“Price Stickiness in Bangladesh Macro and Micro Approach”

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A thesis submitted to the Department of ‘Economics and Social Sciences’ in partial fulfillment of the requirements for the degree of ‘Master of Science in Applied Economics’

Department of Economics and Social Sciences

BRAC University

April 2026

Declaration

It is hereby declared that

1. The thesis submitted is my own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Abstract

This paper investigates the degree of price stickiness in Bangladesh using both macroeconomic and microeconomic approaches. While price rigidity has been extensively studied in developed economies, empirical evidence for developing countries remains limited, particularly in environments with relatively high inflation. This study addresses this gap by estimating price stickiness through a New Keynesian framework and disaggregated price data. The findings suggest that high inflation does not necessarily imply flexible pricing in developing economies. Instead, aggregate price rigidity may arise from the coexistence of highly sticky and relatively flexible prices within the consumption basket.

1 Introduction

Since money is not neutral, which means it is sticky in the short run, nominal change may affect the real economy. This is the main message of Keynesian Economics. Then, Why is price sticky? and How sticky is price? The former question has been controversial and there are several hypotheses: menu cost hypothesis, contract in advance, kinked demand curve hypothesis. To answer the latter question, there are two ways of measuring price stickiness, using micro data directly or estimating the New Keynesian Phillips Curve. We can see how many times price has been changed in the exact term, for example, Higo and Saita (2007), Baudry et al. (2004) and Baumgartner et al. (2005).

Aside from that, the macroeconomic empirics says that there exists a negative correlation between the inflation rate and unemployment rate which is called the Phillips Curve. Nowadays, macroeconomic theory reproduces it as the New Keynesian Phillips Curve (NKPC) based on the assumptions of Calvo type price setting under monopolistic competition. (Calvo, 1983) The assumption of Calvo price setting captures the extent of price change frequency and it affects the coefficient of NKPC. Therefore, we can measure the extent of price stickiness by estimating NKPC.

There are many studies on the topic above in developed countries but little research in developing countries. Macroeconomic stability of developing countries is more crucial than that of developed countries because the economy of developing countries might be vulnerable, and it may be one of key factors when foreign firms make investments. We estimate the extent of price stickiness using both macroeconomic and microeconomic approaches. In the macro framework, price stickiness is captured by the Calvo parameter, which reflects the average frequency of price adjustment. In contrast, the micro data allow us to directly observe the frequency of price changes across goods and regions. These two approaches are complementary in the sense that the micro evidence provides a structural interpretation of the macro parameter. In particular, heterogeneity in price adjustment at the micro level—where some goods exhibit ex-

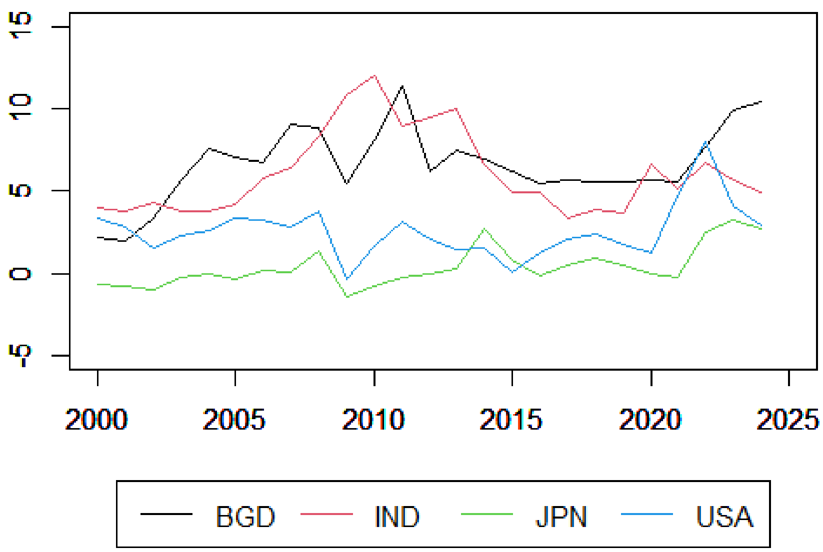


Figure 1: Inflation Rate in % from 2000

tremely infrequent price changes—can account for the high degree of aggregate price stickiness estimated in the macro model. By combining these approaches, this paper not only measures price stickiness but also sheds light on its underlying sources, which may help policymakers in Bangladesh better understand the transmission of monetary policy.

The inflation rate of Bangladesh, 6-7%, is higher than that of many developed countries. Figure 1 shows inflation rate of Bangladesh, India, Japan and United States[1].

However, this paper shows that, to some extent, price is sticky, whereas, in case of high inflation environment, price is believed to be less sticky. This paper also tries to explain why this happens and suggests rough hypothetical model. Our research question, in short, is "why price is sticky even under relatively high inflation rate in Bangladesh?".

The rest of this paper consists of Literature Review, Details of New Keynesian Model, Methodology and results of Macro Approach, Methodology and results of Micro Approach and 5. Concluding Remarks. The last section suggests a hypothetical model which tries to explain why prices in Bangladesh are sticky to some extent despite the

[1] World Bank.

relatively high inflation.

2 Literature Review

We overview research on theoretical and empirical aspects of price stickiness, as well as existing studies in the context of Bangladesh.

The fundamental question is whether prices are sticky. Bils and Klenow (2004) document the existence of price stickiness using micro price data from the Bureau of Labor Statistics in the United States from 1995 to 1997. Similarly, Nakamura and Steinsson (2008) derive several empirical facts on price setting behavior based on a benchmark menu cost model. One of their most relevant findings is that the frequency of price increases strongly covaries with inflation. However, this study focuses on price stickiness under relatively high inflation environments. Kehoe and Midrigan (2015) show that price stickiness persists at the aggregate level even when prices change frequently at the micro level. In addition, Hahn and Marenčák (2020) identify a systematic relationship between inflation and price adjustment behavior.

There is also a large body of theoretical research aimed at guiding optimal monetary policy. For example, Aoki (2001) develops a model with both flexible-price and sticky-price sectors and demonstrates that optimal monetary policy should place greater weight on inflation in the sticky-price sector rather than on aggregate inflation.

A substantial empirical literature estimates the New Keynesian Phillips Curve (NKPC). Gali and Gertler (1999) provide one of the pioneering econometric estimations using U.S. data. Subsequent studies extend this framework to other economies. For example, Huang and Kwan (2022) estimate a sticky information model developed by Mankiw and Reis (2002) and find that prices are stickier than information in Hong Kong. Fuchi and Watanabe (2002) estimate industry-level Phillips Curves using Japanese data and show that the degree of price stickiness varies significantly across industries, with the service sector exhibiting stronger rigidity than manufacturing.

In addition to econometric estimation, calibration-based approaches are also widely used. Smets and Wouters (2003) conduct Bayesian estimation of a medium-scale NK model incorporating price and wage rigidities for the euro area. While Bayesian estimation has become standard in NK-DSGE analysis, it is not without limitations. Minford et al. (2021) show that prior distributions can significantly influence posterior estimates of price stickiness and highlight the potential biases arising from prior selection.

