Growth-Inflation Nexus: Estimation of Threshold Inflation for SAARC-6 Countries

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Abstract

The paper examines growth-inflation nexus for SAARC-6 countries employing non-dynamic fixed effect panel threshold regression (PTR) model for the period 1981-2018. The model is used to test nonlinearity in the effect of inflation on growth and to identify optimal threshold inflation rate. The test procedure takes place sequentially, with testing for multiple thresholds against their alternatives and bootstrapping for determining level of significance as the test-statistic has a nonstandard asymptotic distribution. SAARC region is an interesting case study due to similarity in terms of level of economic development, dependence on oil imports, high population density, etc. on the one hand and yet having diversity in terms of some other socio-economic indicators, most importantly savings behavior, which has a bearing on inflation-growth nexus. The paper finds that high and low inflation levels have an asymmetric effect on growth: statistically insignificant effect when inflation is below 6.16%; and significantly negatively affecting growth beyond this point.

Keywords: Inflation, Growth, Threshold inflation.

Introduction

The relationship between inflation and economic growth has been widely debated in economic literature due to its theoretical importance as well as policy implications. Growing focus on price stability to achieve stable economic growth has put this relationship into a central position in the empirical research relating to the central banking. Two key research questions in this regards are important: (a) what is the nature of relationship between growth and inflation (i.e. linear or nonlinear); and (b) what is that rate of inflation after which it hurts economic growth.

On the nature of the relationship, the empirical evidence is mixed. As given in the next section of this paper, some studies find a positive relationship between the two variables, others find no or negative relationship between inflation and growth. Most recent empirical research work, however, provides enough evidence of nonlinearity in the growth-inflation nexus.

On threshold point also, the empirical evidence is not conclusive and presents different optimal levels or thresholds inflation for developing and developed economies. This diversity in thresholds may arise due to factors including country-specific characteristics, development stage of economies, type of data used (e.g. time series, cross section and panel), and methodological and estimation issues. Threshold estimate produced by different studies for regional economies varies in the range of 4% to 40%.[§]

In case of SAARC region, most of the studies are either country specific, or take countries of the region as part of a broader group of developing countries. We do not find any study using standard panel threshold model to determine optimal threshold inflation for the region. This panel approach was also considered suitable for the region, as it compensates for a lack of data constraints, offers some important longitude dimensions, bring more variability, and less collinearity among the variables than the time series data. Therefore, we studied this relationship in SAARC countries as a region with the flexibility in the model to capture country-specific effects. We also examine the nature of relationship between inflation and growth besides identifying threshold inflation level for SAARC-6 countries using data for the period 1981-2018.[**] The study includes Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka for which relevant data is available for a sufficient time period.

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[§] While Behra and Mishra (2017) suggest 4% threshold inflation for India, Bruno and Easterly (1998) determine 40% inflation as a "natural" breakeven point for developing countries, including SAARC countries.

[**] Instead of using 5-year non-repeating averages, the annual panel data is used due to small number of cross sectional units.

The paper uses non-dynamic fixed-effect panel threshold regression (PTR) model, developed by Hansen (1999) as an important tool for studying many economic phenomena (Wang, 2015). The technique isolates the effects of inflation on economic growth through a series of control variables and allows for non-linear component to capture the relationship. Also, it helps control for time invariant unobserved heterogeneity using fixed effect within transformation. While the significance of threshold effects is tested using LR statistic, the F statistic is employed with bootstrapping to test significance of regime dependent parameters. The method also helps get consistent threshold estimator close to the nominal significance test level. The estimates of threshold inflation can be useful for SAARC central banks for their inflation targeting strategies.

After the above introductory part, the paper presents a review of literature in the next section; section 3 explains the methodology used; section 4 provides a descriptive analysis of data; and section 5 gives results of our estimation. The last section concludes the paper.

Literature Review

The econometric research literature focuses on investigating both the theoretical and empirical aspects of inflation-growth trade-off. However, the empirical findings present mixed evidence, which can be categorized as follows:

1. Inflation has no effect on economic growth [e.g. Sidrauski (1967), Cameron, H. Simpson (1996)].
2. Inflation has a positive impact on economic growth [e.g. Tobin (1965), Mallik and Chowdhury (2001)].
3. Inflation has a negative effect on growth [e.g. Friedman (1956), Stockman (1981), Barro (1996), Andres and Hernando (1997), Saeed (2007), and Khan, A, and S (2018)].
4. The relationship between inflation and growth is nonlinear with a positive effect of inflation on growth below some critical level (threshold point) and negative effect after this level [e.g. Sarel (1996), Ghosh and Phillips (1998), Bruno and Easterly (1998), Khan and Senhadji (2001), Drukker et al. (2005), Mubarik (2005), Shamim and Mortaza (2005), Espinoza et al. (2010), Mohanty, D. and et al (2011), Seleteng et al. (2013), Kremer et al. (2013), Thanh (2015), Ibarra and Trupkin (2016), and Ndoricimpa (2017)].

Different studies have used different approaches and data sets to study the inflation-growth nexus and thus came up with different results. The estimates of thresholds, the subject in which we are interested, also vary across studies. For example, Sarel (1996) found the point of inflection at 8% in his study of 87 countries for the period 1970-90. Bruno and Easterly (1998) studied a cross section of countries for the period 1961-92, and found no evidence of any consistent relationship between growth and inflation except for situations of inflation crises, i.e. 40% or above inflation when growth falls sharply. Khan and Senhadji (2001) calculate threshold within the range of 11%-12% and Drukker et al. (2005) suggest 19.16% threshold in case of full sample of 138 countries and 12.6% for developing countries. Kremer, et al (2013) find threshold level of 17% and Ndoricimpa (2017) finds inflation threshold of 6.7% for the whole sample, 9% for the subsample of low-income countries, and 6.5% for middle-income countries. Similarly, for developed or industrialized economies, the studies find relatively low threshold, for example: Khan and Senhadji (2001) calculate the threshold of 1%–3% for industrialized countries; Drukker et al. (2005) suggest 2.57% threshold; and Kremer, et al (2013) find that of 2%.

For individual countries of SAARC region, Prasad (2001) finds 6.5 % threshold in case of India; Hussain (2005) suggests setting inflation with a range of 4.5-6% for Pakistan; Shamim and Mortaza (2005) suggest a structural break point for Bangladesh at 6%; Singh (2010) finds 6% threshold for India; Bhusal et al. (2011) calculate 6% threshold inflation for Nepal; Behra and Mishra (2016) estimate the threshold inflation level for India at 4%; Arby and Ali (2017) calculate threshold inflation level for Pakistan at 6.05% and 5.67% from two different models; De Silva (2017) suggests 9% threshold for Sri Lanka; and; Hussain and Rahman (2020) recommend inflation target for Pakistan at 5.5 percent within +/- 1.5 band.

