Mushtaq, A. Malik, S., and Akhtar, M. H. (2022). Nonlinear Taylor Rule and Inflation-Targeting In Pakistan: A Time Series Analysis. *Bulletin of Business and Economics*, 11(2), 185-197. https://doi.org/10.5281/zenodo.6584640

Bulletin of Business and Economics
ISSN - 2409 - 9368

NONLINEAR TAYLOR RULE AND INFLATION-TARGETING IN PAKISTAN: A TIME SERIES ANALYSIS

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ABSTRACT

The paper estimates the non-linear Taylor rule of inflation-targeting in Pakistan. Three types of short-term nominal interest rates are used as policy instruments represented by three, six, and twelve-months treasury bills. Using quarterly time series data for the period 2005 (1st Quarter) to 2019 (3rd Quarter), a threshold regression technique has been applied. The study aims to observe the nonlinear behavior of the monetary policy of the central bank. Threshold values are estimated at 2.5% for the output gap, 6.02% for inflation, 7.45% for interest rate, and 0.68 for the exchange rate. The study finds a weak response of output gap and inflation in the context of the backdrop of economic activity, while the interest rate is positive and significant toward the output gap. Results regarding the non-linear Taylor rule by inflation indicate that the exchange rate is negatively significant in high and low inflationary regimes. Results of the study further disclose that inflation and interest rate have negative and significant responses towards exchange rate. Above the threshold value of the exchange rate (0.68) inflation escalates and the interest rate falls with exchange rate depreciation. As a policy implication, it can be suggested that the SBP should control exchange rate depreciation to overcome inflation. SBP should consider the exchange rate stabilization together with the objective of price stability in an inflation-targeting framework.

Keywords: Non-linear Taylor rule, Threshold regression, Treasury bills rate, inflation, output gap, Exchange rate,
JEL Codes: C20, O24

I. INTRODUCTION

Inflation-targeting (IT) is an effective framework to achieve price stability. IT is characterized by price stability as a predominant goal of the central bank. But Predominance of price stability does not mean that central banks may ignore all other monetary policy objectives. But these banks tend to achieve substantial discretion in their objective of price stability via an inflation-targeting framework. This, in turn, helps to achieve other macroeconomic objectives e.g., exchange rate stability. Inflation-targeting focuses to achieve price stability in the economy. Historically, monetary policies have remained tenuous to ensure stability in prices as, during periods of high inflation and deflation, price stability remains undetermined. It is not necessary for all inflation-targeting central banks to have an explicit mandate about the objective of price stability, as the primacy of price stability may be implicitly organized in practice. IT is not mare a rule to achieve price stability but a complete monetary framework to attain stable prices by using suitable monetary policy rules. Moreover, IT delivers alertness regarding the cost of inflation and helps to achieve other goals also. So, the main objective of the inflation-targeting framework is to achieve price stability first, and all other objectives are subordinated (Bernanke et al., 1999; Berg and Jonung, 1999; Debelle, 2009; and Mishkin 2004; Ali and Naeem, 2017; Ali, 2011; Ali, 2015; Ali, 2018; Ali and Bibi, 2017; Ali and Ahmad, 2014; Ali and Audi, 2016; Ali and Audi, 2018; Ali and Rehman, 2015; Ali and Senturk, 2019; Ali and Zulfiqar, 2018; Ali et al., 2016; Ali et al., 2021; Ali et al., 2021; Ali et al., 2015; Arshad and Ali, 2016; Ashraf and Ali, 2018; Audi et al., 2022). However, Inflation-Targeting cannot be an effective instrument without an appropriate monetary policy rule as there exists a robust symbiotic relationship between the two. A successful inflation targeting framework together with appropriate monetary policy rules produces fewer variations in the inflation rate (Taylor, 2000 & Taylor, 2019). The linear standard Taylor rule is the best monetary policy rule with the only objective to stabilize inflation (Carlozzi and

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Taylor 1983, 1985 & Kuhn and Muysken, 2012). But monetary policy behavior may be non-linear and asymmetry when central banks are interested to avoid recession instead of a boom. Monetary policy might be affected by political influence and fluctuation of the business cycle. However, central banks are more aggressive to achieve price stability during a period of boom. Real stabilization will be the objective of the central bank in a period of recession. So, Asymmetric behavior arises due to preferences of the central bank about positivity and negativity of output gap and low and high inflation rate or due to a trade-off between inflation and economic activity (Blinder, 2000; Olmedo, 2002; Cukierman, 2003; and Taylor, 2006; Audi and Ali, 2017; Audi and Ali, 2017; Audi et al., 2021; Audi and Ali, 2016; Audi et al., 2021; Audi et al., 2021; Audi et al., 2021; Haider and Ali, 2015; Kaseem et al., 2019; Roussel et al., 2021; Senturk and Ali, 2021; Mehmood et al., 2022). Non-linearity of monetary policy reaction functions depends upon the nature and functional form of the Philips curve also. Monetary policy tends to be non-linear in case of an asymmetric behavior of the central banks concerning inflation or output. Non-linearity may be because of the cyclical fluctuations (Bruinshoofd and Cardelon, 2005). Non-linearity in the behavior of the central banks might be due to the presence of asymmetry not because of the shape of the Philips curve (Cukierman, 2004). The rest of the discussion is structured as under. Section 2 expounds on the literature review while the data and methodology are discussed in section 3. Section 4 elaborates on results while the final part concludes with policy implications.

