Inflation-Growth Nexus: Estimating the Threshold Level of Inflation for Bangladesh

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Submitted to

Graduate School of Public Policy (GraSPP)

The University of Tokyo

In partial fulfillment of the requirements for the degree

Master of Public Policy, International Program (MPP/IP)

June 2022

Tokyo, Japan

Abstract

It is widely believed that a reasonable level of inflation supplements return to savers, enhances investment, and, therefore, accelerates the country's development process and economic growth. This paper empirically explores the relationship between inflation and economic growth in the context of Bangladesh. Using annual data of inflation and GDP growth over a sample period from 1981 to 2021, this study shows a nonlinear relationship between these two variables and the existence of a threshold level within the range from 5.5 to 6.5 percent. This result implies that inflation above the threshold level harms economic growth, while inflation below that level affects development positively. This paper also shows that inflation in the food sector does not affect economic growth. In contrast, inflation in the non-food sector has a nonlinear relationship with growth and a threshold level within the range from 6.2 to 7.1 percent. These results have important policy implications for domestic policymakers and the development partners working for the country.

Keywords : Bangladesh, economic growth, inflation, threshold level.

Acknowledgements

First, I express my sincere gratitude to Professor Taisuke Nakata, who oversaw my thesis, for his unwavering support and direction during the research process. I would also like to thank Professor Kenichi Ueda for his constructive feedback in the class, which helped me immensely to improve my work quality.

I would also like to express my profound gratitude to my scholarship sponsors – the Government of Japan and the International Monetary Fund – for making this journey possible for me. I am also thankful to my organization, Bangladesh Bank, for permitting me to complete my study in Japan.

In addition, I would like to thank my colleagues at Bangladesh Bank, especially Kazi Shaibal Siddiqui and Saidul Islam, for supporting me in my studies in Japan. I am also thankful to my classmates, who always inspired me in my studies and research work.

I must thank my family, who support and encourage me in all aspects. Finally, I owe everything to Allah, Whose grace and mercy are limitless.

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1 Introduction

Accomplishing higher economic growth with a stable price level remains the key objective of macroeconomic policy in any country, including Bangladesh. It is widely believed that a reasonable level of inflation supplements return to savers, enhances investment, and, therefore, accelerates the country's development process and economic growth. On the other hand, a very high level of inflation may harm the country's development process. Although existing works of literature comprehensively examine the nature of the relationship between inflation and economic growth, the findings remain inconclusive. Many empirical studies documented a nonlinear relationship between the two variables, suggesting that development moves in tandem with inflation at a low level. However, the variables move in opposite directions beyond a certain level of inflation (a.k.a. threshold level). Similar to the cost of high inflation, meager inflation is also costly in terms of output loss. As the monetary policy in Bangladesh supplements the government's effort to attain higher economic growth with moderate inflation, the policymakers must clearly understand the inflation-growth nexus and know how much inflation harms economic growth.

This paper investigates the possible existence of threshold inflation in Bangladesh's inflation–growth relationship using annual data on inflation and growth in the gross domestic product (GDP) over a sample period from 1981 to 2021. This paper answers the following three questions by applying data visualization and three econometric models:

- What is the relationship between inflation and economic growth in Bangladesh?
- If a nonlinear relationship exists, what is the threshold level of inflation in Bangladesh?
- What are the policy implications of the threshold level of inflation for Bangladesh?

The results of the three models, namely the linear model, the quadratic model, and the threshold model, show a nonlinear relationship between inflation and economic growth. Although the quadratic and threshold models result in varying threshold levels, the results are not far from each other. We can conclude the existence of a threshold level within the range from 6.3 to 6.4 percent. Results using a sub-sample of the dataset also support the nonlinearity in the relationship and show the existence of a threshold level within the range from 5.6 to 6.2 percent. Such a structural break suggests a specific numerical target for monetary policy conduct by keeping inflation targets below the threshold. The results using sectoral data show a significant nonlinear relationship between non-food sector inflation and growth and suggest the existence of threshold inflation within a range from 6.2 to 7.1 percent using different methods. Domestic policymakers and the development partners working for Bangladesh can consider this target when formulating and suggesting policies for the country.

The study plan is as follows: after the introduction in section 1, section 2 provides a review of the relevant literature. Section 3 gives a brief overview of the historical inflation and growth with a graphical presentation and tries to observe the relationship between these two macroeconomic variables. While section 4 describes the data and their sources and specifies the models with the methodology for estimation, section 5 analyzes empirical estimates. In section 6, conclusions and policy implications are presented.

2 Literature Review

The strand of literature empirically examining the inflation-growth nexus cannot reach any agreement. McCandless and Weber (1995), analyzing data covering 30 years from 110 countries, conclude that there is no correlation between inflation and the growth rate of real output. In contrast to their findings, other empirical studies show a significant relationship between inflation and growth. Some studies (Barro, 1995; Fischer, 1993; Gregorio, 1993) show a linear relationship, either positive or negative, between the two variables; while others (Bruno & Easterly, 1998; Eggoh & Khan, 2014; Ghosh & Phillips, 1998) highlight the existence of a nonlinear relationship.

Bullard and Keating (1995) examine data from 58 countries and find some evidence of positive effects of inflation on output among low-inflation countries and zero or adverse effects for higher-inflation countries. Sarel (1996) attempts to study the inflation-growth link considering threshold inflation beyond which inflation hurts growth and concludes that threshold inflation of about 8 percent for a pooled sample of numerous countries. Dividing the countries into two groups, such as developed and developing, Khan and Senhadji (2001) highlight that the developing countries with a higher threshold level of inflation have more room to grow with the increase in inflation than their industrial counterparts. The threshold estimates for industrial and developing countries, respectively, are 1-3 percent and 7-11 percent.

Very few studies have been conducted on the relationship between inflation and economic growth in Bangladesh. Ahmed and Mortaza (2005), adopting a cointegration and error correction model, empirically recognize the inflation-growth nexus and estimate the threshold level of inflation to be 6 percent. Paul (2012) examines the inflation-growth nexus for Bangladesh in an EGARCH-M model and finds that growth and inflation adversely affect each other in a lagged manner in Bangladesh. Younus (2012) verifies that inflation and growth exhibit a nonlinear relationship with a threshold level of inflation within 7-8 percent.

However, because of the inconsistency in the findings of different studies in the context of Bangladesh, further investigation is warranted with recent data and methods. Further study in this field will enable us to explore the extent to which inflation affects economic growth and find important policy implications.

3 An Overview of Inflation and Growth

Bangladesh is considered a country with high growth potential in the South Asian region. This country achieved its independence in 1971 and experienced high fluctuations in inflation and growth in the first few years as a new economy. Therefore, data from the financial year (FY) 1981 to 2021 are used to avoid the initial high fluctuations.

Figure 1: Historical Data of Inflation and GDP Growth

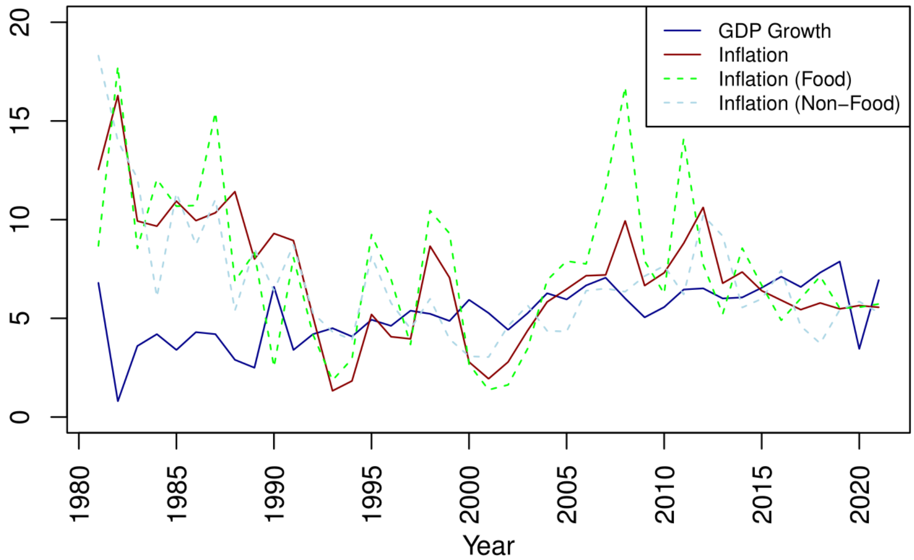


Figure 1 depicts Bangladesh's inflation and real GDP growth rates from 1981 to 2020. From 1981 to 1990, inflation was high in Bangladesh; then, from 1991, it oscillated within a range. On the other hand, growth rate data show less fluctuation than the inflation data and show a slight upward trend. In 2020, due to the COVID-19 outbreak, the country had to go through several extended lockdowns, border restrictions, and shrinkage of economic activities. As a result, the GDP growth dropped sharply from 7.88 percent in 2019 to 3.45 percent in 2020, but there was not much impact on the country's price level. However, prudent initiatives from the government and the central bank helped the economy recover quickly from the shock within one year by achieving a growth of 6.94 percent in 2021. Although it is unwise to conclude anything based on a visual inspection of Figure 1, it illustrates an inverse relationship between inflation and GDP growth rate for the years with high inflation and a positive relationship for the remaining years.

