5. FORWARD-BACKWARD-LOOKING MONETARY POLICY RULES: DERIVATION AND EMPIRICS

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Abstract

We first propose an analytical framework for monetary policy reaction function that includes both forward and backward aspects. The proposed function is then estimated for Pakistan utilizing quarterly data covering the period 1971Q1-2018Q4. The results reveal that the central bank adjusts interest rates by considering both lead (forward) and lagged (backward) aspects of the underlying variables. Yet, our empirical analysis shows that Pakistan's central bank gives relatively more weight to future expected inflation, future exchange rates, and the prior period output when setting the interest rate. Finally, we show that the monetary policymakers in Pakistan have asymmetric preferences regarding interest rate setting. Robustness checks show that the findings hold even after controlling for potential structural breaks.

Keywords: monetary policy reaction functions; asymmetric preferences; interest rates; output and inflation gaps; volatility

JEL Classification: D82; E43; E52; E58

1. Introduction

A growing numbers of researchers have proposed different analytical frameworks to examine how the monetary authority sets domestic interest rates. Many scholars have also examined whether central banks adjust the interest rate in response to expected future changes in both inflation and output or by considering past changes in these variables. In addition to this, several theorists and empiricists have extended monetary policy reaction functions (MPRFs) to open economies to examine the role of foreign exchange rates in monetary policy rules. Finally, we found from reviewing the recent literature on MPRFs that researchers have documented significant evidences on the asymmetric preferences of monetary policymakers regarding interest rate setting.

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Rangarajan (1997), Taylor (1999), and Svensson (1999, 2000) are among the early studies that have described monetary policy rules (MPRs). According to Taylor (1999), MPRs are a reduced form description of the responsiveness of monetary policy instruments, specifically domestic interest rates and money supply, to changes in macroeconomic indicators such as inflation, output, employment, exchange rates, foreign reserves, etc. Since there are wide-ranging agreements on the superiority of a rules-based monetary policies over discretionary policies, several scholars have proposed rules that can be classified into two clusters: targeting monetary rules and market based proposals. The well-known targeting policy rules are Friedman's k-percent money supply growth rule, Taylor's interest-rate rules, McCallum's feedback rules, and inflation targeting rules. However, inflation targeting, nominal income targeting, real and nominal exchange rate targeting, commodity standards, and the free banking are considered market-based proposals.[3] Several academics and policymakers have suggested that these rules are equally valuable in both developed and developing countries for designing effective monetary policies. However, empirical evidence on whether central banks of developing countries follow these rules is very limited.[4]

Several scholars have presented different analytical frameworks to examine central banks' behavior on interest rate setting. At best, the existing frameworks can be classified into two groups. The first group includes the models that relate the responsiveness of the interest rate to backward-looking aspects of macroeconomic indicators (Ball, 1999; Leitemo *et al.,* 2002; Dolado *et al.*, 2004; Mohanty and Klau, 2005; Dolado *et al.,* 2005; Sznajderska, 2014). The second category of studies including Bullard and Mitra (2002); Boeckx (2011); Neuenkirch (2014) and Caglayan *et al.* (2016) has presented an empirical framework for studying MPRs by considering only forward-looking aspects of the underlying variables. However, we did not find any theoretical study that has systematically proposed the analytical structural of MPRs where both forward-looking aspects as well as backward-looking aspects are jointly incorporated. Nevertheless, the monetary policymakers are very much expected to consider both forward- and backward-looking aspects of macroeconomic conditions simultaneously when designing the monetary policy.

Indeed, several scholars have realized the significance of designing economic policies based on a forward-looking approach over and above the backward-looking components. For instance, several decades ago, Keynes (1923, p. 148) said "If we wait until a price movement is actually afoot before applying remedial measures, we may be too late". Similarly, another well-known economist Donald Kohn (1995) said, "Policymakers cannot avoid looking into the future." The words of Alan Greenspan (1994) can be summarized as that the one of main challenges to monetary policymakers is that they interpret current data regarding macroeconomic indicators and financial markets by considering expected future inflationary forces and take courses of actions to encounter those forces in advance. At the empirical level, numerous empiricists have also documented that to design effective monetary policies, the G-7 countries and several other developed economies considerably consider anticipated future changes rather than lagged values of realized macroeconomic outcomes (Clarida and Gertler, 1997; Clarida, Gali, and Gertler, 1998).

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[3] See, for example, Salter (2014) for further details on these rules.

[4] In Pakistan, there are only few studied that have estimated the monetary policy rules (Munir and Qayyum, 2014; Malik and Ahmed, 2010; Agha et al., 2005). However, none of the study systematically proposes MPRF by considering both lagged and lead values of the variables.

We therefore propose an analytical framework for examining monetary policy rules taking into consideration both anticipated future changes in macroeconomic indicators and lagged realized outcomes.[5] To mathematically derive the forward-backward-looking MPRF, we consider three equations by including both forward- and backward-looking aspects of the underlying variables. Our first equation represents aggregate demand, the second equation is aggregate supply, and the third one is the exchange rate equation.

We hypothesize that both lead and lagged outcomes are important in determining contemporary values of the underlying variables in all three equations. The proposed MPRF is then empirically assessed for Pakistan using quarterly data. The empirical analysis covers the period 1971Q1-2018Q4. While doing empirical investigation of the model we also take into account the asymmetric behavior of the monetary policymakers on setting the interest rate. Following Sznajderska (2014), Bec *et al.* (2002), Mohanty and Klau (2005), and Dolado *et al.* (2004), we apply the GMM technique to estimate the empirical model to mitigate the problem of endogeneity. To ensure the robustness of the findings, we re-estimate the model by considering a known structural break in the data. Further, as another robustness check, we also estimate separately a forward-looking and backward-looking MPRF to ensure that one type of rules does not drive the effects of the other type of rules.

Our empirical investigation provides strong support for including both forward and backward variables in MPRF. Specifically, we empirically show that the proposed analytical framework based on both forward-looking and backward-looking aspects of output, inflation, and exchange rates better explains the interest rate-setting behaviour of monetary policymakers. Nevertheless, our empirical analysis suggests that the central bank of Pakistan appears to be more concerned about future expected inflation, the future exchange rate, and the lagged output while setting the nominal interest rate. Moreover, the findings suggest that the policymakers also considerably take into consideration the behavior of foreign real interest rates when setting domestic interest rates. This piece of finding is consistent with the notion that the monetary policy strategies in advanced countries have significant effects on the interest rate-setting behavior of small open and emerging economies.

After having confirmed the empirical validity of the proposed framework for monetary policy rules we examine whether the monetary policymakers allot quite different weights to both positive and negative output and inflation gaps. The empirical results confirm the existing of asymmetric preferences for interest rate setting. Robustness checks show that the effects of forward and backward variables are not driven by the inflation and output volatility indicators as the estimated values of the underlying coefficient remain significant even after excluding the asymmetric preferences from MPRF. Finally, we show that our results are also robust to the possibility of any potential structural break in the data during the study period.

