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EVALUATING THE CHOICE OF OPTIMAL MONETARY POLICY RULES WITHIN THE DSGE FRAMEWORK: EMPIRICAL EVIDENCE FROM PAKISTAN

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Abstract

This study examines the effectiveness of different monetary policy rules for developing economies, specifically focusing on Pakistan. It investigates whether monetary policy would have been more welfare-enhancing had the interest rate, rather than the money supply, been used as the primary policy instrument. A calibration analysis was conducted using quarterly data from 1992Q3 to 2017Q2 within the Pakistan Dynamic Stochastic General Equilibrium (DSGE) model, incorporating parameters from the Taylor and Money Supply rules. Counterfactual simulations revealed that employing the money supply rule as an optimal policy instrument increases output and inflation volatility, whereas the Taylor rule leads to greater macroeconomic stability by minimizing these fluctuations and converging to a steady state. The findings indicate that the price-based rule outperforms the money supply rule, aligning with the monetary policy framework currently followed by the State Bank of Pakistan. This rare outcome underscores the effectiveness of Pakistan's existing monetary policy approach in stabilizing the economy.

INTRODUCTION

An optimal monetary policy is crucial for the stabilization of macroeconomic fluctuations. The State Bank of Pakistan (SBP) claims that promoting economic growth and maintaining price stability is the core objective of monetary policy. Monetary policy not only ensures stability in prices and maintains economic growth but also maximizes employment in the economy. The monetary policy is designed in such a way that it can target inflation and other objectives. Instrument rules are the state contingent reaction functions that link instrument variables with the performance of the economy[1]. The debate about the choice of optimal monetary policy instruments is popular nowadays. However, within various choices, the price of money and quantity of money cannot be used at the same time to influence the target variables[2]. This study develops and estimates a macroeconomic model with the New Keynesian Dynamic Stochastic General Equilibrium (DSGE) setup for the analysis of optimal monetary

[1] (Bennet T McCallum, 1988), (Taylor, 1993)
[2] (Turnovsky, 1975)

policy instruments in Pakistan. Keeping in mind the effective role of monetary policy in the stabilization of an economy, there is a dire need to conduct a monetary policy analysis for Pakistan because economic growth and stability are the major challenges that Pakistan is facing these days. We expect that with the help of such an analysis, we should be able to identify the optimal monetary policy rules. Since monetary policy relies only on the price or quantity rule, the possibility to identify which of the monetary policy rules will be more effective in minimizing output and inflation volatility and achieving the targeted economic growth is also there.

The main objective of SBP is designing monetary policy in such a way as to attain and maintain stability in the general price level. The SBP uses short-term policy rules (Interest Rate and Money Supply) because it cannot influence inflation directly. "Money supply" denotes the quantity of money and "interest rate" is the price of money. The quantity and the price cannot be used to manipulate the economy of the country simultaneously in a free market system.

In microeconomic theory, price and quantity cannot be determined simultaneously; either price is set and the quantity is left to be determined by the market forces or vice versa. Moreover, in this context, the SBP should look into and choose that which is an optimal policy rule. Earlier literature suggests that the money supply seems to be a superior policy rule as compared to the interest rate[3] and the choice of policy rules depends on the economic environment[4]. A related study conducted in Pakistan (Ali & Ahmed, 2014) focuses on the targeting regimes, i.e., price and inflation targeting in a simple stochastic macro model. The present study, however, focuses on the choice of optimal monetary policy rules instead of just focusing on price and inflation targeting.

Past studies have explored the monetary policy rules, and transmission effects in Pakistan (Rafique et al, 2021). In Pakistan, rules of Monetary policy have been analyzed quite broadly and excessively with articles that identify money supply as a policy rule for the monetary policy and transmission analysis (Ali & Ahmed, 2014; Ahmad & Pasha, 2015; Rafique et al, 2021) and with interest rate as a policy rule (Haider, ud Din, & Ghani, 2012). The present study also conducts a counterfactual experiment in which the money supply is set as a policy rule. In addition, to determine whether the monetary policy would have been more welfare enhancing had the interest rate been utilized as the policy rule instead of money supply in a calibration analysis of Pakistan's monetary policy transmission mechanism. Hence, the theoretical baseline adopted in this study belongs to the class of the models called "New Keynesian Dynamic Stochastic General Equilibrium (DSGE)" in the closed economy.

2. Literature Review

The monetary policy framework of Pakistan has evolved. The focus tends towards price stability, which is considered explicitly necessary for the attainment of viable economic growth. It is obvious from the SBP's strategic plan for the period 2016-2020 to adopt flexible inflation targeting by 2020 as several reassuring developments at the institutional level have also happened in this context. We moved from the monetary targeting regime to the interest rate targeting regime, and we are interested in seeking out whether the movement from the regimes prescribed above, has been effective to tame inflation or if we are still relying on the monetary targeting. There has been a remarkable discussion as to how monetary policy should be directed to keep long-run stability in terms of output growth and the price level[5]. Monetary Policy explains the relationship between the quantity of money and the price of money in the economy, in particular when we are discussing the context of Pakistan, monetary policy is in line with the SBP's prime objectives of maintaining price stability, and economic growth. The rules in general require a link between the policy instruments, that is, the price of money, the output gap, and the inflation rate are the goal variables. The interest rates are raised by monetary authorities when the economy is facing high inflation, and the economy operates above the full employment level, i.e., the actual output is above its potential output level.