II. LITERATURE REVIEW

This section provides extensive coverage of extant literature on the Taylor rule, inflation targeting, influence of exchange rate, and short-term nominal interest rate smoothing in the context of Pakistan and the rest of the world. Deniz et al. (2020) estimated nonlinear threshold regression concerning the Taylor rule for the case of Turkey. Findings showed different behaviors of monetary policy authority to determine policy rates by considering different regimes. Lamia and Djelassi (2020) inspected linear and nonlinear Taylor rules for Tunisian monetary policy authority. Results indicated that the central bank of Tunisia followed the nonlinear Taylor rule in the conduction of monetary policy. It was found that when the interest rate was above the threshold level (4.76%), the central bank bound the depreciation in the exchange rate to limit inflation instead of grooming economic activities. Ozdemir (2020) investigated the importance of exchange rates in inflation-targeting monetary policy by estimating the linear Taylor rule. Nonlinearity in reaction function was observed through the nonlinear Taylor rule. Results indicated that monetary policy was asymmetric for the fluctuations of the exchange rate, but this nonlinear behavior was removed after the financial crisis. Tawadros (2019) estimated linear and nonlinear forward-looking monetary policy rules for Australia. The study found that the nonlinear rule best described the behavior of RBA in a forward-looking approach. Ma et al. (2018) estimated the nonlinear Taylor rule with the inclusion of the principle component and incorporate the uncertainty index into the reaction function of FED. Results indicated the responsiveness of the federal reserve towards the increase in uncertainty. The response was made by a fall in the federal fund rate. Fed response was aggressive towards the rise in capacity utilization when inflation was above the threshold level of 2 %. Caporale et al. (2018) investigated the augmented Taylor rule with exchange rate and nonlinear threshold regression instead of the linear model in five emerging economies. The study found that monetary policy reactions were different in all countries for output gap and inflation concerning magnitude and significance, and low and high inflation regimes. The exchange rate has an impact on the high inflation regime. The study found accurate behavior of monetary policies under the nonlinear and augmented Taylor rule.

Tariq and Kakakhel (2018) analyzed reaction functions for SBP by considering the Taylor rule in the open economy. Systematic reaction function was observed for SBP to the fluctuations of the exchange rate. A time-varying response of SBP was considered for inflation and output gap. Castro (2011) analyzed linear and nonlinear Taylor rules for the bank of England, augmented with the exchange rate and with forward-looking behavior. Results exhibited that the bank of England and the European central bank followed a nonlinear Taylor rule but the federal reserve bank followed a linear Taylor rule. Ahmed and Malik (2011) examined reaction functions for SBP. The study found aggressive monetary policy behavior when inflation was above its threshold level of 6.4%, as compared to a low inflationary regime. This aggressive behavior is represented by the existence of nonlinearity. Khakimov et al. (2010) assessed monetary policy rules for the economy of Tukey. Improvement in policy instruments was observed with the step-by-step application of inflation-targeting in Turkey. From the comparison of the Taylor and McCallum rule, it is drawn that the Taylor rule is best within the duration of the second phase of IT. The behavior of the central bank during the whole period is like the basics of the McCallum rule. Ncube and Tshuma (2010) assessed the application of the nonlinear Taylor rule for the African reserve bank. The research found that the central bank described nonlinearity in its behavior. Fluctuations of short-term interest rates showed signals for nonlinear monetary policy behavior. Petersen (2007) examined the non-linear Taylor rule for the economy of the USA and found that FED had changed its Behavior when inflation reached the threshold value. Martin and Milas (2004) evaluated the monetary policy structural model by considering inflation-targeting (IT). Results exhibited that IT was characterized by significant changes in monetary policy and that monetary policy behavior (post-1992) was asymmetry. The research found a nonlinear response of monetary policy towards inflation. The central bank was more aggressive in response when inflation has deviated from its target. By considering the existing literature, this research paper will estimate numerous specifications of the non-linear Taylor rule for Pakistan by using three policy instruments such as three months treasury Bill rate, six months Treasury Bill rate and Twelve months Treasury Bill rate. Moreover, this research estimates non-linear Taylor rules by economic activity, the inflation rate, interest rate, and exchange rate. This type of research is not found in the present literature of Pakistan except in one study by Saghir and Malik, 2017.

III. DATA AND METHODOLOGY

The quarterly sample period is taken from 2005q1 to 2019q3 for the economy of Pakistan. Variables that are used in the study are three months treasury bill rate (TB3), six months treasury bill rate (TB6), twelve months treasury bill rate (TB12), consumer price index (as inflation, INF), the nominal exchange rate (ER), and output gap (OG). The Source of data is the statistical bulletin of SBP. The output gap is estimated through the HP filter. The threshold regression technique has been applied in this research paper.