The paper is arranged in the following six sections. Section 1 presents the background, motivation, and objectives of the paper. Section 2 presents a brief literature review on MPRFs. The derivation of the forward-backward-looking MPRF is presented in Section 3. Section 4 deals with the data and estimation methods. The empirical results and their interpretation are given in Section 5. Section 6 finally presents some key conclusions of the paper.

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[5] *Forward-looking models determine the current value of the dependent variable by considering the expected future value of the independent variables. In contrast, backward-looking models determine the value of the dependent by looking at the preceding values of the independent variables.*

2. Literature Review

There are several studies that have empirically examined monetary policy rules. These studies examined how central banks set the monetary policy. Taylor (1993) has made one of the most prominent efforts in this regard. Specifically, he considered the market interest rate as a continuous process and related it linearly to several macroeconomic factors. Several subsequent studies including, among several others, Clarida, Gali and Gertler (1998), Gerdesmeier and Roffia (2004), and Gorter, Jacobs and de Haan (2008) also estimated MPR proposed by Taylor for several countries across the world. Similarly, Gascoine and Turner (2004) documented that the interest rate-setting decisions of the Bank of England are significantly related to output. They also found that there is statistically insignificant association between the rate of inflation and interest rate-setting decisions. These findings indicate that both output and inflation have a vital role to play in interest rate setting.

Reviewing the recent empirical literature we observe that there are several studies that have examined the empirical validity of MPRs designed based on only the forward-looking approach. Specifically, this strand of literature includes, among several others, Caglayan *et al.* (2016), Neuenkirch (2014), Boeckx (2011), and Bec *et al.* (2002). Neuenkirch (2014) found that the monetary policymakers give more weight to inflation gaps in period when the level of inflation is above its long-run trend. Caglayan *et al.* (2016) provided significant evidence for the open economy policy rules. They also found that both the Canadian central bank of Canada and the Bank of England give asymmetric weights when setting the interest rate. Boeckx (2011) estimating forward-looking Taylor rule found that all the estimated parameters of the model are significant and have the expected sign. Similarly, Yau (2010) estimated the forward-looking MPRF for Taiwan. He found that the inclusion of the central bank's expectations on future expected inflation and output in the model specification yields more accurate estimation of the underlying parameters of the specified empirical models. These findings suggest that researchers can improve the performance of the model by considering forward variables.

Lubik and Schorfheide (2007) also estimated MPRs based on forward-looking aspects of the underlying variablesfor four countries: Australia, Canada, New Zealand, and the United Kingdom. In particular, they estimated Taylor-type rules. These rules state that central banks significantly consider inflation, exchange rates, and output while setting interest rates. They documented evidence that the Australian and New Zealand monetary authorities do not take into account exchange rate-movements while taking interest rate-setting decisions. In contrast, the interest rate-setting decisions in both Canada and the UK are significantly influenced by exchange rate variations.

Surico (2003) found that the monetary policymakers in the USA have asymmetric preferences concerning the inflation and output gaps. Similarly, Bec *et al.* (2002) found that business cycle phases significantly matter in order to implement monetary policy rules. They also found that the USA and Germany both do more care of the rate of inflation during periods of expansion, whereas, during booms, they give more weight to the output gap. Florens *et al.* (2001) by estimating the parameters of Taylor-type rules found that both forward-looking and backward-looking MPRs yield quite different estimates. These differences are mainly attributed to the type of GMM (generalized method of moments) estimation method used to estimate the underlying MPR.

The empirical literature on monetary policy rules based on backward-looking aspects is also huge. Studies that examined the response of the central bank while setting interest rates to lagged actual outcomes include, among many others, Leitemo et al. (2002), Mohanty and Klau (2005), Hooi et al. (2008), and Sznajderska (2014). Specifically, Sznajderska (2014) estimated MPRF for Poland and examined the preferences of monetary policymakers are asymmetric regarding both output and inflation gaps. He found that the monetary policymakers in Poland significantly return to the rate of inflation, particular in periods when it is higher than the target level of inflation.

Malik and Ahmed (2010) argued based on their empirical findings that Pakistan' central bank might design better and more effective monetary policy by considering Taylor-type rules. The empirical findings of Hooi *et al.* (2008) revealed that the monetary policy has quite different effects on the economy over the business cycle. Specifically, they found that the effects on the economy of monetary instruments are stronger and long lasting during downturns as compared to upswings. Dolado *et al.* (2005) investigated optimal MPRs by estimating the non-linear Phillips curve in a quadratic loss framework and found that the rules are non-linear. Further, they found that the policy response of four European central banks is asymmetric to both inflation and output gaps. Dolado *et al.* (2004) also estimated a non-linear Phillips curve by considering asymmetric preferences of policymakers and by supposing that certainty equivalence proposition does not hold. They found that owing to these features, there are substantial asymmetries in both sign and size of the estimates. They also found that US monetary policy exhibits non-linearity in the period after 1983, but not for the period before 1979.

Leitemo *et al.* (2002) and Pelinescu (2012) discussed the exchange-rate channel of monetary policy transmission. Specifically, the authors examined whether the projections of New Keynesian hold for a relatively small open economy. They considered backward-looking Phillips curve along with forward-looking foreign exchange market. They showed that there are considerable differences between the optimal monetary policy under commitment and under discretion. They also found that cost-push shocks in the economy generally lead the exchange-rate channel to emphasize on excessive output stabilization and insufficient sluggishness in monetary policy, which is more likely to occur during a regime of discretionary monetary policy. Pelinescu (2012) discussed the value of the interest rate channel of monetary policy transmission and the complicated impacts of exchange rates in Romania. The author is of the view that any increase in crediting of the national currency leads to appreciation of the Romanian currency. He further showed that this appreciation negatively affects the exports and demand for foreign goods in the economy. The market interest rate is considered to be one of key variables in explaining variations in demand. This empirical finding is consistent with the behavioral of the national bank and projection of the estimated model.

Several other studies have indirectly examined MPRs for several different countries across the world (Nobay and Morgan, 1993; Peel, 2003; Karras, 2007; Ahmed and Malik, 2011; Lento, 2011; Islam, 2011; Aye and Gupta, 2012; Ahsan-ul-Haq, 2013)

Specifically, Ahsan-ul-Haq (2013) argued that the use of revised dataset in the empirical analysis might produce the estimation results that deceive policymakers while making any policy regarding interest rates. Based on the empirical findings, the author is of the view that the central bank of Pakistan set the interest rate based on the Taylor-type rule to harvest desired favorable effects of the monetary policy. Likewise, the study of Aye and Gupta (2012) investigated the influences of monetary policy on several macroeconomic variables in Indian. Their findings reveal that compared to negative monetary policy shocks, the effects of positive shocks are stronger and long lasting. These findings suggest asymmetries in the monetary policy effects. Another study by Ahmed and Malik (2011) also estimated MPRF for Pakistan. Specifically, the authors examined Taylor–type rule in both static and dynamic analytical framework and found that the dynamic version is better in achieving the stabilization of the exchange rate.

