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Inflation in the Open Economy: An Application of the Error Correction Approach to the Recent Experience in Bangladesh

Md. Akhtaruzzaman[1]
October 2005

Abstract

This study employs co-integration and Vector Error Correction Modeling (VECM) technique to identify the variables, which are believed to generate inflation in Bangladesh. Our results support that inflation is negatively related with real income. We observe also that the level as well as the rate of depreciation of exchange rate, growth of money supply ($m1_t$), deposit interest rate ($DEPOINT_t$); each has statistically significant role in explaining the inflationary process of Bangladesh. Thus, the contribution of imported inflation is no less important in the price inflation of Bangladesh. Furthermore, there exists a long run co-integrating relation of the price level with the deviation of actual output over potential output with high coefficient value. The results also show that a three quarter lagged price level strongly explained the inflation rate in the present quarter. So, in the context of Bangladesh the expectation augmented Philips Curve type output gap model is also powerful like the monetary model in explaining inflation which implies that inflation in Bangladesh is not fully a monetary phenomenon. Rather, it is basically generated by the higher or excess growth of monetary variables, especially money supply, compared to the real output growth.

Key words: Inflation, Devaluation, Monetarist model, Output gap model, Co-integration and Error correction modeling (VECM)

JEL Classification: C22, E31, E4, E5

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1. Introduction

In order to increase the rate of economic growth, it is necessary to ensure frequent movement of resources among different economic actors or agents, different consuming units (households) and also between different sectors of the economy. The primary objective of structural adjustment policies has been to hasten these processes. But the success of structural adjustment policies is strongly contingent upon the success of macroeconomic stabilization policies. The maintenance of a stable price level is the prime objective of the stabilization policy. A long lasting price spiral, or in more general term, the chronic inflation is one of the important and key symptoms of macroeconomic imbalances that should be controlled through appropriate stabilization policy (ECLA 1961; Kiguel and Liviatan 1988; Montiel 1989; Dornbusch et al. 1990). Hence controlling inflation is considered as a basic policy target to achieve a sound equilibrium situation in different macroeconomic accounts in the economy such as the current account of the external sector, monetary account and fiscal budget account (Sunkel 1960; Blejer and Cheasty 1988). Evidence shows that different countries have experienced different degrees of inflation. Nevertheless, a consensus has emerged that high and unstable inflation rates are not conducive to economic growth and development (Adekunle 1968 and Bernanke, 2003).

Inflation is an economic outcome that affects the rate of economic growth negatively in the long run and also pushes more people under the poverty line which means inflation aggravates the already existing poverty situation of developing countries (Cardoso 1980). A stable price level encourages investment decisions as well as for the level of consumption. A price spiral obliges the poor people to purchase less that eventually decrease the level of general demand in the economy which in turn affects the economy in the long run by decreasing the production activities (Edel 1969). High inflation reduces return to savers and thus acts as a disincentive to save and invest. In particular, saving in financial form is likely to be discouraged. This complicates the task of mobilizing savings for productive investment. The viability of financial and capital market institutions which act as important intermediaries between savers and investors is impaired. High inflation is also likely to distort the pattern of investment in favour of real estate, gold or other forms of property as hedging devices without adding much to an economy's productive capacity (Barro 1978; Lucas 1973). The international competitiveness of the economy is highly eroded by inflation. It generally encourages capital flight, affects resource distribution, gives rise to inequities in income distribution and aggravates poverty. Last but not the least, a high rate of inflation seriously undermines the popularity of the government.

There are conventional views which indicate that inflation, in a developing country like Bangladesh, is the result of exogenously generated factors and there are others who believe that inflation is primarily generated due to the absence of sound internal economic policies. This paper examines the dominant factors influencing inflation of Bangladesh, presents the empirical results based on an econometric model, and discusses the policy implications.

The remainder of the paper is organized as follows: In section I we outline a brief review of the inflation experience of the Bangladesh Economy since its inception as an independent country. Section II analyzes the different factors that influence the price level in Bangladesh and the theoretical reasons behind such an inflation experience. Section III outlines basic theoretical analysis of the specification of two principal models of inflation expectation. Section IV discusses the database and its sources, and explores the empirical methodology related to the estimation of the price equation and the econometric estimation results are discussed subsequently. Finally, section V summarizes the major findings and their policy implications.

