimates also show that the Central Bank of Iran does not systematically follow any of the well-known instrument rules or hybrid types. According to non-linear rule estimates, in the "low inflation" states, expansionary policies by CBI tend to support economic activity. However, during "high inflation" periods, CBI does not exercise anti-inflation policy but such a stance cannot accommodate output growth. Monetary policy seems to be ineffective if not inappropriate in this state.

The empirical studies mentioned above all employed constant coefficient approach to estimate instrumental rule for Iran. In the last decade, considerable attention has been given to time-varying parameter (TVP) specification of monetary policy rules. There are mainly three reasons that emphasize the need for unsteady parameter specification [Yuksel et.al (2012)]. First, monetary policy rules are based on the attitude of policymakers towards the structure of the economy and opposing objectives of the monetary policy. Therefore, parameters of the policy rules are subject to change because of changing nature of the policy objectives and behavior of policymakers.

Second, central banks utilize broader range of information set while building policy decisions instead of relying only on a single policy rule equation. Thus, for example, if the policy rule is a Taylor-type interest rate rule, then the same levels of output gap and inflation may not produce the same level of interest rate in different periods since the information set used by central banks will be different in those periods. Monetary policy rules with constant parameters likely disregard the impact of model uncertainty in evaluating the behavior of central bank.

Third, unstable nature of the coefficients of a policy rule can be explained by the presence of nonlinearities in the central bank's reaction function. There are a number of studies that show nonlinearities in the monetary policy rules, especially Taylor rule [Taylor and Davradakis (2006), Bunzel and Enders (2010)]. Martin and Milas (2004) provided evidence that the Bank of England tightens monetary policy in a non-linear fashion if the actual inflation rate goes out of a zone around the target inflation rate. Therefore, traditional constant-parameter reaction functions likely ignore the impact of model uncertainty, shifting preferences and nonlinearities of policymaker's choices. This paper estimates a time-varying parameter (TVP) specification of monetary reaction function in Iran.

The structure of the paper is as follows. In Section two, we will provide a broad survey of the literature on monetary policy rules with a time-varying parameter (TVP) specification. In section 3 the estimation methodology is presented. In section 4, data used in estimation procedure is identified. Section 5 presents the results. Section 6 concludes

2. Literature Review on Time Varying Parameters (TVP) Monetary Policy Rules

Time variation in the coefficients of monetary policy reaction functions has been used to demonstrate the potential change in policy maker’s preferences and attitude toward policy making. Time varying parameter monetary policy rules have been modeled by different estimation methods such as subsample analysis, smooth transition regression (STR), Markov switching and the Kalman filter. Survey of various methods as well as the type of instrument rule and countries studied are presented in Table 1.

Table 1. Summary of Literature on TVP Monetary Policy Rules

Methods	Countries	Studies	Type of instrument rule	Existence of time variation
Subsample Estimation	US	Judd and Rudebusch (1998)	A backward-looking Taylor rule	
	US	Orphanides (2004)	A forward-looking Taylor rule	×
Smooth Transition Regression (STR)	UK	Martin and Milas (2004)	A forward-looking Taylor rule	
	US	Petersen (2007)	A backward-looking Taylor rule	
	ECB	Gerlach and Lewis (2010)	A backward-looking Taylor rule	
Markov Switching	US,UK, Germany	Wesche (2006)	A backward-looking Taylor rule	
	US	Murray, Nikolsko-Rzhevskyy and Papell (2014)	A forward-looking Taylor rule	
Kalman Filter	US	Boivin (2005)	A forward-looking Taylor rule	
	US, UK, Germany, France and Italy	Trecroci and Vassalli (2010)	A forward-looking Taylor rule	
	Australia, Canada, New Zealand, Sweden, and the United Kingdom	Baxa, Horvath and vasicek (2013)	A forward-looking Taylor rule	
Extended Kalman Filter	Turkey	Hatipoglu and Alper (2009)	Augmented Taylor rule (exchange rate gap)	

In order to take into account the potential changes in the conduct of monetary policy, one approach is to divide the sample to some subsamples so that in each subsample the policymaker's preferences are different. This approach is based on the presumption that the timing of shifts in policy (structural breaks) is known, and Policy regimes within each sample period are stable. A number of studies that use this approach to estimate monetary policy rule are listed below. Judd and Rudebusch (1998) estimated a backward looking Taylor rule for the Federal Reserve with emphasis on how FED's reaction function has changed over time. Considering three subsamples described by the identity of the Fed Chairman (the terms of Arthur Burns (1970:Q1–1978:Q1), Paul Volcker (1979:Q3–1987:Q2), and Alan Greenspan (1987:Q3– 1997:Q4)), they found that the parameters of the Taylor type rule differ significantly for each sub-period indicating that the monetary policy regime varies in time. Orphanides (2004) estimates a forward-looking Taylor rule for the Federal Reserve for the periods before and after Paul Volcker's appointment as Chairman in 1979. The information that was available to the FOMC in real time from 1966 to 1995 is used in estimation. The results suggest broad similarities in policy reaction during both periods. Based on the results, in these two subsamples, Federal Open Market Committee (FOMC) had a strong reaction to inflation forecasts which contradicts the hypothesis, based on analysis with ex post data, that the instability of the Great Inflation was the result of weak FOMC policy responses to expected inflation.