Islam (2011) using the data over the period 1980Q1-2010Q2 found that the rule based monetary policy is more effective as compared to the one based on discretionary rules. Karras (2007) and Murcia (2003) found that monetary contractions have larger effects on the economy as compared to monetary expansions. Further, they found that as compared to large shocks, small shocks have larger and strong effects. Malik (2007) argued that rather than concentrating on Taylor-type rules, the State Bank of Pakistan should specify the loss function by incorporating both exchange rate stabilization as well as interest rate smoothing. He further found that the central bank of Pakistan gives greater weights to foreign factors when designing the monetary policy.

Kim *et al.* (2005) studied MPRs for the USA during pre-Volcker period (1960-1979). They found that the monetary authority designed the monetary policy based on non-linear MPRs. Similarly, Nobay and Peel (2003) examined MPRs and found that policymakers' asymmetric preference significantly affects the estimates. Another study by Loyaza and Hebbel (2002) provided evidence on the importance of the exchange rate channel for several open economies. They found that those countries have categorical inflation targets had considerably attained lower and less volatile inflation compared the countries that do not have such explicit targets. Yet, they found that output is more volatile in inflation targeting countries.

3. Analytical Framework

In this section, we present an analytical framework for MPRs by taking into account forward as well as and backward variables. Several previous studies such as Ball (1999), Caglayan *et al.* (2016), Bullard and Mitra (2002), Dolado *et al.* (2004), Leitemo *et al.* (2002), and Mohanty and Klau (2005) have also considered the setup similar to us. However, the framework we present in this paper substantially deviates from the approaches proposed by prior studies. One should note that Ball (1999) and Leitemo *et al.* (2002) have proposed only backward-looking specification of MPRs. However, both Caglayan *et al.* (2016) and Bullard and Mitra (2002) considered the empirical framework based on forward-looking aspects to examine monetary policy rules. Unlike these scholars, we present an analytical framework in which both forward-looking aspects as well as backward-looking aspects of the underlying variables are simultaneously included in the model specification. Our analytical framework enables us to empirically study whether the monetary authority considers both forward and backward variables while setting interest rates. The proposed backward-forward-looking MPRF also allows us to examine the asymmetric response of policymakers to lagged and lead values of the underlying variables.

3.1 The Model

We start mathematically derivation of the backward-forward-looking MPRF by presenting three basic equations. Our first equation is investment-saving (IS) curve, which shows how the output is determined. The second equation is Phillips curve, indicating the inflation determination. Finally, our third equation indicates how the real exchange rate is determined.

All three equations have both backward and forward aspects of the underlying empirical determinants

$$y_t = \alpha_1 E_t\, y_{t+1} + \alpha_2 y_{t-1} - \alpha_3(i_t - E_t \pi_{t+1}) + \alpha_4 q_t + \varepsilon^{y}_{t+1} \tag{1}$$

$$\pi_t = \beta_1 E_t \pi_{t+1} + \beta_2 \pi_{t-1} + \beta_3 y_t + \beta_4(E_t q_{t+1} - q_t) + \varepsilon^{\pi}_{t+1} \tag{2}$$

$$q_t = \gamma_1 E_t q_{t+1} + \gamma_2 q_{t-1} - \gamma_3(i_t - E_t\, \pi_{t+1}) + \gamma_4\left(i^{f}_t - E_t \pi^{f}_{t+1}\right) + \varepsilon^{q}_{t+1} \tag{3}$$

In Eq. (1), y_t is output, i_t is the domestic nominal interest rate, π_t denotes the rate of inflation, and q_t is the real exchange rate, which is defined as the price of a unit of foreign currency in domestic currency, E_t denotes future expected value, and ε^{y}_{t+1} is the error term. This equation represents aggregate demand (AD), which is determined both forward- and backward-looking components of the variables. According to this equation, the output in the current period is positively associated with the output in the previous and future period output, negatively affected by the real interest rate, and positively related to the real exchange rate in the current period.

Eq. (2) is considered as aggregate supply (AS), which is represented by Phillips curve. According to this equation, the rate of inflation in the current period is positively related to both past and future expected price levels in the economy as well as positively related to income/aggregate demand. Following the existing literature (Ball, 1999; Leitemo *et al.,* 2002), it is supposed that the inflation rate is positively related to changes in real exchange rates. All variables of Eq. (2) are defined similar to Eq. (1) and ε^{π}_{t+1} is the error term.

Our final equation (Eq. (3)) is exchange rate equation, where i^{f}_t = foreign interest rate, by $E\pi^{f}_{t+1}$= foreign expected rate of inflation, and ε^{q}_{t+1} = error term. Following the previous literature, in this paper, we assume that increased domestic real interest rate results in an appreciation, whereas, increased real foreign interest rates cause a depreciation of the foreign exchange rate of domestic currency. Further, we suppose that the lagged and future expected exchange rates have a positive and significant impact on the current exchange rate.

3.2 Solution of the Model

Considering equations (1) to (3), an intertemporal optimization problem is solved to obtain the monetary policy rule. Specifically, in order to derive MPRF, we do the following.

Putting Eq. (3) into Eq. (1), we get the following model.

$$y_t = \alpha_1 E_t\, y_{t+1} + \alpha_2 y_{t-1} - (\alpha_3 + \alpha_4\gamma_3)(i_t - E_t \pi_{t+1}) + \alpha_4\gamma_1 E_t q_{t+1} + \alpha_4\gamma_2 q_{t-1} + \alpha_4\gamma_4\left(i^{f}_t - E_t \pi^{f}_{t+1}\right) + \alpha_4 \varepsilon^{q}_{t+1} + \varepsilon^{y}_{t+1} \tag{4}$$

Similarly, putting Eq. (3) into Eq. (2) and also incorporating Eq. (4), we attain the following specification.

$$\pi_t = \beta_1 E_t \pi_{t+1} + \beta_2 \pi_{t-1} + \alpha_1\beta_3 E_t y_{t+1} + \alpha_2\beta_3 y_{t-1} - (\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)(i_t - E_t\pi_{t+1}) + \left(\alpha_4\beta_3\gamma_1 + \beta_4(1-\gamma_1)\right)E_t q_{t+1} + \gamma_2 q_{t-1}(\alpha_4\beta_3 - \beta_4) + \gamma_4(\alpha_4\beta_3 - \beta 4)\left(i^{f}_t - E_t\pi^{f}_{t+1}\right) + \beta_3\varepsilon^{y}_{t+1} + (\alpha_4\beta_3 - \beta_4)\varepsilon^{q}_{t+1} + \varepsilon^{\pi}_{t+1} \tag{5}$$

Prior studies have concluded based on the empirical analysis that policymakers generally set the domestic interest rate at the beginning of time "t" by considering the information attained in the previous period before the realization of economic shocks. Therefore, the monetary policymakers minimize the inter-temporal loss function, which is defined as follows:

$$Min\ E_{t-1}\sum_{\tau=0}^{\infty}\delta^{T}L_{t+\tau}$$

where E_{t-1} shows the expectation in the preceding time period, δ^{T} denotes the discount factor, and $L_{t+\tau}$ represents the period loss function.