2. Inflation Experience of the Bangladesh Economy

Inflation figures in Bangladesh during the decade of the 1990s were fairly moderate and have followed a continuously declining trend which has been continuing till FY02 but since FY03 the rate is moving gradually upward. As measured by the consumer price index (12-month average), inflation decelerated from 8.3 percent and 6.7 percent in FY91 and FY96 respectively to 3.9 percent in FY00 and again a further reduction to only 1.9 percent in FY01. In the year FY5 the inflation figure recorded a much higher rate of 6.5 percent.

In the backdrop of such an inflation record, it is useful to look at the performance of Bangladesh in comparison with inflation experience of some other South Asian countries (see the table-2.1). The data presented in the above table shows obviously that Bangladesh has done relatively well in terms of inflation criterion compared to her South Asian partners. During the past decade, it's inflation figure never reached the double-digit level. In every year except FY99 the inflation rate in Bangladesh has been lower than the South Asian average and in most of the years, the rate has been lower than that of the other major economies in South Asia.

Table-2.1: Inflation in Bangladesh and some selected South Asian Countries

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Bangladesh*	8.3	4.6	2.7	3.3	8.9	6.7	4.0	8.7	7.1	2.8	1.9	2.8	4.4	5.8	6.5
India	13.5	9.6	7.5	8.4	10.9	5.7	4.8	6.9	3.3	4.8	3.8	4.2	3.8	3.8	3.9
Pakistan	12.7	10.6	9.8	11.2	13.0	10.8	11.8	7.8	5.7	5.0	6.7	4.8	2.9	7.4	9.9
Sri Lanka	12.2	11.4	11.7	8.4	7.7	15.9	9.6	9.4	4.7	6.5	6.2	9.8	6.3	7.6	14.0
South Asian Average	**13.1**	**9.6**	**7.6**	**8.3**	**10.9**	**6.7**	**5.6**	**7.1**	**4.1**	**5.0**	**4.5**	**5.6**	**4.8**	**5.6**	**8.2**

Source: International Financial Statistics (IFS), International Monetary Fund, Washington DC
**Economic trends, Bangladesh Bank*

This recent experience of fairly low and stable rate of inflation is widely regarded as being the result of last four years' bumper production of food and cereals in the country since the end of record disastrous flood of 1998. The fact that the CPI (base; 1995=100) is heavily weighted toward food items (more than 58-percent) where the share of cereal items including rice in CPI food items represents almost 80 percent. Therefore, the cereals combined have been assigned almost 50-percent weight in the CPI. Thus, any good harvest of rice and other cereals would have a very strong impact in lowering the overall price level in terms of CPI. However there remain doubts among economists, policy-makers and international donors about the true reasons of such low level of inflation. They debated the causes of inflation because most of the direct determinants that is, macroeconomic factors that would cause higher inflation rate were present during the said period but in reality these did not create any upward preassure on prices.

A closer look at the general trend of major macroeconomic variables in Bangladesh will support the above arguments which could be summarised as follows: **Firstly**, a reasonably high growth rate of nominal money supply, say 15-16 percent on average in the last couple of years, has been recorded. Even during the last decade and a half, the rate of inflation in Bangladesh has not kept pace with the growth rate of the money supply. **Secondly**, the nominal devaluation, both high and low in rate, has taken place during whole the decade of 1990s. It has registered a total devaluation of as high as 23.1 percent from September 1995 to October 2000. The largest single devaluation of nearly 6 percent occured on October 2000. **Thirdly**, a catastrophic country-wide flood occured in 1988 which ravaged the economy substantially that caused a heavy shortfall of food and all other agricultural production (Mahmud 1990). **Fourthly**, an alternative measure of excess demand that is deviation of actual output from the trend output (i.e., output gap) has existed during the said period. All these above mentioned factors would in principle be capable of generating high inflationary pressure on general price level. But the inflation experience shows the quite opposite picture. What are then the reasons that created downward pressure on the price level? Only a thorough empirical study based on econometric methods can provide a clearer picture. To this effect, our current effort will be to form four alternative inflation models following the existing literature and undertake empirical estimation of each of the inflation models using multivariate single equation co-integration equation technique with reference to the Bangladesh economy.