[3] (Sargent & Wallace, 1975)
[4] (Niemann, Pichler, & Sorger, 2010) (Poole, 1970), (Benavie & Froyen, 1983), (Woglom, 1979)

There is now a consensus that a short-run tradeoff between inflation and unemployment exists so that the Phillips curve is related to the nominal rigidities in wages and prices. Hence the monetary policy is effective only in the short run. There are two types of monetary policy in the system, expansionary and contractionary monetary policy. The former tends to increase the money supply, output level, and employment in the economy, and it leads us to a problem named dynamic inconsistency (Barro & Gordon, 1983; Chari & Kehoe, 2006; Kydland & Prescott, 1977)[6]. If we go back to the earliest literature, the discussion on rules starts with the study by Simons (1936) as he was the first who started the discussion on rule versus discretion, and his ideas support that economic stability can be achieved by committing to a policy rule.

In the early 1960s, the discussion on rules was started, and M. Friedman (1960) proposed a constant growth rule that money grows at a constant rate. The Friedman rule states that the social cost of creating additional fiat money should equal the opportunity cost of holding money that is faced by the economic agents. A low nominal interest rate leads to a lower level of investment in the economy and implies lower economic growth; this imposes the cost of following the Friedman rule, so it needs to be reassessed. Monetarist believes that inflation is always and everywhere a monetary phenomenon[7]. On the other hand, according to him, if we peg interest rates it will destabilize our economy because it deviates us from the equilibrium determinacy.

In the early 1970s, the problem of inflationary bias and time inconsistency developed in the system for the monetary policy analysis[8]. Whereas in 1980, when money supply began to be used as a policy rule, that shows how a Monetary Authority evades the large fluctuations of output by employing the instruments of base money. The nominal GDP is larger than the target level; the rate of growth of base money will be reduced. It proved to be the automatic stabilization tool for the macroeconomy, and the goal was to reduce the variance of nominal gross national product[9]. Since 1990, most of the hypothetical and empirical work has been done through the McCallum rule (Bennet T McCallum, 1988) that advocates short-term interest rate changes in response to changes in the output gap and the inflation rate. The prescribed rule indicates some issues of money demand instability function and the volatility in the velocity of money.

In the decade of the 1990s, the price-based monetary policy rule was used. Taylor (1993) gives a feedback rule that explains the deviation of the "output, and inflation from the target level." Taylor does the comparison of the actual interest rate that is suggested by the rule in his study. The policy rule used in the Taylor rule is the short-term nominal interest rate, and is reliable with inflation targeting[10]. Taylor (1993) started to use interest rates as a policy instrument in the mid-1980s[11]. Taylor (1993) also claimed in his paper that the money supply could be used as a policy instrument. In the context of the discretion versus rule debate, Tariq Mahmood (2010) mentioned that committing to rule is a better policy for the macroeconomic stability in Pakistan. However, the debate was not meaningful. W. S. Malik & Ahmed (2010) discussed that the price rule would perform better than the discretionary policy stance in a closed economy context.

2.1 Instrument Rules

The instrument rules are the state contingent reaction function that links important variables with the state of the economy (Bennet T McCallum, 1988; Taylor, 1993).

Monetary Targeting Approach

The monetary aggregate, as a rule, assumes that the monetary authority conducts monetary policy by adjusting the money supply[12]. A stable money demand function is a prerequisite for monetary targeting strategy, which in turn requires consistency in velocity (B. Friedman, 1956). With an inconsistent velocity, the use of monetary aggregates

[6] See (Calvo, 1978)
[7] (M. Friedman, 1960)
[8] (Chari & Kehoe, 2006), (Kydland & Prescott, 1977), (Calvo, 1978), (Barro & Gordon, 1983) state that the discretionary policy is time inconsistent policy.
[9] For more see (Bennet T McCallum, 1988)
[10] (Kydland & Prescott, 1977), and (Bennett T McCallum, 1995) proposed the use of discretion in the choice of optimal monetary policy rules to be used for stabilizing output, and inflation.
[11] See (Stuart, 1996)
[12] (Svensson, 1985), (Cooley & Hansen, 1989, 1997, 1998), (Clower, 1967), and (R. E. Lucas & Stokey, 1987).

will lead to uncontrollable inflation. Which is always harmful to the economy.

Interest Rate Targeting Approach

The interest rate rule assumes that SBP uses the Taylor-type rule to react to instabilities in prices and output levels from their equilibrium levels. In the study conducted by Taylor (1993)The Central Bank reportedly selected a short-run nominal interest rate in a manner that is modified with their inflation target. He defined that the nominal interest rate should be set as a reaction to variations of inflation and the output gap.

Another study by Hayat, Ahmed, & Balli (2019) discusses the monetary policy rules in different periods, i.e., monetary, transitory, and interest rate regimes. The three major findings of the study include that money plays its role effectively in explaining business cycle fluctuations. The increased focus on the Taylor rule (interest rate rule) in Pakistan, due to this, the role of the money supply has receded, and the price puzzle suggests that for the policy rule we should use the money supply.

Several studies have explored the monetary policy rules in Pakistan and have been analyzed quite broadly. However, a comparative analysis of rules has been missing all along. The present study aims to determine whether the monetary policy would have been more welfare-enhancing had the interest rate been used as the policy rule instead of money supply in a calibration analysis of Pakistan's monetary policy transmission mechanism.

3. Theoretical Framework

This section arranges the theoretical baseline model for the determination of the choice of optimal monetary policy rules for Pakistan in a DSGE framework. The Monetary Policy setup in this study will follow that of Wenlang and Zhang (Zhang, 2009). The model followed has some underlying assumptions regarding the economic agents. Major changes have been observed in macroeconomic modeling during the last four decades. In 1970, the Keynesian models were criticized because of the lack of theoretical foundations, hence validity was tested by several economists like Lucas and Sims (R. Lucas & Sargent, 1979) among others.