The above review of literature shows that, in general, the relationship between growth and inflation is nonlinear and there exists some threshold inflation rate at which the nature of relationship changes from no or positive relation to negative relation. However, the literature diverges as to where the turning point in inflation-growth nexus occurs.

Methodology

The non-dynamic fixed effect panel threshold regression (PTR) model, developed by Hansen (1999), and promoted by Wang, Q (2015), is adopted in this paper to estimate optimal inflation threshold in SAARC-6 countries using data for the period from 1981 to 2018. The model is implemented by splitting data into various groups according to an observable variable that may be considered as regime parameter. If at least one threshold value is found in a regime, it implies that the relationship between inflation and economic growth is nonlinear. This also points towards exploring the possibility of other regimes. In such a case, the model identifies the thresholds sequentially.[††]

The structural equation for a single threshold model can be written as follows:

$$y_{it} = \mu + \beta' X_{it}(\gamma) + \mu_i + e_{it} \quad (1)$$

with $X_{it}(\gamma) = \begin{pmatrix} x_{it} I(q_{it} \leq \gamma) \\ x_{it} I(q_{it} > \gamma) \end{pmatrix}$ and $\beta = (\beta_1' \, \beta_2')'$.

where, the dependent variable y_{it} is scalar, the threshold variable q_{it} is scalar, γ is the threshold parameter, and the regressor X_{it} is a k vector. The subscript i indexes the individual country while subscript t indexes time. $\boldsymbol{I}(\cdot)$ is the indicator function, which is equal to 1 or 0, depending on the condition term.

The above equation splits the observations into two "regimes", depending upon the relative value of threshold variable q_{it} with respect to the threshold parameter γ. The regimes are identified by slope parameters β_1 and β_2. The threshold variable q_{it} is not time invariant. The parameter u_i is the individual effect, and e_{it} is the disturbance term, which is assumed to be independent and identically distributed (iid) with mean zero and infinite variance σ^2.

As a part of process, we first remove the country-specific fixed effects μ_i from the model to estimate the slope coefficients and optimal threshold point. While this elimination of individual effects is straightforward in linear models, the nonlinear specification (1) requires a more careful treatment. Taking the equation (1) as deviation from mean, we get the following fixed effect model:

$$y_{it}^* = \beta' X_{it}^*(\gamma) + e_{it}^* \quad (2)$$

where, y_{it}^* *and* X_{it}^* are within-group deviations.

We estimate $\hat{\beta}$ from equation (2). For given γ, the slope β can be estimated by ordinary least-squares. The residual sum of square (RSS) is worked out from the above estimated equation, which is also a function of γ. The optimal threshold $\hat{\gamma}$ is obtained where RSS is minimum. While finding the optimal threshold, we keep on changing threshold variable q_{it} in the interval $(\underline{\gamma}, \bar{\gamma})$. In practice, the range of inflation may be unusually a large number and the optimization search for a threshold may be demanding. Hansen (2000), therefore, suggests narrowing the range of inflation to which optimal threshold is most likely to lie.

The next crucial step is to determine the statistical significance of threshold point in such a non-linear model. For this purpose, Hansen (1999) has developed an asymptotic theory for threshold estimate and the slope coefficients. For distribution of threshold estimate, the test for the hypothesis $\gamma = \gamma_0$ (in which, γ_0 is the true value of γ) is required. Hansen (1999) proved that $\hat{\gamma}$ is a consistent estimator for γ, and suggests that the best way to test $\boldsymbol{\gamma = \gamma_0}$ is to construct confidence interval using the "no-rejection region" method with likelihood ratio (LR) test on $\boldsymbol{\gamma}$. Testing for a threshold effect is similar to testing linear model if the coefficients are the same in each regime. The likelihood ratio test of null hypothesis (H_0) is based on F-statistic.

Under H_0, the threshold $\boldsymbol{\gamma}$ is not identified, as F-statistic has a nonstandard asymptotic distribution. Therefore, to test the significance of the threshold effect, Hansen (1999) recommends a bootstrap on the critical values of the F-statistic. Based on this recommendation, the paper adopts the following procedure:

- Step 1: A single-threshold model is fitted to test the significance of threshold effect. Here, H_0, $\beta_1=\beta_2$. Under H_0: there is non-existence of threshold effect in the model (i.e. linear model). If H_0 is rejected, it means the model is non-linear.

[††] For details, see Wang (2015).

- Step 2: The number of threshold is determined by estimating threshold effects of the models sequentially with different thresholds. The testing process continues till the null hypothesis is accepted.
- Step 3: The significance of threshold effect is examined with the given thresholds using LR statistic and bootstrap method. This step not only allows us to confirm the statistical significance of threshold effect but also provides the inference of estimators.

In the above models, dependent variable is growth rate of per capita GDP, and exogenous variable X_{it} includes log of investment as a share of GDP, the log of real GDP per capita of the previous period used as an initial income, the log of terms of trade, the log of share of exports plus imports in the GDP as a measure of openness, log of M2 as percent of GDP, a measure of financial deepening and population growth. A dummy variable is also included to capture the impact of different shocks affecting the SAARC region during 1981-2018. We set $q_{it} = inf_{it}$. The inf_{it} is used as threshold variable (i.e. CPI inflation), and γ_1, and γ_2 denote the threshold parameters, which are assumed to be unknown and needs to be estimated.[‡‡] While the parameter coefficients (i.e. θs) are regime independent, the regimes are marked by regression slope βs.

Data description

In this paper, we consider panel data for SAARC-6 member countries (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) for the period 1981–2018. Since the PTR model requires balance panel data, Afghanistan and Maldives have been excluded due to non-availability of historical data for the period of the analysis. Detail of variables with definition and statistical description is given in table 1.

Table 1: Description of Variables

Variables	Definition, Description
$gypc_{it}$	dlog of real GDP per capita at constant 2010 national prices
$lypc_{it-1}$	log of real per capita GDP at current PPPs for the previous period.
li_{it}	log of share of gross capital formation in GDP at current PPPs
$ltot_{it}$	log of index of exports and imports prices (terms of trade)
inf_{it}	dlog of CPI for the year
$lopn_{it}$	log of share of exports plus imports to GDP ratio
gp_{it}	dlog of population
$lm2_{it}$	log of M2 to GDP ratio, as a measure of financial deepening
Dum_{it}	The dummy variable takes value 0 or 1 to capture impact of international shocks affected the SAARC region during 1981-2018

The data has been extracted from World Development Indicators (WDI) database, IMF's International Financial Statistics, and SAARCFINANCE database. Descriptive statistics of panel data are reported in Appendix 1. Apparently, these statistics indicate existence of some outliers in the dataset, as observed from overall maximum and minimum statistics. It also indicates existence of wide disparities in observations. This is obvious if we take into account the size of SAARC economies included in the sample such as India, Pakistan, Bhutan, Nepal, etc. Similarly, the correlations matrix gives some hints about the nature of the relationship between the variables of interest (Appendix 2). Since the estimated magnitude of significant correlation coefficients is found less than the standard benchmark (i.e. coefficient > 0.7), we need not to drop any variable. This is also confirmed by the mean value of VIF test, which is less than the value of 4 (Pan & J., 2008). This indicates no multicollinearity problem in variables (Appendix 3). Further, the model specification tests (i.e. linktest and ovtest in STATA) are carried out using OLS, the results of which are reported in Appendix 4. The results of these tests indicate that the model is correctly specified.