3. Factors Influencing Inflation in Bangladesh: A Theoretical Outlook

As discussed above the historical evidence suggests that even in the long run, a moderately high rate of excess money supply growth (i,e., net of GDP growth) did not cause inflation in Bangladesh. This raises several important related issues: (1) short-run price movements in Bangladesh may be better explained by changes in real phenomena rather than by changes in the nominal money supply, (2) changes in the nominal money supply may have significant real effects in the long run. These two issues are explained in view of the two fundamental monetarist propositions; **First**, inflation is a purely monetary phenomenon and that in the long run the rate of inflation equals the rate of monetary expansion in excess of the growth of capacity output[2]. **Second**, money supply growth can have no impact on real output in the long run though some impact can be found in the short run. The implication of these propositions would be found in the existence of lags in the relation between money supply and prices and also between money supply and real output. But one of the problems concerning the analysis of lag effect is that it is very difficult to determine the exact length of the lags in these relationships with any degree of certainty. This arises because of the diversity of circumstances and factors associated with monetary disturbances generated at different times in an economy. In fact, the transmission mechanisms linking monetary growth and inflation are also affected by other structural factors and institutional pecularities specific to a developing country like Bangladesh (Agry 1970).

Bangladesh's fiscal policy is closely linked to its monetary policy because public budget deficits are mainly financed by increases in money supply. Theoretically, expansionary fiscal policy would generate an increased supply of high-powered money in the face of frequent adjustment in the budget deficit and can provoke price spiral if there is no excess capacity in the economy (Friedman 1956; Friedman and Kuttner 1992). However, increasing government borrowing from central bank is seen as highly inflationary in the case of Bangladesh. But it should be noted that under the situation of chronic slow down of general demand (i.e. a general glut in the economy) higher public expenditure can create higher economic activity by protecting the falling trend in demand which is finaced by incresed public borrowing (Kiguel 1989). However, there is a general consensus among economists and policy-makers that regulating the growth of money stock is necessary to achieve a fairy stable price level and full employment of an economy (Sims 1972).

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[2] The quantity theory of money as explained by the famous equation of exchange (in growth form $\hat{p} = \hat{m} + \hat{y} - \hat{v}$) explains the fact that in the long-run increase of the money supply in excess of real money demand would increase the price level though in the short-run some real output effect could be produced.

It is to be noticed that, by and large, the monetary policy of Bangladesh gves excessive stress on short run economic stabilization while a lesser degree of importance is given to the issues of long run economic growth. The price effects of such a policy regime depend largely on the output responses realized in both the public and private sectors of the economy. And therefore, the lag effect of money supply on prices is very important to be considered in an inflation model especially in the context of Bangladseh which was experiencing moderately high rate of monetary expansion since the beginning of the last decade.

In a small open economy like Bangladesh the magnitude of the effect of devaluation on domestic inflation is primarily dependent on the share of expenditure on traded goods in total expenditure which is called first order or short run effect assuming the role of money as neutral (Kreinin 1972; Juselius 1992). But the long run effect depends on the overall policy environment in place and also depends on how the prices of non-traded goods respond to a shift of resources away from the sector. When we take for granted the non-neutrality of money, the inflationay impact of devaluation would be different. Implicit in this later assumption is that money is identified both as the causes and cure of the country's balance of payments (BOP) problems.

The monetary authorities expand the monetary base by increasing their stock of assets (credit creation). The increase in the money supply will induce increased expenditures, raising both the levels of imports and national income. Assuming that increases in imports do not offset the increase in expenditure there will be upward pressure on prices. A surplus in the current account balance results from an excess aggregate demand for money relative to supply. This excess demand can be satisfied by an inflow of money (reserves) from abroad and corresponds to the surplus in the current account under fixed or limited flexible exchange rate system. The opposite chain of events would follow from an excess supply of money. This implies that in the long run contractions in the monetary base via outflows of foreign reserves will deteriorate the situation of current account. Thus, in order to remove the deficit in the current account when we use devaluation as a policy strategy, it will exert an upward pressure on domestic price level (Dornbusch and Kuenzler 1988).