The Real Business Cycle (RBC) model explains the response of the rational agent towards the real variable. The new Keynesian Model incorporates the role of nominal rigidities in an economy. Firms produce differentiated goods, and the Calvo mechanism is used to set the wages and prices. The model is an extension of the RBC theory in an economy with sticky wages, and sticky prices. Households maximize a utility function concerning the control variable that is (Money, Consumption, and Work) in an infinite horizon model. Rational expectations were adopted by the New Keynesians (NK) and built models by providing microeconomic foundations to the aggregate relationships among variables of interest in the sticky prices presence. Fischer (1977) showed the impact of monetary policy in stabilizing the economy using a model of long-term wage contracts under rational expectations. Taylor (1979) expanded Fisher's work and showed long-lasting effects using monetary policy even after wages and prices were adjusted.

3.1 The Household Sector

There exists a band of households in the economy indexed by k, (0, and 1).

The objective function with the constraint is maximized by Household k.

$$Et \sum \beta i \, Uk_{t+i} \tag{3.1}$$

The Utility function here is separable in real money balances, consumption, labor, and leisure, where β shows the discount factor.

$$u_{,t} = \frac{1}{1-\sigma}(c_{k,t} - hc_{t-1})^{1-\sigma} + \frac{1}{1-\gamma}\left(\frac{M_{k,t}}{P_t}\right)^{1-\gamma} - \frac{1}{1+\eta}\left(N_{k,t}\right)^{1+\eta}$$

The household enters period t with capital stock$K_{k,}$ nominal money balances $M_{k,-1}$ and bond $B_{k,-1}$, $R_t and\ r_t{}^c$denote gross return of bond and rental of capital, while $C_{k,t}$, $I_{k,t} and\ N_{k,t}$ denote real consumption investment and labor supply in period t.

$$\frac{M_{k,t}}{P_t} + \frac{B_{k,t}}{P_t R_t} + c_{k,t} + I_{k,t} = \frac{M_{k,t-1}}{P_t} + \frac{B_{k,t-1}}{P_t} + \frac{W_{k,t}}{P_t} N_{k,t} + D_{k,t} + T_{k,t} \tag{3.2}$$

Household holds their income in the form of cash balancesM_k, and bondsB_k. $\boldsymbol{W_k}$, Is nominal wage, each household is assumed to own an equal share of firms and receive an aliquot share of real aggregate profits $\boldsymbol{D_k}$, $\boldsymbol{T_k}$, denotes the real net transfer from the government in period *t*.

3.2 Monetary Policy Reaction Function

The optimal monetary policy is crucial for the macro economy to stabilize. Monetary policy in a closed economy, in the short run, monetary policy has the objective of price level stability and reduces the variability in the output gap. Monetary policy attains only price stability in the long run. Monetary policy can achieve inadequate objectives when the economic agent is rational. Monetary policy can achieve its objectives only by committing to some rule,i.e., Taylor rule or McCullum rule (W. Malik & Ahmed, 2007; W. S. Malik & Ahmed, 2010). The following are the two policy rules:

3.2.1. Quantity Rule: Money Supply Rule

$$V_t = I_1 v_{t-1} - I_2 E\pi_{t-1} - I_3 \hat{y}_t + \lambda_{v,t} \quad (3.3)$$

Consumption, which gives real, balances an explicit role in both the output and inflation equilibrium relationships (Walsh, 2017).

3.2.2 Price Rule: Interest Rate Rule

The monetary authority is assumed to conduct policy in the closed economy to target inflation and output gap according to the forward-looking Taylor rule.

$$R_t = \lambda_1 R_{t-1} + (1-\lambda_1)\lambda_2(E\pi_{t+1} - \pi_t) + \lambda_3 \pi_t + \lambda_4 y_t + \chi_R \quad (3.4)$$

Here we follow the Taylor rule that is given by John Taylor in his study of (Taylor, 1993).

3.3 The Linearized Model

For empirical analysis of Chapter 4, the model is log linearized, and the following are the linear rational expectation equations. The hat on a variable shows its deviation from its long-run values or steady state. Moreover, the jumper variable shows the future expectation of that variable, the below equation is consumption with habit formation.

$$\hat{c}_t = \frac{h}{1+h} Et\hat{c}_{t+1} - \frac{1-h}{(1+h)^{\sigma}}(\widehat{R}_t - Et\pi_{t+1}) \quad (3.5)$$

When h=0, this equation reduces to the forward-looking consumption equation, Consumption is dependent on the weighted average of consumption that is past and expected future. The interest elasticity of consumption depends on habit formation determination and also on the intertemporal elasticity of substitution. A high degree of persistence in habit will lead to a decrease in consumption for a given elasticity of substitution.

$$\widehat{C}_t = h\hat{c}_{t-1} + Et\hat{c}_{t+1} - \frac{1-h}{\sigma} E_t r^c{}_{t+1} \quad (3.6)$$

The Goods market equilibrium as

$$\hat{y}_t = \frac{1-\alpha(\theta-1)}{\theta}\hat{c}_t + \frac{1-\alpha(\theta-1)}{\theta}\hat{\imath}_t \quad (3.7)$$