The stationarity of the variables has been checked through panel unit root tests, including the Covariate Augmented Dickey-Fuller (CADF) developed by Pesaran (2003). These tests are also important as all the asymptotic theories for panel threshold (PTR) models require stationary regressors.

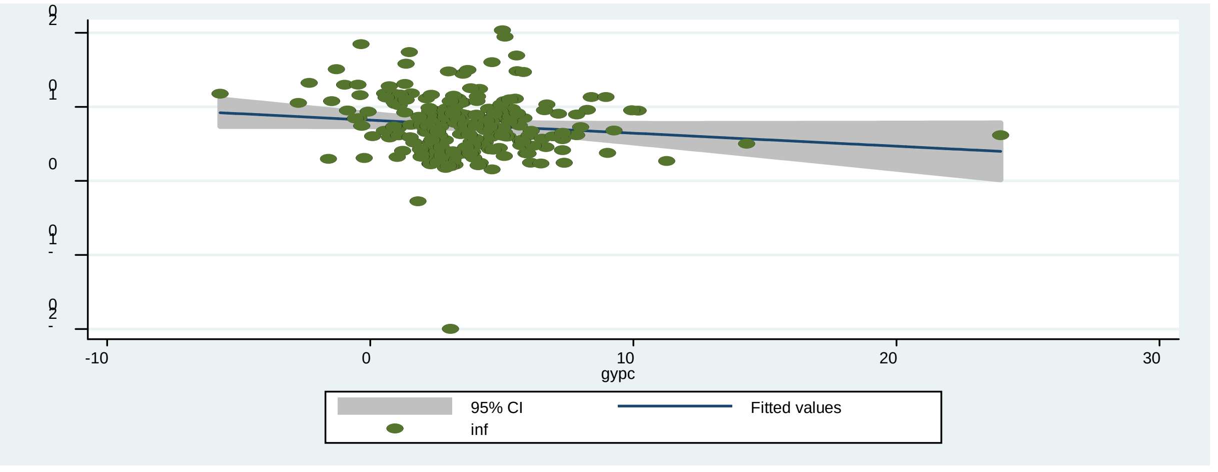
[‡‡] In threshold studies, inflation is used both as a threshold variable and threshold parameter (i.e. a regime dependent regressor) [e.g. Kremer (2009), Ndoricimpa, A. (2017)].

The CADF test is considered a second generation unit root test, as it also allows for cross-sectional dependence with cross section units are heterogeneous.[§§]

The results of unit root tests are reported in Appendix 5**,** which indicate that most of the tests reject null hypothesis of presence of unit root at levels for all variables, except for openness which is first differenced stationary. The CADF test shows that financial deepness is stationery with trend. Further to check robustness of PTR model results, the post estimation tests are conducted, the results of which are reported in Appendix 6.

A plot of inflation and growth shows that two variables have a week negative relationship and observations are clustered around 6 percent inflation [Figure 1(a)]. However, some outliers can also be seen in the Figure, which are legitimate observations, and not the results of errors. Therefore, the extreme values are not removed considering them important piece of information, and its removal can affect quality of the inferences. These panel data series are also checked individually for possibility of nonlinearity factor using the diagnostic plots shown in (1b &1c). These diagnostic plots allow us to check visually whether the data is distributed with a particular distribution: symmetric or not. In case of symmetry in data, the observations should lie on the line in each figure. Since the observations of both the data series do not form a line, we broadly presume that the data is approximately asymmetric

Figure 1(a): GDP per capita growth and inflation relationship



5 The first-generation tests of panel unit root ignore cross section dependence and co-movements of variables amongst the cross section units. To take care of these issues, the second generation tests have been developed.

Figure 1(b): Nonlinearity in Inflation data

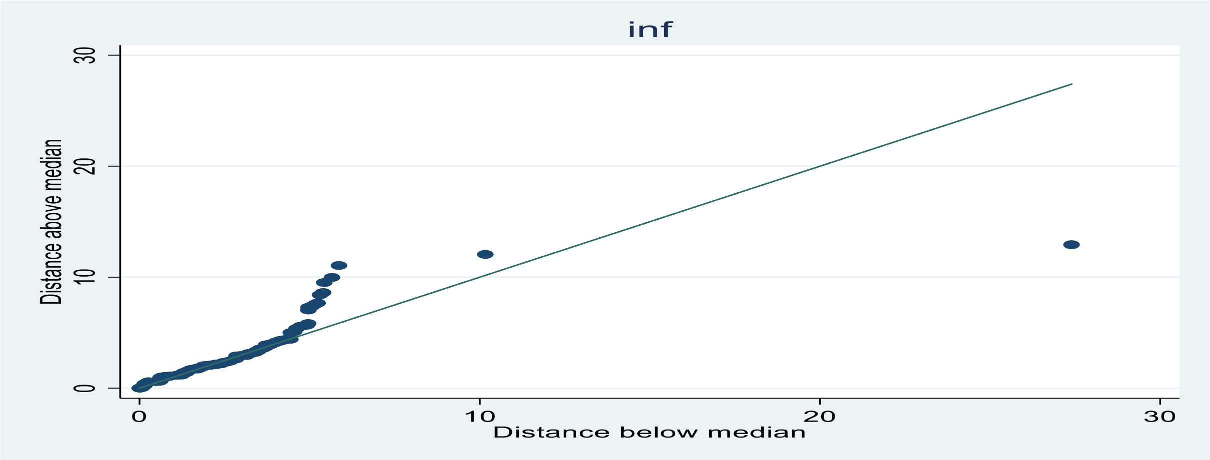
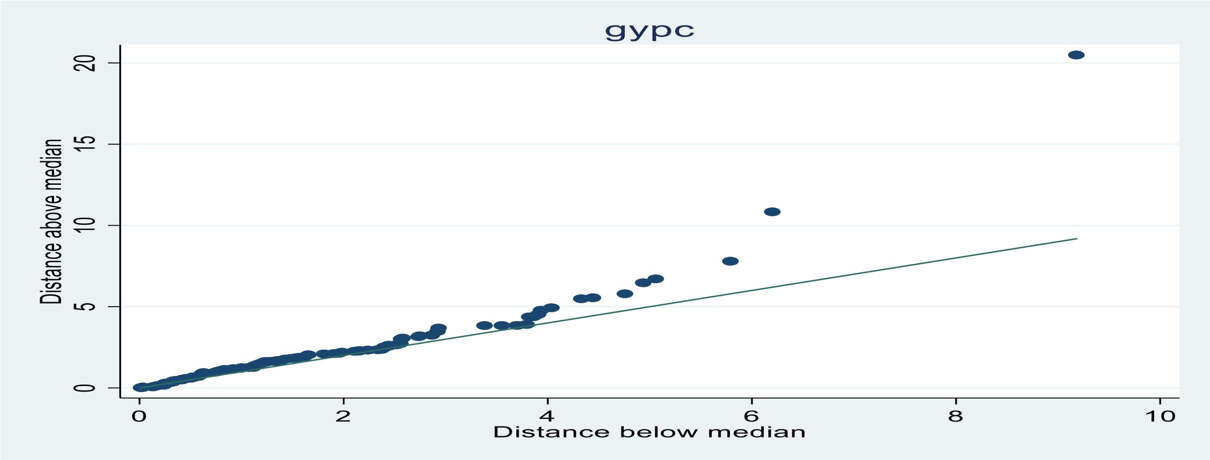