III.I. NON-LINEAR VERSION OF TAYLOR RULE

Linear Taylor rules characterize with short term interest rate time independency to make a change in the economic condition of a country. Olmedo (2002) discussed that concerning business cycle policymaker behavior may be asymmetric, so rules may be non-linear that are exhibiting monetary policy behavior. Taylor and Davradakis (2006) explained two reasons for the nonlinearity of policy reaction function: first is asymmetry preferences of the central bank about positivity and negativity of output gap and low and high inflation rate, second reason for nonlinear reaction functions is a tradeoff between inflation and economic activity. According to Cukierman (2003), central banks want to avoid recession as compared to boom under asymmetry behavior. On the other hand, Olmedo (2002) discussed that political pressure is more responsible for this behavior. Blinder (2000) explained that CB faces a lot of political pressure in pursuing a tight monetary policy to overcome inflation, as compared to pursuing an easy monetary policy to overcome deflation. Bruinshoofd and Candelon (2005) presented that CB is more aggressive to overcome inflation in the period of the boom but in the period of recession central bank has a great focus on achieving real stabilization of the economy and gives less importance to achieving price stability.

Threshold regression in the first type of nonlinear modelling of the Taylor rule assumed different behavior of monetary authorities regarding below and above threshold values of the variable, say inflation and the output gap in the Taylor rule with consideration of discrete jumps. For the second type of nonlinearity, models consist of smooth transition rather than discrete movements of monetary policy from one regime to the other and in switching processes. This study assumed the first type of nonlinearity of asymmetry in the behavior of monetary policy authorities. The study hypothesized that CB behaves differently in recession and boom and similarly in high inflation regimes and low inflation regimes. Econometric estimable forms of nonlinear Taylor rules are as follows:

$$TB3_t = \varphi_0 + \varphi_1 TB3_{t-1} + \varphi_2 I_t INF_t + \varphi_3 I_t OG + \varphi_4 \Delta ER_t + \varepsilon_t \quad \textbf{(1)}$$

$$TB6_t = \varphi_0 + \varphi_1 TB6_{t-1} + \varphi_2 I_t INF_t + \varphi_3 I_t OG + \varphi_4 \Delta ER_t + \varepsilon_t \quad \textbf{(2)}$$

$$TB12_t = \varphi_0 + \varphi_1 TB12_{t-1} + \varphi_2 I_t INF_t + \varphi_3 I_t OG + \varphi_4 \Delta ER_t + \varepsilon_t \quad \textbf{(3)}$$

I_t is indicator taking value 1 for positive output gap and zero for the negative output gap. It takes value 1 if inflation is above the level of threshold and zero when inflation is equal to the threshold or below it. Indicator discussed parameter of one variable in one time e.g. output gap or inflation. So, the study will estimate four cases, two concerning the choice of threshold and two for the choice of allowed variable's coefficients. The appearance of lagged short-term interest rate and differenced exchange rate shows the linearity of policy reaction functions.

III.II. THRESHOLD VALUE ESTIMATION

Data are used to estimate threshold values. Relevant variables were arranged in ascending order then eliminated 15% of the observations from the lower and upper sides of the arranged data. Each value of the remaining data showed threshold potential. An indicator function is generated after assuming each value as a threshold then nonlinear equations are estimated with this indicator. Threshold values of concerned variables are characterized by the lowest value of the residual sum of squares.

IV. RESULTS AND DISCUSSIONS

This section will briefly explain the results and discussion regarding the nonlinear Taylor rule by using TB3, TB6, and TB12 as short-term nominal interest rates of policy instruments. The nonlinear economic response of a policymaker can be estimated through nonlinear regression. Target variables have different values of coefficients in different regimes as policymaker behaves differently in boom as compared to the behavior in recession, same is true that different responses are observed in high inflation regimes as compared to low inflation regimes. This study will apply threshold regression to estimate functions of nonlinear reactions of monetary policy. First of all, threshold values for OG, INF, ER, and interest rate are estimated. Then policy behavior will be checked above and below these values.

IV.I. NON-LINEAR TAYLOR RULES (BY ECONOMIC ACTIVITY)

A dummy variable is constructed that assumes value 1 for boom with a positive output gap and it assumes value zero for recession with a negative output gap, it further assumes value zero for OG as the threshold. Four different specifications are estimated for the Taylor rule by taking three different short-term interest rates instruments TB3, TB6 and TB12. Multiplication of dummy variables with chosen one target variable in each specification has been done to estimate the behavior of policymakers in different regimes of boom and recession. Econometric nonlinear specifications to economic activity for rule 1 with TB3, TB6, and TB12 are as follows:

$$TB(i)_t = \varphi_0 + \varphi_1 INF_t + \varphi_2 \Delta ER_{t-1} + \varphi_3 TB(i)_{t-1} + \varphi_4 OG_t * OGD + \varepsilon_t \quad \textbf{(4)}$$

Econometric nonlinear specifications to economic activity for rule 2 with TB3, TB6, and TB12 are as follows:

$$TB(i)_t = \alpha_0 + \alpha_1 OG_t + \alpha_2 \Delta ER_{t-1} + \alpha_3 TB(i)_{t-1} + \alpha_4 INF_t * OGD + \varepsilon_t \quad \textbf{(5)}$$

The econometric nonlinear specifications for economic activity for rule 3 with TB3, TB6 and TB12 are as follows:

$$TB(i)_t = \beta_0 + \beta_1 OG_t + \beta_2 INF_t + \beta_3 \Delta ER_{t-1} + \beta_4 TB(i) * OGD + \varepsilon_t \quad \textbf{(6)}$$

Econometric nonlinear specifications concerning economic activity for rule 4 with TB3, TB6 and TB12 are as follows:

$$TB(i)_t = \gamma_0 + \gamma_1 OG_t + \gamma_2 INF_t + \gamma_3 TB3(i)_{t-1} + \gamma_4 \Delta ER(-1) * OGD + \varepsilon_t \quad \textbf{(7)}$$

Here OGD is a dummy variable of the threshold of the output gap and (i) takes values 3, 6, and 12 for three months treasury bill rates, six months treasury bill rates, and twelve months treasury bill rates, in the rest of the paper. OG, INF and ER are output gap, inflation rate, and exchange rate. The last term in each equation is the error term. Results of the above equations of econometric specifications are presented in Table 1.

