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Nonlinear Impact of Inflation on Economic Growth in Nepal: A Smooth Transition Regression Approach

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Abstract

Macroeconomic stability is one of the most important macroeconomic goals for all countries. In recent years, the Nepalese economy has been experiencing inflation twice the economic growth rate, posing a threat to macroeconomic stability. Thus, careful investigation of the relationship between inflation and economic growth is required. This study assesses the existence of a nonlinear relationship between inflation and economic growth in the Nepalese context. The assessment is performed by considering the possibility of smoothly changing slope parameters to maximise economic growth or minimise growth losses and to determine the optimal inflation level along with the speed of inflation response to economic growth. The study applies a Logistic Smooth Transition Regression model that Terasvirta (1998, 2004) developed to estimate an optimal inflation rate using annual time-series data from 1976 to 2019. The study finds a nonlinear relationship between inflation and economic growth and estimates an optimal inflation threshold of 6.38±1.36 per cent for the Nepalese economy. It also shows that inflation positively correlates with economic growth up to the threshold level and that the association becomes negative beyond that level. This study suggests that inflation beyond the threshold level harms economic growth, while inflation below has a favourable effect. The findings assist policymakers in making an informed decision, providing leverage in inflation control and creating an atmosphere encouraging economic growth.

Keywords: Inflation, Growth, Nonlinearity, Inflation Threshold, Logistic Smooth Transition Regression, LSTR

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1. Introduction

Economic growth has been a central issue of all governments; therefore, several studies have focused on identifying the factors affecting economic growth. This issue is more important in developing countries that face additional challenges in maintaining macroeconomic stability. In other words, the challenge usually such countries face is attaining high and consistent production growth with low inflation. Keynesian concept of macroeconomic stability advocates maintaining external and internal balance with low inflation to achieve full employment and a stable economy. In particular, after the establishment of a new international monetary system that replaced gold standard and introduced the Bretton Woods system in 1970s (where U.S. dollar became the global currency), most economies experienced high inflation and low economic growth (Bhatta, 2015). The anomaly further strengthened the need to investigate the relationship between these two important variables, i.e., to test whether an inverse relationship exists between inflation and growth. Along with this, research on what levels should the inflation rate be constrained so that it does not start retarding the growth rate was also required.

In most efficient economic decisions, high inflation is detrimental to economic growth by disrupting the functioning of the market economy and thereby distorting resource allocation, due to which the signalling role of relative price changes is disrupted (Fischer, 1993). Thus, the existence and nature of the inflation-growth relationship has been debated (Khan and Senhadji, 2001). To identify the level of inflation that is growth-retarding, it is vital to introduce the concept of nonlinearity in the link between inflation and economic growth (Fischer, 1993; Barro, 1995; Sarel, 1996; Khan and Senhadji, 2001; and Espinoza, Prasad, and Leone, 2010). Nonlinearity implies a positive or no relationship between growth and inflation at lower inflation rates, while the relationship switches to a negative one at a higher rate. In such a nonlinear relationship, it is, therefore, possible to estimate the point of inflection where the relationship sign between the two variables switches (Khan and Senhadji, 2001).

The Nepalese economy is characterised by high inflation and low growth frequently in the study period. For example, between 1976 and 2019, average growth and inflation rates were 4.38 and 8.12 per cent, respectively. It has raised questions about the nonlinear relationship between these two variables. If such a relationship exists, another plausible task would be identifying an appropriate inflation level where the relationship's sign switches, followed by understanding the transition speed from low to high inflation regime. The latter helps to know the speed at which inflation reaches the optimal level beyond which it starts adversely affecting economic growth..

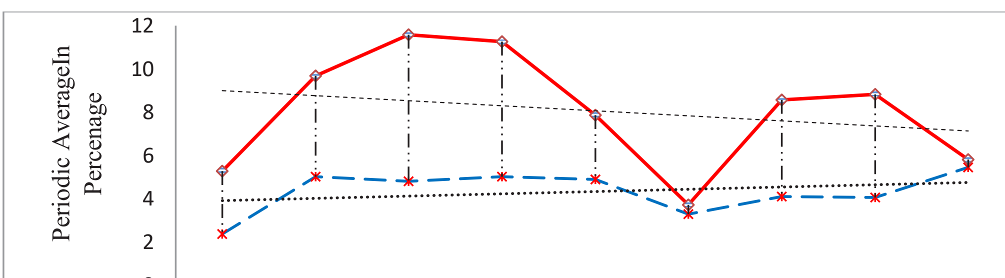
Therefore, this study assesses the existence of any nonlinear relationship between the two variables and then derives the optimal level of inflation where the relationship sign between them switches. The study also delves into calculating the speed of response of inflation to economic growth.

In recent times, nonlinear models are more popular in finance and economics research due to the nonlinear nature of data series. The growth-inflation data trend shows some incidences where very high inflation adversely affected growth. This question has recently become more dominant in the case of the Nepalese economy. Therefore, this study is important to understand the relationship between the two variables seriously. The study applies a Logistic Smooth Transition Regression (LSTR) model developed by Terasvirta (1998, 2004) to annual time series data to estimate an optimal inflation rate and the speed of transition from a low inflation regime to a high inflation.

The paper starts with a brief introduction to the study, followed by a description of the historical pattern of inflation and growth in Nepal; then reviews the relevant literature and discusses the data, variables, theories and empirics used in the study. And then, the paper interprets and discusses the results of the empirical analysis followed by some robustness tests; and concludes with some policy recommendations.

2. Historical Trends of Inflation and Growth in Nepal

Nepal's inflationary experience parallels the rest of South Asia, i.e. it is marked by moderate rate of inflation with periodic fluctuations. In figure 1, inflation is hovering at a one-digit rate except during the two consecutive periods of 1986-1990 and 1991-1995, when the average inflation marked the double-digit rate. Meanwhile, the economic growth rates are usually lower than the inflation rates and exhibit a different trend.



	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05	2006-10	2011-15	2016-19
RGDPg	2.37	5.01	4.8	5.02	4.89	3.29	4.09	4.05	5.45
Inflation	5.28	9.67	11.58	11.27	7.86	3.72	8.56	8.83	5.81

Figure 1: Trend of Inflation and Economic Growth in Nepal (Periodic Average: 1976-2019)

Source: Authors' formulation using NRB, CBS, and MoF data.