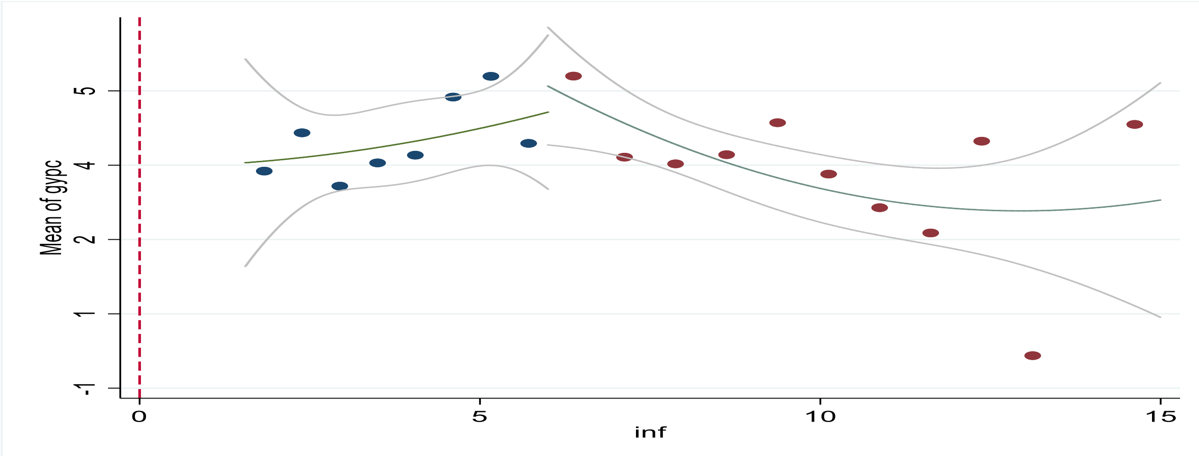
Figure 1(c): Nonlinearity in per capita GDP growth



These figures point, in general, towards existence of a nonlinear relation between inflation and growth. We also examined graphically the existence of nonlinearity in growth-inflation nexus and its breakpoint using cmogram plot developed by Christopher Robert (2010).[9] We use its regression discontinuity features, which split the graph at a particular value of explanatory variable. In fact, it helps know if there exists an observable jump (discontinuity) in the level of the explanatory variable. Figure 2 plots the mean growth (i.e. $gypc_{it}$) conditional on inflation (i.e. inf_{it}), which clearly exhibits a discontinuity in the two fitted lines: the first one shows a positive relationship between inflation and growth. This relationship continues up to the exogenously determined cutoff point (i.e. 6% inflation). However, a turn in this relationship can clearly be seen in the second fitted line after the cutoff/breakpoint, as it shows a negative relationship between the two variables. This provides relatively a strong clue about existence of breakpoint in growth-inflation nexus in SAARC-6 countries.

[9] Christopher Robert, 2010. "CMOGRAM: Stata module to plot histogram-style conditional mean or median graphs," Statistical Software Components S457162, Boston College Department of Economics, revised 11 Sep 2011.

Figure 2: Growth-Inflation Nexus (using regression discontinuity plot)



Source: Authors' computation

Tests for Existence of Threshold Effect

As a first step, we fit a single-threshold model to capture the threshold effect.[10] Here, we test the null hypothesis of a linear model against alternative of single-threshold model. The threshold variable is trimmed off 5% at both sides to enable it to search for threshold estimator.[11] From estimation point of view, the grid option is used to reduce the computation cost (Hansen, 1999). The null of linearity is tested against the threshold model using F-statistic with bootstrapping to estimate critical *p*-values, as it has a nonstandard asymptotic distribution. The asymptotic *p*-values are computed using 300 bootstrap replications. The results of single threshold model are reported in Table 2, which indicate that the null hypothesis of linear model is rejected against alternative of threshold effect, as F-statistic is found significant with a bootstrap *p*-value of 0.046. In other words, the linearity of relationship between growth and inflation does not hold, and it confirms the presence of non-linearity in relationship between the two variables in the context of SAARC-6.

Table 2: Summary of the Test Results of Single Threshold-Effect Model

Model	**F statistic**	**Bootstrap *p*-value**	**Threshold Estimates ($\hat{\gamma}$) (%)**	**95% Confidence Interval**
Single	9.63 *	0.046	6.5463	[5.9177, 6.5575]

Source: Authors' computation. Notes: * p < .05 significance level. H_0: $\gamma = \gamma_0$ and H_a: $\gamma \neq \gamma_0$

The threshold inflation is estimated as 6.5%, which is not optimal (rather a temporary threshold) due to significance of F-statistic at *p*-value of 0.046. This requires fitting more threshold models to capture adequately the nonlinear effects. Therefore, we go a step further and fit double or triple thresholds PTR model. Here, we choose a triple threshold model as the results of double threshold model indicating fitting more threshold models.

Going sequentially, we then fit a triple threshold model to test threshold effects and determine the number of thresholds. The null hypothesis is tested for single-threshold model against the alternative hypothesis of double-threshold model, and so on. In their multiple change point model, Bai and Perron (1998) also find the sequential estimation consistent. For triple threshold model, the bootstrapping and its design, is same as used in the single-threshold model. Both the trimming and grid options also apply here. However, the trimming values for second and third thresholds are set separately.

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[10]The specified model is as following:

$$gypc_{it} = \mu_i + \theta_1 lypc_{it-1} + \theta_2 ltot_{it} + \theta_3 lopn_{it} + \theta_4 lm2_{it} + \theta_5 gp_{it} + \theta_6 li_{it} + \theta_7 Dum_{it} + \beta_{11} inf_{it}\mathbf{I}(inf_{it} \leq \gamma_1) + \beta_{21} inf_{it}\mathbf{I}(inf_{it} > \gamma_2) + e_{it}$$

[11]The trimming value is selected as a priori to contain observations (bottom and top 5% quantiles of the threshold variable), to ensure that the model is well identified for all thresholds.