A few recent studies have extended NK-DSGE frameworks to developing and emerging economies. Sayer and Bhavesh (2023) analyze the effectiveness of monetary and fiscal policy in India using a Bayesian NK-DSGE model and confirm the relevance of price and wage stickiness in explaining macroeconomic dynamics. Similarly, Ufuk et al. (2021) examine post-pandemic recovery policies in Turkey and show that the effectiveness of monetary and fiscal policy depends on country-specific conditions. Furthermore, Denny (2021) introduces state-dependent pricing into a small open economy DSGE model for Indonesia and demonstrates that the assumption about price-setting mechanisms can significantly alter policy implications. At the micro level, Choudhary et al. (2016) provide survey-based evidence from Pakistan and show that price stickiness persists even in relatively high-inflation environments. Their results suggest that factors such as strategic interactions among firms, uncertainty about shocks, and the presence of informal markets play important roles beyond standard menu cost explanations.

There is limited research on inflation dynamics in Bangladesh. Hassan (2012) estimates a Phillips Curve using an output gap derived from the Hodrick–Prescott filter and finds that inflation is positively related to its own lag and negatively related to the output gap. Khan and Sadique (2019) estimate a New Keynesian Phillips Curve using GMM and obtain statistically significant coefficients.

As the above literature shows, a substantial body of research has examined price stickiness in developed economies, and robust empirical and theoretical insights have been accumulated. However, relatively few studies focus on developing economies, particularly under high-inflation environments. This paper contributes to the literature by addressing this gap and by linking macro-level price stickiness to micro-level heterogeneity and behavioral mechanisms.

3 Macro Approach

As we overview, there are two approaches, Macro and Micro Approach to estimate price stickiness. Particularly here, we construct a typical New Keynesian Model, estimating parameters by Bayes Method using GDP gap, GDP deflator and Short Term Interest Rate of Bangladesh and identifying price stickiness as a result.

3.1 New Keynesian Model

The basic concept of the New Keynesian Model is not different from that of General Equilibrium approach which maximizes household's utility and maximizes firms' profits. The difference is monopolistic competition and assumption of Calvo price setting to model price stickiness. There are three markets, Labour, Goods and Money. A representative household determines goods demand and labour supply, representative firm determines labour demand. The Central Bank determines nominal interest rate using the Taylor Rule. The model assumes a closed-economy and therefore discard impacts of export, import and exchange rate. However, thanks to this simplicity of the model, we can compare the results with other countries' estimates.

3.1.1 Representative Household

Assume following utility function where C_t is a aggregated consumption at time t and L_t is labour supply at time t. β is a discount factor and μ and γ are parameters related to labour supply.

$$U_t = \sum_{i=0}^{\infty} \beta^t [\log(C_{t+i}) - \mu L_{t+i}^{\gamma+1}] \tag{1}$$

Here, we assume monopolistic competition model to introduce price stickiness. Monopolistic Competition Model have a lot of firms (Competition Aspect) but they can determine the price since they provide differentiated goods (Monopoly Aspect). Aggregated consumption C_t consists of infinite number of differentiated goods $c_{j,t}$ and household is assumed to have Constant Elasticity of Substitution (CES) utility function.

$$C_t = \left[\int_0^1 c_{j,t}^{\frac{\eta-1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}} \tag{2}$$

In the first step, the household minimizes the expenditure for $c_{j,t}$, which is represented as

$$\min_{\{c_{j,t}\}} \int_0^1 p_{j,t} c_{j,t} dj \ \ s.t. \ C_t - \left[\int_0^1 c_{j,t}^{\frac{\eta-1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}} = 0 \tag{3}$$

Constructing Lagrange omitting subscript t with lagrange multiplier of ψ:

$$\Psi = \int_0^1 p_j c_j dj + \psi \left[C - \left\{ \int_0^1 c_j^{\frac{\eta}{\eta-1}} dj \right\}^{\frac{\eta}{\eta-1}} \right] \tag{4}$$

The solution to the problem is given by $\frac{\partial \Psi}{\partial c_j}$ and the following holds

$$c_j = \left(\frac{p_j}{P} \right)^{-\eta} C \tag{5}$$

Lagrange multiplier ψ is given by

$$\psi = \left[\int_0^1 p_j^{1-\eta} dj \right]^{\frac{1}{1-\eta}} \tag{6}$$

Since nominal consumption $PC = \int_0^1 p_j c_j dj$ is

$$\int_0^1 p_j c_j dj = \int_0^1 \left[\left(\frac{p_j}{\psi} \right)^{-\eta} C \right] p_j dj = \psi C, \tag{7}$$

aggregate price P of aggregate consumption goods C is nothing but ψ. Thus,

$$P = \left[\int_0^1 p_j^{1-\eta} dj \right]^{\frac{1}{1-\eta}} \tag{8}$$

Real Household's budget constraint is given by

$$C_t + \frac{B_t}{P_t} = \frac{W_t L_t}{P_t} + (1 + i_{t-1}) \frac{B_{t-1}}{P_t} + \frac{\tau_{f,t}}{P_t} \tag{9}$$

where B_t is a bond holding (nominal), W_t is a nominal wage and i_t is a nominal interest rate at time t. Solving Household's Utility Maximization (1) subject to (9),

$$\Lambda = \sum_{i=t}^{\infty} \beta^{i-t} \left[\log(C_t) - \mu L_i^{\gamma+1} + \lambda_i \left\{ \frac{W_i L_i}{P_i} + (1 + i_{t-1}) \frac{B_{i-1}}{P_i} + \frac{\tau_{f,i}}{P_i} - C_i - \frac{B_i}{P_i} \right\} \right] \tag{10}$$

and we have First Order Condition with respect to C_t, L_t and B_t as follows, respectively. Note that λ_i is Lagrange multiplier.

$$\frac{1}{C_t} - \lambda_t = 0 \tag{11}$$

$$\frac{W_t \lambda_t}{P_t} - \mu(\gamma + 1)L_t^{\gamma} = 0 \tag{12}$$

$$\frac{\beta(i_t + 1)\lambda_{t+1}}{P_{t+1}} - \frac{\lambda_t}{P_t} = 0 \tag{13}$$

3.1.2 Representative Firm

Production factor is assumed to be Labour only and then production function of firm j at time t is assumed to be $c_{j,t} = A_t L_{j,t}$ where A_t is technical level, which follows AR(1) process, $\ln(A_{t+1}) = \rho_A \ln(A_t) + \epsilon_{t+1}$. Cost minimization problem at the time t is given by

$$\min_{L_{j,t}} \frac{W_t L_{j,t}}{P_t} \quad s.t. \ c_{j,t} = A_t L_{j,t} \tag{14}$$

Constructing Lagrange omitting subscript j as follows

$$\Phi = \frac{W_t L_t}{P_t} + \varphi_t(c_t - A_t L_t) \tag{15}$$

and first order condition $\frac{\partial \Phi}{\partial L_t} = 0$ yields

$$\varphi_t = \frac{W_t}{A_t P_t} \tag{16}$$

Since nominal average cost per unit is given by $\frac{W_t L_t}{c_t} = \frac{W_t}{A_t}$ (see production function), φ_t represents real average cost per unit.