Figure 2 presents the trend in economic growth and inflation rate on an annual basis.

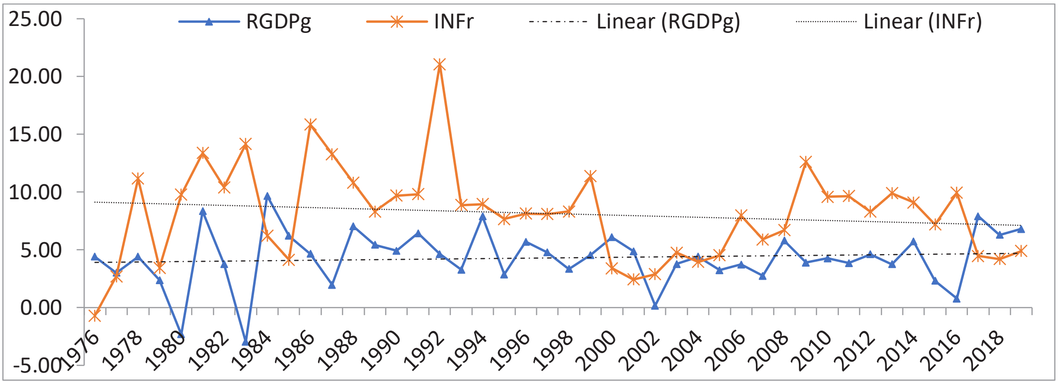


Figure 2: Trend of Inflation and Economic Growth in Nepal (Annual: 1976-2019)[1]

Source: Authors' formulation using NRB, CBS, and MoF data.

The average inflation rate was 8.12%, and the average growth rate was 4.38% from 1976 to 2019. As demonstrated, the inflation rate entered double-digit during the 1970s. This higher inflation is primarily attributed to the oil crisis that happened in the early 1970s and the monetary expansion policy adopted by NRB (Pandey, 2005). The inflation rate was negative at around 0.69% in 1976 due to price control measures taken by India and remained highest at about 21.05% in 1992. The negative inflation rate in 1976 was primarily due to the price control measures taken by India; the monetary tightening eased the pressure on the price, ultimately leading to negative growth.

On the other hand, the highest inflation rate in 1992 was primarily due to the steep price rise of the staple food imported from India and a shortfall in the production of food grains. The steep increase in food prices was induced by the devaluation of Nepalese rupees vis-à-vis the U.S. dollar and other convertible currencies by 20.9 per cent in 1991. In addition, the inflation rate remained high in the 1980s and the first half of the 1990s due to increased petroleum, electricity and fertiliser prices. It was only after the mid-1990s that the inflation rate began to climb down. Since 1999, there has been a significant improvement in the price situation.

1 For this section, inflation is calculated as the percentage change in the price level. In the rest of the study, it is calculated as difference of the natural logs. Both are equivalent in the limit; however the latter is taken as standard and makes for easy interpretation.

In the first half of 2000, the average inflation stood at 3.72% compared to the average of 7.86 % during the second half of the 1990s. Inflation mostly remained below 10% after that. The decline in inflation rates in the last two decades is attributed to the low import prices, tight monetary policy, better food harvest, price control measures in India, and political stability.

3. Literature Review

Several theoretical and empirical studies investigate the inflation-growth nexus. This part makes a theoretical review of the related literature followed by an empirical review of the subject matter.

Mercantilists identified the negative effects of the rise in the inflow of gold bullions in a country since this has the effect of causing inflation and reducing economic growth and international competitiveness by decreasing export surplus (Pentecost, 2000). Classicists held that inflation affects growth implicitly only through its effect on a firm's profit levels and saving (Gokal and Hanif, 2004). The neo-classicists were the first to discuss inflation in the growth theory explicitly and built models with various findings. According to neo-classicists, the money supply determines the permanent rise in inflation, which affects the output growth level. Similarly, Keynesians concluded that there is a short-run positive trade-off between output and change in inflation and no long-term trade-off between inflation and growth (Fabayo & Ajilore, 2004). However, new Keynesian noted that high inflation rates reduce economic growth. Monetarists asserted that prices are affected mainly by the growth rate of the money supply in the long run but have no real effect on economic growth (Ahortor, Adenekan, and Ohemeng 2012). According to new-classicists, during absolute rises in price, a rational firm does not change its production; if there is any unexpected increase in wage or price, it affects the supply of labour and goods, which will have an actual impact on the economy in the short run until economic agents correct their sensible anticipations (Tobin, 1965). In the endogenous model, the degree of effectiveness of inflation on output growth is determined due to the role of money and the quantitative effects of inflation on output growth.

Figure 3 exhibits the channel or transmission mechanism through which inflation may affect growth. The main channel affecting the growth is financial intermediaries, as the development of the financial market has links with a higher level of investment and efficiency (Li, 2006). Indeed, inflationary expectations in an economy can reduce the rate of return of capital, accumulation of human capital, and investment in research and development and inevitably undermine investor confidence in monetary policy direction (Yabu and Kessy, 2015). Hence, high inflation diminishes total factor productivity by making frequent variations in price that may be costly to firms, ultimately affecting the economy's growth. These effects may also cause price instability, putting proficient resource distribution at risk.

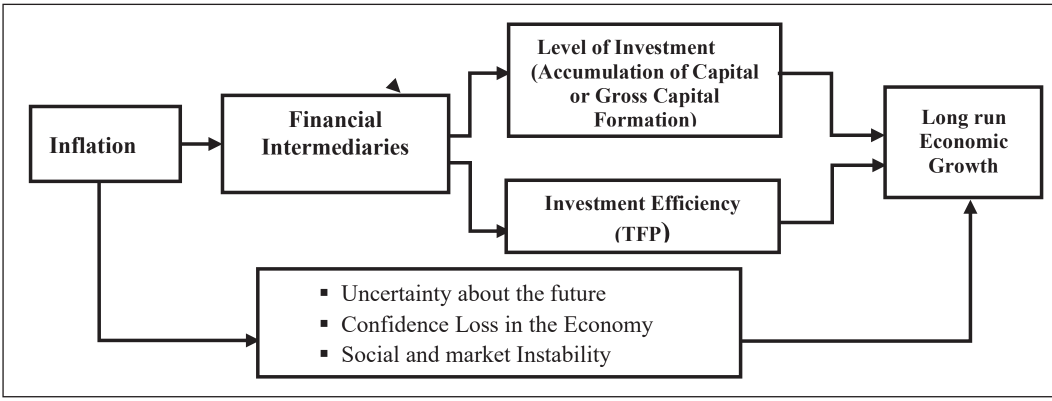


Figure 3: Transmission mechanism from inflation to economic growth

Source: Li. (2006).