Another econometric method for taking into consideration nonlinearity in monetary policy rule is Smooth Transition Regression (STR) model. STR model is a non-linear regression model that allows the regression coefficients to change smoothly from one regime to another – for instance from a low inflation regime to a high inflation regime. To be precise, the STR model belongs to the threshold type of non-linear time series models. In addition, the STR model allows for endogenous regime switches. Martin and Milas (2004) estimated a simple nonlinear instrument rule to analyze UK monetary policy between 1972 and 2000, focusing on the inflation targeting (IT) regime introduced in 1992. They found that the adoption of IT has led to significant changes in monetary policy. Before 1992 the influence of output was stronger than that of inflation. Results show that the influence of inflation has increased a lot after 1992. Petersen (2007) employs the smooth transition regression model and examines whether the Federal Reserve changed its policy rule according to the level of inlfation and/or the output gap. The results show that the Federal Reserve followed a non-linear Taylor rule, once inlfatio approaches a certain threshold; the Federal Reserve adjusts its policy rule and begins to respond more forcefully to inlfation. Gerlach and Lewis (2010) examined European Central Bank (ECB) interest rate setting behavior using a smooth transition methodology that allows for a gradual shift between pre-financial crisis and financial crisis periods. Estimation of reaction functions over the period 1999 2010 shows a swift change in the months following the collapse of Lehman brothers. The ECB appears to have cut rates more aggressively than expected solely on the basis of the worsening of macroeconomic conditions.

Markov switching models are also used to estimate monetary policy reaction functions which are unlikely to be constant over time.[1] Markov switching is a way to model the sequence of different regimes where switching between regimes does not occur deterministically but with a certain probability. These regimes are not classified ex ante but are estimated from the data. This method allows us to investigate how the weights the central bank puts on relevant economic variables like inflation and output change over time. Wesche (2006) estimates monetary policy reaction functions for the United States, the United Kingdom, and Germany, using a Markov-switching model that allows for shifts in the coefficients of the central bank's reaction function as well as for independent shifts in the residual variance. The results indicate that central bank policies can be characterized as falling into a low- and a high-inflation regime. Over time all central banks have assigned changing weights to inflation and the output gap. Using Markov switching model and real time data, Murray, Nikolsko-Rzhevskyy and Papell (2014) estimated a forward looking Taylor rule for FED. Results demonstrated that the reaction of the FED to inflation is regime dependent. They found evidence of two separate regimes so that in pre and post-Volcker periods, the Fed did and did not follow Taylor principle.

If there is more than one change in conduct of monetary policy, it might be appropriate to approximate the changes with the TVP model rather than estimating a multiple break or threshold model. One reason is that this approach requires the estimation of many parameters for each coefficient before and after break points or thresholds. In addition, this approach requires an estimate of the break (threshold) points. In another word, when the number of breaks is large relative to the sample size or the break dates are too close to

1. These models were used in business cycle and exchange rate analysis (Hamilton, 1989; Engel and Hamilton, 1990).

each other, it would be better to use Kalman filter instead of other methods mentioned above.

The Kalman filter is widely used due to its ability to estimate the time varying coefficients of a model even if the exact form of the model is not known. The important advantage of this methodology is that changes in policy regimes and the structure of the economy can be modeled as a gradual evolution of the rules' coefficients. Some studies that use this approach to estimate monetary policy rule are listed below:

Boivin (2006) estimated the forward-looking Taylor rules for Fed by considering an empirical framework that accounts simultaneously for three potential issues consisting of 1) changes in the policy coefficients, 2) the heteroskedasticity in the policy shock, and 3) the real-time nature of the data used. His findings suggest important but gradual changes in the rule coefficients which cannot be adequately captured by the usual split-sample estimation.

Baxa, Horvath and Vasicek (2013) examined the evolution of monetary policy rules in a group of inflation-targeting countries including Australia, Canada, New Zealand, Sweden, and the United Kingdom. They apply a moment-based estimator in a time-varying parameter model with endogenous regressors. Their results demonstrate that the monetary policy rules change gradually. In addition, the response of interest rates to inflation is particularly strong during periods when central bankers want to break high inflation, such as in the United Kingdom or Australia at the beginning of the 1980s. In other words, the response becomes less aggressive after the adoption of inflation targeting. This result suggests that inflation targeting regime could anchor inflation expectations.