Similarly, the trimming proportion is also set for single-threshold model, since the method searches the threshold using previous results. Further, the asymptotic *p*-values are obtained using bootstrap replications. We set 300 bootstrap replications both for double and triple-threshold models. However, 0 (zero) is set for single-threshold model as we need not to apply bootstrap replications again. In this way, we suppress output of bootstrap replications and the fixed-effect regression for single threshold.

The results of triple-threshold model are presented in Table 3. F-statistic for double threshold is found highly significant with a bootstrap *p*-value of 0.00 [F_2=20.20 > $Crit_1$11.3172]. However, the F-statistic for a third threshold is not statistically significant, with a bootstrap *p*-value of 0.3400 [F_3=7.39 < Critical [11.8940]. This indicates that we need not to go further for hunting thresholds. Based on this, we conclude the existence of double thresholds in the regression relationship. Also, we find an optimal inflation threshold of 6.16%, with *p*-value of 0.00. To check preciseness of the threshold estimator we examine the results of LR test, which shows confidence interval [5.9377, 6.4864] around the threshold estimate. This indicates that the preciseness of the threshold estimate is quite good. The remaining analysis is conducted using double threshold model, as the triple model is found insignificant.

Table 3: Summary of the Test Results of Triple Threshold-Effect Model

Threshold estimator (level = 95):

Threshold	**Estimate (%)**	**Lower Bound**	**Upper Bound**
$\hat{\gamma}_1$	6.5463	5.9177	6.5575
$\hat{\gamma}_{21}$	6.2801	6.1233	6.3099
$\hat{\gamma}_{22}$	**6.1635**	5.9377	6.4864
$\hat{\gamma}_4$	11.3329	11.3234	11.4985

Threshold effect test (bootstrap = 0 300 300)

Model	**RSS**	**MSE**	**F statistic**	***p*-value**	$Crit_3$	$Crit_2$	$Crit_1$
Single	-	-	-	-	-	-	-
Double	1126.1556	6.0873	20.05	0.0000	7.2278	8.7470	11.3172
Triple	1082.8780	5.8534	7.39	**0.3400**	11.8940	15.6290	30.0054

Source: Authors' computation. Note: The threshold-effect test reveals that the Single corresponds to H_0 (linear model) and Ha (single threshold model). Similarly, Double corresponds to H_0 (single-threshold model) and Ha (double threshold model), and so forth. γ_{21} and γ_{22} denote the two estimators in a double-threshold model. The critical values $Crit_1$, $Crit_2$, and $Crit_3$ denote significance level at 1%, 5%, and 10%, respectively.

The threshold inflation estimate of 6.16 % seems more reasonable if compared with thresholds found by other studies conducted for individual SAARC members.

Graphical representation of threshold point

We can also get information about the threshold estimates $\hat{\gamma}_1$ and $\hat{\gamma}_2$ using plots of the concentrated likelihood ratio function**.** This is shown in Figure 3, which presents both the first and second threshold inflation estimates. The LR statistics are plotted against different values of thresholds mainly to determine threshold point where the LR statistics are smaller than the critical values. This optimal value of threshold yields the confidence region where the likelihood ratio lies beneath the dotted line. In the upper part of Figure 3, the single threshold is presented which is temporary due to presence of double threshold. Thus, we consider only the second threshold. The least squares estimate of the threshold inflation minimizes the function at 6.16%, with the asymptotic 95% confidence interval region [5.9377, 6.4864]. We can read from this graph that the likelihood ratio lies below the dotted line, which implies that the threshold estimate is quite precise, and the confidence interval is tight indicating little uncertainty

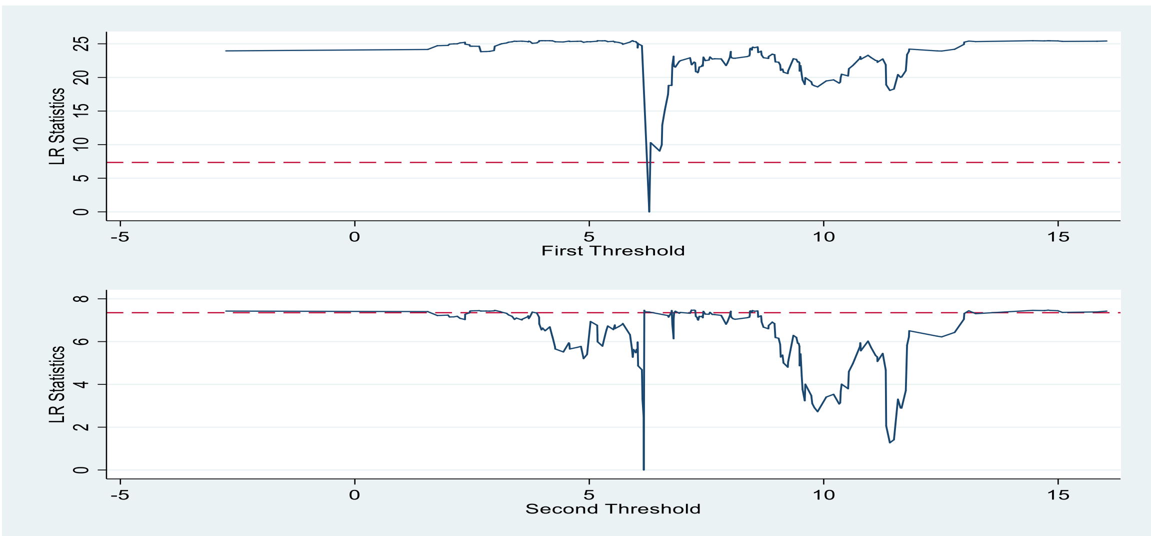
The estimated parameters of double threshold model are presented in Table A-6.[12] The paper suggests 6.16% inflation threshold. Inflation below this point has positive insignificant effect on growth for inflation regime (i.e. $\hat{\beta}_2$=1.03). However, this effect is positively significant in case of first inflation regime. Similarly, inflation has a 10 percent significant negative impact (i.e. $\hat{\beta}_3$=-0.04) when it reaches above this optimal threshold point. The result also indicates that inflation-growth relationship is nonlinear.

To make a comparative analysis, the model is also estimated (with robust standard errors) using fixed effect (FE) model without introducing threshold effect.[13] This also aims to check non-linearity of relationship between inflation and growth, which is evident from negative sign and significance of squared inflation variable (i.e.inf^2_{it}). The other finding reveals that inflation has a positive but insignificant impact on growth. This is consistent with results of double threshold model, which reveals that below the threshold inflation has a positive but insignificant impact on growth. The coefficients sign for other variables are almost similar in both models, except for investment to GDP ratio and openness.