Several theoretical models have discussed the nonlinear relationship between growth and inflation but have reached different conclusions. These theoretical models have debated whether inflation can either support, mislead or have no effect on economic growth. In addition, the models view inflation's effect on output growth as mainly mounting up through human and physical capital or the credit and product market.

Drukker, Gomis-Porqueras, and Hernandez-erme (2005) have concluded that there are four different predictions regarding the influence of inflation on output growth. First, the *Sidrauski Effect* postulates that inflation does not affect economic growth as money is super-neutral in the utility function (Sidrauski, 1967). Second, the *Tobin effect* postulates that money is a substitute for capital; hence inflation positively affects long-term growth (Tobin, 1965). Third, the *Stockman effect* holds that money is complementary to capital at cash in advance, causing inflation to harm growth (Stockman, 1981). Furthermore, fourth, the *Threshold effe*ct postulates that inflation's impact on growth depends on the threshold level, and inflation beyond the threshold level harms economic growth because its impact is due to financial market efficiency. The adverse effect arises from informational frictions that worsen financial market resistance (Huybens and Smith, 1998). Understanding these effects is essential to tease out the effects that explain the nature of the inflation-growth relationship in the Nepalese context and suggest the kind of policy instruments required to direct inflation towards economic growth while ensuring the least adverse effects on the economy.

Several empirical studies have concluded the existence of a negative inflation-growth relationship. Fischer (1993) was the first to inspect the possible existence of a nonlinear relationship between inflation and growth using data from 93 countries. Using arbitrary preferred breakpoints of 15 per cent and 40 per cent in spline regression, he showed a negative relationship between inflation and growth, concluding that the strength of the relationship weakened when inflation exceeded 40%. Barro (1995) confirmed the negative relationship between inflation and economic growth using the data set of 100 countries and concluded that an increase in average inflation by 10 per cent per year reduces the annual real per-capita GDP growth rate by 0.2% to 0.3% and reduce the ratio of investment to GDP by 0.4% to 0.6%. Likewise, Khan and Senhadji (2001), perhaps the most decisive in this line of studies, used the newly developed econometric technique proposed by Chan and Tsay (1998) and Hansen (1999) to examine an unbalanced panel dataset of 140 industrialised and developing countries from the period 1960-1998. They found that the threshold level for industrialised economies is lower at 1-3 per cent compared to the developing ones at 11-12 per cent; the threshold level for the whole sample was 11 per cent.

Espinoza Prasad and Leone (2010) estimated the threshold inflation of about 10 per cent using the LSTR model for the entire sample of 165 countries and concluded that any increase beyond that level would decrease the GDP growth rate except for the advanced countries. They also suggested the need for a prompt policy response to inflation at or above the optimal threshold for non-advanced countries. In line with Espinoza Prasad and Leone's (2010) study using the LSTR model, RBI (2014) found that the lower and upper bound threshold rates of inflation for the Indian economy are 5.8 and 6.7 per cent, respectively. Similarly, the alternative specification using threshold vector autoregressive (TVAR) approximation established the lower and upper bound threshold inflation rates of 4.6 and 6.2 per cent, respectively. Thus, India implemented flexible inflation targeting to fix the inflation rate at 4±2 per cent.

Harb (2016) re-investigated the growth-inflation nexus for 35 Middle East and North Africa (MENA) and Sub-Sahara Africa (SSA) countries employing the LSTR model and found the threshold inflation level of 8.4% and 11.35% for both MENA and SSA countries. This model robustly supported the existing evidence of a nonlinear relationship between inflation and economic growth and endogenously investigated the threshold level of inflation. Oduro-Afriyie (2018) tested the presence of threshold effects in Ghana's headline inflation using the threshold autoregressive (TAR) model and smooth transition autoregressive model using annual data from 1970 to 2015 to identify the inflation-growth nexus. Findings suggest threshold effects exist within Ghana's inflation, with the estimated threshold at 11%.

In the Nepalese context, using annual data from 1975 to 2011 and applying the conditional least square technique developed by Khan and Senhadji (2001), Bhattarai (2014) did not find any threshold effect of inflation for Nepal. This finding is, however, not consistent with the findings of other studies. Bhusal and Silpakar (2011), Bhatta (2015), and NRB (2017) showed that there is a threshold effect and estimated the threshold level of inflation of about 6 per cent.

The current study differs from these studies in the following context. First, the overall fitted model in the study by Bhusal and Silpakar (2011) is poor, as evident from the inclusion of inflation as a single independent variable, thus yielding low R^2. The study also did not further check whether the inflation threshold is significant. The current study conducts multivariate analysis, which is standard in the literature investigating the inflation-growth nexus and further tests the significance of the threshold rate of inflation. Likewise, Bhatta (2015) and NRB (2017) did not estimate the speed of transition from one regime (weak or positive effect of inflation on growth) to another (adverse influence of inflation on economic growth) to identify how quickly inflation penalises growth in Nepalese economy which is done in this study.

4. Data and Methodology

This study follows a quantitative, time-series, and econometric framework for testing hypotheses to identify, analyse, and describe the impact of inflation on economic growth. The study uses annual time series data from the period 1976 to 2019. Major macro-economic variables used in the time-series analysis are real gross domestic product growth rate (RGDPg), inflation rate (INFr), population growth rate (POPg), the growth rate of gross capital formation (GCFg), the growth rate of agricultural production (AGRg), the real effective exchange rate (REERi), and growth rate of the human capital index (HCIg). These variables are constructed based on the data from published reports and statistics of various national and international organisations, including the Ministry of Finance, Nepal Rastra Bank (Central Bank of Nepal), Central Bureau of Statistics, and Penn World Table 10 published by Fed St. Louis Bank of USA. Here, HCIg is built based on average years of schooling and returns to education using the Mincerian methodology. REERi is constructed by taking the trade-weighted composite and inflation-adjusted exchange rate index, which can be derived by taking trade shares of trade partner countries at constant price 2010 and multiplying such trade weights with respective inflation-adjusted exchange rates, i.e.

real exchange rate indices at a constant price, 2010 and summing them up. Other variables such as RGDPg, GCFg, and AGRg are constructed by taking the logarithmic difference of deflated value in 2010, while INFr is also calculated using the logarithmic difference between the current year and previous year's CPI index at the base year 2010. Likewise, POPg is the logarithmic difference between the current and previous year's total population.