Firms can determine price under monopolistic competition setting but firms should make a decision taking into account the possibility that they cannot change prices. Firms cannot freely change the price at each time, whereas they can change at a constant probability, which is called Calvo Price Setting. Thus, Intertemporal profit function is given by

$$\begin{aligned}\Theta_{j,t} &= \sum_{i=0}^{\infty} \frac{\varrho^i}{\prod_{k=1}^{i}(1+i_{t+k-1})} \left(p_{j,t} - P_{t+i}\varphi_{t+i}\right) c_{j,t+i} \\ &= \sum_{i=0}^{\infty} \frac{\varrho^i P_{t+i}}{\prod_{k=1}^{i}(1+i_{t+k-1})} \left(\frac{p_{j,t}}{P_{t+i}} - \varphi_{t+i}\right) \left(\frac{p_{j,t}}{P_{t+i}}\right)^{-\eta} C_{t+i}\end{aligned} \tag{17}$$

using (5) in the 2nd step where ρ is a probability that firm cannot change the price. Note that $P_{t+i}\varphi_{t+i}$ is the average cost. In short, the firm considers possibility that the firm will not able to change the price and maximize expected profits dynamically. From Euler Equation,

$$\frac{1}{1+i_t}\frac{P_{t+1}}{P_t} = \beta\left(\frac{C_t}{C_{t+1}}\right) \tag{18}$$

which yields

$$\frac{P_{t+i}}{\prod_{k=1}^{i}(1+i_{t+k-1})} = \beta^i\left(\frac{C_t}{C_{t+1}}\right) P_t \tag{19}$$

Then, (17) is to be

$$\Theta_{j,t} = P_t C_t \sum_{i=0}^{\infty} \rho^i \beta^i \left[\left(\frac{p_{j,t}}{P_{t+i}}\right)^{1-\eta} - \varphi_{t+i}\left(\frac{p_{j,t}}{P_{t+i}}\right)^{-\eta}\right] \tag{20}$$

FOC with respect to $p_{j,t}$ is represented by

$$P_t C_t \sum_{i=0}^{\infty} \rho^i \beta^i \left[(1-\eta)\frac{p_{j,t}^{-\eta}}{P_{t+i}^{1-\eta}} + \eta\varphi_{t+i}\frac{p_{j,t}^{-\eta-1}}{P_{t+i}^{-\eta}}\right] = 0 \tag{21}$$

Replacing $p_{j,t}$ with p_t^0 since the condition is common for every firm, calculate as follows:

$$\begin{aligned}\sum_{i=0}^{\infty} \rho^i\beta^i(\eta-1)\frac{(p_t^0)^{-\eta}}{P_{t+i}^{1-\eta}} &= \sum_{i=1}^{\infty} \rho^i\beta^i\eta\varphi_{t+i}\frac{(p_t^0)^{-\eta-1}}{P_{t+i}^{-\eta}} \\ p_t^0 \sum_{i=0}^{\infty} \rho^i\beta^i P_{t+i}^{\eta-1} &= \frac{\eta}{\eta-1}\sum_{i=0}^{\infty}\rho^i\beta^i\varphi_{t+i}P_{t+i}^{\eta}\end{aligned} \tag{22}$$

Divided by P_t^η for both right hand side and left hand side and we have

$$\frac{p_t^0}{P_t} = \frac{\eta}{\eta-1}\frac{\sum_{i=0}^{\infty}\rho^i\beta^i\varphi_{t+i}\left(\frac{P_{t+i}}{P_t}\right)^{\eta}}{\sum_{i=0}^{\infty}\rho^i\beta^i\left(\frac{P_{t+i}}{P_t}\right)^{\eta-1}} \tag{23}$$

Suppose F_t as

$$F_t = \sum_{t=0}^{\infty}\rho^i\beta^i\varphi_{t+i}\left(\frac{P_{t+i}}{P_t}\right)^{\eta} \tag{24}$$

and

$$\begin{aligned} F_t &= \varphi_t + \sum_{i=0}^{\infty} \rho^{i+1}\beta^{i+1}\varphi_{t+i+1}\left(\frac{P_{t+i+1}}{P_t}\right)^{\eta} \\ &= \varphi_t + \rho\beta\left(\frac{P_{t+1}}{P_t}\right)^{\eta} F_{t+1} \end{aligned} \tag{25}$$

holds. Similarly,

$$D_t = \sum_{i=0}^{\infty} \rho^i \beta^i \left(\frac{P_{t+i}}{P_t}\right)^{\eta-1} \tag{26}$$

and we have

$$D_t = 1 + \rho\beta\left(\frac{P_{t+1}}{P_t}\right)^{\eta-1} D_{t+1} \tag{27}$$

In summary, (23) is to be

$$\frac{p_t^0}{P_t} = \frac{\eta}{\eta-1}\frac{F_t}{D_t} \tag{28}$$

On the other hand,

$$\begin{aligned} P_t^{1-\eta} &= \int_0^1 \left[(1-\rho)(p_t^0)^{1-\eta} + \rho\, p_{j,t-1}^{1-\eta}\right] dj \\ &= (1-\rho)(p_t^0)^{1-\eta} + \rho P_{t-1}^{1-\eta} \end{aligned} \tag{29}$$

3.1.3 Monetary Policy Rule

To close the model, we have to create monetary policy rule equation. Generally, central bank intends to stabilize inflation rate and economic growth. Simply following Taylor Rule, one of the monetary policy rule here, we have

$$i_t = i^* + \phi_\pi \pi_t + \phi_y \ln\left(\frac{Y_t}{Y_t^n}\right) \tag{30}$$

where Y_t^n is a potential output when flexible price, $\rho = 0$ takes place and i^* is an interest rate under steady state. Note that ϕ_π and ϕ_y are parameters which Central Bank determines. Under this rule, central bank determines nominal interest rate i_t corresponding to the deviation from potential GDP as well as inflation rate. At that time, $\varphi_t = \varphi^n = \frac{\eta-1}{\eta}$.

Substitute (16) and $L_t = \frac{C_t}{A_t}$ for (12) and we have

$$\frac{A_t\varphi_t}{C_t} - \mu(\gamma+1)\left(\frac{C_t}{A_t}\right)^{\gamma} = 0 \tag{31}$$

Table 1: Endogenous Varables

C_t	Consumption at t
φ_t	Average Cost
π_t	$P_t/P_{t-1} - 1$
π_t^0	$p_t^0/P_{t-1} - 1$
F_t	Defined in (24)
D_t	Defined in (26)
A_t	Total Factor Productivity
i_t	Nominal Interest Rate
v_t	Error Term of Monetary Policy Rule

$$C_t^n = A_t \left[\frac{\varphi^n}{\mu(\gamma+1)} \right]^{\frac{1}{\gamma+1}} = A_t C^* \tag{32}$$

where C_t^n is the value of C_t when $\varphi_t = \varphi_t^n$ and C^* is value under steady state of consumption C_t.

Assuming AR(1) process of Error term,

$$v_{t+1} = \rho_v v_t + z_{t+1} \tag{33}$$

where z_t is exogenous and our monetary policy rule is represented by

$$i_t = i^* + \phi_\pi \pi_t + \phi_y \ln \left(\frac{C_t}{A_t C^*} \right) + v_t \tag{34}$$

Notice that $Y_t = C_t$ in goods market equilibrium and therefore $Y_t^n = C_t^n = A_t C^*$.