Trecroci and Vassalli (2010) estimated forward-looking interest rate rules for five large Organization of Economic Cooperation and Development economies (United States, the United Kingdom, Germany, France, and Italy), allowing for time variation in the responses to macroeconomic conditions and in the variance of the policy rate. The coefficient vectors of monetary rules change over time according to the implementation of the Kalman filter algorithm. They find that monetary policies followed by the United States, the United Kingdom, Germany, France, and Italy are best summarized by feedback rules that allow for time variation in their parameters. Estimates point to sizeable differences in the actual conduct of monetary policies even in countries now belonging to the European Monetary Union. Moreover, the time-varying parameter specification outperforms the conventional Taylor rule and generalized method of moment–based estimates of reaction.

One important issue in estimating the Taylor rule is measuring the output gap. The problem of accurately estimating output gap is more difficult in the case of developing countries. Basic procedures such as Hodrick-Prescott (HP) filters and quadratic de-trending methods are widely used in empirical literature. HP filters perform well when estimating potential output in developed economies, where output is less volatile. This filter is poorly suited to developing and emerging economies, where the output is more exposed to exogenous shocks.

Recently, an extended Kalman filter (EKF) technique has been used to estimate simultaneously both time varying parameters (policy coefficients) and unobserved variables, such as expected inflation and potential output. The Kalman filter algorithm, on the other hand, has several advantages over traditional filters [Ozbek and Ozlale (2005) and Orphanides and van Norden (2005)]. First, unlike the HP filter or other de-trending methods, the Kalman filter allows for greater volatility in the trend component and more flexibility in modeling the trend. This is especially crucial for developing economies and it has been one of the main criticisms of the HP filter, which produces too smooth trend for such economies. Second, by including all possible variables in the estimation of the potential output, the Kalman filter utilizes more information in the estimation of the potential output, which results in lower forecast errors. Thirdly, by using the Kalman filter, the problem of incorrectly estimating the trend at the end of the sample period is rather solved.

There are very few studies done for estimating monetary policy rules in emerging economies using DEKF approach. Hatipoglu and Alper (2009) estimated an augmented Taylor policy rule for central bank of Turkey (CBT). They suppose that CBT responds to an exchange rate gap as well as inflation and output gaps. To estimate time-varying parameters and unobserved variables such as the exchange rate target and potential output simultaneously, they employ an extended Kalman filter (EKF), which allows them to trace any changes in central bank behavior, including regime shifts. The results demonstrate that the extended model predicted the behavior of CBT better than the standard Taylor rule. Using post-2001 data from Turkey, they found that CBT has responded to inflation more aggressively over time. Results also show that CBT has mostly ignored the movements in exchange rates during the inflation-targeting period, in line with the classical definition of inflation targeting.

3. Model

We estimate a time varying policy reaction function to analyze the evolution of monetary policy in Iran. We try to find out whether there is a significant time variation in coefficient of CBI reaction function. In this section, we introduce backward and forward looking versions of the hybrid instrumental rule and represent the estimation approach used in this paper.

3.1. Backward looking version of the hybrid rule

We estimate a backward looking version of hybrid rule in which the growth rate of monetary base responds to changes in inflation, output and exchange rate gaps according to equation:

$$mb_t \quad c \quad {}_t mb_{t\ 1} \quad {}_t(\ {}_{t\ 1} \quad \bar{\ }) \quad {}_t(y_{t\ 1}) \quad {}_t(mx_{t\ 1} \quad ox_{t\ 1}) \quad {}_t \qquad (1)$$

Where all coefficients have a t subscript to emphasize that they are potentially time-varying. mb_t is the growth rate of monetary base (monetary policy instrument). $(\ {}_{t\ 1} \quad \bar{\ })$ is lagged inflation gap defined as the difference between past inflation rate and the average inflation[1]. $y_{t\ 1}$ is the first lag of output gap. $(mx_{t\ 1} \quad ox_{t\ 1})$ is the first lag of exchange rate gap defined as the difference between market and official exchange rate. Equation (1) is known as measurement equation in the state-space form.