The descriptive statistics of the variables in Table 1 below confirm that most of the variables selected in this study are normally distributed, as shown by the Jarque-Bera test.

Table 1: Descriptive Statistics of macroeconomic variables used in the analysis

Statistics \ Variable	RGDPg	INFr	REERi	POPg	HCIg	GCFg	AGRg
Mean	4.18	7.73	104.07	2.01	1.23	7.79	2.49
Median	4.31	7.99	101.19	2.25	1.37	9.13	2.98
Maximum	9.24	21.05	127.97	3.75	2.07	41.74	9.86
Minimum	-3.02	-0.69	85.34	1.02	0.36	-26.75	-12.11
Std. Dev.	2.37	3.73	10.89	0.60	0.60	12.45	3.74
Skewness	-0.81	0.41	0.56	0.07	-0.12	-0.15	-1.33
Kurtosis	4.67	3.73	2.35	2.75	1.61	3.95	6.92
Jarque-Bera	9.94	2.23	3.08	0.14	3.60	1.83	41.30
[P-value]	0.01	0.33	0.21	0.93	0.16	0.39	0.00
Sum	184.21	340.07	4579.41	88.84	54.17	342.91	109.78
Sum Sq. Dev.	242.44	599.34	5101.24	15.82	15.65	6667.73	603.11
Observations	44	44	44	44	44	44	44

Source: Authors' Computation using data collected from NRB, CBS, MoF, and Penn World Table 10 published by Fed St. Louis Bank of USA

4.1 Empirical Model: Smooth Transition Regression Model

This study has chosen the Smooth Transition Regression (STR) model as the preferential choice of the empirical framework because of its superiority over other competing nonlinear econometric models (Phiri, Khoza, and Thebe 2016). STR models are used when time series data under study exhibit different behaviours over time such that the series can be divided into various regimes, each with different behaviours. This model provides a method to test the existence of nonlinearities of the smooth transition type, which belongs to the range of nonlinear models for time series known as regime-switching (Terasvirta, 1994). Hence, the STR model conducts the transition between regression regimes smoothly, rendering the model theoretically appealing vis-a-vis other threshold models that impose an abrupt change in the regime coefficients (Phiri, Khoza, and Thebe, 2016). More so, a nonlinear model describes definite characteristics of the time series at hand much better than a linear model (De Gooijer and Kumar, 1992). The design of the STR model is to encompass other nonlinear econometric models like TAR and the Markov-switching (M.S.) models. This model contrasts with the simple threshold models, which assume a sharp switch.

The STR model with a logistic transition function developed by Terasvirta (2004) has the following form.

$$y_t = \varphi z_t + \theta z_t\, G(st; \gamma, c) + u_t \qquad (1)$$

$$= \{\varphi + \theta G(st; \gamma, c)\}\, z_t + u_t,\ \ t = 1 \ldots T \qquad (2)$$

Where, $z_t = (w'_t, x'_t)'$ where $w'_t = (1, y_{t-1} \ldots y_{t-p})'$, and $x'_t = (x_{1t} \ldots x_{kt})'$ represents set of explanatory variables. w'_t is a vector of lags of endogenous variable, y_t, i.e. growth of real GDP (RGDPg) and x'_t is a set of independent variables, i.e. INFr, AGRg, GCFg, POPg, REERi, and HCIg (See the definition above). These explanatory variables are chosen based on previous studies and data availability (e.g., Barro, 1991; Sala-i-Martin, 1997; Durlauf, Johnson and Temple, 2005). In addition, $\varphi = (\varphi_0, \varphi_1, \ldots, \varphi_m)'$ and $\theta = (\theta_0, \theta_1, \ldots, \theta_m)'$ are $((m + 1) \times 1)$ parameter of the linear and the nonlinear part respectively and $u_t \sim iid\ (0, \sigma^2)$. Transition function $G(\gamma, c, s_t)$ is the transition function of s_t (i.e. INFr), is assumed to cause the transition from one regime to another and continuous everywhere in the parameter space for any value of s_t, which is bounded between 0 to1. γ is the slope parameter, and c is the location parameter, i.e. threshold value, usually defined as a linear combination of the lag value of y_t. Further, Van Dijk, Terasvirta, and Frances (2002) also assume an exogenous variable, x_t, as the transition variable.

Equation 2 indicates that the model can be interpreted as a linear model with stochastic time-varying coefficients, i.e. $\varphi + \theta\, G(s_t; \gamma, c)$. There are many choices of transition function, with the first-order logistic function as the most popular, which is expressed as follows;

$$G(s_t; \gamma, c) = (1 + \exp[-\gamma \textstyle\prod_{k=1}^{K} (s_t - c_k)^{-1}]) \qquad (3)$$

Where $\gamma > 0$ is an identifying restriction which determines the smoothness of the transition and c is location parameters. Equations (1) and (3) jointly define the LSTR model. The common choices for k are k = 1 and k = 2. For k = 1, the parameters $\varphi + \theta\, G(\gamma, c, s_t)$ change monotonically as a function of s_t from φ to $\varphi + \theta$. Slope parameter γ controls the slope, and c is the location of the transition function. The transition function $G(\gamma, c, s_t)$ depends on the transition variable s_t, the slope parameter γ, and the vector of location parameters c. The transition variable s_t can be part of z_t or another variable, such as $s_t = t$ (trend). The LSTR model with k = 1 (LSTR1) can characterise asymmetric behaviour. When $\gamma = 0$, the transition function $G(\gamma, c, s_t) = 1/2$, and thus the STR model (1) nests the linear model while $\gamma \rightarrow \infty$, the LSTR1 model approaches the switching regression model with two regimes that have equal variances.

The modelling cycle has three stages: model specification (testing linearity, identifying transition function), estimation of the model, and evaluation (such as no remaining nonlinearity and parameter constancy). The various stages in the modeling cycle are discussed in Annex 1.