3.1.4 Summary of the Model

Goods market equilibrium yields $C_t = A_t L_t$. Then, we have nine endogenous variables with nine equations as specified below.

$$(1 + \pi_{t+1}) \frac{C_{t+1}}{C_t} = \beta(1 + i_t) \tag{35}$$

Table 2: Parameters

β	Discount Rate
μ	Weight for disutility from Labour
γ	Inverse of Elasticity of Labuor Supply
ρ	Probability that Firm cannot change price
η	Price Elasticity of Demand
ϕ_π	Coefficient of Monetary Policy for Inflation Rate
ϕ_y	Coefficient of Monetary Policy for GDP gap
ρ_A	Coefficient of AR(1)
ρ_v	Coefficient of AR(1)

$$\frac{1+\pi_t^0}{1+\pi_t} = \frac{\eta}{\eta-1}\frac{F_t}{D_t} \tag{36}$$

$$F_t = \varphi_t + \rho\beta(1+\pi_{t+1})^\eta F_{t+1} \tag{37}$$

$$D_t = 1 + \rho\beta(1+\pi_{t+1})^{\eta-1} D_{t+1} \tag{38}$$

$$(1+\pi_t)^{1-\eta} = (1-\rho)(1+\pi_t^0)^{1-\eta} + \rho \tag{39}$$

$$i_t = i^* + \phi_\pi \pi_t + \phi_y \ln\left(\frac{C_t}{A_t C^*}\right) + v_t \tag{40}$$

$$v_{t+1} = \rho_v v_t + z_{t+1} \tag{41}$$

$$\ln(A_{t+1}) = \rho_A \ln(A_t) + \epsilon_{t+1} \tag{42}$$

$$\varphi_t = \mu(\gamma+1)\left(\frac{C_t}{A_t}\right)^{\gamma+1} \tag{43}$$

(35) is intertemporal consumption euler equation. (36), (37) and (38) are related to firm's profit maximization condition (28). (39) is derived from (29). (40) and (41) are related to monetary policy rule. (42) is AR(1) process of total factor productivity and (43) is same as (31).

3.1.5 Steady State

Solution of nine endogenous variables to the nine equations above under steady state are given by

$$\begin{aligned}
\pi^* &= \pi^{0*} = v^* = 0 \\
i^* &= \frac{1-\beta}{\beta} \\
D^* &= \frac{1}{1-\rho\beta} \\
F^* &= \frac{\eta-1}{\eta(1-\rho\beta)} \\
\varphi^* &= \frac{\eta-1}{\eta} \\
A^* &= 1 \\
C^* &= \left[\frac{\eta-1}{\mu(\gamma+1)\eta}\right]^{\frac{1}{\gamma+1}}
\end{aligned} \tag{44}$$

3.1.6 Log-linearization

Log linearize (36), (37), (38) and (39) and we have

$$\pi_t^0 - \pi_t = \hat{F}_t - \hat{D}_t \tag{45}$$

$$\pi_t = (1-\varrho\beta)\pi_t^0 \tag{46}$$

$$\hat{F}_t = (1-\varrho\beta)\hat{\varphi}_t + \varrho\beta(\eta\pi_{t+1} + \hat{F}_{t+1}) \tag{47}$$

$$\hat{D}_t = \varrho\beta[(\eta-1)\pi_{t+1} + \hat{D}_{t+1}] \tag{48}$$

Substitute (46) and (47) for (44) and we have

$$\pi_t^0 - \pi_t = (1-\rho\beta)\hat{\varphi}_t + \rho\beta\pi_{t+1}^0 \tag{49}$$

and also substitute (45) into (48)

$$\pi_t = \frac{(1-\rho)(1-\rho\beta)}{\rho}\hat{\varphi}_t + \beta\pi_{t+1} \tag{50}$$

Log linearize (43)

$$\hat{\varphi}_t = (\gamma+1)(\hat{c}_t - \hat{a}_t) \tag{51}$$

where $\hat{a}_t = \ln(A_t)$ and $\hat{c}_t = \log(C_t) - \log(C^*)$. Define $\kappa = \frac{(1-\rho)(1-\rho\beta)(\gamma+1)}{\rho}$ and $\hat{x}_t = \hat{c}_t - \hat{a}_t$, we have New Keynesian Phillips Curve by substituting (50) into (49) as

$$\pi_t = \kappa \hat{x}_t + \beta \pi_{t+1} \tag{52}$$

Note that $\hat{x}_t$ represents GDP gap because

$$\begin{aligned} \hat{x}_t &= \hat{c}_t - \hat{a}_t \\ &= \log(C_t) - \log(C^*) - \log(A_t) \\ &= \log(C_t) - \log(C_t^n) \end{aligned} \tag{53}$$

using (32) and also note that C_t represents GDP in the model. From Euler Equation, we have New Keynesian IS Curve as

$$\hat{x_t} = \hat{x_{t+1}} - (\hat{i_t} - \pi_{t+1} - \hat{r_t^n}) \tag{54}$$

where $\hat{r_t^n} = \hat{a_{t+1}} - \hat{a}_t$ and $\hat{i_t} = i_t - i^*$. Since $\epsilon_{t+1} = 0$ at t and $\hat{a}_{t+1} = \rho_A \hat{a}_t + \epsilon_{t+1}$,

$$\hat{r_t^n} = (\rho_A - 1)\hat{a}_t \tag{55}$$

In this model, there are five log-linearized equations below:

$$\hat{x}_t = \hat{x}_{t+1} - (\hat{i_t} - \pi_{t+1} - \hat{r}_t^n) \tag{56}$$

$$\pi_t = \beta \pi_{t+1} + \kappa \hat{x}_t \tag{57}$$

$$\hat{i_t} = (1 + \tilde{\phi_\pi})\pi_t + \phi_y \hat{x}_t + v_t \tag{58}$$

$$v_{t+1} = \rho_v v_t + z_{t+1} \tag{59}$$

$$\hat{a_{t+1}} = \rho_A \hat{a}_t + \varepsilon_{t+1} \tag{60}$$

$$\hat{r}_t^n = (\rho_A - 1)\hat{a}_t \tag{61}$$

3.2 Macro Approach Methodology

3.2.1 Estimation Method

Dynare, one of the software for the calibration of economic models, and octave, one of the programming language can allow us to find the solution where parameters fit the data. Here, we follow Hasumi (2020) and conduct Bayes estimation. The bayesian theory is different from the frequentist theory in the points that parameters are considered as random variable and data is considered as constant, whereas parameters are seen as constant and data is seen as random variable in the frequentist theory. Fundamental procedure for the Bayes estimation using Bayes' theorem is, (i) assume prior distribution $p(\theta)$, (ii) substitute data $p(y|\theta) = l(\theta; y^{obs})$ and (iii) evaluate posterior distribution $p(\theta|y^{obs})$ (e.g. mean, standard deviation or median).

$$\begin{aligned} p(\theta|y^{obs}) &= \frac{p(y|\theta)p(\theta)}{\int l(\theta; y^{obs})p(\theta)d\theta} \\ &= \frac{l(\theta; y^{obs})p(\theta)}{\int l(\theta; y^{obs})p(\theta)d\theta} \end{aligned} \tag{62}$$

Since we cannot analytically acquire posterior probability distribution and its mean, standard deviation, etc, we Markov Chain Monte Carlo method (MCMC). MCMC generates random number following posterior distribution and we can calculate mean and standard deviation from that random number generated. More specifically, here we employ Metropolis-Hastings (M-H) algorithm to develop posterior distribution.