A production function is like

$$\hat{\boldsymbol{y}}_{\boldsymbol{t}} = \hat{\boldsymbol{z}}_{\boldsymbol{t}} + \boldsymbol{\alpha}\hat{\boldsymbol{N}}_{\boldsymbol{t}}(\boldsymbol{1}-\boldsymbol{\alpha})\hat{\boldsymbol{K}}_{\boldsymbol{t}} \quad (3.8)$$

$$\hat{z}_t = (1-\kappa)z_{t-1} + \epsilon_t \quad (3.9)$$

Where N_t *and* $K_t$the capital, labor used in production, and the technology that is used in production, α shows the productivity parameter. Where z_t ˆ is White Noise. Capital accumulation equation

$$\hat{\boldsymbol{K}}_{\boldsymbol{t+1}} = (\boldsymbol{1}-\boldsymbol{\delta})\hat{\boldsymbol{K}}_{\boldsymbol{t}} + \boldsymbol{\delta L_t} \quad (3.10)$$

The above equation shows that capital accumulates over time.

$$\pi_t = \frac{\omega}{1-\beta\omega^2}\pi_{t-1} + \frac{2-\omega-\beta\omega+\beta\omega^2}{1+\beta\omega^2} Et\pi_{t+1} + (1-\omega)(1-\beta\omega)\hat{\varphi}_t \quad (3.11)$$

The new Keynesian forward-looking Phillip curve is given below

$$\widehat{\varphi}_t = \alpha\widehat{\varpi}_t + (1-\alpha)r_t{}^c - \hat{z}_t$$
(3.12)

Here inflation depends on the previous and forward-looking expectations and the present marginal cost, and the marginal cost is a function of the rental rate on capital, the real wage, and the productivity factor.

$$\frac{\overline{\varpi_t}}{\emptyset} = (1+\eta l)\xi(\varpi_{t-1}+\pi_{t-1}) - (1+\beta)(1+\eta l)\xi\pi_t + (1+\eta l)\xi\beta Et((\varpi_{t+1}+\pi_{t+1}) + (1-\beta\xi)(1-\xi)\times[\eta\widehat{N}_t + \frac{\sigma}{1-h}(\widehat{c_t} - hc\widehat{_{t-1}})$$
(3.13)

The real wage is a function of expected current and past inflation, and the expected and past real wage.

$$\widehat{m}_t = \frac{\sigma}{(1-h)\gamma}\hat{c}_t - \frac{\sigma h}{(1-h)\gamma}\hat{c}_{t-1} - \frac{1}{\gamma}\widehat{R}_t$$
(3.14)

The above equation shows that money demand depends on the current and past consumption decisions and the rate of return.

$$\widehat{m}_t = \widehat{m}_{t-1} - \pi_t - v_t$$
(3.15)

The real money supply depends on its lag, the inflation rate, and the growth of the money supply.

$$v_t = I_1 V_{T-1} - I_2 E\pi_{t-1} - I_3\hat{y}_t + \lambda_{v,t}$$
(3.16)

v_t Shows the short-run nominal money supply and the optimal money supply rule depends on the inflation and output gap[13] here we compute this for the money supply rule for Pakistan.

$$\widehat{N}_t = r_t{}^c - \widehat{k}_t - \overline{\varpi}_t$$
(3.17)

[13] (The study sets money supply as a policy instrument, the optimal money supply rule is set as a function of output gap, and inflation). (Taylor, 1979)

The equation shows that the employment level depends on the capital stock, wages, and rental rate.

4. Methodology: Calibration Analysis

There are various approaches used for determining the parameter values of the NK DSGE models in the empirical literature. Some of the notable methods are structural VAR, GMM, and the Bayesian technique. Where the model's dynamic properties are studied through calibration and other simulation techniques. Among all available methodologies, the Bayesian technique is assumed to be superior to other econometric techniques; however, for robust estimation, we need some micro-survey-based parameter values which are not available for Pakistan. Due to this reason, this study accomplishes the estimation task in two steps. First, using the GMM technique, the policy reaction function parameters are retrieved using quarterly data for Pakistan. In the second step, use the estimated parameters along with some borrowed parameters from the most relevant studies like (Haider, Jan, & Hyder, 2012), the final estimation is carried out through calibration.

4.1 Generalized Method Of Moment

This study has used GMM analysis to estimate the Taylor rule for Pakistan. The New Keynesian models can be estimated via different methods, i.e., Structural Vector Autoregressive (SVAR), Maximum Likelihood method, Bayesian technique, and calibration technique to study the model's dynamic response. The calibration analysis uses the structure parameters directly to generate Impulse response functions (IRFS), variance decomposition analysis, and forecast the reactions of the macroeconomy to various shocks. GMM methodology is used when an endogeneity problem arises in the model.

Calibration analysis is famous nowadays in the field of macroeconomics. The existing literature suggests that the Bayesian technique has gained remarkable attraction (Schorfheide, 2000) when we simulate the models by incorporating the prior information. The technique is used to relate to the conflicting DSGE models of consumption as Smets & Wouters (2003) examine for the Eurozone. Bayesian estimation fits the full-solved DSGE model in contrast to GMM estimation, which is based on a specific equilibrium relationship for a particular purpose. A Bayesian

technique is a link between calibration and the maximum likelihood method. The calibration is done through the prior information (parameters) and the maximum likelihood method is done through the estimation process built on opposing the model with data.