Following Boivin (2006) and Kim and Nelson (2006), we allow the coefficients assumed to follow a random walk:

$${}_t \quad {}_{t\ 1} \quad {}_{,t} \qquad {}_{,t} \quad i.i.d.N(0, \ {}^2_{,t}) \qquad (2)$$

$${}_t \quad {}_{t\ 1} \quad {}_{,t} \qquad {}_{,t} \quad i.i.d.N(0, \ {}^2_{,t}) \qquad (3)$$

1. Average is computed during 1991:2 to 2014:4. We omitted inflation rates that are greater than two standard deviation above the mean and then used average of remaining inflation rates. Using this approach, the average inflation equals 16.9 percent.

$$_{t} \quad _{t\ 1} \quad _{,t} \quad _{,t} \quad i.i.d.N(0, \ ^{2}_{\ ,t}) \tag{4}$$

$$_{t} \quad _{t\ 1} \quad _{,t} \quad _{,t} \quad i.i.d.N(0, \ ^{2}_{\ ,t}) \tag{5}$$

The transition equations (2) to (5) describe the time-varying coefficients as a random walk process without drift. We use Kalman (1960) filter to estimate this time-varying parameter model.

3.2. Forward looking version of hybrid rule

We estimate a forward looking version of hybrid rule in which the growth rate of monetary base responds to changes in expected inflation and expected output gap according to equation (6):

$$mb_t \quad c \quad {}_t mb_{t\ 1} \quad {}_{t\ \ t\ h} \quad {}_t y_{t\ h_y} \quad {}_t (mx_{t\ h_x} \quad ox_{t\ h_x}) \quad {}_t \tag{6}$$

$_{t\ h}$ and $y_{t\ h_y}$ are the expected inflation and output gap, respectively at horizons h and h_y. Similarly, $mx_{t\ h_x}$ and $ox_{t\ h_x}$ are the expected market and official exchange rate at h_x horizon. Equation (6) is known as the measurement equation in the state-space form. We allow the coefficients assumed to follow a random walk process without drift.

The Kalman (1960) filter is usually used in estimating the time-varying parameter models. However, a successful application of the Kalman filter critically depends upon the assumption that the regressors are uncorrelated with the disturbance terms. With endogenous regressors, the Kalman filter provides us with invalid inferences of the model (Kim, 2006).

In forward-looking policy rules, the expected inflation and output gap is correlated with the disturbance term ($_t$), so the Kalman filter applied to a state-space representation delivers inconsistent estimates. Kim (2006) proposes a two-step approach for estimating the time-varying coefficient model with endogenous regressors. We can write equations (7) to (9) for expected inflation, output and exchange rate gap:

$$ {}_{h} \quad K_t \quad {}_{t} \quad u_t \qquad\qquad u_t \quad i.i.d.N(0, \; {}^{2}_{u_t}) \qquad (7)$$

$$ y_{t \;\; h_y} \quad I_t \quad {}_{t} \quad {}_{t} \qquad\qquad {}_{t} \quad i.i.d.N(0, \; {}^{2}_{t}) \qquad (8)$$

$$ (mx_{t \;\; h_x} \quad ox_{t \;\; h_x}) \quad J_t \quad {}_{t} \quad {}_{t} \qquad\qquad {}_{t} \quad i.i.d.N(0, \; {}^{2}_{t}) \qquad (9)$$

Where K_t, I_t and J_t are vectors of instrumental variables. Following Kim (2006), we rewrite the above equations in the form of state space:

$$ X_t \quad Z_t \quad {}_{t} \quad e_t \qquad\qquad e_t \quad i.i.d.N(0, \; {}^{2}_{e_t}) \qquad (10)$$

$$ {}_{t} \quad {}_{t\;1} \quad {}_{t} \qquad\qquad {}_{t} \quad i.i.d.N(0, \; {}^{2}_{t}) \qquad (11)$$

Endogeneity in Equation (6) is caused by the correlation between $_t$ and e_t. Equations (10) and (11) are the measurement and transition equations respectively in state space representation. X_t is a vector of endogenous regressors. Z_t is a vector of instrumental variables. e_t and $_t$ are not correlated with each other.

Two step estimation approach proposed by Kim (2006) is used as follows: In the first step, we estimate the state space model given by Equations (10) and (11) using conventional Kalman filter. Then, we obtain the standardized residual $\hat{e}_t$. In order to solve the endogeneity problem, we can decompose the $_t$ into two components: $_e\hat{e}_t$ which is correlated with the explanatory variables, and $_t$ which is uncorrelated with the explanatory variables. In the second step, we estimate equation (6) by taking into account the bias correction term ($\hat{e}_t$) as regressor:

$$ mb_t \quad c \quad {}_{t}mb_{t\;1} \quad {}_{t \;\; t \;\; h} \quad {}_{t}y_{t \;\; h_y} \quad {}_{t}(mx_{t \;\; h_x} \quad ox_{t \;\; h_x}) \quad {}_{e}\hat{e}_t \quad {}_{t} \qquad (12)$$

Along with transition equations using the Kalman filter. $_t$ is uncorrelated with e_t . In other words, by implementing appropriate bias correction terms obtained from the first-step regression, the conventional Kalman filter is applied in estimating state space model given by equation (12) as measurement and 4 transition equations defined as a random walk process without drift.