However, under a fixed rate regime that rules out devaluation as a policy instrument, the exchange rate provides a nominal anchor. The other domestic variables such as money supply and prices have to adjust to this anchor. In such circumstances, one can expect that the exchange rate anchor imposes 'monetary discipline effect' in the sense that policy makers will be less inclined to pursue expansionary monetary policy (Tanzi and Blejer 1982). It is also argued that for a given rate of monetary expansion, there would be less inflation under a fixed exchange rate regime. The reason is that some of the excess money will be absorbed by increased current account deficit in the balance of payments, and will not translate into higher prices (Branson 1979). The implication of the above arguments is that under an exchange rate regime that permits devaluation as a policy tool, one can expect higher inflation. Moreover, as discussed earlier, devaluation directly increases the domestic prices of traded goods and the demand switch can also cause an increase in the price of non-traded goods if their supply is not perfectly elastic (Neyberg 1979).

On the other hand, devaluation may also have a dampening effect on inflation because of its potentially contractionary impact on aggregate demand. There are a number of reasons behind this possibility. First, the initial increase in the general price level reduces the real money balance and creates an excess demand for money. Firms and households would then reduce their spending to adjust to the lower real money balances. Second, the fall in real wages of workers caused by domestic price rise effectively redistributes income in favour of owners of capital (Purvis 1979). If the latter have a lower marginal propensity to consume, the effect on aggregate demand will be negative. Third, devaluation can have a contractionary impact if it worsens the trade balance in the specific circumstances of a particular country.

Several empirical studies yield mixed results in view of the theoretical aspects as explained above. On the basis of a pooled time-series and cross-section data from 12 developing countries, Edwards (1991) concluded that devaluation exerted a small contractionary effect in the first year. The effect was reversed in the second year and became expansionary. In the long run it failed to generate any effect on inflation. The studies on the emerging open economy such as Bangladesh that investigate the link between devaluation and inflation also show conflicting results. Thus, Taslim (1982) and Nazma (1991) reported a statistically significant relationship between inflation and devaluation. Hossain (1989) found the efficacy of the Monetarist model in explaining the determinants of inflation in Bangladesh. Kabir (1984) and Nazma (1991) found that devaluation has a significant impact on the inflationary situation of Bangladesh.

The present study differs from the previous studies on Bangladesh's inflation in the sense that it adopts a more robust econometric technique which was not applied earlier. Using co-integration and error correction modeling technique and incorporating more recent data set, the present study tries to find out whether the role of exchange rate depreciation is becoming stronger than the domestic variables such as output gap or excess monetary growth. All the previous studies were done using the observation period when the economy of Bangladesh had not yet undergone into a reasonable transformation in terms of globalization (the increasing trend of integration of the national economy in the global market) and both the real and financial markets of Bangladesh were not fully liberalized or opened to external competition. Hence, the earlier studies could not fully capture the impact of trade liberalization and financial reforms such as the flexible foreign exchange rate or the domestic interest rate changes on the domestic price level.

Therefore, the present study will attempt to identify the real parameters which include not only the domestic sector variables but also the foreign sector elements that determine the inflationary situation of Bangladesh. In doing so, the study will try to incorporate the role of exchange rate depreciation and interest rates on inflation in Bangladesh as the most dominant factors in explaining the inflation behavior. Thus the main hypothesis of the present study is to test to what extent the change of domestic financial market conditions as well as foreign sector changes have affected inflation in Bangladesh.

4. The Theoretical Model

The analyses reported above support the idea that excess domestic demand, generated by expansionary fiscal and monetary policies, could be the principal force behind the high rate of inflation in the previous decades of 1970s and 1980s. But the subsequent pattern of low to moderate inflation in the decade of 1990s and in also in the current decade may be attributed to the high real income growth more, and specifically a spectecular growth of agricultural output *(during 1999-2002)* that played a significant deflationary role by increasing the demand for real money balances. The fact that the relative strength of the impact of money growth and devaluation was seen as weaker because of its lag effects at various lengths which was much discussed in the previous section of the paper.