Diagnostic tests

To check robustness of PTR estimates, the post estimation tests are conducted, which are reported in Table A-7. The Breusch-Pagan test is conducted to check cross-sectional independence in the residuals. The test's result indicates non-existence of cross sectional dependence in residuals, as the null hypothesis is

Figure 3: LR statistic of two thresholds



rejected with 0.48 *p*-value. To validate this result, the Pesaran (2004) test for cross-sectional dependence in fixed effects models is employed.[14] Result of the test also confirms non-existence of cross-sectional dependence across the countries, as the null is rejected with a *p*-value of 0.99. Secondly, the Born & Breitung (2016) test is used to check serial correlation in panel data. The test regresses current demeaned residuals on past demeaned and bias-corrected residuals (up to order lags) using a heteroscedasticity and autocorrelation robust estimator. The test results indicate that the null hypothesis of no serial correlation up to second order is rejected as the Q(p)-statistic is insignificant with 0.953 *p*-value. This shows absence of serial correlation problem up to the 2^{nd} order. Thirdly, the heteroscedasticity problem is tested using a

[12] The results of double threshold model without standard errors are reported to help give some idea about overall significance of the model, as F statistic is not reported in case of model with robust standard errors.

[13] The F statistic of FE model (without robust standard errors) is also a roughly check to know overall significance of the model.

[14] Pesaran, M.H. (2004) "General diagnostic tests for cross section dependence in panels", Cambridge Working Papers in Economics, 0435, University of Cambridge.

modified Wald statistic for group-wise heteroscedasticity in the residuals, following Greene (2000, p. 598).[15] The most likely deviation from homoscedastic errors in panel data could be due to error variances specific to the cross-sectional units, which can be corrected with robust standard errors. During estimation, the option of

cluster/robust standard error is incorporated in the PTR model. The test result indicates presence of heteroscedasticity, which is not an area of concern as the models uses cluster corrected robust standard errors. Finally, the PTR model handles the unobserved heterogeneity problem by fixed effect within transformation and using all regime independent variables as exogenous.

Concluding remarks

This paper estimates threshold inflation in six countries of the SAARC region by using fixed-effect panel threshold regression (PTR) model developed by Hansen (1999). As methodology works through a sequence, we employed initially a single-threshold model to test the null hypothesis of no threshold model. The null of model is rejected at 5% significance level, which indicates that at least one threshold exist, thus confirming non-linearity in growth-inflation nexus; and the threshold estimator of single threshold model is temporary implying presence of more regimes.

In the next step, multiple thresholds model is run to find out further threshold effects and an optimal threshold estimate. The paper finds the existence of double threshold effect, and determines an optimal threshold inflation of 6.16% for SAARC-6 countries. The preciseness of threshold is validated by confidence interval region [5.9377, 6.4864%].

The threshold inflation of 6.16% is also in line with threshold estimates produced by other studies conducted for individual SAARC members. It also validates the findings of those studies which found a threshold effect or nonlinearity in relationship between growth and inflation for individual SAARC members. This paper finds that below the threshold point, inflation has an insignificant positive effect on growth (i.e. $\hat{\beta}_2$=1.04). While above the threshold level, it has a negative significant impact on growth (i.e. $\hat{\beta}_3$=-0.04). The existence of threshold inflation rate has policy implication that in order to support growth inflation should be targeted at threshold rate.

[15] Greene, W. Econometric Analysis. New York: Prentice-Hall. 2000.

References

Ahmed, and Mortaza, M. (2005). Inflation and Economic Growth in Bangladesh: 1981–2005, Working Paper Series No. WP 0604. Bangladesh: Policy Analysis Unit (PAU), Bangladesh Bank.

Andres, and Hernando. (1997). Does Inflation Harm Economic Growth? Evidence for the OECD, NBER Working Paper No. 6062, Issued in June 1997.

Arby, and Ali. (2017). Threshold Inflation in Pakistan, *SBP Working Paper Series*, 1994.

Baglan, D., and *Yoldas*, E. (2014). Non-linearity in the Inflation-Growth Relationship in Developing Economies: Evidence from a Semiparametric Panel Model, DOI:10.17016/feds.2014.51

Bai, J., Perron, P. (1998). Estimating and Testing Linear Models with Multiple Structural Changes, *Econometrica*, 66, 47-78.

Barro, R.J. (1996). Inflation and Growth, Federal Reserve Bank St. Louis Review, 78,153-169.

Behera, J. (2014). Inflation and its Impact on Economic Growth, Evidence from Six South Asian Countries. *Journal of Economics and Sustainable Development*, 5(7),145-154.

Behera, and Mishra, K. (2016). Inflation and Economic Growth in BRICS, Evidence from ARDL Bound Testing Approach. *Asian Journal of Economic Modelling*, 4(1), 1-17

Bhaduri, N. S. (2007). Revisiting the Growth Inflation Nexus: A Wavelet Analysis, Working Paper, No. 77/2013, Chennai, India: Madras School of Economics.

Bhusal, T. Prasad and et al. (2011). Growth and Inflation: Estimation of Threshold Point for Nepal. *Economic Journal of Development Issues*, 13 & 14, 1-2, Combined Issue.

Bick, Alexander. (2010). Threshold Effects of Inflation on Economic Growth in Developing Countries. *Economics Letters*, 108, 126–129

Biswas, and Siddique, M.N. (2016). Determining the Growth Maximizing Threshold Level of Inflation in Bangladesh, Research Department Bangladesh Bank, Working Paper Series, No. 1602.

Bittencourt, M. (2012). Inflation and Economic Growth in Latin America: Some Panel Time-Series Evidence. *Economic Modelling*, 29(2), 333-340.

Bruno, M., and W. Easterly. (1998). Inflation Crises and Long-run Growth. *Journal of Monetary Economics*, 41, 3-26.

Burdekin, et al. (2004). When Does Inflation Hurt Economic Growth? Different Non-linearities for Different Economies. *Journal of Macroeconomics*, 26, 519–532

Cameron, N. Simpson. (1996). Stylized Facts and Stylized Illusions: Inflation and Productivity Revisited. *Canadian Journal of Economics*. 29,152-162.

Drukker, D., & P. (2005). Threshold Effects in the Relationship between Inflation and Growth: A New Panel Data Approach, http,//www.uh.edu/~cmurray/TCE/papers/Drukker.pdf.

Edwards, S. (1997). Openness, Productivity and Growth, What Do We Really Know?. *NBER Working Paper Series*, Working Paper 5970, March 1997

Eggoh, J.C. and M. Khan. (2014). On the Nonlinear Relationship Between Inflation and Economic Growth, Research in Economics. 68(2), 133-143

Espinoza, & Prasad, A. (2010). Estimating the Inflation-Growth Nexus- A Smooth Transition Model, IMF Working Papers, WP/10/76.

Fischer, S. (1993). The Role of Macroeconomic Factors in Growth. *Journal of Monetary Economics*, 32, 485-512.

Friedman, M. (1956). *The Quantity Theory of Money: A Restatement*, In M. Friedman (ed.). Studies in the Quantity Theory of Money. Chicago: University of Chicago Press, 3–21.