4. Data

We used quarterly data. The sample period is 1990:2-2014:4[1]. The dependent variable is the growth rate of money base. The inflation is measured as the year-on-year change in the CPI. Following Einian and Barakchian (2012), output gap is deifned as deviations of log of output (real GDP) from its trend using two stage Hodrick-Prescott iflter with smoothing parameter (lambda=677,1). The cyclical seasonal movements are removed from series by implementing a seasonal adjustment method[2].

5. Results

In this section, we present the estimates of backward and forward looking hybrid monetary rules to detect any systematic reaction to the macroeconomic variables of interest to the central bank.

5.1. Backward-looking rule

The results of the estimation of the time varying backward looking hybrid rule are represented in figure 1[3]. The monetary instrument smoothing parameter, first lag of the growth rate of money base, is found to have values between 0.14 and 0.58, which is lower than typically reported by time-invariant

1. Source: CBI.
2. We use census X12 adjustment method for removing the seasonal component of time series.
3. Due to the fact that oil revenue has an important role in the economy of Iran, we tested another specification for backward PRF in which exchange rate gap is replaced by oil revenue gap according to the view point of the referee. The results are reported in appendix A. Based on results, the evolution of the coefficient of the oil revenue gap is not significant over the whole sample. In addition, there is not a significant change in the coefficient of inflation and output gaps under this alternative specification.

estimates of monetary policy rules [Jalali Naini and Hematy (2013)]. Based on confidence bands showed in figure 1A, variation of smoothing parameter is significant at 5% level. The graph of this coefficient has two peaks; one in 1997:2 and the other in 2006:3.

Examination of the evolution of the reaction of monetary policy instrument to the inflation gap indicates that during 1991:2 to 1998:1, the coefficients are both positive and significant (Figure 1B). In other words, during this period, central bank accommodated the inflationary pressures by increasing the growth rate of money base. Note that in this period the economy was hit by terms of trade, fiscal and balance of payment shocks and hence, the central bank might not have had a clear and obvious policy choice to control the growth rate of monetary base. Based on confidence bands, we cannot definitely make any conclusion regarding the sign of the coefficient of inflation gap during 1998:2 to 2014:2; since the confidence bands include zero line.

Figure 1. Estimates of the Time Varying Backward Looking Hybrid Rule

Figure 1A- The evolution of the monetary instrument smoothing parameter

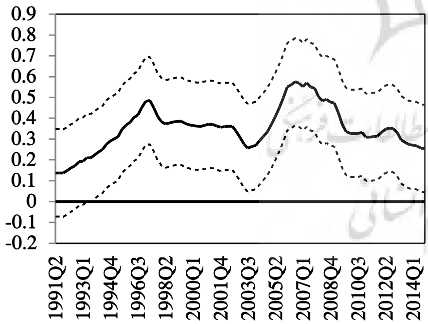


Figure 1B- The evolution of the response of monetary instrument to the inflation gap

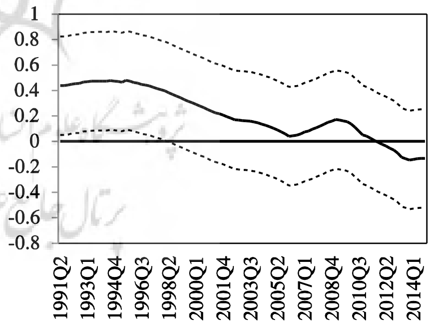


Figure 1C- The evolution of the response of monetary instrument to the output gap

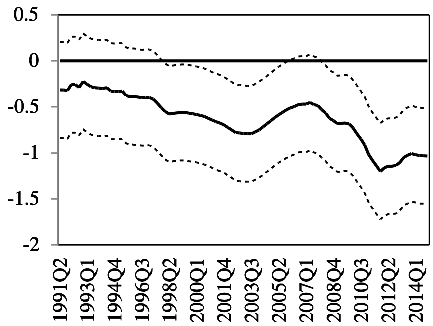
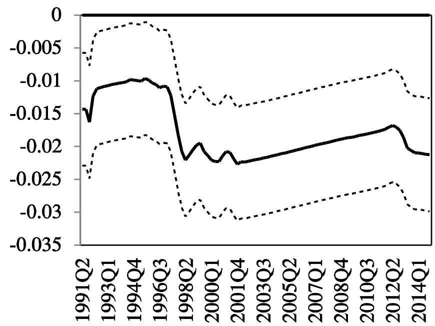


Figure 1D- The evolution of the response of monetary instrument to the exchange rate gap



Source: Authors' findings.
Note: Time-varying response coefficients in backward hybrid policy rule along with 95% confidence bands.