5. Results and Discussion

The result of the application of the STR model is presented in this section. Earlier, a unit toot test was conducted to confirm that the variables used in the model were stationary.[3] Later, different tests and estimations are conducted, as suggested in various stages identified in the modeling cycle in Annex 1. Finally, serial correlation-LM and ARCH tests are performed as a part of the diagnostic test for the existence of autocorrelation and heteroscedasticity.[2]

5.1 Unit Root Test for Non-Linear Dynamics

Time series data whose statistical properties change over time is called a non-stationary time series, which means that there is a unit root in the time series. Moreover, a unit root test tests a time series variable's non-stationary nature and if it possesses a unit root.[3] The traditional unit root tests lack power when the model under the alternative

2 Diagnostic tests are carried out to evaluate model residuals, and also serve as tests of model adequacy. Autocorrelation and serial correlation LM tests checks whether the error terms in the time series of one period is correlated with the error of another period. It intends to check whether there is a pattern or trend in error terms over time. Heteroscedasticity test ensures that the variance of error terms do not change over time. ARCH test, an Autoregressive Conditional Heteroscedasticity test, analyzes volatility in time series data in order to forecast future volatility.

3 If the variables in the regression model are not stationary, then it can be proved that the standard assumptions for asymptotic analysis will not be valid. Due to presence of unit root in the time series, the results obtained from estimation may be spurious and do not give real estimate of coefficient.

hypothesis is nonlinear, especially models with structural changes in levels and trends. In nonlinear time series, the outcome of the traditional unit root tests is most likely misleading and perceives the impact of shocks on the economy as permanent. Various unit root tests remain effective in the presence of a structural break (Hansen, 1999). Thus, this study applies a unit root test developed by Zivot and Andrews (1992) to test whether the study variables are stationary or not.

Table 2: Zivot Andrews (Z.A.) Unit Root Test for Nonlinear Series

Test Variables	Intercept	Intercept &Trend	Decision
RGDP growth	-9.319*	-9.256*	I(0)
Inflation rate	-6.808*	-5.954**	I(0)
Growth rate of Gross Capital Formation	-11.412*	-10.511*	I(0)
Agriculture Growth	-9.158*	-9.639*	I(0)
Population growth	-6.072*	-5.734*	I(0)
Real effective exchange rate	-6.072*	-6.614*	I(0)
Growth Rate of Human Capital	-11.127*	-10.472*	I(0)

Source: Authors' estimation

*Note: *, ** represent 1%, 5% significance level.*

Table 2 shows that all the study variables are integrated of order zero or are I (0) process at intercepts, and intercept and trend at 1 % and 5% significance levels. This means that the study variables are stationary and, therefore, free from unit root problems.

5.2 Logistic Smooth Transition Regression (LSTR) Model for Nonlinearity

The smooth transition regression model follows the same concept of discrete threshold regression (T.R.) models but differs in regime-switching, which occurs smoothly when an observed variable crosses the unobserved thresholds. STR model is defined by its transition function; STR with a logistic transition function is Logistic Smooth Transition regression. It is a useful model that can be used to model nonlinear datasets. Due to smooth response, STR models are more realistic dynamics than their discrete TR counterparts. The estimation deals with specialised views of the transition function and weights. As aforementioned, the STR model offers many tests, such as linearity against STR alternatives, no remaining nonlinearity, parameter constancy etc. It also tests conventional diagnostic tests such as heteroscedasticity and serial correlation.

5.2.1 Linearity Test and Model Selection

Table 3 confirms that inflation, which is also a variable of interest, is an appropriate transition variable for the model.

Table 3: Linearity Test for Inflation as Transition Variable and Model Selection

Tests	Null Hypothesis	F-statistic	p-value	Decision
Linearity Tests	$H_{04}: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	4.440	0.001	The H_{0i} test uses i^{th} order Taylor expansion ($\beta_j=0$ for all j>i). Alternative of no linearity is accepted.
	$H_{03}: \beta_1 = \beta_2 = \beta_3 = 0$	4.440	0.001	
	$H_{02}: \beta_1 = \beta_2 = 0$	5.929	0.000	
	$H_{01}: \beta_1 = 0$	8..743	0.000	
Terasvirta Sequential Tests	$H_3: \beta_3 = 0$	0.689	0.608	Recommended: first-order logistic; Pr Pr (H2) => Pr (H3)
	$H_2: \beta_2 = 0 \mid \beta_3 = 0$	1.516	0.219	
	$H_1: \beta_1 = 0 \mid \beta_2 = \beta_3 = 0$	8.743	0.000	
Escribano-Jorda Tests	$H_{0L}: \beta_2 = \beta_4 = 0$	1.295	0.108	Recommended: first-orders logistics. Pr (H0L) >= Pr (H0E) with Pr (H0E) >= .05.
	$H_{0E}: \beta_1 = \beta_3 = 0$	2.065	0.042	

Source: Authors' estimation

The linearity test of inflation is first checked using the test of L.M. statistics of the F version developed by Luukkonen, Saikkonen, and Terasvirta (1988) to determine whether the model follows a nonlinear framework or not. The decision rule is based on a sequence of nested hypotheses that test for the order of the polynomial in auxiliary regression as Taylor expansion.[4]

As shown in Table 3, the test rejected the null hypothesis of linearity. Likewise, the decision rule for selecting the STR model using Terasvirta sequential and Escribano-Jorda tests suggests using a first-order logistic smooth transition model.

5.2.2 LSTR Model Estimation

The LSTR model is suitable for the model as a nonlinear regression along with monotonically changing transition variables over time. The transition function between regimes accepts a different type of expected dynamic performance.

For model estimation, the SIC is dimension-consistent (Terasvirta, 1994). So, the SIC lag length criterion finds the maximum lag order of one for the RGDPg variable. The initial value for slope coefficient (γ) and location parameter (c) from grid search is estimated to be 10 and 6.12, respectively, for the Broyden-Fletcher-Goldfarb-Shanno (BFGS) iteration process and the estimation of the parameter from nonlinear least squares (NLLS). Table 4 shows the results of the nonlinear estimation of the LSTR model.