Following the previous studies including Murcia (2000), Nobay and Peel (2003), Murcia (2003), and Surico (2003), we define the loss function as follows to achieve the objective of the study.

$$L(\pi_t\ ,\ y_t)=\frac{1}{\mu^2}\left(e^{\mu(\pi_t-\pi^*)}-\mu(\pi_t-\pi^*)-1\right)+\frac{\lambda}{\gamma^2}\ (e^{\gamma y_t}-\gamma y_t-1) \qquad (6)$$

In Eq. (6), μ and γ illustrate asymmetries in the objective function of output and inflation gaps, respectively. Policymakers' preferences concerning inflation stabilization are normalized to 1 as it is considered in the pervious studies. Finally, the parameter λ expresses aversion of the policy preference toward output dynamics around its long-term level.

Taking the first derivative of Eq. (6) with respect to the interest rate, i, we get the following expression.

$$\frac{\partial L(\pi_t,y_t)}{\partial i}=\frac{1}{\mu^2}\ (\mathrm{e}^{\mu(\pi_t-\pi^*)}\ .\mu.\frac{d}{di}(\pi_t-\pi^*)-\mu(\pi_t-\pi^*))+\frac{\lambda}{\gamma^2}\ (\mathrm{e}^{\gamma y_t}.\frac{d}{di}\ (\gamma y_t)-\gamma y_t) \qquad (6a)$$

Now, substituting value of both y_t and π_t in Eq. (6a), we obtain the following.

$$\begin{aligned}\frac{\partial L(\pi_t,y_t)}{\partial i}&=\frac{1}{\mu^2}\ (\mathrm{e}^{\mu(\pi_t-\pi^*)}\ .\mu.\frac{d}{di}\ (\beta_1E_t\pi_{t+1}+\beta_2\pi_{t-1}+\alpha_1\beta_3E_ty_{t+1}+\alpha_2\beta_3y_{t-1}-\\&\left(\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3\right)(i_t-E_t\pi_{t+1})+\left(\alpha_4\beta_3\gamma_1+\beta_4(1-\gamma_1)\right)E_tq_{t+1}+\gamma_2q_{t-1}(\alpha_4\beta_3-\\&\beta_4)+(\alpha_4\beta_3-\beta_4)\left(i_t^f-E\pi_{t+1}^f\right)+\beta_3\varepsilon_{t+1}^y+(\alpha_4\beta_3-\beta\_4)\varepsilon_{t+1}^q+\varepsilon_{t+1}^\pi-\pi^*\big)-\\&\mu\big(\beta_1E_t\pi_{t+1}+\beta_2\pi_{t-1}+\alpha_1\beta_3E_ty_{t+1}+\alpha_2\beta_3y_{t-1}-(\beta_4\gamma_3+\beta_3(\alpha_3+\alpha_4\gamma_3))(i_t-E_t\pi_{t+1})+\\&(\alpha_4\beta_3\gamma_1+\beta_4(1-\gamma_1))E_tq_{t+1}+\gamma_2q_{t-1}(\alpha_4\beta_3-\beta_4)+\gamma_4(\alpha_4\beta_3-\beta_4)\left(i_t^f-E\pi_{t+1}^f\right)+\\&\beta_3\varepsilon_{t+1}^y+(\alpha_4\beta_3-\beta_4)\varepsilon_{t+1}^q+\varepsilon_{t+1}^\pi-\pi^*\big)+\frac{\lambda}{\gamma^2}\ (\mathrm{e}^{\gamma y_t}.\gamma\frac{d}{di}\ \big(\alpha_1E_ty_{t+1}+\alpha_2y_{t-1}-\\&(\alpha_3+\alpha_4\gamma_3)(i_t-E_t\pi_{t+1})+\alpha_4\gamma_1E_tq_{t+1}+\alpha_4\gamma_2q_{t-1}+\alpha_4\gamma_4\left(i_t^f-E\pi_{t+1}^f\right)+\alpha_4\varepsilon_{t+1}^q+\varepsilon_{t+1}^y\big)-\\&\gamma(\alpha_1E_ty_{t+1}+\alpha_2y_{t-1}-(\alpha_3+\alpha_4\gamma_3)(i_t-E_t\pi_{t+1})+\alpha_4\gamma_1E_tq_{t+1}+\ \alpha_4\gamma_2q_{t-1}+\\&\alpha_4\gamma_4\left(i_t^f-E_t\pi_{t+1}^f\right)+\alpha_4\varepsilon_{t+1}^q+\varepsilon_{t+1}^y\end{aligned} \qquad (6b)$$

Rearranging and simplifying the above equation, we get

$$\begin{aligned}\frac{\partial L(\pi_t,y_t)}{\partial i}&=\frac{1}{\mu^2}\ \left(\mathrm{e}^{\mu(\pi_t-\pi^*)}\ .\mu(\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3)\right)-\mu\left(\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3\right)\ +\\&\frac{\lambda}{\gamma^2}\ [(\mathrm{e}^{\gamma y_t}.\gamma(-(\alpha_3+\alpha_4\gamma_3))-\ \gamma(-(\alpha_3+\alpha_4\gamma_3)]\end{aligned} \qquad (7)$$

After further simplification, the above equation takes the following form

$$\frac{\partial L(\pi_t,y_t)}{\partial i}=\frac{1}{\mu}(\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3))\left[e^{\mu(\pi_t-\pi^*)}-1\right]-\frac{\lambda}{\gamma}(\alpha_3+\alpha_4\gamma_3)[e^{\gamma y_t}-1] \qquad (8)$$

Now by applying expectations we can re-write the above equation as follows.

$$\frac{\partial L(\pi_t, y_t)}{\partial i} = \frac{1}{\mu}(\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)E_t\left[e^{\mu(\pi_t - \pi^*)} - 1\right] - \frac{\lambda}{\gamma}(\alpha_3 + \alpha_4\gamma_3)E_t[e^{\gamma y_t} - 1 \quad (9)$$

Next, we apply the log normal distribution rule, which turns $E_t(e^{\mu(\pi_t - \pi^*)})$ into $(e^{\mu E_{t-1}(\pi_t - \pi^*) + (\mu^2/2)\sigma^2{}_{\pi,t}})$. The term $E_{t-1}(\pi_t - \pi^*)$ shows the mean of the series, while the term $(\mu^2/2)\sigma^2{}_{\pi,t}$ is the conditional variance of the series. Since the output gap is assumed a zero mean, normally distributed process (Sooreea, 2008; Surico, 2007), the log normal distribution of $E_t(e^{\gamma y_t})$ gives $e^{\frac{\gamma^2}{2}\sigma^2{}_{y,t}}$. Thus, we can re-write Eq. (9) in the following way.

$$\frac{\partial L(\pi_t, y_t)}{\partial i} = \frac{1}{\mu}(\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)\left[e^{\mu E_{t-1}(\pi_t - \pi^*) + \frac{\mu^2}{2}\ \sigma^2_{\pi,t}} - 1\right] - \frac{\lambda}{\gamma}(\alpha_3 + \alpha_4\gamma_3)[e^{\frac{\gamma^2}{2}\sigma^2_{y,t}} - 1] \quad (10)$$