Practically, we substitute (61) into (56), add cost push shock e_t into (57) and postulate $\beta = 0.99$ not to be estimated. In addition, $\tilde{\phi}_\pi = \phi_\pi - 1$ so that $\phi_\pi > 1$ holds because of technical issues[2]. Accordingly, we have

$$
\begin{aligned}
\hat{x}_t &= \hat{x}_{t+1} - (\hat{i}_t - \pi_{t+1}) + (\rho_A - 1)\hat{a}_t \\
\pi_t &= \beta\pi_{t+1} + \kappa\hat{x}_t + e_t \\
\hat{i}_t &= (1 + \tilde{\phi}_\pi)\pi_t + \phi_y\hat{x}_t + v_t \\
v_{t+1} &= \rho_v v_t + Z_{t+1} \\
\hat{a}_{t+1} &= \rho_A\hat{a}_t + \epsilon_{t+1}
\end{aligned} \tag{63}
$$

where ϵ_t, z_t and e_t are independently and normally distributed with mean 0 and standard deviation of σ_ϵ, σ_z and σ_e.

In summary, parameters to be estimated are $\boldsymbol{\theta} = \{\gamma, \rho, \tilde{\phi}_\pi, \phi_y, \rho_A, \rho_v, \sigma_\epsilon, \sigma_z, \sigma_e\}$ and, by Blanchard and Khan (BK) way, we can exhibit

$$
\boldsymbol{\alpha}_{t+1} = D(\boldsymbol{\theta})\boldsymbol{\alpha}_t + R\boldsymbol{\eta}_t, \quad \boldsymbol{\eta} \sim \mathcal{MN}(\mathbf{0}, Q(\boldsymbol{\theta})) \tag{64}
$$

where

$$
\boldsymbol{\alpha}_t = \begin{bmatrix} \hat{x}_t \\ \pi_t \\ \hat{i}_t \\ v_t \\ \hat{a}_t \end{bmatrix}, \quad \boldsymbol{\eta} = \begin{bmatrix} \epsilon_{t+1} \\ z_{t+1} \\ e_{t+1} \end{bmatrix}, \quad R = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix} \tag{65}
$$

which is transition equation of state space model.

As for observation equation, define as follows

$$
\begin{aligned}
x_t^{obs} - \bar{x}^{obs} &= \hat{x}_t \\
\pi_t^{obs} - \bar{\pi}^{obs} &= \pi_t \\
(i_t^{obs} - \bar{i}^{obs})/4 &= \hat{i}_t
\end{aligned} \tag{66}
$$

where $\bar{x}^{obs}$, $\bar{\pi}^{obs}$ and $\bar{i}^{obs}$ are average in the whole periods for each sequence and annual

[2] $\kappa(\phi_\pi - 1) + (1 - \beta)\phi_y > 0$ is necessary and sufficient condition to make the model determinate and have unique solution.

nominal interest rate is transformed to quarterly. In the matrix form,

$$\boldsymbol{y}_t = Z\boldsymbol{\alpha}_t, \quad Z = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \tag{67}$$

where $\boldsymbol{y}_t = \left[x_t^{obs} - \bar{x}^{obs},\ \pi_t^{obs} - \bar{\pi}^{obs},\ (i_t^{obs} - \bar{i}^{obs})/4\right]'$. We provide details on data and processing method in the subsequent section.

The prior distributions are chosen to be consistent with the theoretical restrictions of the model parameters, as well as with existing empirical studies in the DSGE literature. Inverse of labor supply elasticity γ and monetary policy rule coefficients, $\tilde{\phi}_\pi$ and $\tilde{\phi}_y$ are obviously grater than 0 so they are expected to follow Gamma distribution. In particular, γ must take positive values to ensure well-defined household optimization. Similarly, the policy reaction coefficients $\tilde{\phi}_\pi$ and $\tilde{\phi}_y$ are assumed to be positive, reflecting the standard assumption that the central bank raises the nominal interest rate in response to increases in inflation and output gap. Second, the parameter ρ, which governs price persistence in the model, is bounded between zero and one. This restriction naturally arises because ρ is probability. To respect this support, we assume that ρ follows a Beta distribution. The Beta distribution is commonly used in the DSGE literature for parameters defined on the unit interval, as it allows for flexible shapes while ensuring that the support remains within $(0, 1)$. Similarly, the autoregressive coefficients of the AR(1) processes are theoretically required to satisfy $|\rho| < 1$ for stationarity. In this paper, we further restrict attention to positive persistence, which is consistent with the empirical behavior of most macroeconomic time series exhibiting positive serial correlation. Under this restriction, we again adopt Beta distributions for these parameters, ensuring both stationarity and economically plausible persistence. Since there is no prior research on the price stickiness in Bangladesh, we use prior mean and prior variance same as Hasumi (2020). Parameters, their prior distributions, prior means and prior veriance assumed are summarized in Table 3.

Finally, the Metropolis–Hastings algorithm proceeds as follows: Starting from an

Table 3: Prior Distributions for Estimated Parameters

Parameter	Distribution	Prior Mean	Std. Dev.	Interpretation
γ	Gamma	5.0	2.0	Inverse of labor supply elasticity
ϱ	Beta	0.9	0.05	Calvo price stickiness
$\tilde{\phi}_\pi$	Gamma	0.5	0.25	Taylor rule coef. (inflation)
ϕ_y	Gamma	0.5	0.25	Taylor rule coef. (output gap)
ρ_A	Beta	0.9	0.05	Persistence of technology shock
ρ_v	Beta	0.7	0.10	Persistence of policy shock

initial value $\boldsymbol{\theta}^{(0)}$, (i) a candidate parameter vector $\tilde{\boldsymbol{\theta}}$ is drawn from a multivariate normal proposal distribution centered at $\boldsymbol{\theta}^{(i-1)}$, (ii) the model is solved using the BK method and the likelihood is computed via the Kalman filter, (iii) the prior density and acceptance probability are evaluated, and (iv) the candidate draw is accepted or rejected accordingly. This procedure is repeated iteratively. Number of iteration here is 125,000, number of chain is two and first 25,000 is disposed since it generally has a major impact of initial value.

3.2.2 Data

Following Hasumi (2020), we use Short term interest rate, GDP deflator and GDP gap for input of the model. Quarterly real GDP and nominal GDP estimated by BBS are available from 2015 Q1 to 2024 Q4. Note that Real GDP is based on the price in the FY 2015-16 and seasonal adjustment is applied for both real and nominal GDP by

Table 4: Posterior Distributions for Estimated Parameters

Parameter	Posterior Mean	90% HPD interval	
γ	4.3354	1.5482	7.1039
ρ	0.9550	0.9317	0.9801
$\tilde{\phi}_\pi$	0.3024	0.0750	0.5286
ϕ_y	1.2008	0.7671	1.6648
ρ_A	0.9401	0.9178	0.9628
ρ_v	0.8333	0.7685	0.9015

taking moving average. (e.g. $GDP_{2017Q3} = (GDP_{2017Q3} + GDP_{2017Q2} + GDP_{2017Q1} + GDP_{2016Q4})/4$). We have total 34 samples. Seasonal adjusted GDP deflator is given by $GDP\ deflator_t = \frac{Nominal\ GDP_t}{Real\ GDP_t} \times 100$, which is shown in Appendix 1 Figure A.2. Since GDP gap is not available in Bangladesh, we decompose GDP into trend and cycle component by conducting HP filter method with smoothing parameter $\lambda = 1600$, which is normally used for quarterly data and cycle component is used as GDP gap. Trend and Cycle decomposition is given by Appendix 1 Figure A.1. Data on short term nominal interest rate (call money rate) is taken from Annual Report of Bangladesh Bank, shown in Appendix 1 Figure A.3. Actual input to the model is gap between observed value and average of whole period. Interest rate is divided by four to convert yearly rate into quarterly rate.