Threshold values are zero and 2.5 for the output gap. Four specifications of the nonlinear Taylor rule are estimated with three short-term interest rates as dependent variables, further, each specification is sub-divided into boom and recession criteria. Results of rule 1 present that the adjusted R-square is high (above 0.9) and the value of DW is low which shows misspecification and signal of autocorrelation. LM statistics also show autocorrelation in the error terms for the case of TB3 and TB6 but for TB 12 LM shows no autocorrelation. Coefficients of lagged dependent variables are high (above 0.80), showing the importance of smoothing variable addition in the model. Coefficients of differenced lagged exchange rates are insignificant and negative for TB3 and TB6 but positive and remained insignificant for TB12. It is showing that exchange rate stabilization is not the objective of SBP over output and price stability in Pakistan. This result is robust. Results of Rule 1 show that response coefficients of output regarding economic activity remain the same in boom and recession with TB3 and with TB6. As coefficients values of output gap when multiplied by the dummy variable are insignificant, but significant only in boom with TB12 that indicates weak response as 90 per cent confidence is required to reject the null hypothesis that response coefficient is zero.

In rule 2, response coefficients are negative for inflation both in boom and in recession in all equations. However, response coefficients of INF are significant only in the boom state of the economy under TB3, and TB 12. With TB6, it remains negative but significant both in boom and in recession, but the response coefficient shows a weak response as 90 per cent confidence is required to reject the null hypothesis that the response coefficient is zero, when the threshold value of the output gap is zero. Taylor's principle is still dissatisfied as coefficients are less than 1, this is also a robust result. Rule 3 shows that response coefficients for TB are positive and significant both in boom and in recession. Rule 4 shows that response coefficients of differenced lagged exchange rates are insignificant showing no response of exchange rate toward economic activity in both states of the economy. It is observed that the adjusted R-square is high in each specification it is the result of the inclusion of lagged short-term interest rate as the independent variable in the model. It might be possible that the threshold value is other than zero. The study found a 2.5% of threshold value for the output gap. Response coefficients of interest rate are positive and significant both above and below the output gap threshold value of 2.5%. F-statistic has estimated with the null hypothesis that response coefficients are the same above and below the threshold value of the output gap.

IV.II. NON-LINEAR TAYLOR RULES (BY INFLATION RATE)

The threshold value for the inflation rate is 6.02%, above this value, there is a high inflation regime, and below its low inflation regime will be observed. Each equation is multiplied by a dummy variable that assumes a threshold value of 1 for a high inflationary regime. Relevant estimated results are shown in Table 2.
The econometric specifications for threshold regression of nonlinear Taylor rules by inflation rate with TB3, TB6, and TB12 of Rule 1 are as follows:

$$TB(i)_t = \eta_0 + \eta_1 INF_t + \eta_2 \Delta ER_{t-1} + \eta_3 TB(i)_{t-1} + \eta_4 OG_t * INFD + \varepsilon_t \quad \textbf{(8)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by inflation rate with TB3, TB6, and TB12 of Rule 2 are as follows:

$$TB(i)_t = \lambda_0 + \lambda_1 OG_t + \lambda_2 \Delta ER_{t-1} + \lambda_3 TB(i)_{t-1} + \lambda_4 INF_t * INFD + \varepsilon_t \quad \textbf{(9)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by inflation rate with TB3, TB6, and TB12 of Rule 3 are as follows:

$$TB(i)_t = \sigma_0 + \sigma_1 OG_t + \sigma_2 INF_t + \sigma_3 TB(i)_{t-1} + \sigma_4 \Delta ER_{t-1} * INFD + \varepsilon_t \quad \textbf{(10)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by inflation rate with TB3, TB6, and TB12 of Rule 4 are as follows:

$$TB(i)_t = \phi_0 + \phi_1 OG_t + \phi_2 INF_t + \phi_3 \Delta ER_{t-1} + \phi_4 TB(i)_t * INFD + \varepsilon_t \quad \textbf{(11)}$$

Table 2 shows that adjusted R-Square is high in each specification above 0.9 with TB3, above 0.85 with TB6, and above 0.80 with TB12. The value of DW is also high in each specification. F-statistics has estimated with the null hypothesis that the response coefficient of the target variable is the same in both inflationary regimes, its probability values are given in parenthesis. Results show that the coefficient of the output gap is negative and insignificant in both inflationary regimes. Coefficients of inflation are also negative and insignificant in both regimes. Response coefficients of differenced lagged exchange rate are significantly negative only with TB6, no matter that inflation is above the threshold or below it, but are positive and insignificant with TB3, and negative and insignificant with TB12. Moreover, response coefficients of interest rates in both regimes are positive, insignificant for TB3, negative, and insignificant for TB6 and TB12.