Figure 2: Relationship between Inflation and GDP Growth

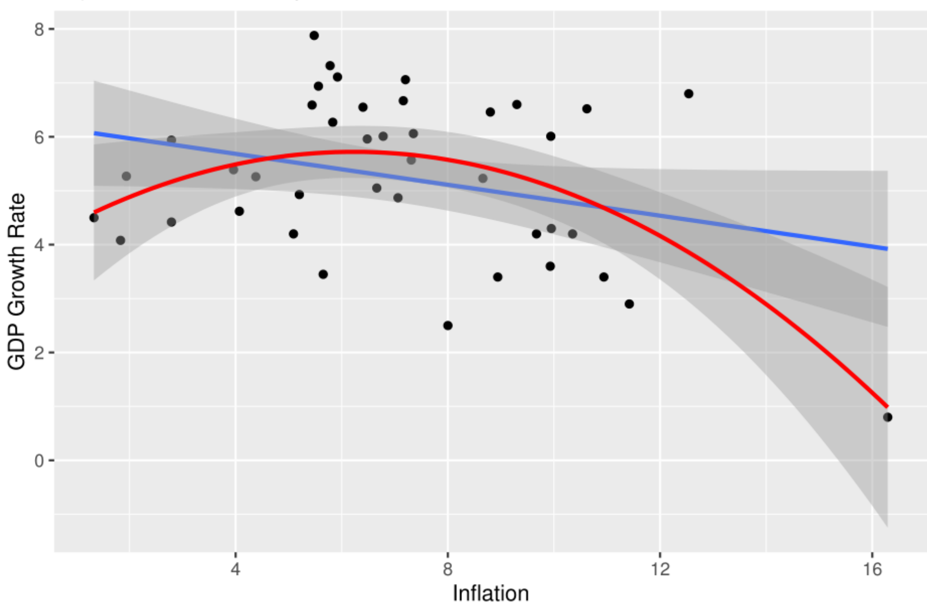


Figure 2 shows the relationship between inflation and growth with a scatter plot. Here, the fitted linear line represents a negative relationship between inflation and growth. On the other hand, the quadratic fitted curve shows a nonlinear relationship between the two variables. At low inflation levels, the growth increases with inflation, but after a certain level, the relationship changes. The critical point is that the relationship between GDP growth and inflation depends on a particular country's threshold level of inflation. From Figure 2, we can guess that Bangladesh's threshold level of inflation is approximately 6 percent. This level will be computed precisely in the latter part of this paper using both the quadratic and threshold models.

4 Methodology and Model Specification

To examine the relationship between inflation and GDP growth, three models are estimated using the Ordinary Least Square (OLS) estimation method, taking inflation as independent and GDP growth as dependent variables, and using annual data from 1981 to 2021. This study also checks the effect of two major sectoral inflation on development using inflation data for the food and non-food sectors.

Population growth, changes in investment as a percentage of GDP, changes in terms of trade, and one-year lagged GDP growth are used as control variables for all the models. The selection of the control variables is based on existing literature. Fischer (1993) includes investment in his model to show that inflation reduces growth by reducing investment and productivity growth. Moreover, Mankiw et al. (1992) also include investment and population growth in their growth model. This study uses changes in investment as a percentage of GDP instead of growth in the gross investment to make them comparable. The changes in the terms of trade (TOT) data were used as a control variable to eliminate the negative correlation between the growth and inflation caused by external supply shocks (Sarel, 1996).

Yearly consumer price index (CPI) inflation data and real GDP growth (annual percentage) data are used based on the latest base year for FY1981 to FY2021. Except for the terms of trade data[1], all data are collected from various issues of "Economic Trends," a Bangladesh Bank publication. The terms of trade data are collected from the World Development Indicators of the World Bank.

4.1 Linear Model

The simplified model is specified as follows:

$$\Delta y_t = \alpha + \beta_1 \pi_t + \gamma X_t + u_t \dots\dots\dots\dots\dots.(1)$$

where, Δy_t is the real GDP growth rate, π_t is the inflation rate, X_t is a vector of the control variables, and u_t is the error term.

4.2 Quadratic Model

A nonlinear model using the same data set has also been estimated that can be defined by the following quadratic equation:

[1] Terms of trade data are available up to 2020 at the source, and 2021 data is extrapolated by taking the average of the previous three years' data.

$$\Delta y_t = \alpha + \beta_1 \pi_t + \beta_2 \pi_t^2 + \gamma X_t + u_t \dots\dots\dots\dots\dots (2)$$

where, Δy_t is the real GDP growth rate, π_t is the inflation rate, X_t is a vector of the control variables, and u_t is the error term. It is expected that $\beta_1 > 0$ and $\beta_2 < 0$. The following two conditions must be satisfied to find the threshold level of inflation from the quadratic model shown in equation (2).

i. $\frac{d\Delta y_t}{d\pi_t} = 0$ and
ii. $\frac{d^2 \Delta y_t}{d\pi_t^2} < 0$

4.3 Threshold Model

By incorporating the extra inflation term introduced by Sarel (1996) in equation (1), the threshold model is specified as follows:

$$\Delta y_t = \alpha + \beta_1 \pi_t + \beta_2 D_t (\pi_t - \pi^*) + \gamma X_t + u_t \dots\dots\dots (3)$$

where, Δy_t is the real GDP growth rate, π_t is the inflation rate, D_t is a dummy for extra inflation, $\pi*$ the assumed threshold inflation, X_t is a vector of the control variables, and u_t is the error term. The dummy for extra inflation, D_t, takes the value 1, if $\pi_t > \pi^*$ and 0 otherwise.

By prior expectation, $\beta_1 > 0$ and $\beta_2 < 0$, because extra inflation harms GDP growth. By assumption, a small unit change from the threshold level causes harm to GDP growth. However, to determine the threshold level, the magnitude of β_2 must be so large that the sum of the coefficients of both inflation and extra inflation must be negative, i.e., $(\beta_1 + \beta_2) < 0$.

The study extracts the value of threshold inflation from the entire time series. In search of the threshold level of inflation, the OLS regression is applied iteratively with different assumed structural break values (π^*) ranging from 4 to 9. Estimating OLS regression taking different assumed threshold values (π^*) will generate a series of regression estimates.

Among the series of regression estimates, the threshold level of inflation π^* is the one at which a structural break is suspected with the highest R-squared or minimum residual sum of squares (RSS). In addition, the sum of the coefficients of both the level of inflation π_t and extra inflation $(\pi_t - \pi^*)$ is negative and statistically significant. A slight increase in inflation above the threshold level results in lower GDP growth. Inflation below the threshold level is bearable, and higher GDP growth is possible by allowing inflation up to this threshold level.

5 Empirical Results

Before estimating the models, some fundamental analysis of the data is done. The following table presents some summary statistics of the data for having an overall idea of the data set.

Table 1: Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
GDPGR	41	5.241	1.506	0.800	4.200	6.520	7.880
INF	41	7.092	3.124	1.330	5.440	9.300	16.290
INFF	41	7.554	3.931	1.380	5.220	9.250	17.760
INFNF	41	6.857	3.100	3.040	4.610	8.160	18.310
POPGR	41	1.617	0.738	0.080	1.270	1.940	4.450
INVCH	41	0.405	0.652	−0.900	0.060	0.720	2.720
TOTCH	41	−1.726	8.038	−29.540	−5.100	2.190	26.420

From Table 1, we can see the average growth in real output for Bangladesh was 5.24 percent and the average inflation was 7.09 in the sample period. Moreover, inflation data show more variations compared to the growth data. On average, the country experienced more inflation in the food sector and had more fluctuations in this sector in the sample period.

Table 2: Correlation Matrix

	GDPGR	GDPGR_L1	INF	INF_L1	POPGR	INVCH	TOTCH
GDPGR	1	0.326	-0.297	-0.394	-0.299	0.421	-0.175
GDPGR_L1	0.326	1	-0.048	-0.289	-0.362	0.224	0.248
INF	-0.297	-0.048	1	0.729	0.333	-0.025	0.109
INF_L1	-0.394	-0.289	0.729	1	0.307	-0.344	0.058
POPGR	-0.299	-0.362	0.333	0.307	1	0.047	0.089
INVCH	0.421	0.224	-0.025	-0.344	0.047	1	-0.174
TOTCH	-0.175	0.248	0.109	0.058	0.089	-0.174	1

Table 2 shows pairwise correlations between the variables used in the regression. Except for the correlation between inflation (INF) and one-year lagged inflation (INF_L1), which is about 0.73, none of the correlations are high enough to cause a multicollinearity problem in the regression. As inflation and lagged inflation are not used in the same regression, the high correlation between these two is not an issue.

Table 3: Pairwise Granger-causality Test

Null Hypothesis	**Lag**	**F statistic**	**p-value**
Inflation does not Granger-cause GDP growth	3	0.4502	0.718
GDP growth does not Granger-cause inflation	3	0.5309	0.663

Granger causality (Granger, 1969) is checked between inflation and GDP growth data where an optimal lag of 3 is decided using minimum Akaike Information Criteria (AIC) criteria. Table 3 shows the test results, and using the F-test, we cannot reject the null hypotheses for the variables in either direction. Therefore, we can conclude that there is no Granger causality between growth and inflation. More precisely, there is no linear causation between inflation and economic development. This causality results contradict the findings of Younus (2012) that the causality runs from inflation to growth.