Linearizing the above equation around the point $(e^{\mu E_{t-1}(\pi_t - \pi^*) + (\mu^2/2)\sigma^2{}_{\pi,t}}) = (0, 0)$ and $e^{\frac{\gamma^2}{2}\sigma^2{}_{y,t}} = (0, 0)$, we have the following.

$$\frac{\partial L(\pi_t, y_t)}{\partial i} = \frac{1}{\mu}(\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)(\mu E_{t-1}(\pi_t - \pi^*) + \frac{\mu^2}{2}\sigma^2_{\pi,t}) - \frac{\lambda}{\gamma}(\alpha_3 + \alpha_4\gamma_3)(\frac{\gamma^2}{2}\sigma^2_{y,t}) = 0 \quad (11)$$

Now solving the above equation for π_t, we get

$$E_{t-1}\pi_t = \pi^* - \frac{\mu}{2}\sigma^2_{\pi,t} + \frac{\lambda(\alpha_3 + \alpha_4\gamma_3)}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3} \cdot \frac{\gamma}{2}\sigma^2_{y,t} \quad (12)$$

Taking conditional expectations of Eq. (5), we get the following.

$$E_{t-1}\pi_t = \beta_1 E_t\pi_{t+1} + \alpha_1\beta_3 E_t y_{t+1} + \left(\beta_1 - \beta_4 + \beta_3(\alpha_3 + \alpha_4)\right)E_t\pi_{t+1} + (\alpha_4\beta_3\gamma_1 + \beta_4(1 - \gamma_1)E_t q_{t+1} + \gamma_2(\alpha_4\beta_3 - \beta_4)E_{t-2}q_{t-1} + \beta_2 E_{t-2}\pi_{t-1} + \alpha_2\beta_3 E_{t-2}y_{t-1} - (\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)E_{t-1}(i_t - E_t\pi_{t+1}) + \gamma_4(\alpha_4\beta_3 - \beta_4)E_{t-1}\left(i_t^f - E_t\pi_{t+1}^f\right) \quad (13)$$

Putting the value of $E_{t-1}\pi_t$ from Eq. (13) into Eq. (12), we get the following equation

$$\beta_1 E_t\pi_{t+1} + \alpha_1\beta_3 E_t y_{t+1} + \left(\beta_1 - \beta_4 + \beta_3(\alpha_3 + \alpha_4)\right)E_t\pi_{t+1} + (\alpha_4\beta_3\gamma_1 + \beta_4(1 - \gamma_1)E_t q_{t+1} + \gamma_2(\alpha_4\beta_3 - \beta_4)E_{t-2}q_{t-1} + \beta_2 E_{t-2}\pi_{t-1} + \alpha_2\beta_3 E_{t-2}y_{t-1} - (\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3)E_{t-1}(i_t - E_t\pi_{t+1}) + \gamma_4(\alpha_4\beta_3 - \beta_4)E_{t-1}\left(i_t^f - E_t\pi_{t+1}^f\right) = \pi^* - \frac{\mu}{2}\sigma^2_{\pi,t} + \frac{\lambda(\alpha_3 + \alpha_4\gamma_3)}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3} \cdot \frac{\gamma}{2}\sigma^2_{y,t} \quad 14)$$

Finally, solving Eq. (14) for the interest rate i_t we get the desired forward-backward-looking MPRF, which is expressed as follows.

$$i_t = \psi_0 + \psi_1 E_t y_{t+1} + \psi_2 E_{t-2}y_{t-1} + \psi_3 E_t\pi_{t+1} + \psi_4 E_{t-2}\pi_{t-1} + \psi_5 E_{t-2}q_{t+1} + \psi_6 E_t q_{t-1} + \psi_7\left(i_t^f - E_t\pi_{t+1}^f\right) + \psi_8\sigma^2_{\pi,t} - \psi_9\sigma^2_{y,t} + \mu_t \quad (15)$$

where,

$$\psi_0 = -\frac{\pi^*}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3}, \qquad \psi_1 = \frac{\alpha_1\beta_3}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3}$$

$$\psi_2 = \frac{\alpha_2\beta_3}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3}, \qquad \psi_3 = \frac{\beta_1 + \beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3}{\beta_3(\alpha_3 + \alpha_4\gamma_3) - \beta_4\gamma_3}$$

$$\psi_4 = \frac{\beta_2}{\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3}, \qquad \psi_5 = \frac{\beta_4(1-\gamma_1)}{\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3}$$

$$\psi_6 = \frac{\gamma_2(\alpha_4\beta_3-\beta_4)}{\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3}, \qquad \psi_7 = \frac{\gamma_4(\alpha_4\beta_3-\beta_4)}{\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3}$$

$$\psi_8 = \frac{\mu/2}{\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3}, \qquad \psi_9 = \frac{-[\lambda\gamma(\alpha_3+\alpha_4)]}{2[\beta_3(\alpha_3+\alpha_4\gamma_3)-\beta_4\gamma_3]^2}$$

The derived MPRF given in Eq. (15) includes both forward-looking and backward-looking aspects of all the underlying variables. One should also note that the terms $\psi_2 E_{t-2}y_{t-1}$, $\psi_5 E_{t-2}q_{t-1}$, and $\psi_6 E_{t-2}\pi_{t-1}$ are additional in our MPRF as compared to MPRFs presented in the existing literature. As in Whelan (2013), according to rational expectations, since $E_{t-1}(p_t) = p_t + \varepsilon_t$, $E_{t-2}(p_{t-1}) = p_{t-1} + \varepsilon_{t-1}$ and $E_t(p_{t+1}) = p_{t+1} + \varepsilon_{t+1}$. Therefore, Eq. (15) can be rewritten as follows.

$$i_t = \psi_0 + \psi_1 y_{t+1} + \psi_2 y_{t-1} + \psi_3\pi_{t+1} + \psi_4\pi_{t-1} + \psi_5 q_{t+1} + \psi_6 q_{t-1} + \psi_7\left(i_t^f - \pi_{t+1}^f\right) + \psi_8\sigma_{\pi,t}^2 - \psi_9\sigma_{y,t}^2 + \mu_t \tag{16}$$

4. Data and Estimation Method

4.1 Data

To empirically examine how the central banks respond to different backward and forward variables while setting interest rates, we estimate the proposed backward-forward MPRF for Pakistan, a small open and emerging economy. To carry out the empirical analysis, quarterly data on the underlying variables are used to get the reliable, consistent, efficient estimates. The analysis covers the period 1971Q1-2018Q4. As it is in Eq. (16), the interest rate is dependent variable while the one-period lagged and lead output, one-period lagged and lead rate of inflation, one-period lagged and lead exchange rates are independent variables in the model. In addition to this, the current value of foreign real interest rates, output and inflation volatility are also included in the specification. The data on the required variables are taken from IFS database managed by International Monetary Fund (IMF). Following prior researches on the MPRF, we consider the USA as a foreign country.