IV.III. NON-LINEAR TAYLOR RULES (BY INTEREST RATE)

Nonlinear Taylor rules concerning interest rates are estimated in this section. The regime for high-interest rate is attached with the period of high-interest rate and the low-interest rate regime is attached with the low-interest rate period. The threshold value for interest rate is found at 7.45%, it is expected that policy behavior is different in different regimes of interest rate. Again, four specifications are estimated for the nonlinear Taylor rule for interest rate. Results are presented in Table 3. The econometric specifications for threshold regression of nonlinear Taylor rules by short-term interest rates with TB3, TB6, and TB12 of Rule 1 are as follows:

$$TB(i)_t = \vartheta_0 + \vartheta_1 INF_t + \vartheta_2 \Delta ER_{t-1} + \vartheta_3 TB(i)_{t-1} + \vartheta_4 OG_t * TBD + \varepsilon_t \quad (12)$$

The econometric specifications for threshold regression of nonlinear Taylor rules by short-term interest rates with TB3, TB6, and TB12 of Rule 2 are as follows:

$$TB(i)_t = \varsigma_0 + \varsigma_1 OG_t + \varsigma_2 \Delta ER_{t-1} + \varsigma_3 TB(i)_{t-1} + \varsigma_4 INF_t * TBD + \varepsilon_t \quad (13)$$

The econometric specifications for threshold regression of nonlinear Taylor rules by short-term interest rates with TB3, TB6, and TB12 of Rule 3 are as follows:

$$TB(i)_t = \upsilon_0 + \upsilon_1 OG_t + \upsilon_2 INF_t + \upsilon_3 TB(i)_{t-1} + \upsilon_4 \Delta ER_{t-1} * TBD + \varepsilon_t \quad (14)$$

The econometric specifications for threshold regression of nonlinear Taylor rules by short-term interest rates with TB3, TB6, and TB12 of Rule 4 are as follows:

$$TB(i)_t = \varpi_0 + \varpi_1 OG_t + \varpi_2 INF_t + \varpi_3 \Delta ER_{t-1} + \varpi_4 TB(i)_{t-1} * TBD + \varepsilon_t \quad (15)$$

Results are shown in Table 3.

Table 1: Threshold Regression Estimates of Non-Linear Taylor Rules (By Economic Activity)

	Rule 1						Rule 2					
	TB3		TB6		TB12		TB3		TB6		TB12	
C	0.735 (0.05)	0.781 (0.03)	1.084 (0.01)	1.072 (0.01)	1.361 (0.01)	1.475 (0.00)	0.985 (0.00)	1.109 (0.00)	1.257 (0.00)	1.385 (0.00)	1.304 0.00	1.496 (0.00)
OG	-----	-----	-----	-----	-----	-----	0.046 (0.30)	0.066 0.21	0.088 (0.08)	0.112 (0.05)	0.107 (0.12)	0.126 (0.10)
INF	0.047 (0.03)	0.049 (0.04)	0.046 (0.10)	0.048 (0.05)	0.068 (0.05)	0.072 (0.03)	-----	-----	-----	-----		-----
D(ER(-1)	-0.015 (0.33)	-0.018 (0.30)	-0.008 (0.72)	-0.010 (0.56)	0.0056 (0.86)	0.0021 (0.93)	-0.015 (0.27)	-0.008 (0.60)	-0.007 (0.65)	0.0004 (0.97)	0.001 (0.93)	0.0093 (0.70)
TB(-1)	0.858 (0.00)	0.855 (0.00)	0.830 (0.00)	0.824 (0.00)	0.779 (0.00)	0.770 (0.00)	0.761 (0.00)	0.827 (0.00)	0.717 (0.00)	0.801 (0.00)	0.692 (0.00)	0.775 (0.00)
OG*OGD	0.879 (0.10)	0.330 (0.11)	0.257 (0.58)	0.361 (0.16)	1.140 (0.07)	0.257 (0.45)	-----	-----	-----	-----		-----
INF*OGD	-----	-----	-----	-----	-----	-----	-0.038 (0.10)	-0.027 (0.32)	-0.063 (0.01)	-0.049 (0.10)	-0.065 (0.06)	-0.047 (0.24)
TB*OGD	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
D(ER(-1)*OGD	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Adj-R2	0.93	0.93	0.87	0.87	0.81	0.80	0.93	0.92	0.90	0.87	0.84	0.81
DW	0.86	0.87	1.36	1.39	1.55	1.49	1.07	0.87	1.69	1.37	1.79	1.46
LM Stat	12.64 (0.00)	12.31 (0.00)	2.67 (0.08)	2.46 (0.09)	1.50 (0.23)	2.25 (0.11)	7.28 (0.00)	11.05 (0.00)	0.49 (0.61)	2.44 (0.09)	1.59 (0.21)	2.25 (0.11)
F-stat (Prob)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 1: Threshold Regression Estimates of Non-Linear Taylor Rules (By Economic Activity)