Table 4: LSTR Model Estimation (RGDP growth as the dependent variable)

Regime	Variable Name	Coefficient	Prob.
Linear part(r=1)	RGDP growth(-1)	0.135	0.0000
	Real effective exchange rate	0.129	0.0001
	Inflation rate	0.390	0.0977
	Population growth	1.205	0.0343
	Growth rate of Human capital	1.503	0.0422
	Growth rate of Gross Capital Formation	0.114	0.0000
	Agriculture Growth	0.239	0.0001

4 The p-value of the Terasvirta sequential test of H_{02} is less than H_{03}. Likewise, the p-value of Escribano and Jorda test of H_{0L} is much larger than the ones corresponding to testing H_{0E}. This heuristic decision rule is based on expressing the parameter vectors β_1, β_2 and β_3 from auxiliary regression parameterizing third order Taylor polynomial as functions of the parameters γ, c and θ and the first three partial derivatives of the transition function G_i^* at the point $\gamma = 0$. (For detail, follow annex).

Nonlinear part(r=2) [*1]	RGDP growth(-1)	-0.205	0.1060	
	Real effective exchange rate	-0.221	0.0001	
	Inflation Rate	-0.110	0.6706	
	Population growth	-0.506	0.1345	
	Growth Rate of Human Capital	-1.737	0.0335	
	Growth rate of Gross Capital Formation	-0.062	0.0001	
	Agriculture Growth	0.518	0.0000	
Estimated Parameter	SLOPE (γ)	1.389	0.0089	
	THRESHOLD (c)	6.381	0.0000	
Statistical Tools And Forecast	R-squared	0.816	RMSE	0.662
	Adjusted R^2	0.691	MAE	0.685
	F-stat	6.549	MAPE	22.59
	Prob (F-statistic)	0.000	Theil Inequality Coefficient	0.066
	SIC	4.447	Theil U2 Coefficient	0.144
	D-W stat	2.190	Symmetric MAPE	18.30

Source: Authors' estimation

The LSTR estimates in Table 4 show that the inflation threshold estimate is 6.38±1.36 per cent with a smoothing slope parameter (γ) of 1.39 (arctangent angle; 54.26^0). Thus, the transition variable's slope coefficient (γ) between the lower and upper regime is monotonically changing with moderate speed. The estimation of the inflation threshold and its slope coefficient is significant at the 1% level.

Table 5: Confidence Interval of Threshold Level and Slope Coefficient

Variable	Coefficient	90% CI		95% CI		99% CI	
		Low	High	Low	High	Low	High
Slope (γ)	1.39	0.55	2.22	0.38	2.39	0.02	2.75

Threshold (C)	6.38	5.25	7.50	5.02	7.73	4.54	8.21
		6.38±1.13		6.38±1.36		6.38±1.82	

Source: Authors' estimation

Table 5 shows the confidence interval of the threshold level of inflation and the slope coefficient. The threshold level of inflation at confidence levels of 90, 95, and 99 per cent are estimated to be 6.38±1.13, 6.38±1.36, and 6.38±1.82, respectively. Considering the important policy question of whether inflation is quickly penalising growth, the study further analyses the speed at which inflation becomes costly.

Figure 4 shows the transition function plotted against the inflation rate with the transition function weight graph of inflation as the threshold variable. The figure shows that the transition function increases monotonically from zero to unity. Inflation retards growth moderately with the slope of 1.39 (i.e.54.26^0 angles) moving from the lower to the upper regime. This fairly moderate transition speed implies inflation harms growth after exceeding the threshold.

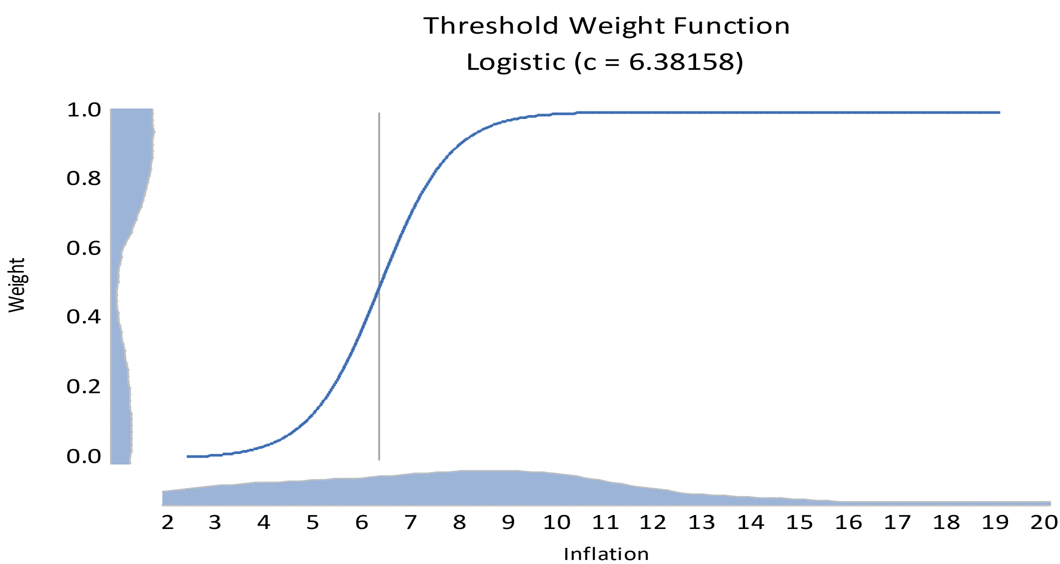


Figure 4: Graphical Presentation of Transition Function

Source: Authors' estimation

The finding of this study is quite important for inflation targeting by Central Bank to create an environment conducive to sustained and higher economic growth. The threshold rate of inflation of 6.38±1.36 found in this study is closer and consistent with the inflation threshold target employed by Nepal Rastra Bank (NRB), which is about 6 per cent NRB (2017). Thus, NRB's inflation target lies within a range estimated by this study.