5.1 Linear Model

Table 4 shows the estimation results of the linear model shown in equation (1) with current and lagged inflation data.

Table 4: Linear Model Regression Results

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
π_t	-0.143^{*}		-0.111	
	(0.074)		(0.076)	
π_{t-1}		-0.188^{**}		-0.088
		(0.071)		(0.076)
$GDPGR_{t-1}$			0.235	0.180
			(0.167)	(0.169)
$INVCH_t$			0.745^{*}	0.744^{*}
			(0.426)	(0.438)
$POPGR_t$			-0.305	-0.373
			(0.331)	(0.326)
$TOTCH_t$			-0.025	-0.025
			(0.028)	(0.029)
Intercept	6.258^{***}	6.542^{***}	4.942^{***}	5.191^{***}
	(0.570)	(0.553)	(1.198)	(1.309)
Observations	41	40	40	40
R^2	0.088	0.155	0.338	0.323
Adjusted R^2	0.065	0.133	0.241	0.224
Residual Std. Error	1.457	1.401	1.311	1.325
F Statistic	3.782^{*}	6.985^{**}	3.479^{**}	3.248^{**}

Note: *p<0.1; **p<0.05; ***p<0.01

The simple inflation-growth linear model shows a negative relationship between GDP growth and inflation, and this result is consistent with Figure 2. However, only for the model with lagged inflation and no controls, the coefficient for inflation is statistically significant at the 5 percent level. Furthermore, this model explains only 15.5 percent of the total variations in real output growth. The statistically significant result of column 2 can be attributed to omitted variable bias as the coefficient for inflation losses significance after adding control variables in column 4.

5.2 Quadratic Model

The quadratic econometric model shown in equation (2) is estimated by utilizing the OLS method, and the results are shown in Table 5.

Table 5: Quadratic Model Regression Results

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
π_t	0.583**		0.637***	
	(0.231)		(0.194)	
π_t^2	−0.047***		−0.050***	
	(0.014)		(0.012)	
π_{t-1}		0.430*		0.393
		(0.229)		(0.248)
π_{t-1}^2		−0.040***		−0.033*
		(0.014)		(0.016)
$GDPGR_{t-1}$			0.265*	0.051
			(0.138)	(0.173)
$INVCH_t$			0.695*	0.508
			(0.353)	(0.436)
$POPGR_t$			−0.159	−0.329
			(0.276)	(0.313)
$TOTCH_t$			−0.018	−0.032
			(0.023)	(0.028)
Intercept	3.905***	4.550***	2.238*	4.444***
	(0.881)	(0.871)	(1.193)	(1.306)
Threshold	6.23	5.39	6.39	5.91
Observations	41	40	40	40
R^2	0.289	0.304	0.560	0.398
Adjusted R^2	0.252	0.267	0.480	0.289
Residual Std. Error	1.303	1.288	1.085	1.269
F Statistic	7.725***	8.095***	7.001***	3.641***
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 5 shows that the quadratic model fits better than the linear model as the R-squared row shows higher values compared to the linear model results. In the first three columns, the coefficients for the linear and quadratic terms of inflation are jointly significant at a 5 percent level. However, the model results with lagged inflation in column 2 lose the significance after adding control variables in column 4. According to the estimates of the quadratic models, the one with the current period inflation and control variables is the best-fitted one and describes almost 56 percent of the variations in the output growth for the sample period. Using first-order and second-order conditions mentioned in the methodology, we can calculate the threshold level of inflation at 6.39 percent from quadratic model 3 estimates in Table 5.

Table A2, Figure A1, and Figure A2 in Appendix A show the different diagnostic test results for the quadratic model 3 in Table 5. The Breusch-Pagan test and the White test results show that we cannot reject the null hypothesis meaning residuals are distributed with equal variance, i.e., no heteroscedasticity in the residuals. The Jarque Bera test and the histogram of residuals confirm that the residuals are normally distributed. Finally, the autocorrelation function plot in Figure A2 shows that the error terms do not show any pattern for significant serial correlations. Therefore, the OLS estimates for quadratic model 3 in Table 5 are both statistically significant and unbiased.

5.3 Threshold Model

The threshold model is estimated by iterating different assumed structural break (π^*) values ranging from 4 to 9 with 0.05 increments. The results are summarized in Table 6. (Figure A3 of Appendix A shows the results graphically.)

Table 6: Threshold Model Results

Variable	Control variables	Threshold level	Adj. R-squared	$\boldsymbol{\beta_1}$ & $\boldsymbol{\beta_2}$ are jointly significant at a 5% level
Inflation	No	6	0.27	Yes
	Yes	6.3	0.45	Yes
Lagged Inflation	No	6.4	0.45	Yes
	Yes	6.35	0.45	Yes

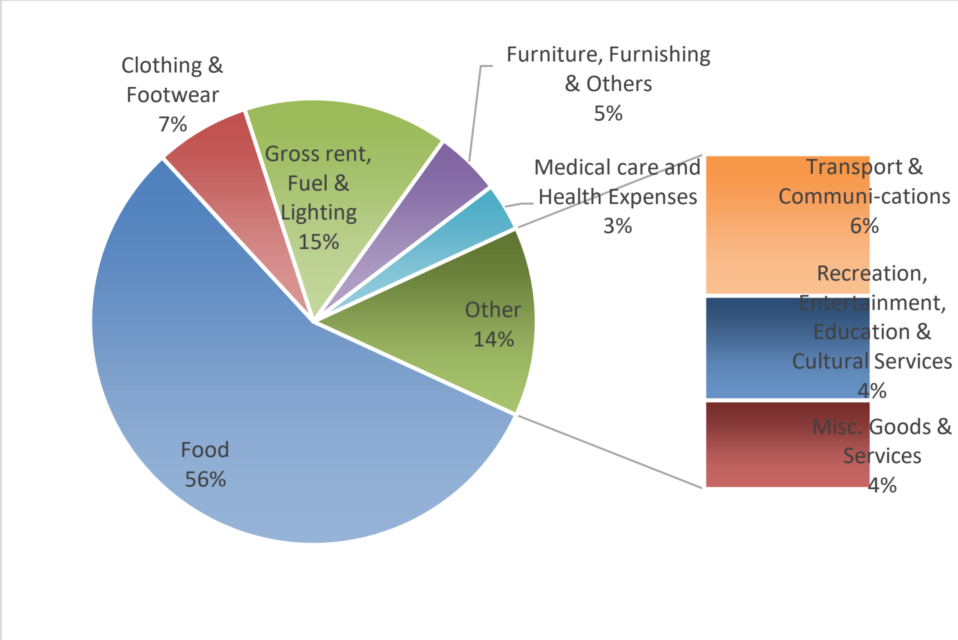
The iterations are done in four different scenarios, with current and lagged inflation data and both with and without control variables. The threshold levels based on each model are the assumed structural break points at which adjusted R^2 is maximum. The results from the models are statistically significant at a 5 percent level and very close to each other. The threshold model results imply that the relationship between inflation and growth is nonlinear, and a threshold point exists within 6 to 6.4 percent. These results are also very close to the results of the quadratic model.

The threshold model results for both inflation and lagged inflation with control variables are tested for heteroscedasticity, normality, and serial correlation in the residuals. Table A3, Figure A4, and Figure A5 in Appendix A show the different diagnostic test results. The Breusch-Pagan test and the White test results in Table A3 show that residuals are homoscedastic for the model with inflation and are heteroscedastic for the model with lagged inflation. Therefore, the estimates resulting from the threshold model using lagged inflation are biased. The Jarque Bera test and the histogram of residuals confirm that the residuals are normally distributed for both models. Autocorrelation function plots show that the error terms are not serially correlated. Therefore, the OLS estimates for the threshold model using current inflation and control variables are both statistically significant and unbiased, suggesting a threshold inflation level of 6.3 percent.

5.4 Results for Sectoral Data

All three models, namely linear, quadratic, and threshold, check the relationship between sectoral inflation and growth. The following figure shows the current composition of the consumer price index of Bangladesh and the major items included in the non-food sector.

Figure 3: Weights in Consumer Price Index



The linear model results using food and non-food data are shown in Table B1 and Table B2 in Appendix B. Food sector inflation does not show any significant relationship with growth. The coefficient for inflation is only significant for one year lagged non-food inflation data. The results show a negative relationship between lagged non-food inflation and GDP growth. With control variables, lagged non-food inflation explains approximately 38 percent of the variations in GDP growth.

Table 7: Quadratic Model Results for Food and Non-Food Sectors

Variable	**Control variables**	**Threshold level**	**Adj. R-squared**	**β_1 & β_2 are jointly significant at a 5% level**
Inflation (Food)	No	6.26	0.06	No
	Yes	6.19	0.25	No
Lagged Inflation (Food)	No	7.31	0.03	No
	Yes	9.02	0.19	No
Inflation (Non-Food)	No	12.93	0.06	No
	Yes	6.24	0.34	Yes
Lagged Inflation (Non-Food)	No	5.19	0.28	Yes
	Yes	6.79	0.39	Yes

Table 7 summarizes the quadratic model results using food and non-food inflation (detailed results are in Table B3 and B4 in Appendix B). Similar to the linear model results, the estimates are not significant for food inflation for the quadratic model. Although estimates are not significant for the current period of non-food inflation without controls, the results are statistically significant for the other three scenarios. With control variables, the quadratic models with the non-food inflation explain more variations than the linear models implying that non-food inflation and growth have a nonlinear relationship. The regression results show the presence of a threshold level at 6.24 percent using current inflation and at 6.79 percent using lagged inflation. These results are close to the results from regression using overall inflation data.