Our empirical work focuses on modeling and estimating the changes of price level index. To measure the impact of relevant explanatory variables discussed above and predict the likely inflationary outcome of a specific mix of policy measures and exogenous factors, two alternative inflation models are derived, that is, we follow two approaches. First, we derive a simple monetarist equation following Herberger's formulation (1963) which is based on the theory of demand for real money balances and that relates the inflation rate to the rates of growth of real income and money supply, and the cost of holding money. In the second instance, we model inflation through an output gap equation. Both models are demand-oriented, although one emphasizes monetary elements and the other real activity. Neither the monetary model nor the real activity model captures the structural or cost-push aspects of inflation which, we believe, have significant role in price inflation of Bangladesh. Therefore, in order to capture the role of imported inflation in price formation as a cost-push pressure we incorporate in both models variables like world/foreign price and foreign exchange rate[3]. The equations of two inflation models are derived and analysed in the next section below.

4.1 The Monetarist Model

Our monetarist model assumes that changes in money supply are exogenous rather than being determined jointly with price changes. The model also assumes that changes in real income are exogenous, not jointly determined with money supply changes. In the context of Bangladesh that assumption is plausible, since almost a quarter (but much larger in earlier decades) of our output originates in agriculture where output depends on exogenous factors such as weather and technology. To derive the inflation or the price equation in the monetarist line we start from a simple model of price determination in which the overall consumer price level (P_t) is a weighted average of the price of tradable goods (P_t^T) and non-tradable goods (P_t^N) and can be represented in log linear form as below:

$$logP_t = \alpha \, logP_t^N + (1-\alpha) \, logP_t^T , \qquad (1)$$

where α represents the share of non-tradable goods in the consumer price index. The price of tradable goods (P_t^T) is determined exogenously in the world market, with their price in the domestic currency terms being a function of the foreign prices (P_t^f) and the exchange rate (E_t) as:

$$logP_t^T = logE_t + logP_t^f , \qquad (2)$$

It implies that both an increase in the (E_t) and an increase in foreign prices will lead to an increase in the overall price level, that is, imported inflation is equal to the change in the (E_t) plus the foreign inflation rate.

The price of non-tradable goods (P_t^N) is assumed to be determined in the domestic money market so that the demand for non-tradables moves in line with overall demand in the economy. As a result, the price of non-tradable goods is determined by the money market equilibrium condition, real money supply (M_t^s/P_t) equals real money demand (M_t^d), which yields the following equation for non-tradable goods prices:

$$logP_t^N = \beta \, (logM_t^s - logM_t^d), \qquad (3)$$

where M_t^s represents the nominal outstanding stock of money, M_t^d is the demand for real money balances and β is a scale factor representing the relationship between economy-wide demand and demand for non-tradable goods. The aggregate demand for real money balances (M_t^d) is assumed to be determined by the level of real income, Y_t, inflationary expectation (Pe_t), and the opportunity cost of holding money, (rate of interest r_t, that is, the rate of return) vis-a-vis other assets (real or financial):

[3] The economy of Bangladesh is increasingly open as evidenced by the fact that more than 35 percent of our GDP is from external sector activities (import and export). Many of the import goods are raw materials and inputs and also our exports are highly import dependent. The higher international price of importables along with the exchange rate depreciation has direct contribution in raising the cost of industrial as well as agricultural production. Thus, the increase of the price of importables is treated as a cost-push pressure in local price upsurge.

$$logM_t^d = a_1 \, logY_t - a_2 \, Pe_t - a_3 \, r_t , \qquad (4)$$

The expected rate of inflation in period (t) is formed, based on adaptive expectations, as:

$$Pe_t = d_1 \, \Delta logP_{t-1} + (1-d_1) \, logP_{t-1}, \qquad (5)$$

where ($\Delta logP_{t-1}$) represents actual inflation in period t-1 (where denotes first difference operator, i.e., ($logP_t = logP_t - logP_{t-1}$) and p_{t-1} is the expected rate of inflation in period *t-1*. Substituting equations (5) into equation (4) yields the following log linear money demand function:

$$logM_t^d = a_1 \, logY_t - a_2 \, d_1 \, \Delta logP_{t-1} - a_2 \, (1-d_1) \, logP_{t-1} - a_3 \, r_t , \qquad (6)$$