4.2 Data Analysis

Quarterly data over the period 1992:1-2016:4 was used to estimate the parameters of the two specified monetary policy instruments i.e. money supply rule, and the interest rate rule. Closed economy model consists of fourteen endogenous variables and three exogenous shocks. The endogenous variables included for estimation are the interest rate, output gap, money supply, and inflation. The data on the interest rate, inflation, and money supply are obtained from the IFS database from 1992Q1 to 2016Q4. 1) Real GDP quarterly is used as the output's proxy. We followed (A. R. Kemal, 2004) to generate the series. At first, the original data is converted into the new base (2000=100). We used the Hedrick Prescott filter to detrend the series from its log run values. Interest rate (Call money rate), Inflation (CPI), and M2 are used for the analysis.
The most commonly used rate is the federal fund rate (Bernanke & Blinder, 1992) and discount rate (the discount rate is not found in Pakistan). Another type of interest rate, a money rate is widely used in Pakistan. We first convert all variables into log form except interest rate. HP filter is utilized to remove the long-run trend from the actual series.

4.3 Parameterization

The model calibration is set in a manner that is consistent with existing literature. Most of the parameters are taken from the previous studies (see e.g., S. Ahmed, Ahmed, Khan, Pasha, & Rehman, 2012) Consistent according to the special case that is to be considered above. It is anticipated that $\beta = 0.99$, which implies a riskless annual return of approximately 4% in the steady-state. The particular parameters are quite useful for our model's simulations in the case of Pakistan and take the value of β from the study of Bukhari & Khan, (2008) and S. Ahmed et al., (2012).

Table A1: Key Structural Parameter Values for Model Calibrations

Parameters Sign	Description	Value
β	Subjective discount factor	0.99
γ	The household's preference for money-holding	0.52
$h^{\wedge}$	Degree of habit formation	0.36
δ	Capital depreciation rate	0.03
σ	Relative risk aversion	0.59
ω	The share of each firm	0.65
α	Consumption share in total output	0.6
$1-\alpha$	Investment share in total output	0.4
η	Elasticity of work effort to real wage	1.00

κ	A share in technology shock	0.5
λ_1	The interest rate coefficient of the Taylor rule	0.80
λ_2	Coefficient of inflation in the Taylor rule	0.19
λ_3	Coefficient of output gap in Taylor rule	0.007
I_1	The lag of growth of money in the money supply rule	0.99
	The coefficient of inflation in the money supply	0.016
I_2 I_3	The coefficient of the output gap in the money supply	

The habit parameter (h) = 0.36, which is a little lower than its prior mean of 0.5. Value of the parameter indicates that the degree of habit perseverance in consumption is fairly low as related to modern economies (Lubik & Schorfheide, 2005). We take this parameter from the study by Bukhari & Khan, (2008). For the coefficient of relative risk aversion of the household, we take the value of sigma from the study of S. Ahmed et al., (2012) as σ=0.59. This large value is reliable with the discussed little value of habit persistence too. (1- omega) firms adjust their prices optimally, and Omega firms represent that prices can be adjusted by all the firms in each period by following some rule. We report the value ω=0.65 from Haider, Jan, et al., 2012; Haider, ud Din, et al., 2012). The depreciation rate is reported as 0.03, which indicates a per annum valuation of capital is by 12 percent. The depreciation rate value similar to this was also used by S. Ahmed et al., (2012), and Bukhari & Khan (2008) for Pakistan's macro economy.

We are working in the closed economy framework, so Y = C+ I represent consumption share and investment share in output, which is 0.6 and 0.4 respectively. The alpha, share of labor, and capital in output, and we compute the value of alpha from other studies (see e.g., W. Ahmed, Haider, & Iqbal, 2012; Haider, Jan, et al., 2012; Haider, ud Din, et al., 2012)- inverse nexus of the elasticity of work effort for real wage η=1.00 from the work of Bukhari & Khan (2008); Gamma (W. Ahmed et al., 2012; Haider, Jan, et al., 2012; Haider, ud Din, et al., 2012) as γ=0.52. Kappa is reported as 0.5 a share in technology shocks. The parameter value of the money supply rule and Taylor rule are estimated through GMM; the quarterly data is used for the estimation purpose. The value of the lag of interest rate is 0.80, the parameter for inflation is 0.19, and the output gap is 0.007 in the case of Pakistan. The parameter of the money supply rule is estimated through quarterly data, the lag of money supply is 0.99, and the inflation and output are reported as 0.0016 and 0.0012. These values are based on the estimation and are not reported from any existing literature. We use this prior information to calibrate the DSGE model for the closed economy.

5. Calibration Estimation And Analysis

This section is aimed at calibrating and analyzing the NK DSGE model derived in the previous section. To estimate the model correctly, the variables need to be transformed according to the requirements of the theory. A summary and a visual presentation of the variables are provided about the time under observation to facilitate a profound understanding. IRFS are retrieved and the variance decompositions

of the key macro-economic variable against the structural shocks for short-run analysis are obtained.

5.1. Monetary Policy in Pakistan

Monetary policy includes the State Bank's use of instruments to affect interest rates or money supply in the economy to keep overall prices and financial markets stable. Low and stable inflation offers favorable conditions for sustainable growth and employment generations over time.

Quantity Rule

We assume that the money supply is relatively determined by the central bank and also by non-policy shocks. We take a look at the money supply process. It has important bearings on the behavior of monetary policy. The most important player is the central bank. Its movements highly describe the money supply. The study estimates the parameters of a quantity rule for Pakistan by GMM.

$$\boldsymbol{V_t = 0.99v_{t-1} - 0.016E\pi_{t-1} - 0.012\hat{y}_t + \lambda_{v,t}} \quad (1)$$

π_t denotes the inflation rate, output gap is represented by $\hat{y}_t$and the expectation factor is E[14]. A dynamic model is employed and the money supply is taken as a policy instrument. It is stated by Taylor that the money supply is a function of inflation and output gap.