Table B5, Figure B1, and Figure B2 in Appendix B show the different diagnostic test results for the quadratic models with both current and lagged non-food inflation data. The Breusch-Pagan test and the White test results show that we cannot reject the null hypothesis meaning residuals are distributed with equal variance, i.e., no heteroscedasticity in the residuals. The Jarque Bera tests and the histograms of residuals confirm that the residuals are normally distributed. Finally, autocorrelation function plots in Figure B2 show no pattern in the autocorrelations of the error terms. Therefore, the OLS estimates for quadratic models with both current and lagged non-food inflation data are statistically significant and unbiased.

Table 8: Threshold Model Results for Food and Non-Food Sectors

Variable	Control variables	Threshold level	Adj. R-squared	$\boldsymbol{\beta_1}$ & $\boldsymbol{\beta_2}$ are jointly significant at a 5% level
Inflation (Food)	No	5.05	0.08	No
	Yes	5.3	0.25	No
Lagged Inflation (Food)	No	6	0.09	No
	Yes	5.6	0.24	No
Inflation (Non-food)	No	9	0.04	No
	Yes	6.5	0.34	Yes
Lagged Inflation (Non-food)	No	7.7	0.28	Yes
	Yes	7.05	0.43	Yes

Table 8 summarizes the results of the threshold model using food and non-food inflation data. Similar to the results of the quadratic model, food inflation does not show a significant relationship with growth. With control variables, non-food inflation significantly influences development using current and lagged data and the presence of thresholds at 6.5 percent and 7.05 percent, respectively.

The different diagnostic test results for threshold models are presented in Table B6, Figure B3, and Figure B4 in Appendix B. According to the Breusch-Pagan test and the White test results, there is no heteroscedasticity in the residuals. The Jarque Bera test and the histogram of residuals confirm that the residuals are normally distributed. Lastly, autocorrelation function plots in Figure B4 show no significant pattern in the serial correlation of error terms. Therefore, current and lagged data estimates are significant and unbiased.

5.5 Results for Sub-sample of Data

To test the validity of the results discussed above, this study re-runs regressions in a sub-sample of the dataset from 1991 to 2019. In this sub-sample, the period of very high inflation from FY1981 to FY1990 and the period after the COVID-19 outbreak from FY2020 are omitted. The results for the subsample using the three models are given below.

Table 9: Linear Model Results for Sub-Sample

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
π_t	0.141 (0.083)		0.025 (0.073)	
π_{t-1}		0.073 (0.083)		0.035 (0.065)
$GDPGR_{t-1}$			0.582*** (0.196)	0.584*** (0.174)
$INVCH_t$			0.935** (0.351)	0.959** (0.352)
$POPGR_t$			−0.872* (0.432)	−0.883** (0.419)
$TOTCH_t$			−0.048* (0.027)	−0.051* (0.027)
Intercept	4.865*** (0.527)	5.254*** (0.541)	2.939** (1.344)	2.866** (1.270)
Observations	29	29	29	29
R^2	0.096	0.028	0.619	0.621
Adjusted R^2	0.063	-0.008	0.536	0.539
Residual Std. Error	1.043	1.082	0.734	0.732
F Statistic	2.878	0.776	7.463***	7.548***
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 9 shows the linear model results using the sub-sample. In contrast with the total sample results, these results show a positive relationship between inflation and growth, although not statistically significant. The change in the relationship pattern may be due to omitting periods with high inflation that harm economic growth. These results again support the nonlinear relationship between inflation and output growth.

Table 10: Quadratic Model Results for Sub-Sample

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
π_t	0.674*		0.496**	
	(0.333)		(0.234)	
π_t^2	−0.046		−0.040**	
	(0.028)		(0.019)	
π_{t-1}		1.062***		0.530*
		(0.305)		(0.266)
π_{t-1}^2		−0.085***		−0.043*
		(0.026)		(0.022)
$GDPGR_{t-1}$			0.549***	0.512***
			(0.184)	(0.169)
$INVCH_t$			0.914**	0.665*
			(0.328)	(0.368)
$POPGR_t$			−0.922**	−0.787*
			(0.404)	(0.400)
$TOTCH_t$			−0.044*	−0.040
			(0.025)	(0.027)
$Intercept$	3.585***	2.879***	2.060	2.120
	(0.930)	(0.849)	(1.321)	(1.264)
Threshold	7.27	6.25	6.16	6.22
Observations	29	29	29	29
R^2	0.182	0.319	0.683	0.675
Adjusted R^2	0.119	0.266	0.596	0.587
Residual Std. Error	1.012	0.923	0.685	0.693
F Statistic	2.888*	6.078***	7.887***	7.624***
Note:			*p<0.1; **p<0.05; ***p<0.01	

The results for the quadratic model using the sub-sample are shown in Table 10. The better-fitted quadratic model results confirm the nonlinear relationship between the two macroeconomic variables. Like the total sample results for the sub-sample, only the model with current inflation is significant after adding control variables and shows a threshold level of 6.16 percent. The diagnostic test results in Table C3, Figure C2, and Figure C3 confirm the validity of the estimates by showing that residuals are homoscedastic, normally distributed, and have no serial correlation.

Table 11: Threshold Model Results for Sub-Sample

Variable	Control variables	Threshold level	Adj. R-squared	β_1 & β_2 are jointly significant at a 5% level
Inflation	No	5.8	0.19	Yes
	Yes	5.6	0.63	Yes
Lagged Inflation	No	6.25	0.35	Yes
	Yes	6.45	0.60	No

Table 11 presents the results of the threshold models using the sub-sample. In contrast to the results using total sample threshold level estimates using lagged inflation and control variables are not statistically significant. This result can be related to the diagnostic test results for the same model using the total sample, where heteroscedasticity in residuals was found. In addition, the threshold levels found using the same period inflation data are slightly lower than the total sample results. The diagnostic test results in Table C4, Figure C5, and Figure C6 confirm the validity of the estimates by showing that residuals are homoscedastic, normally distributed, and have no serial correlation.

6 Conclusion

The study paper examines the relationship between inflation and economic growth and determines a threshold level of inflation in the case of Bangladesh. In this paper, three models have been used to diagnose the inflation-growth relationship in Bangladesh empirically. Empirical results based on time series annual data containing the entire sample period

(FY1981-2021) show a statistically significant structural break in the relationship between growth and inflation. According to the quadratic model, the threshold level of inflation is at 6.39 percent, and based on the threshold model, the threshold level is at 6.3 percent. Using a sub-sample of the data from FY1991 to FY2019, the threshold levels estimated by quadratic and threshold models are 6.16 percent and 5.6 percent, respectively. Although different methods end up with varying threshold levels, it can be concluded that the threshold level is within the range from 5.5 to 6.5 percent. This study also shows that inflation in the food sector does not affect the country's economic growth, and this may be due to less sensitivity of consumption to changes in the price level in the food sector. On the other hand, non-food sector inflation shows a nonlinear relationship with real GDP growth and the existence of a structural break within the range from 6.24 to 7.05 percent.

Sarel (1996) suggests that a threshold level provides a specific numerical target for monetary policymakers to keep inflation targets below the structural breakpoint. The critical point is that the main precondition for sustained growth is macroeconomic stability with sufficient infrastructure. A vital window is the effect of inflation on investment which can affect economic growth. Low or moderate inflation indicates macroeconomic soundness and creates a pleasant atmosphere for investment. The result of this study might be helpful for policymakers in providing some clues in setting an optimal inflation target.

This study is not without its limitations. First, the relevant control variables in this study are selected based on existing literature and data availability, which may have led to a specification bias. The relevant control variables should have been chosen using an appropriate econometric technique. Second, this study does not consider the level of inflation that is too low for economic growth and the level of inflation that does not impact economic growth. Finally, this study does not explain how inflation affects the country's economic development. The limitation of this study calls for further research on the topic.