3.3 Macro Approach Result and Discussion

Under stated setting above, we estimate posterior distribution and Table 4 shows the result, mean and 90% HPD interval. The Geweke (1992) convergence tests, based on the comparison of the means of the early and late parts of the Markov chain, indicate successful convergence for all parameters when using tapered spectral density estimators to adjust for autocorrelation. Our interest, mean of Calvo price stickiness ρ is 0.9550, which is higher than prior mean. Therefore, we can conclude that price in Bangladesh is very sticky even though inflation rate (GDP deflator) is relatively high, quarterly around 0.8-1.8%, which means annually 4% to 10% and even stickier than that of Japan. Hasumi (2020) shows $\rho = 0.94$ using data from 1980 to 1999 in Japan, whereas GDP deflator of Japan is around 1% to 0%. Price stickiness ρ of Australia estimated in 1993 Q2 to 2011 Q1 is 0.88, that of Canada (1991 Q1–2011 Q1) is 0.96 and that of New Zealand (1990 Q1–2011 Q1) is 0.97. (Abbas et al., 2016) Sayer and Bhavesh (2020) derives $\rho = 0.68$ in India. Inflation rate of those three countries is around 0-5% in the period so High price stickiness of Bangladesh under 4% to 10% is remarkable and characteristic.

Posterior mean of γ is smaller than prior, which means labour supply is more elastic than expected. Regarding monetary policy rule, central bank corresponds to GDP gap more strictly and reflect it on nominal interest rate comparing the coefficients of inflation and GDP gap. Though the analysis period is different, price stickiness in Bangladesh under approximately 6-7% CPI inflation rate is higher than that of Japan under very little inflation rate. In general, price is expected to be flexible under high inflation rate environment because firm cannot endure the original price under that environment. However, this paper proposes price stickiness even under relatively high inflation rate, which is counterintuitive.

4 Micro Approach

Different from indirect approach, which reproduce price stickiness by estimating NKPC, this section tries to find it by disaggregated price data. In case of developed countries, micro data becomes more and more prevailing thanks to POS system. It yields day-to-day, goods-to-goods, and store-to-store data, which encourages us to research a movement of price. However, in case of developing countries, retailers sell products without POS system and there is no track. This might be one of the reasons of less amount of research on price stickiness in developing countries.

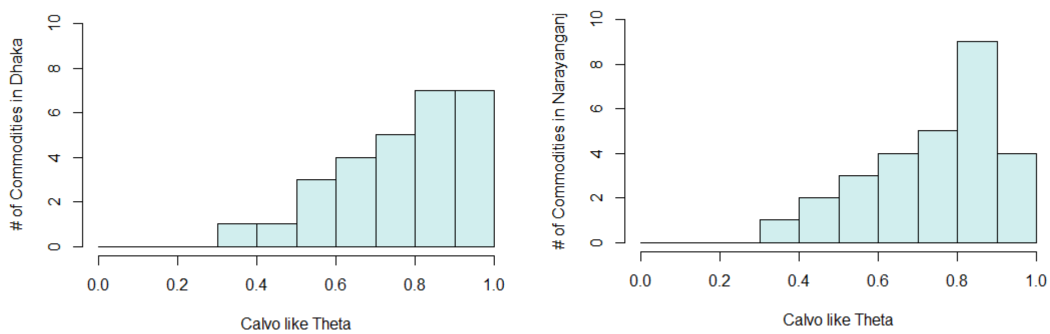
Although fine-grained store-level price data are not available in Bangladesh, the

Bangladesh Bureau of Statistics (BBS) provides disaggregated price information in its "Monthly Statistical Bulletin-Bangladesh." In particular, we use the dataset titled "Average Retail Prices of Essential Consumer Goods at Principal Towns." Wholesale price generally persists more than retail price because of business practice and long run relationship between stakeholders. Hence, we focus on retail price, which is generally more flexible.

We use the data from 2016 April to August 2025 (Maximum available in their web site). While these data report average prices rather than price time series at the individual store level, they provide time series of prices for specific goods at the regional level. Therefore, although not strictly micro-level data, these series retain a sufficient degree of disaggregation to capture item-level price dynamics. In this sense, they can be interpreted as a proxy for micro price data and are suitable for analyzing price movements of individual goods. Our subject is set for 28 industrial products (Refer to Appendix 2) in 8 representative cities, Dhaka, Narayanganj, Chattogram, Rajshahi, Khulna, Sylhet, Rangpur and Barishal, not for perishable goods such as fresh foods, which is almost non-sticky because of seasonality. Observation period is 108, though it actually varies due to missing value.

Price stickiness indicator based on Calvo model is very simple, whose formula is one minus the number of price change divided by total period. Surprisingly, price of Disprin Tablet and matches has not changed for 9 years. Pencil, Bidi, Shoes, etc similarly has Calvo like theta of more than 0.9. On the other hand, Tobacco has by far less Calvo theta than others, 0.40. Distribution of price stickiness in Dhaka and Narayanganj are shown in the graph below. For other cities, refer to Appendix 2. In Dhaka city, the number of commodities with Calvo like Theta within 0.8 to 1.0 is the largest, 14 in total out of 28. Price stickiness in Dhaka city is stronger than that of Narayanganj. Distribution in each city varies but most of the commodities have Calvo like theta of greter than 0.4, which means same price during nine months and therefore its price does not change frequently.

This investigation suggests an answer to the contradiction, why is aggregated price sticky even under aggregated high inflation? The answer is that price Stickiness varies across commodities. Though some are very sticky and others are less sticky in disaggregated level, stickiness in aggregated level in the basket (CPI) might be high because of the way of aggregation. Another candidate of answer is as follows. For some reasons, price change incurs some cost, like menu cost hypothesis. Then, frequency of the change is low but the extent of the change is high, which leads to high inflation of aggregated level.



(a) Dhaka **(b)** Narayanganj

Figure 2: Calvo like Theta

5 Hypothetical and Conceptual Model

This conceptual model tries to explain why there is price stickiness for some commodities even under high inflation rate. So far, macroeconomists have advocated the existence of menu cost hypothesis and price becomes sticky due to the menu cost. However, under high inflation environment, a firm cannot endure the current price and profit gained is expected to be higher than the menu cost. So, only menu cost hypothesis does not fully explain the situation happened in high inflation environment. Here, we suggest people's belief on the price as well as menu cost and try to explain price stickiness under high inflation. Since a firm has menu cost to change price, price stickiness takes place. Because of price stickiness, people tend to have a belief that price does not change. In other words, consumer has 0% inflation expectation for specific goods. Then, people will not accept price increase in the short run and thus firm has no power against price setting because people will run away from the firm. Once its relation is fixed, it will be equilibrium and it's very difficult to deviate from the equilibrium. Though this model has no mathematical representation, it is useful to explain the situation and future extension might be helpful.

Research on people's belief on inflation and price stickiness has not been sufficient but one of the proceedings is Diamond et al. (2020). It discusses formation of of consumer inflation expectation. The structure of the their model and our conceptual model is completely different, However, it can be referred as the similar type.