	Rule 3						Rule 4					
	TB3		TB6		TB12		TB3		TB6		TB12	
C	3.697 (0.00)	0.761 (0.01)	5.261 (0.00)	5.268 (0.00)	6.254 (0.00)	6.396 (0.00)	1.135 (0.00)	1.149 (0.00)	1.441 (0.00)	1.450 (0.00)	1.640 (0.00)	1.658 (0.00)
OG	-0.066 (0.04)	-0.086 (0.03)	-0.072 (0.02)	-0.062 (0.02)	-0.077 (0.03)	-0.083 (0.00)	0.020 (0.50)	0.019 (0.51)	0.036 (0.33)	0.036 (0.35)	0.058 (0.21)	0.059 (0.20)
INF	0.078 (0.00)	0.071 (0.00)	0.034 (0.00)	0.033 (0.00)	0.059 (0.00)	0.053 (0.00)	0.074 (0.00)	0.073 (0.00)	0.073 (0.00)	0.073 (0.00)	0.079 (0.00)	0.081 (0.00)
D(ER(-1)	-0.010 (0.29)	-0.014 (0.25)	-0.005 (0.58)	-0.002 (0.76)	0.002 (0.84)	-0.003 (0.72)	-----	-----	-----	-----	-----	-----
TB(-1)	-----	-----	-----	-----	-----	-----	0.812 (0.00)	0.810 (0.00)	0.790 (0.00)	0.787 (0.00)	0.764 (0.00)	0.770 (0.00)
OG*OGD	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
INF*OGD	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

TB*OGD	0.068 (0.00)	0.052 (0.02)	0.057 (0.00)	0.046 (0.00)	0.049 (0.02)	0.036 (0.05)	-----	-----	-----	-----	-----	-----
D(ER(-1)*OGD	-----	-----	-----	-----	-----	-----	0.013 (0.71)	0.011 (0.74)	-0.012 (0.78)	-0.013 (0.77)	-0.034 (0.54)	-0.031 (0.48)
Adj-R2	0.95	0.94	0.96	0.96	0.95	0.96	0.92	0.92	0.87	0.87	0.82	0.81
DW	1.04	0.98	1.60	1.77	1.90	2.15	0.80	0.82	1.92	1.25	1.44	1.43
LM Stat	9.98 (0.00)	10.62 (0.00)	1.75 (0.18)	0.36 (0.69)	0.66 (0.52)	1.41 (0.25)	11.09 (0.00)	10.44 (0.00)	3.18 0.04	2.94 (0.00)	1.49 0.09	2.33 0.10
F-stat(Prob)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2: Threshold Regression Estimates of Non-Linear Taylor Rules (By Inflation Rate)

	TB3				TB6				TB12			
	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4
C	0.455 (0.21)	1.7898 (0.00)	1.168 (0.00)	1.36 (0.00)	0.785 (0.06)	1.994 (0.00)	1.468 (0.00)	1.509 (0.00)	1.187 (0.04)	2.169 (0.00)	1.638 (0.00)	1.652 (0.00)
OG	---	0.047 (0.36)	0.020 (0.52)	0.017 (0.70)	---	0.096 (0.11)	0.035 (0.35)	0.066 (0.19)	---	0.114 (0.17)	0.058 (0.24)	0.080 (0.25)
INF	0.054 (0.01)	---	0.071 (0.00)	0.072 (0.00)	0.053 (0.00)	---	0.071 (0.00)	0.070 (0.00)	0.080 (0.01)	---	0.080 (0.00)	0.079 (0.00)
D(ER(-1)	-0.008 (0.58)	-0.013 (0.41)	---	-0.009 (0.56)	-0.001 (0.93)	-0.003 (0.84)	---	0.001 (0.91)	0.013 (0.93)	0.020 (0.43)	---	0.011 (0.66)
TB(-1)	0.909 (0.00)	0.794 (0.00)	0.808 (0.00)	---	0.873 (0.00)	0.772 (0.00)	0.784 (0.00)	---	0.822 (0.00)	0.772 (0.00)	0.766 (0.00)	---
OG*INFD	-0.044 (0.74)	---	---	---	-0.010 (0.94)	---	---	---	-0.210 (0.94)	---	---	---
INF*INFD	---	-0.02 (0.29)	---	---	---	-0.050 (0.10)	---	---	---	-0.039 (0.37)	---	---
D(ER(-1)*INFD	---	---	0.011 (0.76)	---	---		-0.013 (0.03)	---	---		-0.033 (0.58)	---
TB*INFD	---	---	---	0.003 (0.90)	---	---	---	-0.028 (0.36)	---			-0.022 (0.61)
Adj-R2	0.93	0.93	0.92	0.92	0.88	0.88	0.86	0.87	0.82	0.81	0.80	0.80
DW	2.2	1.1	0.83	0.74	1.54	1.47	2.58	1.23	1.59	1.24	1.44	1.42
F-stat (Prob)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3: Threshold Regression Estimates of Non-Linear Taylor Rules (By Interest Rate)