Based on figure 1C, the coefficient of output gap is negative and significant during 1998:1 to 2014:4 (except in 2006:1 to 2007:4). That is, the central bank has attempted to close the output gap by reducing the growth rate of money base.

Examining the response of monetary instrument to the exchange rate gap indicates that during whole period, this coefficient is negative and significant. The negative coefficient implies that the central bank has sold dollars in market when there is a gap between market and official exchange rate. As a result of selling dollars, foreign reserve of central bank and accordingly, money base have decreased.

5.1. Forward-looking instrumental rule

The results of the estimation of the time varying forward looking hybrid rule are represented in figure 2. According to the results, the coefficient of the monetary instrument smoothing parameter evolves between 0 and 0.48. Based on figure 2A, the highest amount of this coefficient is seen in 2006:1. In comparison to constant coefficient estimation results, the estimated coefficient of the smoothing parameter is smaller.[1] The forward looking estimates show

1. Jalali Naeini and Hematy (2013) estimated linear form of forward looking hybrid rule using GMM method. Based on their result, the estimated smoothing parameter equals 0.75.

that the Central Bank of Iran does not systematically follow an instrument rule to fight inflation. During the whole sample, there is no quarter in which the inflation gap coefficient is negative and significant (Figure 2B). In other words, CBI has not modified monetary instrument to close the inflation gap during 1991:4 to 2014:4.

Approximately, similar to backward looking estimates, the coefficient of output gap is negative and significant over 2011:4-2014:4 (Figure 2C). That is, CBI has attempted to close the output gap. In other periods, we cannot argue about the sign of this coefficient since the confidence bands includes zero line.

Unlike backward looking estimates, the evolution of exchange rate coefficient is not statistically significant over the sample period. Therefore, the hypothesis that "CBI regulates exchange rate market through sale and purchase of foreign currency" cannot be confirmed based on forward looking estimates.

6. Conclusion

Determining how monetary policy reacts to changes in key economic variables has been of major interest to monetary economists. Estimates of monetary policy rules (reaction functions) are a widely used method for this purpose. In practice, estimates of instrument rules have been used to describe how the central bank alters its policy in response to expected macroeconomic events. In this paper we examined the evolution of monetary policy rule in Iran. To be exact, we provided time varying coefficient estimates for hybrid instrument rules for Iran applying Kalman (1960) filter.

Our main findings are threefold. First, monetary policy rule changes over time, pointing to the importance of applying a time-varying estimation framework. Second, the monetary instrument smoothing parameter is much lower than typically reported by previous time-invariant estimates of policy rules. Third, Central Bank of Iran does not systematically follow instrumental rule to fight inflation. During the whole sample, there is no quarter in which the inflation gap coefficient is negative and significant.

Figure 2. Estimates of Time Varying Forward Looking Hybrid Rule

Figure 2A- The evolution of the monetary instrument smoothing parameter

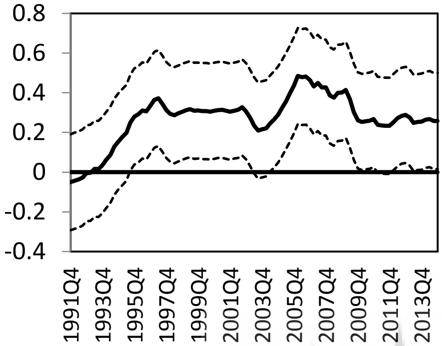


Figure 2B- The evolution of the response of monetary instrument to the inflation gap

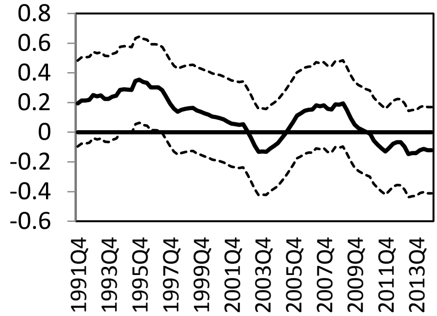


Figure 2C- The evolution of the response of monetary instrument to the output gap