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Appendix A. Results Using Inflation Data

Table A1: Unit Root Test Results

Variables	Augmented Dickey-Fuller Test						Phillips–Perron Test					
	Without trend			With trend			Without trend			With trend		
	Statistic	p-value	Lag	Statistic	p-value	Lag	Statistic	p-value	Lag	Statistic	p-value	Lag
GDPGR	-1.5303	0.5185	10	-9.3303	0.0000	0	-5.7024	0.0000	10	-10.088	0.0000	10
INF	-3.8823	0.0022	10	-3.2980	0.0666	1	-2.5738	0.0985	10	-2.638	0.2627	10
INFF	-2.5238	0.1098	4	-2.4678	0.3443	4	-4.1759	0.0007	10	-4.414	0.0021	10
INFNF	-2.1137	0.2391	4	-1.9436	0.6318	4	-4.9304	0.0000	10	-4.730	0.0006	10
POPGR	-3.5855	0.0060	1	-5.5154	0.0000	0	-4.5464	0.0002	10	-5.607	0.0000	10
INVCH	-3.4544	0.0092	3	-3.2176	0.0809	3	-6.0289	0.0000	10	-6.085	0.0000	10
TOTCH	-7.9922	0.0000	0	-7.8919	0.0000	0	-8.4732	0.0000	10	-8.393	0.0000	10

Table A2: Diagnostic Test Results for Quadratic Model

Test name	**Statistic**	**p-value**	**Conclusion**
Breusch–Pagan Test	4.21	0.65	The error term has a constant variance (no heteroscedasticity)
White Test	8.60	0.74	
Jarque-Bera Test	0.77	0.68	Residuals are normally distributed

Figure A1: Histogram of Quadratic Model Residuals

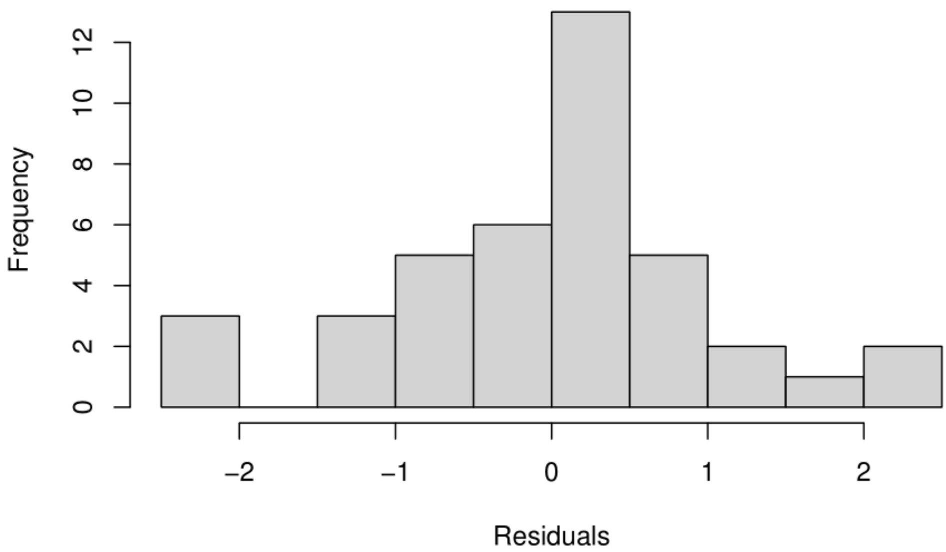


Figure A2: Auto-Correlation Function of Quadratic Model Residuals

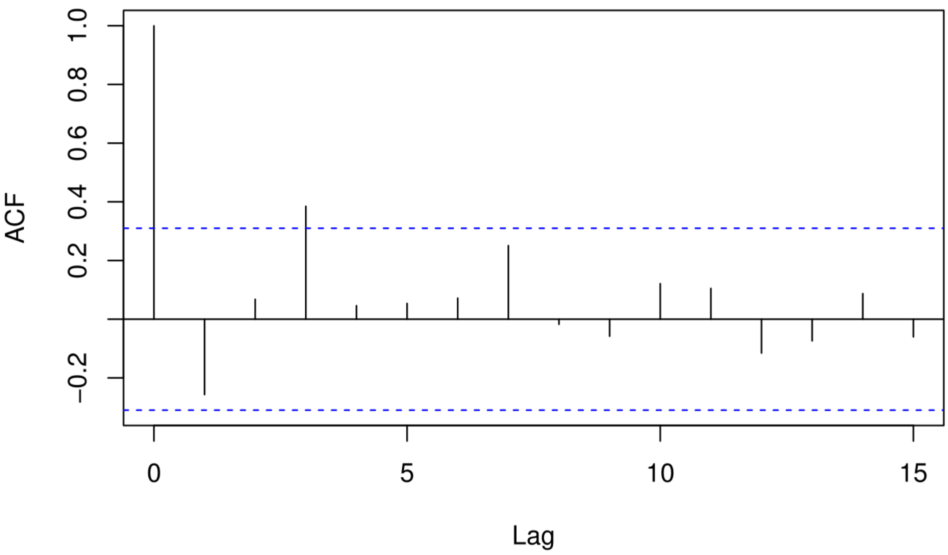


Figure A3: Threshold Model Estimates

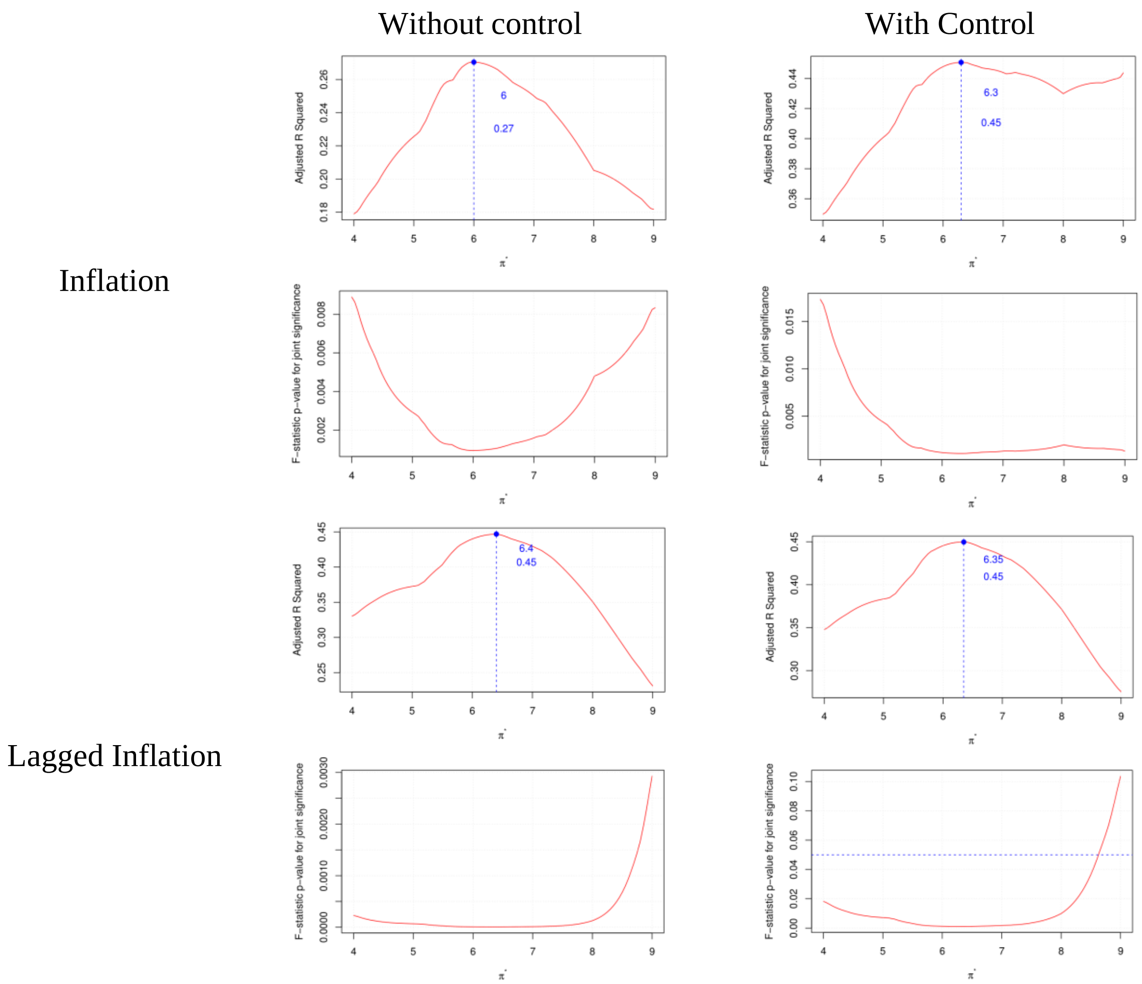
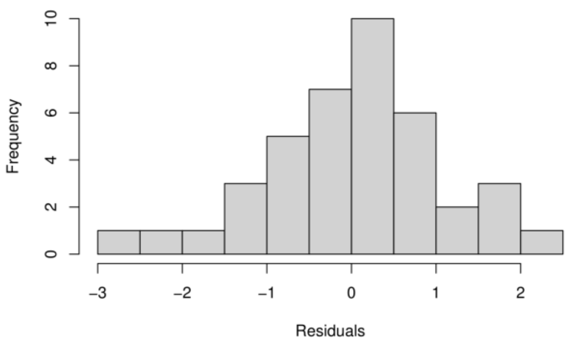


Table A3: Diagnostic Test Results for Threshold Model

	Test name	Statistic	p-value	Conclusion
Inflation	Breusch–Pagan Test	3.77	0.71	Residuals are distributed with equal variance (i.e., homoscedasticity)
	White Test	9.22	0.68	
	Jarque-Bera Test	0.16	0.92	Residuals are normally distributed
Lagged Inflation	Breusch–Pagan Test	16.53	0.01	Residuals are distributed with unequal variance (i.e., heteroscedasticity)
	White Test	26.4	0.01	
	Jarque-Bera Test	0.48	0.79	Residuals are normally distributed