	TB3				TB6				TB12			
	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4
C	0.811 (0.01)	1.824 (0.00)	1.106 (0.00)	4.066 (0.00)	0.999 (0.01)	1.682 (0.00)	1.469 (0.00)	3.468 (0.00)	1.389 (0.006)	2.765 (0.00)	1.735 (0.00)	5.405 (0.00)
OG	---	-0.032 (0.32)	0.025 (0.43)	-0.017 (0.47)	---	0.004 (0.89)	0.034 (0.36)	0.039 (0.21)	---	0.031 (0.48)	0.050 (0.30)	-0.048 (0.26)
INF	0.061 (0.00)	---	0.074 (0.00)	0.031 (0.03)	0.058 (0.00)	---	0.074 (0.00)	0.061 (0.00)	0.068 (0.00)	---	0.081 (0.00)	0.045 (0.04)
D(ER(-1)	-0.013 (0.36)	-0.014 (0.32)	---	0.004 (0.70)	-0.005 (0.73)	-0.002 (0.87)	---	-0.013 (0.41)	0.002 (0.90)	-0.002 (0.91)	---	0.014 (0.47)
TB(-1)	0.861 (0.00)	0.800 (0.00)	0.823 (0.00)	---	0.850 (0.00)	0.690 (0.00)	0.789 (0.00)	---	0.803 (0.00)	0.561 (0.00)	0.753 (0.00)	---
OG*TBD	-0.239 (0.00)	---	---	---	-0.287 (0.00)	---	---	---	-0.356 (0.00)	---	---	---
INF*TBD	---	-0.084 (0.09)	---	---	---	-0.012 (0.81)	---	---	---	-0.198 (0.02)	---	---
D(ER(-1)*TBD	---	---	0.040 (0.63)	---	---		-0.023 (0.81)	---	---		-0.072 (0.51)	---
TB*TBD	---	---	---	0.207 (0.00)	---	---	---	0.105 (0.03)	---			0.316 (0.00)
Adj-R2	0.93	0.91	0.92	0.95	0.92	0.91	0.87	0.91	0.84	0.85	0.81	0.88
DW	1.9	1.2	0.77	0.93	1.28	1.25	1.21	1.13	1.74	1.55	1.42	1.97
F-stat (Prob)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4: Threshold Regression Estimates of Non-Linear Taylor Rules (By Exchange Rate)

	TB3				TB6				TB12			
	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4	Rule 1	Rule 2	Rule 3	Rule 4
C	1.141 (0.00)	0.978 (0.00)	1.130 (0.00)	4.450 (0.00)	1.420 (0.00)	1.682 (0.00)	1.440 (0.00)	3.183 (0.00)	1.701 (0.006)	2.028 (0.00)	1.251 (0.02)	2.559 (0.00)
OG	---	-0.009 (0.72)	0.022 (0.47)	0.031 (0.24)	---	0.004 (0.89)	0.035 (0.34)	0.049 (0.10)	---	0.025 (0.55)	0.083 (0.10)	0.061 (0.17)
INF	0.075 (0.00)	---	0.075 (0.00)	0.082 (0.00)	0.074 (0.00)	---	0.074 (0.00)	0.069 (0.00)	0.823 (0.00)	---	0.781 (0.00)	0.040 (0.14)
D(ER(-1)	-0.008 (0.58)	-0.018 (0.25)	---	-0.017 (0.22)	-0.007 (0.97)	-0.002 (0.87)	---	-0.009 (0.59)	0.009 (0.70)	-0.026 (0.26)	---	0.034 (0.16)
TB(-1)	0.820 (0.00)	0.758 (0.00)	0.822 (0.00)	---	0.791 (0.00)	0.690 (0.00)	0.789 (0.00)	---	0.753 (0.00)	0.657 (0.00)	0.808 (0.00)	---
OG*ERD	0.006 (0.94)	---	---	---	-0.011 (0.90)	---	---	---	-0.043 (0.74)	---	---	---
INF*ERD	---	-0.015 (0.69)	---	---	---	-0.012 (0.81)	---	---	---	-0.128 (0.00)	---	---
D(ER(-1)*ERD	---	---	-0.016 (0.62)	---	---		0.006 (0.86)	---	---		-0.039 (0.46)	---
TB*ERD	---	---	---	0.006 (0.80)	---	---	---	-0.029 (0.33)	---			-0.130 (0.00)
Adj-R2	0.83	0.93	0.92	0.94	0.87	0.91	0.87	0.92	0.81	0.85	0.80	0.84
DW	1.7	1.5	0.76	1.04	1.24	1.25	1.23	1.17	1.40	1.70	1.62	1.58
F-stat (Prob)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3 shows that adjusted R-square and DW are high in values in all specifications. F-statistic has estimated with the null hypothesis that coefficients of response variables are the same in both regimes of interest rates. Significant probability values of the F-statistic show that all coefficients of target variables are the same in both regimes. Coefficients of the output gap are negative, significant, and not the same in both regimes of interest rate. Response coefficients of inflation are insignificant in all specifications. Response coefficients for the differenced lagged exchange rate are also insignificant. However, response coefficients of interest rate smoothing are positive and significant but behave differently in high regimes as compared to low-interest-rate regimes.

IV.IV. NON-LINEAR TAYLOR RULES (BY EXCHANGE RATE)

Nonlinear Taylor rules concerning interest rates are estimated in this section. Nonlinearity attached to the exchange rate becomes significant when exchange rate depreciation lies above the threshold value by assigning value 1 to the dummy variable. The threshold value for the exchange rate is found at 0.68, it is expected that policy behavior is different above and below the threshold value. Again, four specifications are estimated for the nonlinear Taylor rule for the exchange rate. Results are presented in Table 4.