We can here say that the money supply rule is insignificant for Pakistan because the signs of all the variables are inconsistent with the theory. We used these parametric values to calibrate the model.

Price Rule

The interest rate rule is more probable to be chosen when the inconsistency of the money market instabilities is larger.

$$\boldsymbol{R_t = 0.80R_{t-1} + 0.40(E\pi_{t+1} - \pi_t) + 0.19\pi_t + (-0.007)y_t + \chi_R} \quad (2)$$

The Taylor rule is a simple equation, a rule of thumb—that is expected to define the interest rate choices of the Federal Reserve's Federal Open Market Committee (FOMC)[15]. The present study attempts to estimate the parameters of the Taylor rule with GMM using quarterly data from 1992Q3 to 2017Q2. The equation shows that the interest rate is positively related to the inflation gap and lag of interest rate and negatively related to current inflation and output gap, which is consistent with the theory. The results show that the coefficient of the output gap is insignificant and that if one unit increases the output gap, the interest rate decreases by 0.007 units.

5.2 Calibration Results

5.2.1 Impulse Response Function

The IRFS of endogenous variables on exogenous shocks, money supply, interest rate, and technology shocks will be obtained, and some stimulating outcomes. The effects of the money supply shock in Taylor's rule by the real wage, capital stock, consumption, investment, and output gap rise. The real interest rate decreases instantly, indicating a liquidity effect behind an inflation effect: two years' future the real interest rate begins to rise against the increase of inflation. Smets & Wouters (2002) report no liquidity effect under the money supply shock.

The negative shock in the money supply causes a rise in interest rates, which leads to a decrease in consumption and investment decisions, and then the output decreases. In impulse response, the analysis of the money supply rule is ineffective because it increases volatility in inflation and output. It takes time to converge to the equilibrium steady state. In the money supply rule, a money supply shock increases the money growth rate, and the money supply and inflation decrease, initially, the interest rate falls, after that it will tend to rise. This is shown in Figure 1: IRF - Response of money supply shock to money supply rule and Figure 2: IRF - Response of money supply shock to money supply rule respectively.

[14] (Taylor, 1979)

[15] (Taylor, 1993)

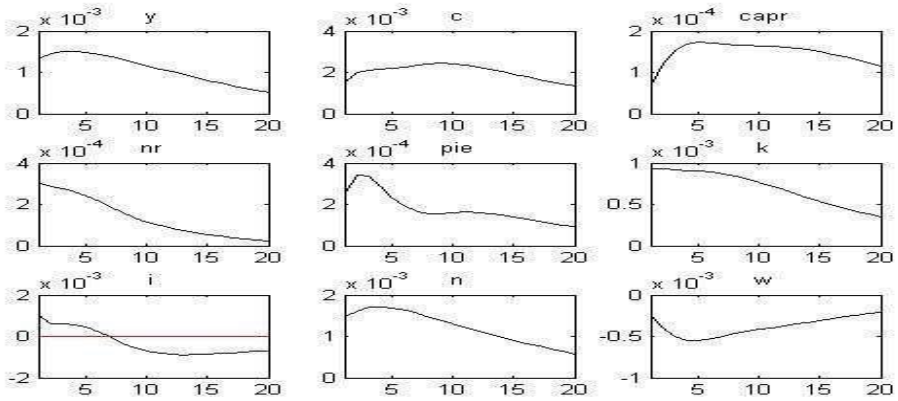

Figure 1: *IRFS - Response of money supply shock to money supply rule*

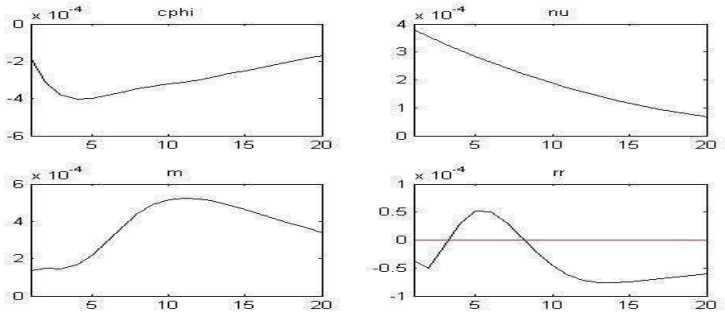

Figure 2: *IRFS Response of money supply shock to money supply rule*

When we compare money supply shock in interest rate and money supply rule, the reaction of all variables to money supply shock is the same, the consistency only lies in the effects' magnitude.