Figure A4: Histogram of Threshold Model Residuals

Inflation



Lagged Inflation

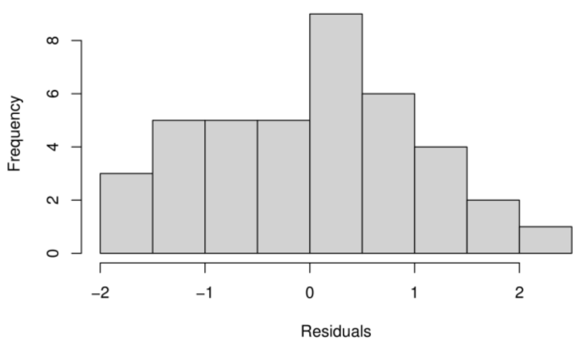
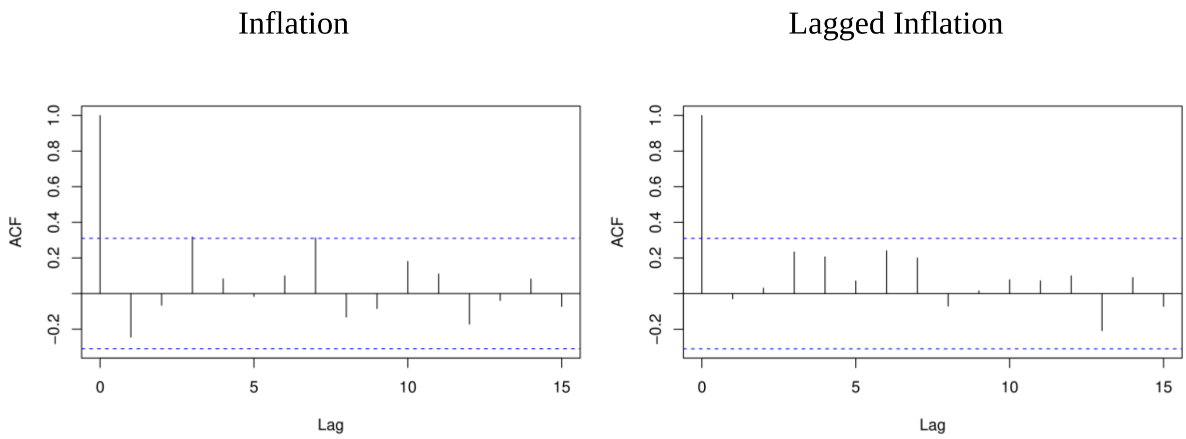


Figure A5: Auto-Correlation Function for Threshold Model Residuals



Appendix B. Results Using Sectoral Data

Table B1: Linear Model Results for Food Inflation

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
$\pi_{F,t}$	−0.089		−0.074	
	(0.060)		(0.058)	
$\pi_{F,t-1}$		−0.057		0.008
		(0.061)		(0.058)
$GDPGR_{t-1}$			0.271	0.209
			(0.174)	(0.173)
$INVCH_t$			0.763*	0.914**
			(0.429)	(0.435)
$POPGR_t$			−0.331	−0.468
			(0.332)	(0.322)
$TOTCH_t$			−0.031	−0.026
			(0.029)	(0.029)
Intercept	5.916***	5.633***	4.562***	4.440***
	(0.507)	(0.520)	(1.173)	(1.344)
Observations	41	40	40	40
R^2	0.054	0.022	0.329	0.297
Adjusted R^2	0.030	-0.003	0.230	0.194
Residual Std. Error	1.483	1.507	1.320	1.351
F Statistic	2.241	0.870	3.330**	2.872**
Note:				*p<0.1; **p<0.05; ***p<0.01

Table B2: Linear Model Results for Non-Food Inflation

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
$\pi_{NF,t}$	-0.130^{*}		-0.169^{*}	
	(0.075)		(0.091)	
$\pi_{NF,t-1}$		-0.234^{***}		-0.171^{**}
		(0.068)		(0.079)
$GDPGR_{t-1}$			0.186	0.218
			(0.163)	(0.160)
$INVCH_t$			0.659	0.584
			(0.425)	(0.425)
$POPGR_t$			-0.361	-0.110
			(0.311)	(0.344)
$TOTCH_t$			-0.018	-0.038
			(0.028)	(0.028)
Intercept	6.134^{***}	6.818^{***}	5.667^{***}	5.161^{***}
	(0.563)	(0.515)	(1.295)	(1.163)
Observations	41	40	40	40
R^2	0.072	0.237	0.362	0.382
Adjusted R^2	0.048	0.217	0.268	0.291
Residual Std. Error	1.470	1.331	1.287	1.267
F Statistic	3.017^{*}	11.834^{***}	3.862^{***}	4.198^{***}

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table B3: Quadratic Model Results for Food Inflation

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
$\pi_{F,t}$	0.212		0.187	
	(0.208)		(0.189)	
$\pi_{F,t}^2$	−0.017		−0.015	
	(0.011)		(0.010)	
$\pi_{F,t-1}$		0.262		0.193
		(0.211)		(0.199)
$\pi_{F,t-1}^2$		−0.018		−0.011
		(0.011)		(0.011)
$GDPGR_{t-1}$			0.321*	0.167
			(0.175)	(0.178)
$INVCH_t$			0.648	0.846*
			(0.430)	(0.441)
$POPGR_t$			−0.236	−0.511
			(0.333)	(0.325)
$TOTCH_t$			−0.038	−0.024
			(0.029)	(0.029)
Intercept	4.862***	4.522***	3.305**	4.136***
	(0.860)	(0.871)	(1.448)	(1.381)
Observations	41	40	40	40
R^2	0.108	0.084	0.368	0.316
Adjusted R^2	0.061	0.034	0.254	0.192
Residual Std. Error	1.460	1.478	1.300	1.352
F Statistic	2.290	1.690	3.209**	2.547**
Note:				*p<0.1; **p<0.05; ***p<0.01

Table B4: Quadratic Model Results for Non-Food Inflation

	Dependent variable:			
	GDP Growth			
	(1)	(2)	(3)	(4)
$\pi_{NF,t}$	−0.475		0.675*	
	(0.301)		(0.398)	
$\pi^2_{NF,t}$	0.018		−0.054**	
	(0.016)		(0.025)	
$\pi_{NF,t-1}$		0.289		0.438*
		(0.263)		(0.253)
$\pi^2_{NF,t-1}$		−0.028**		−0.032**
		(0.014)		(0.013)
$GDPGR_{t-1}$			0.187	0.283*
			(0.154)	(0.151)
$INVCH_t$			0.580	0.610
			(0.405)	(0.395)
$POPGR_t$			−0.364	−0.056
			(0.296)	(0.320)
$TOTCH_t$			−0.014	−0.034
			(0.027)	(0.026)
Intercept	7.462***	4.800***	2.829	2.374
	(1.254)	(1.099)	(1.793)	(1.546)
Observations	41	40	40	40
R^2	0.105	0.316	0.442	0.482
Adjusted R^2	0.058	0.279	0.341	0.387
Residual Std. Error	1.462	1.278	1.222	1.178
F Statistic	2.224	8.533***	4.359***	5.108***

Note: *p<0.1; **p<0.05; ***p<0.01

Table B5: Diagnostic Test Results for Quadratic Model with Non-Food Inflation

	Test name	Statistic	p-value	Conclusion
Non-Food Inflation	Breusch–Pagan Test	5.13	0.53	Residuals are distributed with equal variance (i.e., homoscedasticity)
	White Test	12.9	0.38	
	Jarque-Bera Test	0.82	0.66	Residuals are normally distributed
Lagged Non-Food Inflation	Breusch–Pagan Test	4.23	0.65	Residuals are distributed with equal variance (i.e., homoscedasticity)
	White Test	13.6	0.33	
	Jarque-Bera Test	0.04	0.98	Residuals are normally distributed

Figure B1: Histogram of Quadratic Model Residuals with Non-Food Inflation

Non-Food Inflation

Non-Food Lagged Inflation

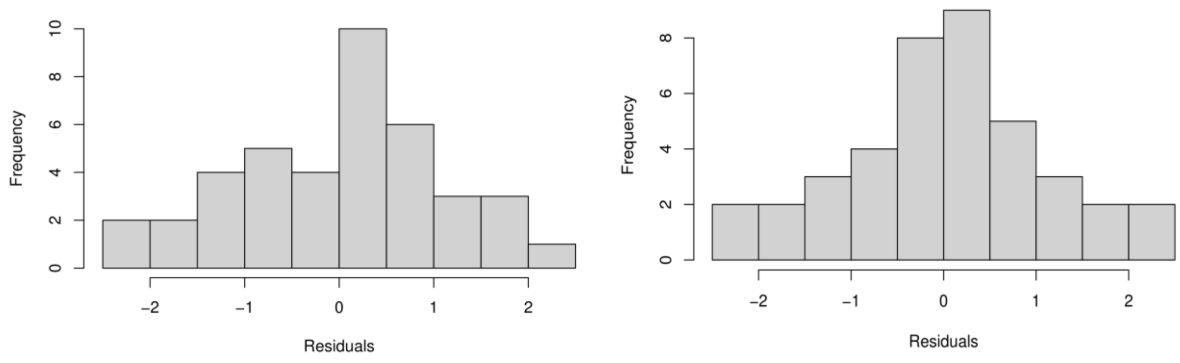


Figure B2: Auto-Correlation Function for Quadratic Model Residuals with Non-Food Inflation