The econometric specifications for threshold regression of nonlinear Taylor rules by exchange rate with TB3, TB6, and TB12 of Rule 1 are as follows:

$$TB(i)_t = \omega_0 + \omega_1 INF_t + \omega_2 \Delta ER_{t-1} + \omega_3 TB(i)_{t-1} + \omega_4 OG_t * ERD + \varepsilon_t \quad \textbf{(16)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by exchange rate with TB3, TB6, and TB12 of Rule 2 are as follows:

$$TB(i)_t = \tau_0 + \tau_1 OG_t + \tau_2 \Delta ER_{t-1} + \tau_3 TB(i)_{t-1} + \tau_4 INF_t * ERD + \varepsilon_t \quad \textbf{(17)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by exchange rate with TB3, TB6, and TB12 of Rule 3 are as follows:

$$TB(i)_t = \xi_0 + \xi_1 OG_t + \xi_2 INF_t + \xi_3 TB(i)_{t-1} + \xi_4 \Delta ER_{t-1} * ERD + \varepsilon_t \quad \textbf{(18)}$$

The econometric specifications for threshold regression of nonlinear Taylor rules by exchange rate with TB3, TB6, and TB12 of Rule 4 are as follows:

$$TB(i)_t = \psi_0 + \psi_1 OG_t + \psi_2 INF_t + \psi_3 \Delta ER_{t-1} + \psi_4 TB(i)_{t-1} * ERD + \varepsilon_t \quad \textbf{(19)}$$

Results of threshold nonlinear regression estimation by exchange rate are presented in Table 4.

F-statistic has estimated with the null hypothesis that response coefficients behave the same above and below the threshold value. The significance of the F-statistic is the rejection of the null hypothesis in the favor of the alternative hypothesis that the depreciation of the exchange rate lies above the threshold value. Adjusted R-square and DW both are high in values, indicating the inclusion of lagged dependent variable and no autocorrelation respectively. Response of output gap to the depreciation is insignificant in all specifications. Response of inflation to depreciation is negative and insignificant with TB3 and TB6 but negative and significant with TB12, indicating that at above the threshold value inflation rises with depreciation. Response coefficients of differenced lagged exchange rates are insignificant. The interest rate also shows an insignificant response of depreciation above the threshold value under TB6 and TB3 but indicates a negative and significant under TB 12 that shows a decline in interest rate with exchange rate depreciation at the above threshold. This result is consistent with Lamia and Djelassi (2020). Moreover, the result indicates that SBP does not intervene in the exchange market to stabilize inflation rather it declines the interest rate at the time of high depreciation.

V. CONCLUDING REMARKS

This paper examines different specifications of the non-linear Taylor rule of inflation-targeting for the economy of Pakistan. The paper aims to check the non-linear policy behavior of the State Bank of Pakistan. Threshold regression has applied with quarterly data taken from 2005q1-2019q3. Three months Treasury bill rate, six months Treasury bill rate, and twelve months Treasury bill rate are taken as policy instruments. Threshold regression applies to four models of the non-linear Taylor rule such as by economic activity; inflation rate; interest rate; and exchange rate. Threshold regression of nonlinear Taylor rule assumes different behavior of monetary authorities regarding below and above threshold values of the considering variable. Threshold values are estimated at 2.5 % for the output gap. Response coefficients of output gap with economic activity remain the same in both boom and recession with TB3 and TB6, but significant in boom with TB12 that specifies weak response. Response coefficients of interest rate are positive and significant above and below the output gap of the threshold value which is 2.5%. The threshold value for the inflation rate is 6.02%. Above the threshold value, high inflation regime is observed and below this low inflation regime is observed. The threshold value for interest rate is 7.45%; it expects that policy behavior is different in different regimes of interest rate. Coefficients of the output gap are negative, significant, and not the same in both regimes of interest rate. However, response coefficients of interest rate smoothing are positive and significant but behave inversely in the high regime as compared to the low-interest rate regime. The threshold value for the exchange rate is 0.68 and it is expected that SBP behaves differently above and below it. Output gap response to the depreciation is insignificant in all specifications. Inflation response to depreciation is negative and insignificant with TB3 and TB6. But negative and significant inflation response is found towards depreciation with TB12, it is the indication that at above 0.68 inflation rises with depreciation. Response coefficients of differenced lagged exchange rate and interest rate are insignificant. The response coefficient is negative and significant under TB 12 which shows a fall in interest rate with exchange rate depreciation above 0.68. This result specifies that SBP does not interfere in the exchange market to stabilize inflation rather it declines the interest rate at the time of high depreciation. Moreover, in all specifications of the non-linear Taylor rule, it is found that SBP does not follow the Taylor rule and that exchange rate stabilization is ignored. A shortcoming that arises is related to data on GDP, quarterly data sets are not available in Pakistan, it is the authors' calculation with the help of statistical tools to convert the annual available data into quarterly time series. As a policy implication, it is suggested that SBP should control depreciation in the exchange rate to overcome inflation. SBP should consider exchange rate stabilization together with the objective of price stability in an inflation-targeting framework.

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