The positive coefficient of inflation shows that inflation affects growth positively in the lower regime, while the negative coefficient of inflation shows that inflation has a detrimental effect on growth in the upper regime. In other words, in the lower regime, inflation supports the growth of RGDP. The inflation coefficient is statistically insignificant, particularly in the upper regime, which can be partly attributed to the lower number of observations because of the sample split between high and low regimes. This study, therefore, relies on the statistical significance of inflation threshold (c) and slope coefficients (γ), which are estimated based on the full sample size as observed transition variable (s_t), to argue for the validity of its major findings. In addition, the result of the inflation threshold is consistent with the finding by Bhatta (2015) and Bhusal and Silpakar (2010) in the case of Nepal and RBI (2014) in the case of India. This result is also in line with the theoretical predictions of Fischer (1993), Huybens and Smith (1998), Sarel (1995), and Khan and Senhadji (2001). The only study by Bhattarai (2011) shows Nepal has no such threshold level effect.

Regarding other control variables, there is a positive effect of the agricultural growth rate, the growth rate of gross capital formation, the real effective exchange rate, population growth, and human capital growth on the country's economic growth in the lower regime and as expected. However, these impacts vary with the regime change. For instance, in the upper regime, the result negatively affects most of the variables except agricultural growth due to the distortionary impact of inflation beyond a threshold level. For example, when compared to the linear regime, the coefficient estimate is negative for gross capital formation in the nonlinear regime because the inflationary expectations may reduce the rate of return of capital, accumulation of human capital, investment in research and development, and thereby undermine investor confidence regarding the direction of monetary policy (Yabu and Kessy, 2015). In addition, foreign direct investment may not be coming due to political instability and the absence of an investment-friendly environment. These internal and external factors can squeeze the effect of gross capital formation. Thus, this study's findings point to the severe consequences of high inflation on the economy's growth prospects.

The objective of monetary policy in Nepal is to attain higher growth with low inflation levels (price stability), thereby encouraging the adoption of frameworks for targeting inflation. The financial and goods market of developing countries are exposed to government intervention and supply shocks, leading to highly volatile inflation rates, consequently affecting consumption, investment, and production behaviours.

Furthermore, past experiences and empirical studies suggest that high inflation distorts the decision of the private sector on investment, saving and production, which ultimately leads to slower economic growth (Barro, 1995). Therefore, the strategy to control inflation is most important for inflation-targeting regimes making the central bank accountable for keeping inflation low which helps to counter the time-inconsistency problem (Mishkin, 1997). The determination of a suitable threshold level of inflation will provide policymakers feedback about the role of money supply and will authorise them to handle different policies, i.e. inflation targeting (Lopez-Villavicencio and Mignon, 2011).

6. Misspecification and Diagnostic Tests

The tests for no remaining nonlinearity indicate that the model either captures all the nonlinear effects in the inflation-growth relationship for transition variables as inflation in the model or not.

Table 6: Misspecification Test

	No remaining nonlinearity tests		Parameter constancy Test	
Null Hypothesis	F-statistic	p-value	F-statistic	p-value
H03: $\beta_1 = \beta_2 = \beta_3 = 0$	2.286	0.0871	NAN*	NAN*
H02: $\beta_1 = \beta_2 = 0$	2.321	0.0774	NAN*	NAN*
H01: $\beta_1 = 0$	0.856	0.5573	0.223	0.2353

Source: Authors' estimation

Note: NAN due to matrix inversion problem as stated by Yaya & Shittu (2016).*

Table 6 shows the LSTR model with two regimes as the most appropriate model with inflation as a transition variable. Likewise, the null hypothesis of the constant parameter test is also accepted. This means that the model is free from parameter inconstancy.

Furthermore, serial correlation and heteroscedasticity diagnostic tests are conducted using Serial Correlation-LM and ARCH tests, respectively.

Table 7: Diagnostic Test for LSTR Model

Test performed	Statistics	
Serial Correlation: LM Test:- H_0: No serial correlation up to 2 lags	Observed R^2	Prob. χ^2 (2)
	1.286	0.7052
Heteroskedasticity Test: ARCH:- H_0: Homokedasticity	Observed R^2	Prob. χ^2 (2)
	0.084	0.7717

Source: Authors' estimates

The test results in Table 7 show that the LSTR model passes all diagnostic tests. In other words, regression residuals are estimated to be free of any ARCH effects and autocorrelation

7. Conclusion

For the estimation of the optimal rate of inflation, this study applied the STR model as developed by Terasvirta (1998, 2004) to a yearly data from the period 1976 to 2019. The study revealed the existence of non-linear relationship between inflation and economic growth and the optimal inflation rate of 6.38±1.36 percent. The study also shows that inflation retards growth moderately with a slope coefficient of 1.39. The transition variable, i.e., inflation, moves at a moderate speed from a lower regime where it plays a supportive role to a higher regime where inflation hurts growth. The positive coefficient of inflation shows that inflation affects growth positively in the lower regime, while the negative coefficient of inflation shows that inflation has a detrimental effect on growth in the upper regime. In other words, in the lower regime below the threshold level, inflation supports the growth of RGDP. Therefore, the results indicate that inflation beyond the optimal level hurts economic growth and has a positive effect below the estimated optimal range.

This study shall guide policymakers in supporting inflation targeting policy to achieve macroeconomic stability. Therefore, the central bank needs to adopt such policies to keep inflation below the threshold which provides an environment for financial deepening and maximising the returns on investment. Besides, this study also contributes to empirical literature based on the endogenous growth model by finding the band of optimal inflation level within which the monetary authority should try to keep the inflation rate.

This study is not without limitations. First, the coefficient estimate in the study should not be taken as conclusive given the data limitations due to sample splitting for both regimes and should be further validated using sufficient observations adopting robust methods. Second, as Mejia-Reyes, Osborn, & Sensier (2004) also recognises, the STR model entails a complicated estimation process and therefore needs to rely on TAR for the diagnostic checks of the model estimate.