Non-Food Inflation | Lagged Non-Food Inflation

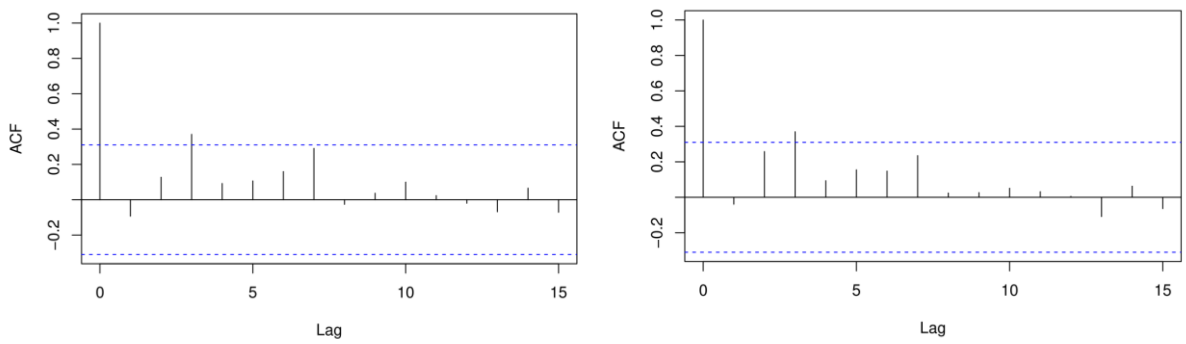
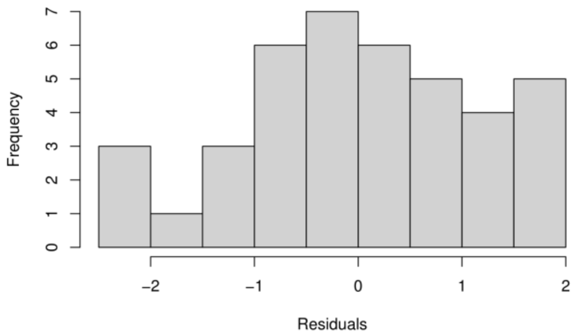


Table B6: Diagnostic Test Results for Threshold Model with Non-Food Inflation

	Test name	Statistic	p-value	Conclusion
Non-Food Inflation	Breusch–Pagan Test	4.74	0.58	Residuals are distributed with equal variance (i.e., homoscedasticity)
	White Test	11.4	0.50	
	Jarque-Bera Test	1.12	0.57	Residuals are normally distributed
Lagged Non-Food Inflation	Breusch–Pagan Test	4.03	0.67	Residuals are distributed with equal variance (i.e., homoscedasticity)
	White Test	14.7	0.26	
	Jarque-Bera Test	0.15	0.93	Residuals are normally distributed

Figure B3: Histogram of Threshold Model Residuals with Non-Food Inflation

Non-Food Inflation



Lagged Non-Food Inflation

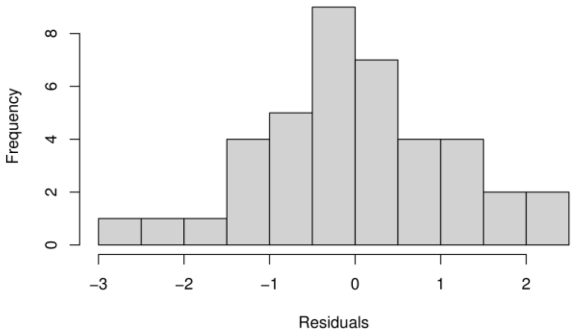
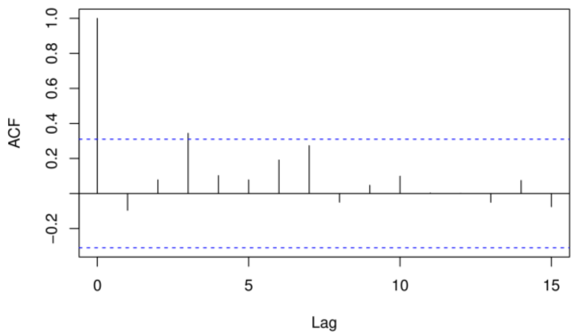
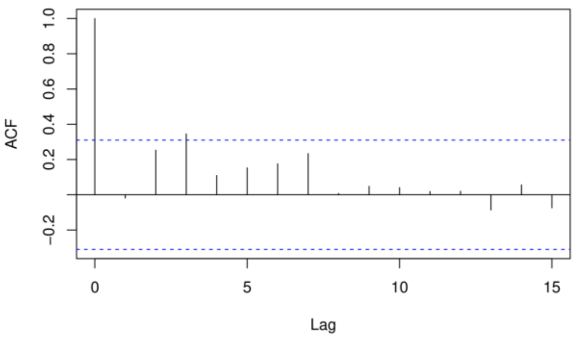


Figure B4: Auto-Correlation Function for Threshold Model Residuals with Non-Food Inflation

Non-Food Inflation



Lagged Non-Food Inflation



Appendix C. Results Using Sub-sample of Data

Figure C1: Relationship between inflation and GDP Growth

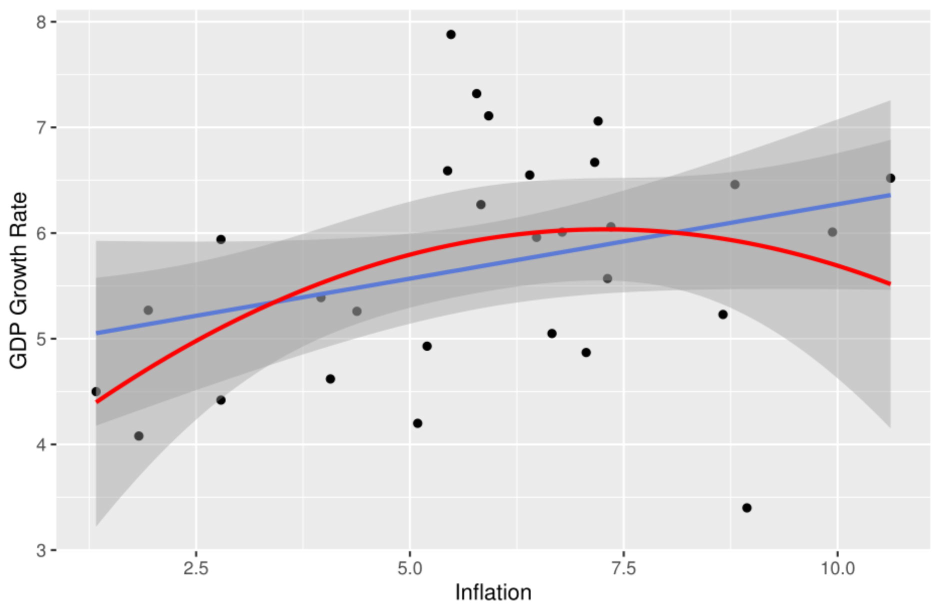


Table C1: Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
GDPGR	29	5.697	1.078	3.400	4.930	6.520	7.880
INF	29	5.903	2.375	1.330	4.380	7.200	10.620
INFF	29	6.788	3.580	1.380	4.180	8.080	16.720
INFNF	29	5.795	1.813	3.040	4.370	6.510	10.210
POPGR	29	1.463	0.401	0.080	1.290	1.800	2.120
INVCH	29	0.543	0.415	0.010	0.190	0.830	1.610
TOTCH	29	−1.780	5.359	−10.040	−5.100	1.070	9.470

Table C2: Correlation Matrix

	GDPGR	GDPGR_L1	INF	INF_L1	POPGR	INVCH	TOTCH
GDPGR	1	0.630	0.310	0.170	-0.440	0.250	-0.100
GDPGR_L1	0.630	1	0.510	0.380	-0.430	-0.060	0.250
INF	0.310	0.510	1	0.600	0.070	0.080	0.130
INF_L1	0.170	0.380	0.600	1	0.060	-0.060	0.300
POPGR	-0.440	-0.430	0.070	0.060	1	0.290	-0.040
INVCH	0.250	-0.060	0.080	-0.060	0.290	1	-0.050
TOTCH	-0.100	0.250	0.130	0.300	-0.040	-0.050	1

Table C3: Diagnostic Test Results for Quadratic Model for Sub-Sample

Test name	**Statistic**	**p-value**	**Conclusion**
Breusch–Pagan Test	10.2	0.12	The error term has a constant variance (no heteroscedasticity)
White Test	16.8	0.16	
Jarque-Bera Test	0.68	0.71	Residuals are normally distributed