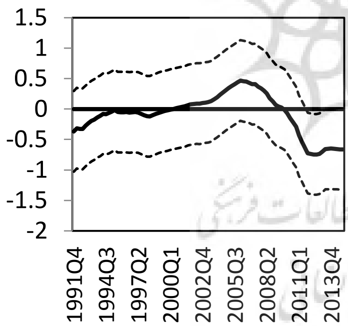
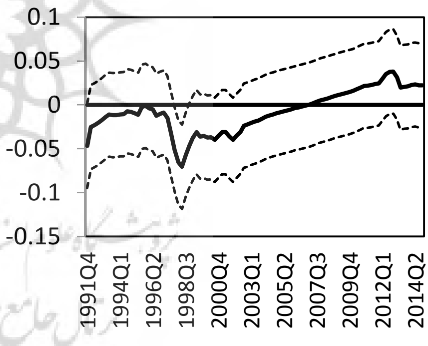


Figure 2D- The evolution of the response of monetary instrument to the exchange rate gap



Source: Authors' calculations.
Note: Time-varying response coefficients in forward hybrid policy rule along with 95% confidence bands.

What stands out in the empirical tests carried out in this paper is the persistence displayed by the policy instruments, in particular, monetary base growth rate. Empirical results produced in this paper show that while the coefficient of one-period lagged monetary base growth rate tend to fluctuate in between periods, it tends to converge to a long run average. Moreover, monetary base growth rate during the 1990:2-2014:4 period is strongly depicted as an AR(1) process. Our interpretation of the empirical findings is similar to our previous paper on the subject (Jalali-Naini and Hematy 2013). To be more specific, the results imply a process in which either the policy-maker elects to stick with a policy of accommodation in an environment of chronic inflation or inertial inflation trend with occasional fluctuations or flare ups of the rate of inflation, due to potentially high cost of breaking the growth trend. This approach to policy was more prevalent in both the developed and the developing countries during the 1970s and in the early 1980s. Alternatively, this process is the outcome of political and economic forces that impinge on the policy maker to follow an accommodating monetary stance. This is very similar to chronic inflation episodes that used to be widely present in the emerging countries, but at long run, it has become a less frequent occurrence as a consequence of undertaking macroeconomic reforms and institutionalizing more disciplined monetary policies. Economic history has shown that individuals and economic systems can live with moderate chronic inflation for extended periods of time, because, in many circumstances, the stake holders' incentive for changing it is not sufficiently strong. In the absence of large external shocks, the rate of inflation in the "moderate chronic inflation" regimes fluctuates around an average rate of 15 to 30 per cent for the countries in the sample examined by Dornbusch and Fischer (1993) and 18.46 per cent per annum in Iran during 1990:2-2014:4 period. Under this regime, inflation indexation provides some protection for the workers, higher prices are passed on by firms to consumers, and with the presence of bracket creep inflation tax can help government financing. Periodic nominal wage and price adjustments imitate the ongoing price and cost inflation. Wages are set to capture all or part of past inflation. Firms periodically adjust their prices to cover higher costs. In such a setting, monetary growth becomes endogenous with respect to the nominal rescaling of the economy and fiscal (as well as quasi-fiscal) requirements instead of reacting to the evolving macroeconomic conditions. Since the economic and political costs of stopping chronic inflation are significant, ending persistent inflation has always been a challenge to policy makers. In the absence of monetary policy autonomy, fiscal discipline, and structural measures to enhance productive capacity, demand-side growth and redistributive policies require monetary and credit expansion. Prolongation of these policies generate chronic inflation and an accommodating monetary process.

References

Baxa, J., R. Horvath, and B. Vasicek, (2010). “How Does Monetary Policy Change? Evidence on Inflation Targeting Countries”. *Macroeconomic Dynamics*, 18, 2014, 593–630.

Boivin, Jean (2006). “Has U.S. Monetary Policy Changed? Evidence from Drifting Coefficients and Real-time Data”. *Journal of Money, Credit and Banking* 38(5), 1143–1174.

Engel, C.M., and J.D. Hamilton, (1990). “Long Swings in the Dollar: Are they in the Data and do Markets Know It?” *American Economic Review* 80 (4), 689–713.

Hamilton, J.D. (1989). “A New Approach to the Economic Analysis of Non-stationary Time Series and the Business Cycle”. *Econometrica* 57 (2), 357–384.

Jalali-Naini, A. R., and M. Hemmaty, (2013). “Threshold Effects in the Monetary Policy Reaction Function: Evidence from Central Bank of Iran”. *Journal of Money and Economy*, 8(1), pp. 1-30.

Judd, J. P., and G. D. Rudebusch, (1998). “Taylor's Rule and the Fed: 1970-1997”. *Economic Review-Federal Reserve Bank of San Francisco,* 3-16.

Khatai, M. and R. Seyfipour, (2005). “Monetary Policy Instrument Rule in Iran: Case Study of the Third Five-year Development Plan.” *Economic Research Quarterly*, No.73, 233-267.