We estimate ARCH models to generate inflation and output volatilities. The ARCH estimates for the volatility of output are given in Table A.1 of the Appendix, whereas, the ARCH estimation results for the inflation volatility are given in Table A.2 of the Appendix. For the output volatility, the log of quarterly GDP is used and for the inflation volatility, the first-difference of log CPI is utilized. Quarterly GDP are obtained from the annual GDP using the following process.

There are several methods that can be used to derive quarterly data from annual data. However, one of the well-known and well-accepted methods in the literature is the proportional Denton procedure (hereafter PDP). In this study, we use this method to get quarterly estimates from annual GDP.[6] To perform the interpolation, the PDP uses high-frequency indicators that are highly correlated to the underlying low-frequency variables. Given this requirement, in this study, industrial production index (hereafter IPI) is considered as observed quarterly (high-frequency) indicator to interpolate annual GDP.

[6] *See Rashid and Jehan (2013) for a comparison of different methods of interpolation.*

As in Denton (1970, 1971), the PDP is described as follows. Let I be an integer. Further, suppose that we want I per year intra-annual time periods, which are quarters in our case. Let T be total number of years and the time series of interest spans over T years. Thus, it has $n = I \times T$ total number of observations.

The following column-vector represents the original data.

$$y = [y_1, y_2, \dots, y_n]' \tag{17}$$

It is also assumed that a column-vector of T annual sums is available to use from another dataset. This vector is expressed in the following form.

$$x = [x_1, x_2, \dots, x_n]' \tag{18}$$

To derive a new column vector, say w, after making the required adjustments in the preliminary given vector, say y, in his seminal work, Denton (1970, 1971) recommended the following method.

$$w = [w_1, w_2, \dots, w_n]' \tag{19}$$

This procedure fulfills the two necessary conditions. First, it is the minimization of distortions of the underlying primary series. The second condition states that the sum of I observations of the derived (obtained) time series in a given year should be equal to the given annual value for that year. More specifically, Denton (1970, 1971) proposed a penalty function, which is denoted by $p(w, x)$, and the vector w is selected to minimize the penalty function by considering the following constraint function.

$$\sum_{(N-1)I+1}^{NI} w_t = x_N \qquad for\ N = 1, 2, \dots, T \tag{20}$$

To obtain the solution, Denton (1970, 1971) defined the Lagrange function as follows.

$$L = (w - y)'A(w - y) - 2\varphi'(x - B'w) \tag{21}$$

In Eq. (21), $(w - y)'A(w - y)$ is the specified form penalty function, which is quadratic. A is a symmetric $n \times n$ nonsingular matrix.[7] φ and $B\ (n \times T)$ are defined as follows.

$$\varphi = [\varphi_1, \varphi_2, \dots, \varphi_n]' \quad and \qquad B = \begin{bmatrix} j & 0 & \cdots & 0 \\ 0 & j & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & j \end{bmatrix}$$

where j is a $I - dimentional$ column vector. The each element of j is one and 0 being $I - dimentional$ null column vector. Taking the first derivatives of Eq. (21) with respect to w and φ elements, we can obtain the requited solution of the equation. Specifically, setting the partial derivatives to zero and solving them for the required values we get the following.

$$\begin{bmatrix} w \\ \varphi \end{bmatrix} = \begin{bmatrix} A & B \\ B' & 0 \end{bmatrix} \begin{bmatrix} A & 0 \\ B' & I \end{bmatrix} \begin{bmatrix} y \\ d \end{bmatrix} \tag{22}$$

where I represents an identity matrix having $T \times T$ dimension and 0 is the null matrix of $T \times T$ dimension. d is the vector of discrepancies between the two sets of annual totals and is described as $d = x - B'w$. Consequently, the possible solution for vector w is expressed as $w = y + Cd$, where $C = A^{-1}B(B'A^{-1}B)^{-1}$. Therefore, one should note that the

[7] *See Denton (1971) for the definition of* A.

adjusted estimates are equal to the original figures plus linear combinations of disparities of both sets of annual sums.

4.2 Empirical Model

As above-mentioned, the objective of this paper is twofold. The first objective is to present an analytical framework for monetary policy rules by considering both forward-looking and backward-looking aspects of the underlying variables. The second objective is to empirically estimate the proposed model for Pakistan. Therefore, in this sub-section, we display our empirical model as follows.

$$i_t = \psi_0 + \psi_1 y_{t+1} + \psi_2 y_{t-1} + \psi_3 \pi_{t+1} + \psi_4 \pi_{t-1} + \psi_5 q_{t+1} + \psi_6 q_{t-1} + \psi_7 (i_t^f - \pi_{t+1}^f) + \psi_8 \sigma_{\pi,t}^2 - \psi_9 \sigma_{y,t}^2 + \mu_t \quad (23)$$

where,

y_{t-1} = Backward/Lag output, y_{t+1}= Forward/Lead output

π_{t+1} = Forward/Lead inflation, π_{t-1}= Backward/Lag inflation

q_{t+1}= Forward /Lead exchange rate, q_{t-1}= Backward /Lag exchange rate

$r_t^f = (i_t^f - \pi_{t+1}^f)$ = Foreign real interest rate, $\sigma_{\pi,t}^2$ = Inflation volatility

$\sigma_{y,t}^2$ = Output volatility

4.3 Estimation Technique

Reviewing the empirical literature on MPRs we find that different studies have used different econometric methods to estimate MPRF. The most commonly used estimation methods are OLS, VAR, TSLS, GMM, VECM, and probit and logit models. However, Murcia (2007) showed that the generalized method of moments (GMM) estimator yields more accurate estimation than the maximum likelihood method. Several other researchers such as Shibamoto (2008), Dolado *et al.* (2005), and Clarida *et al.* (1998) have also used the GMM estimator for carrying out the empirical analysis. To estimate the model, we also use the GMM estimator. Further, following Murcia (2003), we generate proxies for the inflation volatility and output gap by estimating ARCH models.

There is an increasing trend towards using the GMM method. If there is heteroskedasticity in the data, then the GMM estimator would be considered efficient as compared to the instrumental variable (IV) estimator. It is well accepted that the GMM estimators are relatively more consistent, efficient, and asymptotically normal. Further, this method is also suitable for estimating any non-linear dynamic model even in the case when we do not know full and accurate specifications of the probability distribution of the underlying variables.

This estimation method is very flexible and it permits scholars to use a different set of instruments. Further, the researchers may define a different lag structure for each set of instruments. Nevertheless, the reliability, accuracy, and robustness of the results critically depend on whether the instruments are independent from the error term. Thus, to ensure the validity of the instruments, this study applies Hansen's (1982) J-test. The estimated J-test statistics are given in each table present in the next section. The statistics provide strong evidence that the instruments are not correlated with the estimated residuals and fulfill the orthogonality condition.

5. Estimation Results

We start by checking the time series properties of the underlying variables. Particularly, we use the KPSS unit root test to identify the order of integration of the variables. The test statistics are calculated without and with a linear time trend in the specification. Following the existing literature we apply Bartlett Kernal as a spectral estimation method. The Newey-West (1994) bandwidth procedure is used to decide the optimal bandwidth for estimation. The results of the test reveal that all the underlying variables are stationary at their levels except the market interest rate, the foreign real interest rate, and the exchange rate.[8] However, these variables become stationary at their first differences.