Ghosh, and Philips. (1998). Warning: Inflation may be Harmful to your Growth, IMF Staff Papers.

Gonzalez, A., and Dijk, D. (2005), Panel Smooth Transition Regression Models, SSE/EFI Working Paper Series in Economics and Finance, No. 604

Hansen, B. E. (1997). Inference in TAR Models, Studies in Nonlinear Dynamics and Econometrics 2, 1-16.

Hansen, B.E. (1999). Threshold Effects in Non-Dynamic Panels, Estimation: Testing, and Inference. *Journal of Econometrics*, 93(2), 345-368.

Hussain, F. and Rehman (2020), Estimation of Medium Term Inflation Target for Pakistan, *State Bank of Pakistan Working Paper Series*, No.104, February 2020.

Hussain, M. (2005). Inflation and growth: Estimation of Threshold Point for Pakistan, *Pakistan Business Review*, 7(3), 1-15.

Ibarra, R. and D. Trupkin (2016). Reexamining the Relationship Between Inflation and Growth: Do Institutions Matter in Developing Countries? *Economic Modelling*, 52, 332-351

Im, K. S, Pesaran, & Shin. (2003). Testing for Unit roots in Heterogeneous Panels. *Journal of Econometrics,* 115, 53-74.

Iqbal, and S. (2009). Investment, Inflation and Economic Growth Nexus. *The Pakistan Development Review*, 863-874.

Kennedy P. (1992). *A Guide to Econometrics*. Oxford, Blackwell.

Khan, and Ssnhadji, A.S. (2001). Threshold Effects in the Relationship Between Inflation and Growth, IMF Staff papers, 48(1),1-21.

Khan, A, and S. (2018). Inflation and the Economic Growth: Evidence from Five Asian Countries. *Pakistan Journal of Applied Economics*, 28 (2), 235-252, Winter 2018

Kremer, and Nautz. (2013). Inflation and Growth, New Evidence from a Dynamic Panel Threshold Analysis, *Empirical Economics*, 44(2), 861-878

Lee, and Y. (2005). Inflationary Threshold Effects in the Relationship Between Financial Development and Economic Growth: Evidence from Taiwan and Japan. *Asian Pacific Development Journal*, 8,123-135.

Levin, and Chu. (2002). Unit Root Tests in Panel Data, Asymptotic and Finite-sample Properties, *Journal of Econometrics*, 108, 1–24.

Mallik, and Chowdhury. (2001). Inflation and Economic Growth, Evidence from Four South Asian Countries. *Asia Pacific Development Journal*, 8, 123-134.

Mengistus, and Adams. (2007). Foreign Direct Investment, Governance and Economic Development in Developing Countries. *The Journal of Social, Political, and Economic Studies*.

Miguel Sidrauski. (1967). Inflation and Economic Growth. *Journal of Political Economy*. 75(6), 796-810.

Mohanty, D. et al. (2011). Inflation threshold in India: An empirical investigation, Reserve Bank of India, Working Paper Series, No. 18.

Moshiri, A. and Sepehri. (2004). Inflation- Growth Profiles Across Countries: Evidence from Developing and Developed Countries. *International Review of Applied Economics*, 18(2), 191-207

Mubarik, and R. (2005). Inflation and Growth: An Estimate of the Threshold Level of Inflation in Pakistan, *State Bank of Pakistan Working Paper Series*.

Ndoricimpa, A. (2017). Threshold Effects of Inflation on Economic Growth in Africa: Evidence from a Dynamic Panel Threshold Regression, *African Development Group, working Paper Series*, No 249–January 2017.

Omay, T., Khan, E. (2010). Re-examining the Threshold Effects in the Inflation-Growth Nexus with Cross Sectionally Dependent Nonlinear Panel: Evidence from Six Industrializes Economies. *Economic Modelling*, 27, 996-1005.

Pan, Y, and Jackson, R. T. (2008). Ethnic Difference in the Relationship Between Acute Inflammation and Serum ferritin in US Adult Males. *Epidemiology and Infection*, 136, 421-431.

Saeed, A. J. (2007). Inflation and Economic Growth in Kuwait 1985–2005: Evidence from Co-integration and Error Correction Model. *Journal of Applied Econometrics and International Development*, 7,143-155.

Sarel, M. (1996). Non-linear effects of inflation on economic growth, *IMF Working Paper* No. WP/95/96.

Seleteng, M., and et al. (2013). Non-linearities in Inflation-Growth Nexus in the SADC Region: Panel Smooth Transition Regression Approach. *Economic Modelling*, 30, 149-156

Singh, P. (2010). Searching Threshold Inflation for India. *Economics Bulletin*, 30(4), 3209-3220.

Solow, R. (1956). A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics*, 70, 65-94.

Stockman. (1981). Anticipated Inflation and the Capital Stock in a Cash-in-Advance Economy. *Journal of Monetary Economics*, 8, 387-393

Temple, J. (2000). Inflation and Growth, Stories Short and Tall. *Journal of Economic Surveys*, 14, 395-426

Thanh, S.D. (2015). Threshold Effects of Inflation on Growth in the ASEAN-5 Countries: A Panel Smooth Transition Regression Approach. *Journal of Economics, Finance and Administrative Science*, 20(38), 41-48.

Tobin, J. (1965). Money and Economic Growth, *Econometrica*, 33, 671-684.

Tong, H. (1990). *Non-Linear Time Series: A Dynamical System Approach*. Oxford University Press.

Wang, Q. (2015). Fixed-Effect Panel Threshold Model using Stata. *The Stata Journal*, 15(1), 121-134.

Appendix

Appendix 1: Descriptive Statistics on GDP Growth and Inflation (SAARC-6 Countries)

Variable	Obs	Mean	Std. Dev	Min	Max
$gypc_{it}$	228	3.684	2.818	-5.710	23.961
inf_{it}	228	7.555	4.042	-19.977	20.347
$lypci_{it-1}$	222	7.917	0.603	6.845	9.383
$liyr_{it}$	228	3.268	0.438	0.0	4.290
gp_{it}	228	1.750	0.814	-1.719	4.143
$lm2_{it}$	228	3.756	0.403	2.643	4.692
$ltot_{it}$	228	4.945	0.316	4.127	5.535
$lopn_{it}$	228	3.744	0.513	2.503	4.733
Dum_{it}	228	0.1579	0.365	0	1

Appendix 2: Correlation Matrix

Variable	$gypc_{it}$	inf_{it}	$lypci_{it-1}$	$liyr_{it}$	gp_{it}	$lm2_{it}$	$ltot_{it}$	$lopn_{it}$	Dum_{it}
$gypc_{it}$	1.000								
inf_{it}	-0.123	1.000							
$lypci_{it-1}$	0.214*	-0.107	1.000						
$liyr_{it}$	0.405*	-0.191*	0.405*	1.000					
gp_{it}	-0.138*	-0.089	-0.382*	-0.317*	1.000				
$lm2_{it}$	0.101	-0.286*	0.464*	-0.506*	-0.224*	1.000			
$ltot_{it}$	-0.347*	-0.007	-0.409*	-0.506*	0.258*	-0.174*	1.000		
$lopn_{it}$	0.285*	-0.009	0.527*	0.612*	-0.381*	0.193*	-0.486*	1.000	
Dum_{it}	-0.038	0.157*	0.074	0.066	-0.064	0.120	-0.044	0.108	1.000

Source: Authors computation; Note: * $p < .05$ level of significance.