While the conceptual framework presented above provides an intuitive explanation for price stickiness under high inflation, its applicability is subject to several conditions. First, the mechanism is most relevant for goods for which consumers form strong and stable price beliefs. In particular, frequently purchased essential and non-perishable goods or services are more likely to exhibit this type of behavior, as consumers have well-established reference prices. Second, the mechanism relies on the idea that consumers may react strongly to price increases in the short run. Even for essential goods, consumers may temporarily reduce purchases, switch to alternative sellers, or delay consumption when prices deviate from their reference levels. Therefore, the mechanism is more likely to operate in markets where such short-run behavioral responses are significant. This does not necessarily imply high long-run price elasticity, but rather reflects short-run resistance to deviations from reference prices. Third, the argument relies on the presence of monopolistic competition, as introduced in Chapter 3. In contrast, under perfect competition, where firms are price takers, this mechanism would be less relevant.

Finally, the model is less applicable in environments where inflation expectations are already high and widely recognized. In such cases, consumers anticipate price increases, and firms face less resistance when adjusting prices. Similarly, for goods with low purchase frequency or weak consumer price awareness, the formation of a "0% inflation expectation" is less likely.

Despite these limitations and simplifying assumptions, the framework provides a useful complementary perspective to the traditional menu cost explanation by incorporating consumer beliefs into price-setting behavior. In this sense, it offers a microeconomic foundation that is consistent with, and potentially extendable to, modern macroeconomic models.

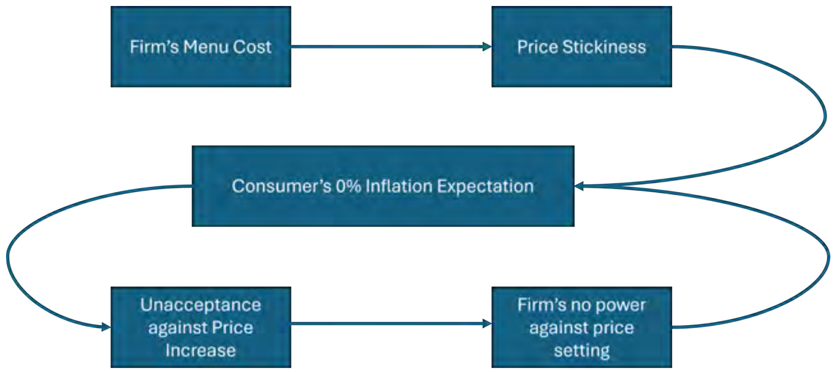


Figure 3: Hypothetical Model

6 Concluding Remarks

In order to know how sticky the price is in Bangladesh, we conduct Bayes estimation and measure Calvo price stickiness based on basic New Keynesian Model as well as estimation of price stickiness for 28 industrial product. Bayes estimation result is credible enough and then robust to show the price stickiness in Bangladesh in view of Macro aggregated indicator and this is one of the pioneering estimation of New Keynesian Model in Bangladesh. In view of disaggregation, estimation of price stickiness for each industrial product shows some product (e.g. match) are so sticky and others are more or less flexible. From those two investigation, we come to know that there is macro price stickiness in Bangladesh even under relatively high inflation and its stickiness stems from mixture of severely sticky product price and less sticky product price. The question to be solved in the next step is why some products have very sticky price even under high inflation rate. Here, we suggest one hypothetical and conceptual model to answer it.

Based on the estimation results, several policy implications can be derived. Within the framework of the model, monetary policy plays an important role in stabilizing inflation and output fluctuations. In particular, adjustments in the nominal interest rate affect price dynamics and help reduce the output gap, thereby contributing to macroeconomic stability. However, it is important to interpret these implications with caution in the context of Bangladesh. The effectiveness of the interest rate channel may be limited due to structural features of the economy, such as underdeveloped financial markets, imperfect transmission from policy rates to market rates, and the significant role of supply-side factors, especially in food and energy prices. Therefore, while the result implies the importance of monetary policy such as raising the policy rate, its actual impact depends on the strength of the transmission mechanism. In practice, monetary policy may need to be complemented by other policy measures, including exchange rate management, macroprudential tools, and supply-side interventions.

In addition, since short-term nominal interest rates are not constrained by the zero lower bound, conventional monetary policy remains a relevant tool. Nevertheless, the policy effectiveness hinges on institutional and market conditions specific to Bangladesh.

We have many rooms for the improvement of this estimation. First, collecting quarterly data and then increasing the number of samples, which leads to more robust results. Second, prior distribution setting. As Minfold et al. (2021) shows, the result we calculate may highly depend on prior distribution. To guarantee the robustness, almost same result with other prior distributions are required. Third, the number of MCMC replication, though it takes so much time due to the computational load. In parallel, we can estimate New Keynesian Phillips Curve econometrically and endorse each of the result.

On the other hand, remaining tasks are also revealed in this research. Differences in a tendency of price stickiness across Sectors as well as regions are one of the interesting topic. Creating a mathematical model of what we suggested in Section 5 is also prospective. Ample literature on price stickiness in the context of Bangladesh may largely help Bangladesh Bank make a rational decision on Monetary Policy, which coincides the stream of Evidence Based Policy Making in the world.

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Appendix 1

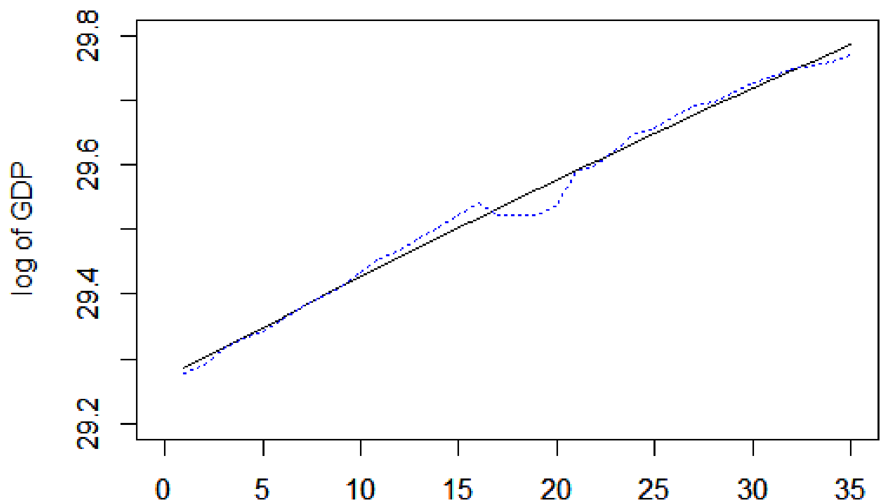


Figure A.1: Trend Cycle Decomposition[3]

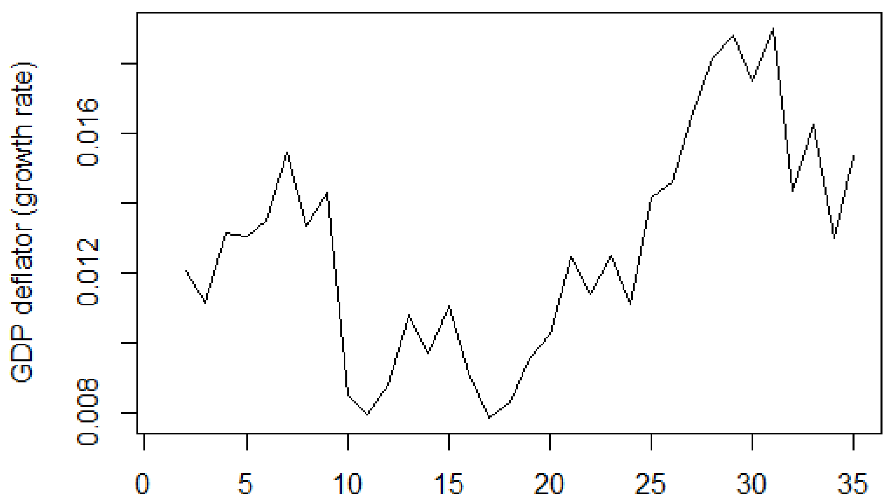


Figure A.2: GDP deflator[3]