Kim, C. J. (2006). “Time-varying-parameter Models with Endogenous Regressors”. *Economics Letters* 91, 21–26.

Kim, C. J. and R. Charles Nelson, (2006). “Estimation of a Forward-looking Monetary Policy Rule: A Time-varying Parameter Model Using Ex-post Data”. *Journal of Monetary Economics* 1949–1966.

Martin, C., and C. Milas, (2004). “Modeling Monetary Policy: Inflation Targeting in Practice”. *Economica*, 71(282), 209-221.

Murray, C. J., A. Nikolsko-Rzhevskyy, and D.H. Papell, (2013). “Markov Switching and the Taylor Principle”. *Macroeconomic Dynamics*, 1-18.

Orphanides, A. (2004). “Monetary Policy Rules, Macroeconomic Stability, and Inflation: A View from the Trenches”. *Journal of Money, Credit and Banking*, 151-175.

Petersen, K. (2007). “Does the Federal Reserve Follow a Non-linear Taylor Rule?” *Department of Economics Working Paper Series*, Working Paper.

Sims, C. A., and T. Zha, (2006). “Were the Regime Switches in US Monetary Policy?” *The American Economic Review*, 54-81.

Surico, P. (2007). “The Fed's Monetary Policy Rule and US Inflation: The Case of Asymmetric Preferences”. *Journal of Economic Dynamics and Control*, 31(1), 305-324.

Taylor M. and E. Davradakis, (2006). “Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom.” *Studies in Nonlinear Dynamics & Econometrics*, Volume 10, Issue 4.

Taylor, J. B. (1993). “Discretion versus Policy Rules in Practice”. *Carnegie-Rochester Conference Series on Public Policy* (Vol. 39, pp. 195-214). North-Holland.

Trecroci, C., and M. Vassalli, (2010). “Monetary Policy Regime Shifts: New Evidence from Time-Varying Interest Rate Rules.” *Economic Inquiry*, 48(4), 933-950.

Wesche, K., (2006). “Estimating Central Banks’ Preferences from a Time-varying Empirical Reaction Function”. *European Economic Review* 50, 1951–1974.

Yuksel, E., K. Metin-Ozcan, and O. Hatipoglu, (2012). “A Survey on Time-varying Parameter Taylor Rule: A Model Modified with Interest Rate Pass-through”. *Economic Systems, 37(1), 122-134.*

Appendix

Figure A1- Robustness Analysis

Figure 1A- The evolution of the monetary instrument smoothing parameter

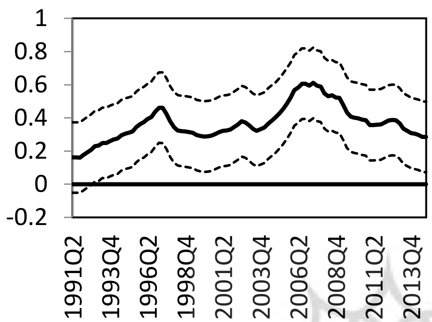


Figure 1B- The evolution of the response of monetary instrument to the inflation gap

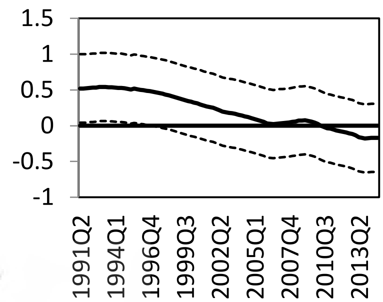


Figure 1C- The evolution of the response of monetary instrument to the output gap

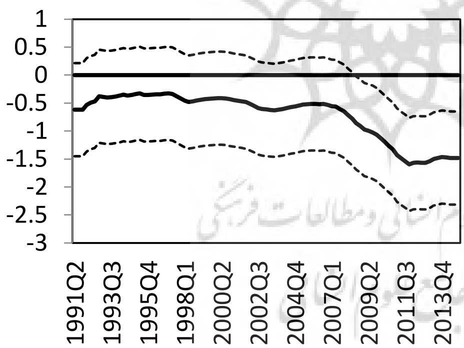
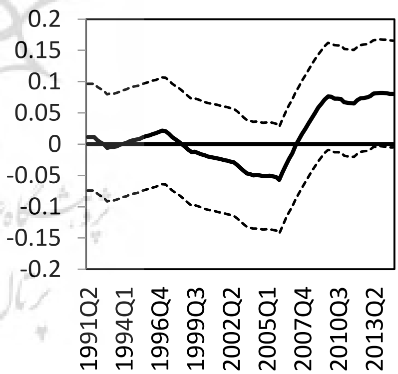


Figure 1D- The evolution of the response of monetary instrument to the oil revenue gap



Note: Time-varying response coefficients along with 95% confidence bands.