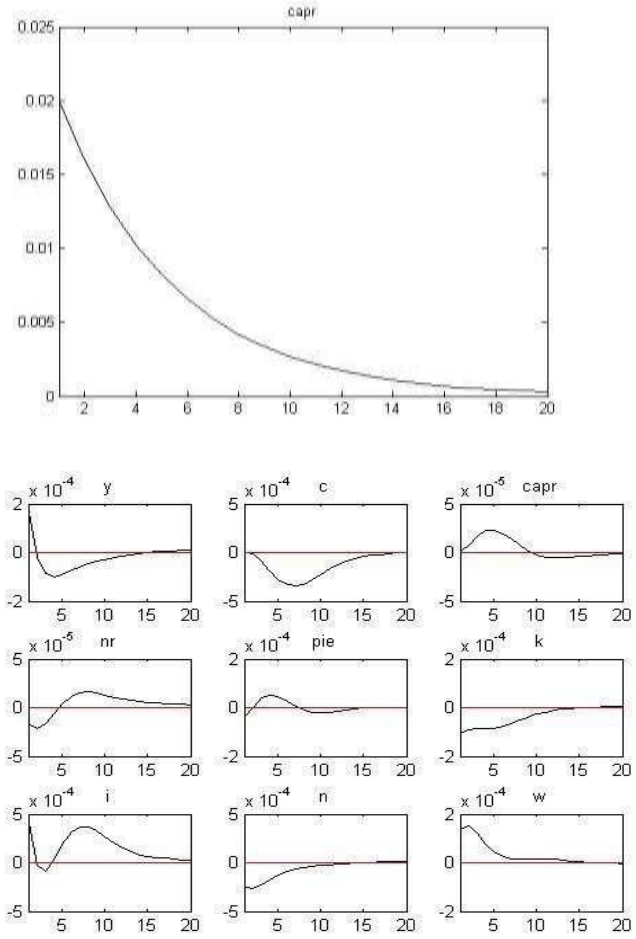

Figure 3: IRFS Response of interest rate shock to interest rate rule

An interest rate shock increases the interest rate, but it decreases over time, the resultant increase in consumption, investment output level, and rate of inflation series shows that it converges to the state of the equilibrium in approximately 20 time horizons.

All the variables in the model, when we had a Taylor-type rule converge to the equilibrium, so we can say this is an effective rule. The vertical axis represents the deviation of variables from the steady value; the red line shows the steady-state level. In Taylor's rule, the output (y) shows that initially, it is increasing when we give a shock to the interest rate, it will take time to achieve the steady-state level. Here we are interested in the inflation and output gap. We observe that at times the shock appears in the economy, the monetary authority uses interest rate as a policy rule, and it minimizes the output gap and inflation volatility. So it moves around the equilibrium and after some time, it will attain steady-state equilibrium. The output gap initially deviates from the equilibrium and it converges to a steady state after experiencing shocks to the economy**.** In this figure, we can see that all the variables converge to the equilibrium except the money supply rule. It increases initially when the shock is observed in the economy, and after some time it deviates the money supply from the state of the equilibrium.

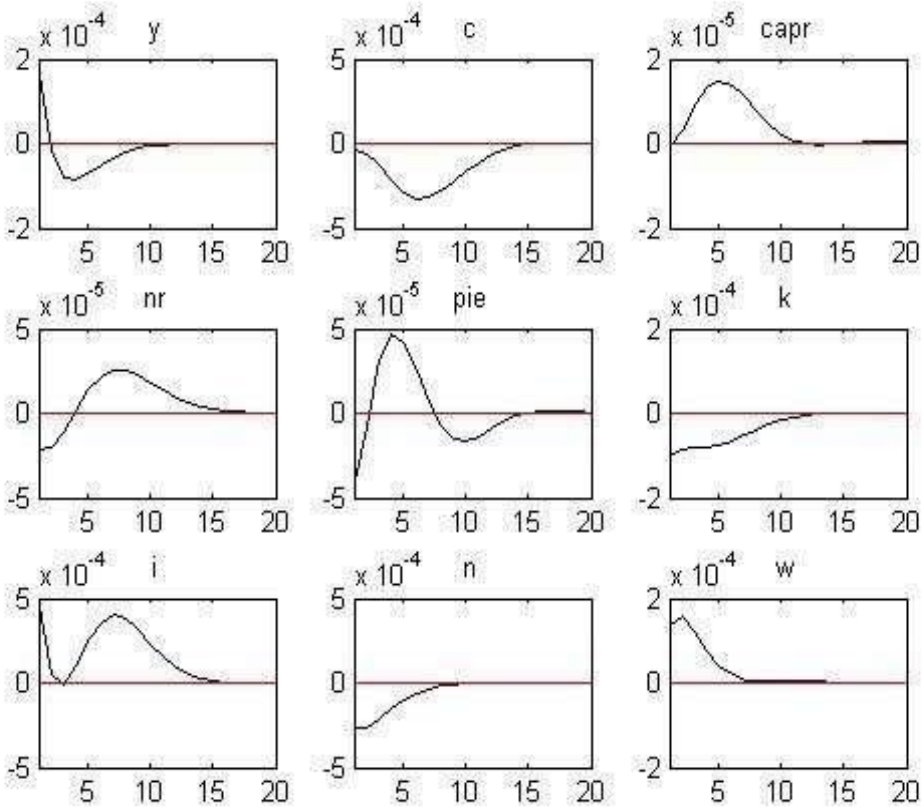

Figure 4: IRFS - Response of productivity shock to Taylor rule

Figure 4: IRF - Response of productivity shock to Taylor rule shows that when a technology shock is given to the economy, it will increase productivity. Here for our purpose, we are interested in the output gap, and inflation only, the larger the fluctuations are observed in inflation and the minimum in the output gap, and ultimately all the endogenous variables converge towards the equilibrium converge toward equilibrium after 15 years.