[3] 1=2015Q4, 2=2016Q1,..., 38=2024Q2

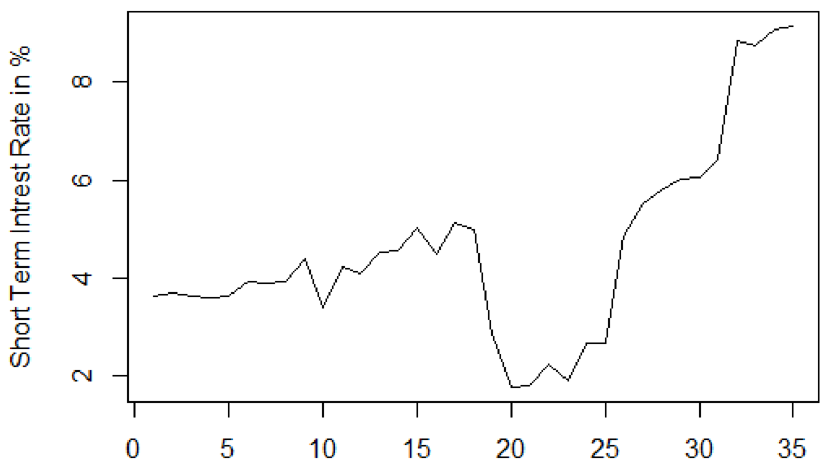
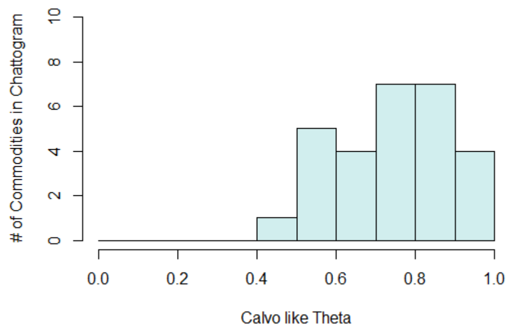
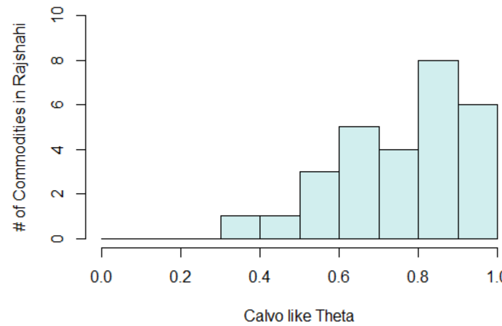


Figure A.3: Short Term Interest Rate[3]

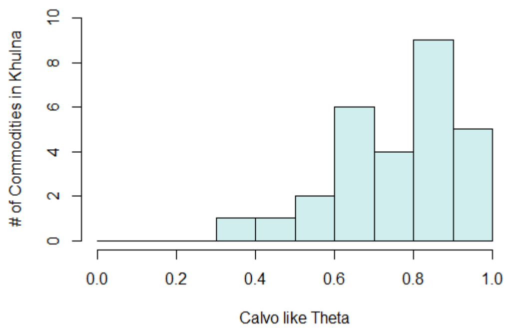
Appendix 2



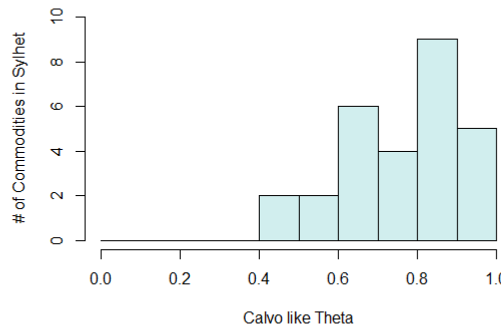
(a) Chattogram



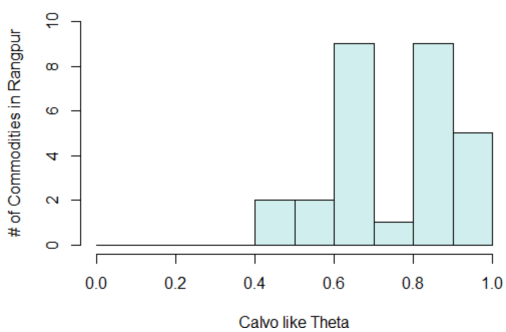
(b) Rajshahi



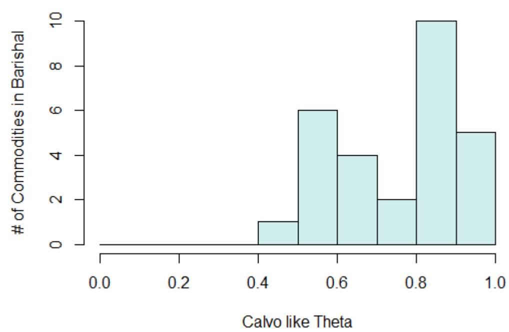
(c) Khulna



(d) Sylhet



(e) Rangpur



(f) Barishal

Figure A.4: Calvo like Theta

Table A.1: Commodity List

Category	Commodity	Specification	Unit
Fuel and Lighting	Firewood	Gazari Split	Quintal
		Mango tree Split	Quintal
	Matches	40 stick box	Each
	Kerosene	White	Litre
Clothing & Footware	Saree	Local Mill-40*40 Midium Quality	5 yrd each
	Long Cloth	Medium Quality Local	Metre
	Drill	Local Khaki Medium Quality	Metre
	Genji	36 size superior quality	Each
	Shoes	Gents Bata Rubber sole std. size	pair
Personal Care	Toilet Soap	Lux Int'l Medium Size	Each
	Washing Soap	Tibet 570 (Pack of 4)	Each
		Pancha No.1 Equivalent	Each
	Talcum Powder	Tibet Local	Each
	Face cream (vanishing)	Ponds Medium 50grm	Each
	Hair Oils	Cocoanut Unscented (Imported)	Each
Medical Care	Displin Asplin	Tablet	Each
	Penicillin	Glaxo, 5 lakhs	Each
Baby Food	Lactozen (half cream)	400grm Tin	Each
	Ovaltine	1 lb. tin	Each
	Horlics	Big bottle (400 grm pot)	Each
Educational Expenses	Paper	Fullscape white 10 lbs	Quire
	Pencil	Deer brand medium	Each
Other Misc. Items	Betal Leaf (Paan)	Medium Size	Birah (80pcs)
	Betal Nut (Supari)	Tanti Whole	Kg
	Tobacco	Leaf Motihari	Kg
	Bidi	Local best pkt of 25 sticks	Each
Cigarettes	Gold Leaf	Pkt of 20 sticks	Each
	Star	Pkt of 20 sticks (Flitter)	Each