Consequently, the price of non-tradable goods can be derived after substituting equation (6) into equation (3) as:

$$logP_t^N = \beta \, (logM_t^s - a_1 \, logY_t + a_2 \, d_1 \, \Delta logP_{t-1} + a_2 \, (1-d_1) \, logP_{t-1} + a_3 \, r_t) \qquad (7)$$

To get the final price function, equation (2) and (7) can then be substituted into equation (1) as:

$$logP_t = \alpha \, \beta \, [logM_t^s - a_1 \, logY_t + a_2 \, d_1 \Delta logP_{t-1} + a_2 \, (1-d_1) \, logP_{t-1} + a_3 \, r_t \,] + (1-\alpha) \, (logE_t + logP_t^f) \qquad (8a)$$

Based on the underlying assumptions discussed above, the following a priori assupmtions can be made regarding the signs of the explanatory variables as:

$$logP_t = f \, (\underset{+}{logM_t^s}, \; \underset{-}{logY_t}, \; \underset{+}{\Delta logP_{t-1}}, \; \underset{+}{r_t}, \; \underset{+}{logE_t}, \; \underset{+}{logP_t^f}) \qquad (8b)$$

where any increase in nominal money stock (M_t^s), expected rate of inflation ($\Delta logP_{t-1}$), exchange rate (E_t), and world price of tradable goods (P_t^f) lead to an increase in prices (P_t) in period (t). Again, an increase in the opportunity cost of holding money, that is, a rise in nominal interest rate (own rate of return, r_t), by reducing the demand for money balances, will also result in an increase in prices, while an increase in real income (Y_t) is expected to expand the demand for real money for transactions and, in turn, lead to a decline in prices (P_t).

4.2 The Output Gap Model

Our so-called output gap equation is developed along the spirit of standard hypothesis of expectations-augmented Philips Curve hypothesis in determining domestic component of inflation (Sargent and Wallace 1973). It is also known as real activity model that relates the inflation rate to the percentage deviation of output from its trend and to price expectations. For Western economies, inflation is expected to be positively related to the deviation of output from trend, following a general expectations-augmented Philips Curve relationship. For the predominantly agricultural economy like Bangladesh, however, the expected relationship may be reverse; that is, a stagflation relationship may be the natural one. A rise in agricultural output caused by good weather should lead to a decline or deceleration in agricultural prices and an increase in output in industrial sector as raw material costs decline and urban wage demands are dampened (Sheehey 1976; Kabir 1984).

To derive the output gap model, we start from equation (1) (same as the one used while constructing the monetarist model) but specified in inflation rates (rather than price levels). Consumer price inflation is a weighted average of domestic inflation (π_t^D) and imported inflation (π_t^M) with τ as the share of imported goods in the consumer price index:

$$log\pi_t = \tau \, log\pi_t^M + (1-\tau) \, log\pi_t^D , \qquad (9)$$

Again, with the price of imported goods, which is equal to the exchange rate times the foreign price level, determined in the world market, imported inflation is a function of the change in exchange plus the foreign inflation rate which can be written in log linear form as :

$$log\pi_t^M \;=\; \Delta logE_t \;+\; log\pi_t^f\,, \tag{10}$$

where Δ denotes first difference operator, i.e., $\Delta logE_t = 100*(logE_t - logE_{t-1})$
Inflation in the non-tradable goods sector (domestic inflation) is assumed to be determined by the standard expectations-augmented Philips Curve form:

$$log\pi_t^D \;=\; log\pi_t^e \;+\; \mu\,(logY_t - logY_t^*)\,, \tag{11}$$

where Y_t is the level of actual output, Y_t^* is the level of potential output and π_t^e are inflation expectations (which may be proxied by lags of the inflation rate). The output gap (Y_t - Y_t^*), in turn, is determined by lags of interest rates (the instrument of monetary policy) and real exchange rate changes:

$$Y_t - Y_t^* \;=\; C + A(L)\,i_t \;+\; B(L)\;(\Delta E_t - \pi_t), \tag{12}$$

where again, Δ denotes first difference operator and L is the lag operator e.g., E_{t-i}, here *i* indicates the ith lag. Substituting equations (11) and (12) into equation (10) results in a model where inflation is a function of the output gap, exchanges rate changes and foreign inflation. Monetary policy influences inflation through the impact of interest rates on the output gap as formulated in equation (13), and the exchange rate influences on inflation and the output gap. Solving for $_t$ yields :

$$\pi_t \;=\; C_o + C_1(L)\,log(Y_t - Y_t^*) + C_2(L)\,log\pi_t^e + C_3(L)\,\Delta logE_t + C_4(L)\,log\pi_t^f\;, \tag{13a}$$

where L is again the lag operator and Δ is the difference operator. Here the lags of actual inflation are used as a proxy for inflation expectations in the absence of any survey measures of inflation expectations. Based on the underlying assumptions discussed above, the following a priori assupmtions can be made regarding the signs of the explanatory variables as:

$$\pi_t \;=\; f\,(\;\underset{+}{(L)log(Y_t - Y_t^*)},\quad \underset{+}{(L)log\pi_t^e},\quad \underset{+}{(L)\Delta logE_t}\,,\quad \underset{+}{(L)log\pi_t^f}\;) \tag{13b}$$

where any increase in output gap (Y_t-Y_t^*), expected rate of inflation (π_t^e), exchange rate (E_t), and world price of tradable goods (π_t^f) lead to an increase in the inflation rate (π_t) in period (t). The inflation forecast, however, need not be solely derived from a single model; at times, one may need to incorporate a large number of variables in forming the inflation forecasts, particularly when understanding of the structural economic relationships is not known with certainty.

5. Data and Estimation Methodology

Time series for quarterly GDP data is not available in Bangladesh. But, timely data is available on agricultural production on a quarterly basis. Consequently, we thought that we can choose between two options ; i) a quantum index of industrial (manufacturing) production can be used as a proxy for output which is, in fact, one real alternative as there are published data, or ii) we can construct quarterly GDP by our own method. Later we found that industrial quantum index did not show statistical significance in econometric estimation which implies that industrial growth does not appear to influence inflation. To us, this result seems plausible from the fact that industrial quantum index of Bangladesh covers only large scale manufacturing output, and the latter constitutes a small fraction of our total GDP (less than 10 percent). Again, on an annual basis, GDP growth and growth of industrial output have a very low degree of correlation. In other words, growth in large scale manufacturing output may not be a good proxy for overall GDP growth. So we exclude this variable from econometric model. Consequently, we construct quarterly GDP data and use in our econometric model estimation[4]. We have applied co-integration technique and vector error correction method (VEC) in estimating the econometric function. All the variables used are in log forms except interest rates, and the rate of currency depreciation. The sample period used in the estimation work is 1973.1 to 2002.2[5]. The dependent variable is consumer price index (P). All the statistical figures except GDP are taken from the IMF's data file 'International Financial Statistics (IFS)'.

5.1 Empirical Methodology and Estimations of Co-integration Relations and Error Correction Models for price formation Function

Having established the vector of variables of interest in our money demand model we proceed with the econometric estimation. The empirical analysis pursued involves a number of steps. First, unit root tests are conducted to determine whether the variables included in the empirical analysis are stationary and also the order of integration of each series. Second, the co-integration relation between consumer price index (P) and the variables specified in equation (8b) and (13b) were tested for using four different inflation models which are basically derived from the two broad macro-based models of inflation. We have observed that there exists four co-integrating relations (which shown correct signs for independent variables) specified from the two basic theoretical models: monetary model and output gap model. Third, single equation error correction models were obtained for each of the co-integrating relations. The four ECMs corresponding to each co-integrating relation also show more or less the correct representation for short run adjustments of the long run dynamic equilibrium between variables of interest established in their co-integration relations which we will discuss subsequently in this section.