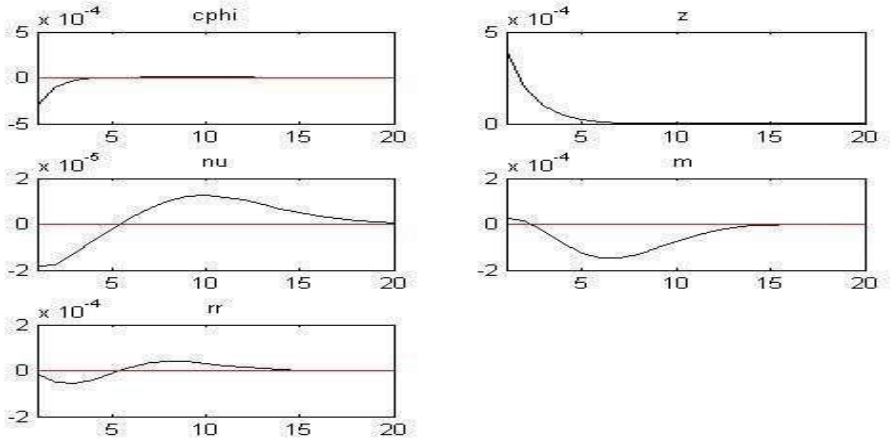

Figure 5: IRFS - Response of productivity shock to money supply rule

Figure 5: IRF - Response of productivity shock to money supply rule shows that the money supply in the economy increases and it converges slowly to the equilibrium, Consumption increases but the fall in the investment crowds out this effect and the output decreases, this is different from the Taylor's rule where the output increases. A positive shock to productivity increases the marginal cost, but after 1st quarter, it will converge to its steady state. The increases in interest rates and inflation are similar to those in Taylor's rule.

5.2.2. Quantitative Results

To counterpart the quantitative analysis, Table 5.6.1 shows the standard deviation in percent of the output gap and inflation under the prescribed monetary policy rules. The numbers confirm some of the findings of this study that were already evident from the visual inspection of IRFS. Thus, it can be seen that the elements that the Taylor rule shows excess smoothness and minimize output and inflation volatility. To improve economic activity, committing to a rule has more advantages over discretion in modern economics. Our results show that the Taylor rule is in use by the central bank to enhance the macro-economy. Utilizing money supply as a policy rule shows inconstancy in output and inflation in counterfactual analysis that can be taken as a deviation from it.

Table A1: Cyclical Properties of Alternative Policy Rules

Variable	Money supply rule	Taylor rule
Output	0.08	0.02
Inflation rate	0.03	0.01
Total	0.01	0.03

Note: *standard deviation in percent.*

Here the result reveals that the counterfactual experiment leads us to deviate from the steady state, the output, and inflation volatility is high when using money supply as a policy instrument because in this modern era, if we do not want to trace money, we make transactions. The Taylor rule outperforms the money supply rule because, from this table, we can see that this rule minimizes output and inflation volatility.

Table A2: Pairwise Correlation Matrix

	Output Gap	Interest Rate	Inflation	Money Supply
Output Gap	1.00			
Interest Rate	-0.03	1.00		
Inflation	-0.37	-0.02	1.00	
Money Supply	0.14	0.01	0.36	1.00

It is suggested by the correlation analysis that the output gap is positively related to the money supply. In addition, negatively related to the interest rate, and inflation, which is too consistent with the theory. Output gap and inflation are positively related to money supply. The table of correlation analysis is shown below:

Table 3: Forecast error variance decomposition analysis

	Technology shock	Money Supply shock	Interest rate shock
Output	88.22	11.86	0.00
Interest rate	0.00	0.01	99.99
Inflation rate	47.61	51.48	0.00
Money Supply	5.51	95.03	0.00

The variance decomposition suggests that the main source of variation in the output gap is productivity shock. The productivity shock accounts for 88% variation in the output gap. The second contributor to the output gap is money supply shock, which accounts for forecast error variance that is equal to 11.88%. The interest rate cannot contribute to the output gap. Interest rate shock is the only contributor to the interest rate, which accounts for 100% forecast error variance, and money supply somehow accounts for the interest rate. The major contributors to inflation are money supply and productivity shock. A money supply shock is the main contributor to variation in money supply forecast error variance. The variance decomposition analysis is reported below.

6. Conclusion

Conducting monetary policy with money supply as a policy rule becomes more difficult in Pakistan. This study overviewed different monetary policy rules, generally, whereas the price of money and the quantity of money are compared in a theoretical and empirical framework. It is perceived that designing optimal rules often leads to complex rules that cannot be implemented easily (Adema & Sterken, 2005). Financial sector development also enables the State Bank of Pakistan to use its price-based instrument. Without a continuously stable demand for money, monetary targeting is an ill-advised policy rule. Since the monetary targeting strategy loses its grip due to the variation in inflation, inflation itself becomes harmful to the economy if it is not kept in check. This is simply not possible if the country sticks to monetary targeting because that way, it loses control over the potential variations in inflation. Friedman suggests that inflation is always and everywhere a monetary phenomenon. According to him, if we use the interest rate as a policy rule, it will destabilize the macroeconomy.

After calibrating the model, the interest rate has turned out to be a better policy rule for minimizing the output and inflation volatility. It also satisfies the three preconditions of an optimal monetary policy rule, which are measurability, controllability, and predictability. Financial sector development also enables the State Bank of Pakistan to use its price-based instrument. Without a continuously stable demand for money, monetary targeting is an ill-advised policy rule. Our result is consistent with the existing literature (see e.g., Omer & Saqib, 2009; W. S. Malik & Ahmed, 2010) that the interest rate is a better policy rule than what has already been in practice.

Policy Recommendations

Fortunately, the outcome of the present academic exercise has been consistent with the rule being followed by the SBP. Even though a rare outcome, this has to be the case in all policy areas. This study will be extended for further research by incorporating the open economy rules i.e. exchange rate as a policy rule in the model and comparing the three reaction functions (i.e. interest rate, money supply, and exchange rate) to examine the optimal rule when monetary policy is conducted in a developing economy like Pakistan within a DSGE framework.

Disclosure statement

No potential conflict of interest was reported by the authors.

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