5.1 Monetary Policy Reaction Function

5.1.1 Estimation with Asymmetric Preference

We estimate the proposed MPRF to investigate whether lagged and lead values of the underlying macroeconomic variables have an important role to play in setting the nominal interest rate by the State Bank of Pakistan. Specifically, using quarterly date, we estimate the model given in equation (23) by applying the GMM estimator. The results are given in Table 1. The estimated J-test provides evidence that the instruments used in the estimation are valid and orthogonal to the estimated residuals.

Table 1 presents the estimation results for MPRF when we consider asymmetric preferences of policymakers. We can see from the table that the estimated coefficients of all the variables appear statistically significant at either the 1% or 5% level of significance. This implies that the interest rate is significantly related to both past realized values and the future expected values of the underlying variables. These results provide strong support to the proposed forward- and backward-looking monetary policy reaction function. These findings also suggest that the monetary policymakers take into consideration both forward- and backward-looking aspects of the underlying variables when setting the interest rate in the economy.

Table 1

Forward-Backward-Looking MPRF with Asymmetric Preferences

Variables	Coefficient	p-value
Constant	-1.25	0.045
y_{t+1}	1.22	0.011
y_{t-1}	1.95	0.000
π_{t+1}	0.37	0.012
π_{t-1}	-0.15	0.000
q_{t+1}	-0.34	0.001
q_{t-1}	-0.27	0.022
$\sigma^2_{\pi,t}$	-2.65	0.003
$\sigma^2_{y,t}$	-1.54	0.039
r^f_t	0.84	0.008
J-statistics	$\chi^2 = 16.76$	p-value = 0.27

[8] We do not present the results of the unit root test to economize on space. However, the results are available from the authors.

The estimated coefficients of y_{t+1} and y_{t-1} are positive and statistically different from zero, indicating that both lead and lagged values of output have positive impacts on the interest rate. Yet, the point estimates of output coefficient suggest that one-period lagged output has relatively stronger impacts on the interest rate. The positive impact of lead output on interest rates suggests that the central bank actually over predicts output growth. Consequently, the monetary policy authority increases the interest rate in the economy, which may cause inflation in the future by increasing cost of borrowing and in turn, production costs. Jehan (2013) has also reported similar findings. One-period lagged output coefficient indicates that the State Bank of Pakistan is likely to design tight monetary policy by increasing interest rates in response to higher output in the preceding year. These results are generally in line with the findings of Malik (2007) and Dolado *et al.* (2005). Further, we also notice that the monetary policymakers respond quite differently to the past and future expected rate of inflation. The sign of the estimated coefficients suggests that the responsiveness of the interest rate to one-period prior rate of inflation is negative, whereas, the expectation about future rate of inflation is positively associated with the rate of interest. This finding suggests that the monetary policymakers are likely to raise the interest rate when they expect high future inflation. The point estimates of inflation coefficient provide an indication that the central bank gives more consideration to the expected future inflation as compared to the past inflation. Jehan (2013) and Batini (2003) also present the similar results. The intuition for this finding is given below.

As in the exchange rate equation (equation (3)), the foreign real interest rate is positively, significantly related to the exchange rate. This positive association will ultimately result in higher levels of output. Consequently, if the authorities have an objective to control inflation in the future, then they may increase the domestic interest rate to decrease the demand for loanable funds. Our results suggest that Pakistan's central bank should follow an active monetary policy. Specifically, the increase in the interest rate should be more than the increase in the expected future inflation caused by the variations in the foreign policy variables. Caglayan *et al.* (2016) also document similar results.

The estimates regarding the exchange rate reveal that the lagged exchange rate is negatively and significantly related to the interest rate. This finding suggests the mean reverting behavior of foreign exchange rates, implying that the central bank should not reverse its interest rate actions. This result is in accordance with the finding of Ball (1999). The one-period lead exchange rates have also negative and statistically significant impacts on interest rates. This finding implies that the monetary policymakers are likely to set the lower interest rate when they have expectation that foreign exchange rates will be higher in the future. Previously, Caglayan *et al.* (2016) also reported the negative effect of lead exchange rates on the domestic interest rate. Comparing the effect of both lead and lagged exchange rates we observe that the interest rate is more sensitive to the expected future exchange rate than the past exchange rate. We also show that the foreign inflation has significant and positive impacts on the domestic interest rate, revealing that the authority also consider price levels in the foreign country while setting domestic interest rates.

Last, but not the least, looking at the estimates of asymmetric preferences, we find that the sign of estimated coefficient of the inflation volatility is negative and appears statistically significant at the 1% level of significance. The point estimate of the inflation volatility coefficient is -2.56. This result implies that the sensitivity of domestic interest rates to unexpected variations in the rate of inflation is negative. This negative response suggests that the central bank decreases the interest rate to may get the stable economic environment. This finding is in line with the findings presented by Bec *et al.* (2002), Murcia

(2003), Dolado *et al.* (2004) and Jehan (2013). These studies have also documented that the inflation volatility has negative and significant influences on the behavior of monetary policymakers.

We also observe that the estimated coefficient of output volatility is negative and statistically different from zero at any acceptable level of significance. The negative effect of output volatility on the interest rates implies that the monetary policymakers are more responsive to output contractions than output expansions while setting interest rates in the economy. Said differently, output contractions trigger monetary policymakers to design loose monetary policy by lowering the rate of interest. These results are in line with the findings presented in the existing literature (Caglayan *et al.* (2016) and Surico (2007)).

5.1.2 MPRF without Asymmetric Preferences

After having established the impacts of both forward and backward macroeconomic variables on the behavior of monetary policymakers in the presence of asymmetric preferences, we present another set of the results by excluding the asymmetric preferences from the specification. We present these results to ensure that the inclusion of asymmetric preferences in the analytical framework does not have any significant influence on the parameters of the other variables present in the model. Another objective of this exercise is to compare the results with those studies that do not consider asymmetric preferences of policymakers while estimating the MPRFs. Table 2 presents the results. Overall, the estimates are similar to those presented in Table 1. All the variables have expected sign and are statistically significant. Hence, we can conclude that the results regarding the effects of forward- and backward-looking aspects of macroeconomic variables on the behavior of monetary policymakers are not driven by the presence of asymmetric preferences in the specification. The estimates presented in Table 2 also reveal that our results are similar to the findings of those studies that do not include asymmetric preferences of monetary policymakers in the specification when estimating MPRs.

Table 2

Forward-Backward-Looking MPRF without Asymmetric Preferences

Variables	Coefficient	p-value
Constant	2.38	0.000
y_{t+1}	1.87	0.002
y_{t-1}	2.71	0.004
π_{t+1}	0.42	0.024
π_{t-1}	-0.35	0.000
q_{t+1}	-0.82	0.013
q_{t-1}	-0.52	0.030
r_t^f	0.75	0.017
J- statistics	χ^2 = 15.28	p-value = 0.41

5.2 Robustness Tests

In this subsection, we present several robustness checks to ensure the soundness of our findings. First, we re-estimate the proposed monetary policy reaction function by taking into account the structural break in the data. There are several studies in the literature that have estimated either forward-looking or backward-looking monetary rules. One can argue the backward and the forward terms included in a single framework may correlate and the one type of term may drive the impact of the other type. Therefore, we also estimate the forward- and backward-looking monetary rules separately as a robustness check.