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Annex 1: Various Stages in Modeling Cycle

Stage 1: Specification of Model

Testing Linearity: The specification stage of the modelling cycle consists of linearity tests against the STR model. The STR model is not identified if the data generating process is homogeneous, and a homogeneity test is necessary to avoid the estimation of unidentified models. Thus, the STR model (equations 1 and 3) is jointly reduced to homogeneous equations by imposing H_0: $\gamma = 0$ or: β_1=0. Tests associated are nonstandard under the null hypothesis. STR model contains unspecified nuisance parameters. Location parameter c is not particularly identified if the test is under the null hypothesis. This also is the case for β_1 under H_0 and γ under Luukkonen, Saikkonen, and Terasvirta (1988) test homogeneity using null hypothesis H_0: $\gamma = 0$. It is to overcome this problem, replaced by the transition function F (s_t; γ, c) by its third-order Taylor expansion around $\gamma = 0$. The auxiliary regression after re-parameterisation is;

$$y_t=\beta_0' z_t+\beta_1' z_t s_t+......+\beta_j' z_t s_{tj}+u_t' \qquad ....(4)$$

$$y_t=\beta_0' z_t + \sum_{j=1}^{3}\beta_j' \hat{z}'_t s_t^{\,j} +u_t^*, \quad t = 1,2, ...,T \, ...(5)$$

Where the parameter vectors β_1' .... β_j' are multiples of γ. Testing H_0: γ =0 in (3.6) is equivalent to testing the null hypothesis H_0: $\beta_1'= \beta_2'=\beta_3'= 0$ (Each β_j' j = 1, 2, 3) in equation (4). This is a null hypothesis in a linear (in parameters) model and conveniently tested by an LM test of F statistic using to test the null hypothesis for a small sample size. Denoting the sum of squared residuals under H_1 as SSR_0 (two-regime STR model), the LM test of F statistic form is defined as;

$$LM_F = \frac{(SSR_0-SSR_1/jk)}{(SSR_0/(TN-N-a(k+1))} \qquad ....(6)$$

If, H_0: $\beta_1'= \beta_2'=\beta_3'= 0$ is rejected, the model can be proceeded for estimation by selecting the transition function.

Selection of Transition Function: Terasvirta (1994) proposed a sequence of tests for choosing the transition function between k=1 and k=2. Within the STR framework, using the auxiliary regression (6) with k=3, the null hypothesis, H_0: $\beta'_1=\beta'_2=\beta'_3= 0$, is rejected, then,

$$H_{04} : \beta_3'=0, \quad H_{03} : \beta_2'=0/\beta_3'=0, \qquad H_{02} : \beta_1'=0/\beta_2'=\beta_3'=0$$

These hypotheses are tested by the ordinary LM Test (F statistics) and denoted as F_4,

F_3, and F_2. The decision rule is that the k=1 (LSTR1) is chosen if the p-value of H_{02} is the lowest (i.e. strongly rejection of H_{02}). Conversely, the k=2 (LSTR2) is selected if the p-value of H_{03} is the lowest (i.e. strongly rejecting H_{03}).

Stage 2: Estimation of Model:

In the specified STR model, nonlinear least squares or with maximum likelihood estimation estimate the parameters (θ, φ, γ, and c) in equation (1) under the assumption of normally distributed errors. NLLS determine the values of these parameters that minimise the concentrated sum of squared errors. The practical issue is that the selection of starting values for γ and c such that $\gamma > 0$, $c_{k,\,min} > \min(s_t)$, $c_{k,max} < \max(s_t)$ where k = 1 ..., K. The optimal values are those which minimise the residual sum of squares (RSS) by iteration process. Nonlinear least square (NLS) is used to determine the parameters φ_i, θ_i, γ, c. The nonlinear function is as follows;

$$y_t = f(z_t; \varphi_i, \theta_i, \gamma, c) + u_t \quad \text{.................................} \quad (7)$$

And, for φ_i, θ_i, γ, c is the NLS estimator denoted by λ.

$$\hat{\lambda} = \text{argmin}\lambda \sum_{t=1}^{T} (y_t - F(z_t; \lambda))^2 = \text{argmin}\lambda \sum_{t=1}^{T} u_t^2 \text{ . ... } (8)$$

Stage 3: Evaluation by Misspecification Test

Test of No Remaining Nonlinearity: After fitting the STR, it should check whether there is remaining nonlinearity in the model or not. The test of no remaining nonlinearity is, in fact, twofold. It is a misspecification test and a tool for determining the number of transitions in the model (Terasvirta, 2004). The test assumes that the type of the remaining nonlinearity is again of the STR type. The alternative auxiliary is;

$$y_t = \varphi' z_t + \theta' G(\gamma_1, c_1, s_{1t}) + \psi' z_t H(\gamma_2, c_2, s_{2t}) + u_t \text{..................} (9)$$

Where H is another transition function and $u_t \sim \text{iid } N(0, \sigma^2)$. To test this alternative, the auxiliary model is:

$$y_t = \beta_0' z_t + \theta' z_t G(\gamma_1, c_1, s_{1t}) + \sum_{j=1}^{3} \beta_j' \hat{z}^t s_t^j + u_t \text{.....................} (10)$$

The null hypothesis of no remaining nonlinearity is H_0: $\beta_1 = \beta_2 = \beta_3 = 0$ (Each $\beta_{j,}$ j = 1, 2, 3). If the null hypothesis fails to reject, there is no remaining nonlinearity.

Test of Parameter Constancy: No constancy of parameters may indicate the misspecification of the model. The null hypothesis is tested for constant parameters against the alternative of smooth continuous change in parameters. The alternative is as follows:

$$y_t=\varphi(t)' z_t+ \theta(t)' z_t G(\gamma_1, c_1, s_{1t})+\psi' z_t H(\gamma_2, c_2, s_{2t})+u_t \quad ....(11)$$

Where $\varphi(t)= \varphi+\lambda_\varphi H(\gamma_\varphi,c_\varphi, t^*)$ and $\theta(t)= \theta+\lambda_\theta H(\gamma_\theta, c_\theta, t^*)$

With, $t'=t/T$ and $u_t \sim iidN(0, \sigma^2)$. The null hypothesis of no change in parameters is $\gamma\varphi = \gamma_\varnothing = 0$. The parameters γ and c are assumed to be constant. The following nonlinear auxiliary regression is as follows;

$$y_t=\beta_0' z_t+\sum_{j=1}^{3}\beta_0'\hat{z}'_t(t^*)^j+ \sum_{j=1}^{3}\beta_0'\hat{z}'_t(t^*)^j G(\gamma_1, c_1, s_t) + u^*_t \quad .... (12)$$

If the null hypothesis fails to reject, that is $\gamma_\varphi=\gamma_{\theta,}$ parameters are constant over time.

Other statistical tools and diagnostic tests: LM test for autocorrelation and ARCH test for heteroscedasticity is performed as other conventional diagnostic tests. Bayesian Schwartz information criteria (BIC) are also used for identifying A.R. order. The structural break unit root test is to perform the stationary of variables identified.

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