Figure C2: Histogram of Quadratic Model Residuals for Sub-Sample

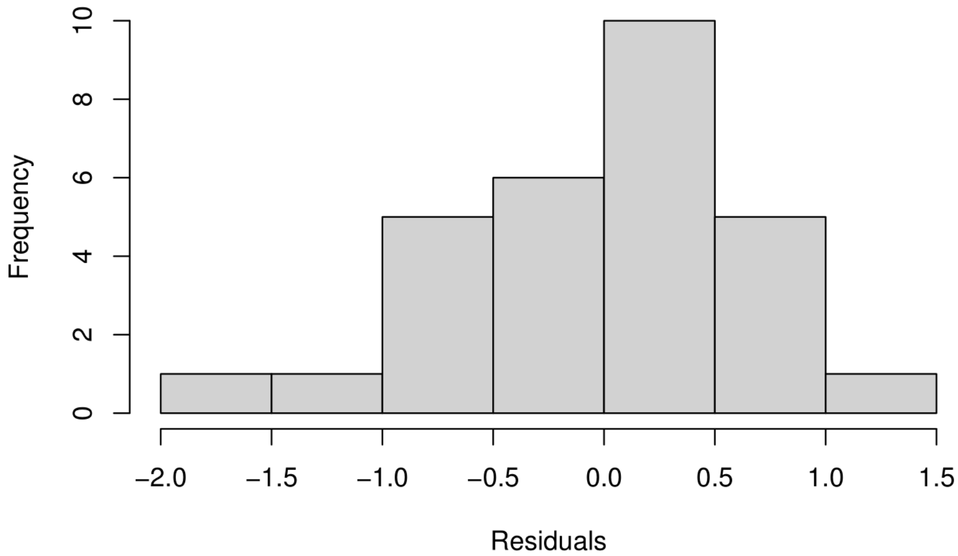


Figure C3: Auto-Correlation Function of Quadratic Model Residuals for Sub-Sample

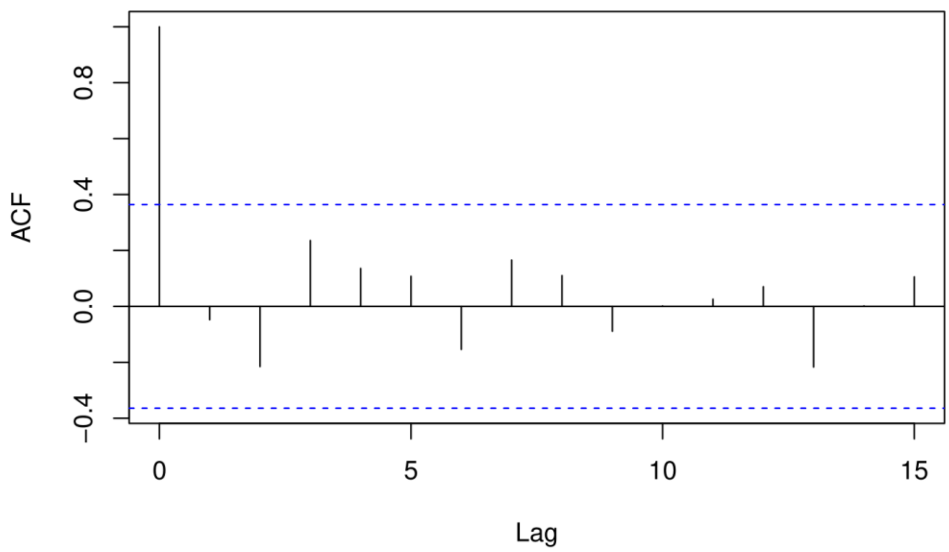


Figure C4: Threshold Model Results for Sub-sample

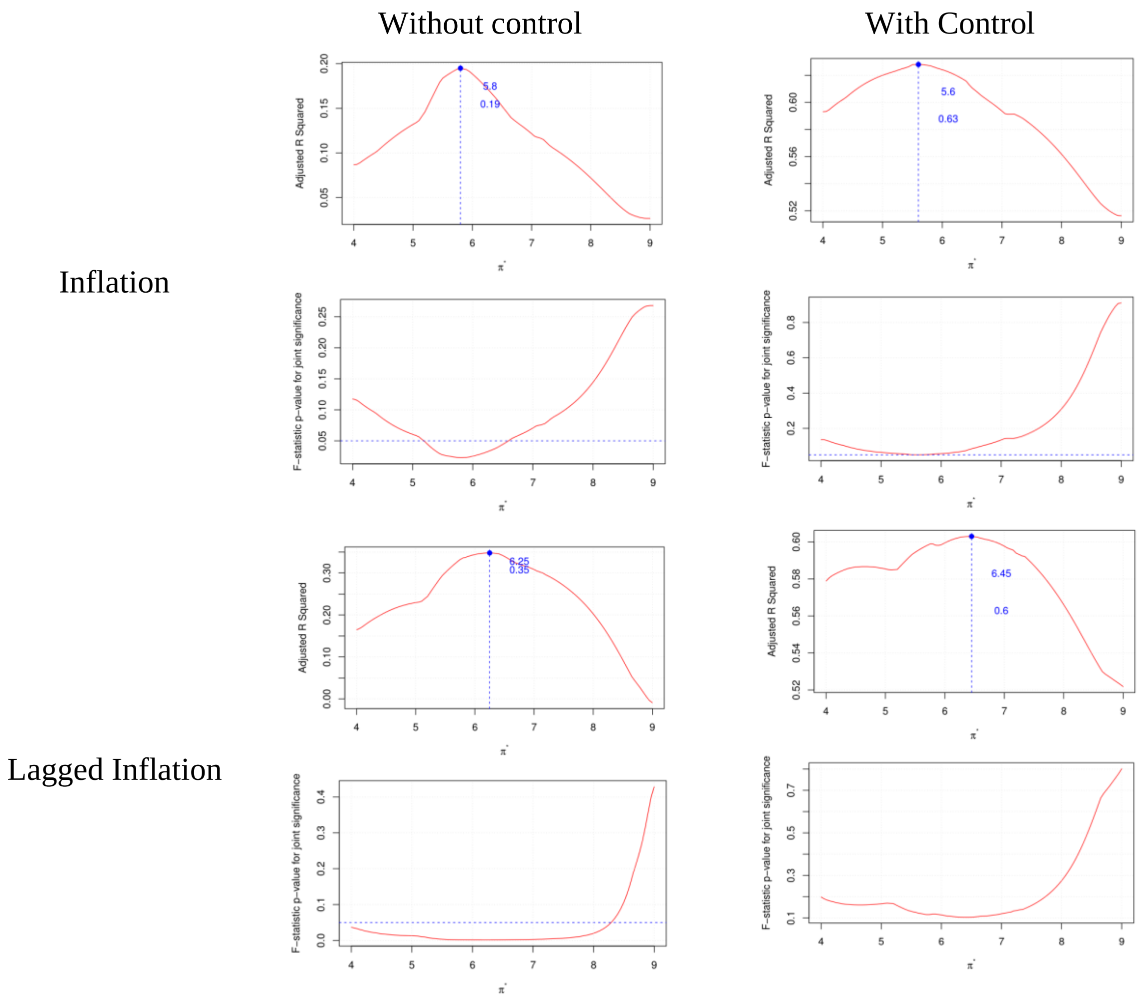


Table C4: Diagnostic Test Results for Threshold Model for Sub-Sample

Test name	**Statistic**	**p-value**	**Conclusion**
Breusch–Pagan Test	9.58	0.14	The error term has a constant variance (no heteroscedasticity)
White Test	17.4	0.13	
Jarque-Bera Test	0.53	0.76	Residuals are normally distributed

Figure C5: Histogram of Threshold Model Residuals for Sub-Sample

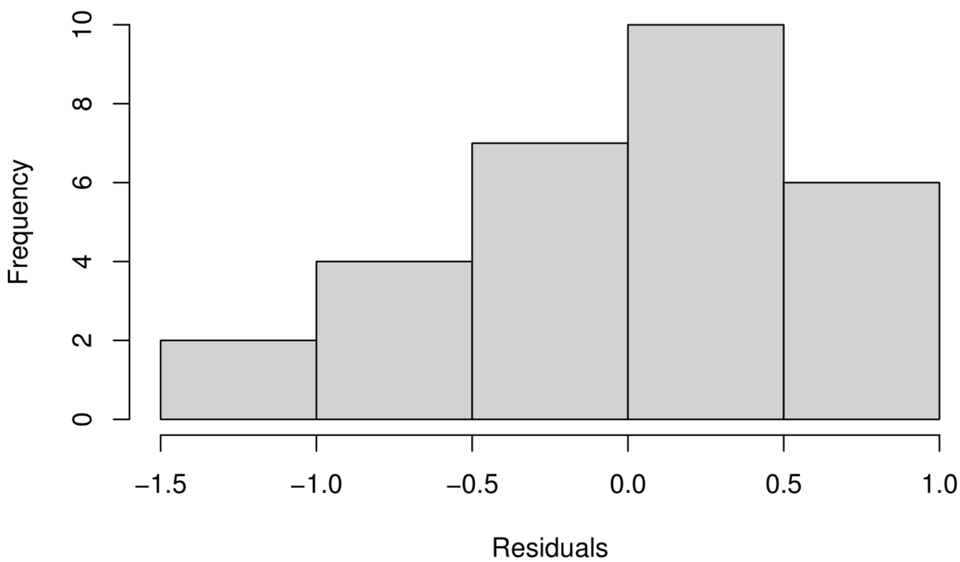


Figure C6: Auto-Correlation Function of Threshold Model Residuals for Sub-Sample