Appendix 3: Results of VIF Multicollinearity Test

Variable	VIF	1/VIF
$lypci_{it-1}$	2.61	0.383039
$lopn_{it}$	2.44	0.409799
$liyr_{it}$	1.87	0.534641
$ltot_{it}$	1.65	0.605686
$lm2_{it}$	1.51	0.663928
gp_{it}	1.30	0.772104
inf_{it}	1.22	0.816538
Dum_{it}	1.07	0.937331
Mean VIF	**1.71**	

Source: Authors computation

Appendix 4: Model Specification Test

(a): Specification link test for single-equation models

Source	SS	df	MS	Number of obs = 222	
Model	323.630	2	161.815	Prob > F = 0.000	
Residual	1406.600	219	6.423	R-squared = 0.187	
				Adj R-squared = 0.179	
Total	1730.231	221	7.829	Root MSE = 2.5343	
$gypc_{it}$	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf. Interval]**
_hat	2.075	0.852	2.43	0.016	0.3953 3.754
_hatsq	-0.133	0.104	**-1.28**	**0.202**	-0.338 .0718
_cons	-1.968	1.636	-1.20	0.230	-5.192 1.256

Source: Authors computation. Note the link test is carried our run after OLS. The predicted variable **_hatsq** is not significant, which indicate that our model is correctly specified.

(b): Ramsey model specification error test (RESET) for omitted variables

Ramsey RESET test using powers of the fitted values of **$gypc_{it}$** Ho: model has no omitted variables	
F(3, 210) =	9.66
Prob > F =	**0.00**

Source: Authors computation. Note: the RESET test is carried out after OLS. The *p*-value is highly significant which indicates that we need not to reconsider the model, as there are no omitted variables in the model.

Appendix 5: Results of Panel-based Unit Root Tests

t-values	CADF	LLC	IPS	Fisher-type	CADF	LLC	IPS	Fisher-type
	With trend				Trend not included (with demean)			
$gypc_{it}$	-6.17*	-5.09*	-8.02*	79.79*	-5.34*	-5.89*	-7.72*	86.03*
$lpci_{it-1}$	1.17	0.32	2.00	2.33	-1.2***	1.34	0.26	18.63***
inf_{it}	-4.38*	-2.80	-6.06*	44.92*	-5.02*	- 5.60*	-9.78*	34.46*
gp_{it}	-0.45	-4.31	-4.55*	27.22*	-1.69**	-1.4***	-1.9**	52.51*
$lm2_{it}$	-0.54	-0.29	0.07	17.25	-1.80**	-1.06	0.79	4.33
$dlm2_{it}$	-6.38*	-6.86*	-7.56*	77.47*	-5.53*	-6.16*	-6.52*	97.57*
$liyr_{it}$	-0.66	1.34	-5.95*	6.76	-2.68*	1.27	-3.02*	27.74*
$dlopn_{it}$	-5.40*	-4.70*	-8.60*	94.07*	-6.48 *	-7.60*	-12.0*	73.90*
$lopn_{it}$	1.30	0.73	0.80	6.26	-0.61	-0.10	0.78	6.26
$ltot_{it}$	-3.09*	-1.7**	-0.78	18.2***	-2.16**	-1.63**	-0.44	23.42**

Source: Authors' computation. Note: * p < .01 , ** p < .05 and *** p < .10 levels, respectively.
Note: CADF is test of unit root with cross sectional dependence.

Appendix 6: Regression Estimates, Double Threshold Model and Fixed Effect Model

Variables	Double Threshold Model (fixed effect regression)		FE Model (without threshold)	
	With Robust SE	Without Robust SE	With Robust SE	Without Robust SE
$lpci_{it-1}$	0.54	0.54	0.36	0.81
	(0.72)	(0.70)	(0.98)	(1.01)
$lopn_{it}$	1.31	1.31	-0.04	1.68
	(2.12)***	(1.31)***	(-0.06)	(2.18)**
li_{it}	-0.201	0.039	2.07	0.05
	(-2.14)**	(0.03)	(1.69)***	(0.05)
$ltot_{it}$	-1.56	-1.56	-1.68	-1.82
	(-2.55)**	(-1.56)**	(-3.90)*	(-2.48)*
pg_{it}	0 .026	0.026	0.047	0.18
	(0.39)	(0.10)	(0.21)	(0.67)
$lm2_{it}$	-0.66	-0.66	-0.78	-1.27
	(-0.55)	(-0.63)	(-0.85)	(-1.16)
Dum_{it}	-0.30	-0.30	-0.28	-0.37
	(-0.63)	(-0.67)	(-0.71)	(-0.80)
inf_{it}	-	-	0.028	0.012
			(0.87)	(0.22)
inf^2_{it}	-	-	-0.007	-0.007
			(-3.43)*	(-2.25)**
Constant	4.57	4.57	5.75	4.78
	(1.11)	(0.71)	(1.24)	(0.72)
Observations	222	222	222	222
F(10,206)	-	4.62*	-	2.61*
Corr(u_i, Xb)	-0.08	-0.08	0	0

Regime Dependent Regressors (Double Threshold Model)				
Inflation (inf_{it})	Estimated Coefficient			
$\hat{\beta}_2$	1.04	1.04	-	-
	(1.13)	(4.37)*		
$\hat{\beta}_3$	-0.04	-0.04	-	-
	(-2.23)***	(-0.97)		

Source: Authors' computation. Note: * p < .01, ** p < .05 and *** p < .1 levels, respectively. SE denotes standard errors.

Appendix 7: Post Estimation Diagnostic Tests

	Results of Diagnostic Test	Remarks
1	Breusch-Pagan LM test of cross sectional independence, chi2(15) = 14.601, Pr = **0.4805**	Pr value of 0.4805 indicates no cross sectional dependence.
2	Pesaran's test of cross sectional independence = -0.001, Pr = **0.9993**	Pr value of 0.993 indicates no cross sectional dependence.
3	Bias-corrected Born and Breitung (2016) Q(p)-test, Post Estimation: Q(p)-stat = 0.10, p-value = **0.953**	Pr value of 0.953 indicates the presence of no serial correlation.
4	Modified Wald test for groupwise heteroscedasticity in fixed effect regression model, chi2(6)= 5.89, Prob>chi2= **0.0002**	Pr value of 0.0002 indicates the presence of no group wise heteroscedasticity.

Source: Authors' computation