5.2.1 Taking into Account Structural Breaks

In Table 1, we presented the estimation results of Eq. (23) without taking into account structural breaks in the data during the examined period. However, one can assume the structural break may affect the precision of the parameters of the monetary reaction function. To ensure that the estimates presented in Table 1 are robust to the presence of any possible structural break in the data, we consider national reforms of 1992 as a potential structural change in the economy and re-estimate the model depicted in Eq. (23). To carry out this exercise, we generate a dummy variable, which takes value 1 for the period after 1992 and 0 otherwise.

The results of this robustness test are given in Table 3. The estimation results provide evidence that the estimated coefficients on all the underplaying variables are similar, both in terms of sign and statistical significance, to those presented in Table 1. In particular, we find that the effects of both forward-looking and backward-looking dimension of the variables appear statistically significant even after taking into account the known structural break at 1992 in the data. The estimates of asymmetric preferences are also similar to our previous findings given in Table 1. Thus, we can conclude that the empirical results on the monetary policy rules that we present in this paper are robust to the presence of any possible structural break in the data.

Table 3

Forward-Backward-Looking MPRF: Taking Structural Breaks into Account

Variables	Coefficient	p-value
Constant	0.98	0.045
y_{t+1}	1.31	0.012
y_{t-1}	2.25	0.004
π_{t+1}	0.37	0.002
π_{t-1}	-0.23	0.031
q_{t+1}	-0.63	0.000
q_{t-1}	-0.24	0.007
$\sigma^2_{\pi,t}$	-2.89	0.000
$\sigma^2_{y,t}$	-1.45	0.046
r^f_t	0.98	0.003
J-statistics	$\chi^2 = 16.75$	p-value = 0.36

5.2.3 Estimating Forward-Looking and Backward-Looking Specifications Separately

It is quite possible that the backward (lag) and forward (lead) variables included in the specification may correlate with each other and thus, it is possibility that the one type of variables may drive the effects on the interest rate of the other type of variables. Therefore, to avoid ourselves from such possibility, we re-estimate MPRF where only forward-looking terms are incorporated in the specification. In other words, we present the results where we do not take into account the lagged output, the lagged inflation, and the lagged exchange rate. The results are given in Table 4. These results are consistent with those reported earlier in Table 1. The estimated coefficients of all the variables are significantly different from zero, indicating that their effects on the behavior of the central bank are statistically significant.

Table 4

Estimated Forward-Looking MPRF

Variables	Coefficient	p-value
Constant	-2.55	0.000
y_{t+1}	-0.64	0.006
π_{t+1}	0.19	0.027
q_{t+1}	-0.23	0.046
r_t^f	0.68	0.002
$\sigma_{y,t}^2$	-4.17	0.000
$\sigma_{\pi,t}^2$	-3.76	0.000
J-statistics	$\chi^2 = 10.54$	p-value = 0.43

Finally, we present another set of results by estimating only the backward-looking monetary policy reaction function. The estimates given in Table 5 indicate that the lagged value of output and the past period realized inflation both have significant and positive impacts on the interest rate setting. However, the previous period exchange rate is significantly and negatively related to the interest rate decisions of the central bank. We also show that the inflation and output volatility both negatively affect the interest rate, albeit the impact of the former is substantially higher than the later. Taken together, the robustness checks show that the estimates on the effects of forward- and backward-looking aspects are not only robust to different specifications of MPRF but also remain robust even after taking into account the possibility of possible structural breaks in the dataset during the examined period. In sum, our empirical investigation provides strong support to the proposed forward-backward-looking MPRF.

Table 5

Estimated Backward-Looking MPRF

Variables	Coefficient	P-value
Constant	-2.13	0.062
y_{t-1}	2.53	0.000
π_{t-1}	0.29	0.044
q_{t-1}	-0.36	0.000
$\sigma_{\pi,t}^2$	-3.72	0.003
$\sigma_{y,t}^2$	-2.11	0.002
r_t^f	0.86	0.000
J- statistic	χ^2=25.29	P-value = 0.27

6. Conclusions and Policy Implications

In this paper, we first propose an analytical framework for MPRF that includes both forward-looking and backward-looking aspects of the underlying determinants of interest rates. In order to examine how relevant the derived forward-backward-looking MPRF is in practice, the proposed function is then estimated for Pakistan using quarterly data covering the period 1971Q1-2018Q4. The asymmetric preferences of the monetary policymakers are also taken into account while estimating the monetary policy reaction function. The ARCH models are estimated for quarterly consumer prices index and gross domestic product in order to generate proxies for inflation and output volatilities. To mitigate the problem of endogeneity, we apply the GMM estimator to estimate the proposed model. Finally, we apply several robustness tests to ensure the reliability of the estimation results.

Our empirical results provide significant evidence that the central bank adjusts interest rates by considerably considering both lead (forward) and lagged (backward) aspects of the underlying macroeconomic variables. However, we find that the monetary policymakers assign relatively more weight to the future expected inflation, future exchange rates, and the prior period output when setting the interest rate. We also find significant evidence of the presence of asymmetric preferences regarding interest rate setting. Specifically, we find that both the output and inflation volatility are negatively related to interest rate setting. This suggests that the State Bank of Pakistan is likely to respond more to output contractions than it does to the output expansion. Our empirical results also indicate that the central bank of Pakistan is more worried about the rate of inflation as compared to output while setting interest rates. Another interesting result of this paper is that the foreign real interest rate variable is also significant in determination of the domestic interest rate. The robustness checks show that the findings hold even after controlling for structural breaks in the data and even when we estimate the forward- and backward-looking monetary policy rules separately.

The findings of this paper are of a great significance to policymakers to set the interest rate under different macroeconomic conditions. The findings are also useful in predicting the behavior of the monetary policymakers regarding interest rate setting. By considering both foreword- and backward-looking dimensions of the macroeconomic indicators the central bank of Pakistan will be able to more effectively stabilize the economy. Further, empirical evidence, particularly from developing and emerging economies, on the proposed forward- and backward-looking monetary policy reaction function will definitely enhance our understanding of the monetary policy rules.

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Appendix

Table A.1: Estimates for Output Volatility				
	Coefficient	Std. Error	Z-Statistics	Probability
Constant	0.675	0.125	5.400	0.000
AR(1)	0.587	0.096	6.114	0.000

Variance Equation

Constant	0.145	0.006	24.167	0.000
ARCH(1)	0.826	0.256	3.226	0.001

Table A.2: Estimates for Inflation Volatility				
	Coefficient	Std. Error	Z-Statistics	Probability
Constant	0.037	0.002	18.500	0.000

Variance Equation

Constant	0.005	0.001	5.000	0.000
ARCH(1)	0.653	0.112	5.830	0.000