5.2 Stationarity of Time Series Data

To have a meaningful understanding of the relationship between two or more economic variables using regression technique, we need that the time series (TS) satisfy some stationarity properties. Non-stationarity in a TS generally arises due to the presence of trends in the data which is stochastic in nature (random walk process) and it confirms that the data has a unit root process. Stochastic behavior of TS is sometimes characterized by what is called drifts (first upward and then downward). Any regression result with non-stationary TS provide spurious relationships between variables and therefore, provide misleading implication of the relationship. However, the presence of a deterministic trend indicates that the series has no unit root process and it is a required condition to provide valid economic implication of the empirical results generated from statistical estimation techniques. Therefore, the variables in the economic model are required to be tested for its stationarity property and the order of its long-run integration prior

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[4] In constructing quarterly GDP we follow seasonal factors for the variation of agricultural production. We first categorized major argicultural crops into 6 groups: three varieties of rice, wheat, tea and jute, production of all of which have been heavily influenced by seasonality. For example, in rice production we have three major harvesting periods; Aman rice (October-December); Boro rice (April-June); Aus rice (July-September). For other three agricultural goods the harvesting periods are: wheat (January-March), tea (July-December) and jute (July-September). For other major sectoral output i,e, industrial and service sector output there are very little seasonal variation and therefore, their output are distributed equally into four quarters of each year. It is notable that at present there is a project in the BBS on the quarterly estimation of GDP in Bangladesh which is in progress and in fact, the preliminary draft of the project shows the similarity of fixing the harvesting periods of six agricultural production but try to estimate the seasonal variation of industrial and service sector output as well.

[5] The selection of the sample period which is not updated (1973.1-2002.2) in our econometric estimation is partly due to the paucity of data and partly due to time constraint. The forthcoming version of the paper will use the updated data in the estimation.

to estimating a statistical relationship among them. The tests of stationarity in the TS of all the variables in question are performed by applying the popular Augmented Dickey-Fuller (ADF) test. Let an *AR(1)* process :

$$x_t = \rho x_{t-1} + By_t + u_t \qquad (14)$$

where y_{ts} are optional exogenous variables which may contain a constant or a constant and a time trend, ρ and B are parameters to be estimated, and the u_t is the stochastic error term that follows some classical assumptions:

$E(u_t) = 0,\ Var(u_t) = \sigma^2$ *and* $Cov(u_t, u_{t-1}) = 0$ (i, e., white noise disturbances)

Now if $\rho = 1$, we say that the stochastic variable x_t has a unit root. (simple DF)
The ADF test is based on the estimation of regression of the following general specification; eq. (16) which is an alternative (for general *p*th variables, *AR(p))* form of above *AR(1)* process expressed in first difference term of the variables that is, $\Delta x_t = (x_t - x_{t-1})$. For higher order serial correlation, the assumption of white noise disturbances is violated which is corrected parametrically in the ADF)

$$\Delta x_t = \alpha_0 + \alpha_1 t + \alpha_2 x_{t-1} + \sum_{i=0}^{p} \theta_p \Delta x_{t-p} + \varepsilon_t \qquad (15)$$

where Δ is the first difference operator, α_0 is the intercept (constant), t denotes a linear time trend (optional exogenous or deterministic variables) and α_1, α_2 and θ_i are the coefficients where $\alpha_2 = \rho\text{-}1$. The random variable ε_t is a normally distributed white noise error term (that is, the residual series ε_t is free of any significant autocorrelation and it is NID with mean 0 and SD constant).

The lag length *p* is set so as to ensure that any autocorrelation in Δx_t is absorbed, and the error term is distributed as white noise. Using quarterly data, we find that by initially setting p = 6, all residual autocorrelation is captured. In eq. (16) we test the null hypothesis that the series x_t have unit roots that is $H_0 : \alpha_2 = 0$ ($\rho=1$) against the alternative $H_1 : \alpha_2 \neq 0$ by comparing the calculated tau (τ)-ratio (severer the than conventional t-ratio) of α_2 with critical values based on the simulations response surface in Mackinnon (1991 and 1996) which are essentially adjusted t-values[6]. If the absolute value of the calculated τ-ratio is greater than the critical value, then the H_0 of a unit root (non-stationarity) is rejected and the time series x_t can be defined as integrated of order zero, I(0) in levels and hence, treated as stationary. Additionally, tests for unit root can be done with or without the constant and time trends. For example, our eq.(16) includes both constant and time trend as a general form.

5.3 Result of Unit Root Test

The results of ADF unit root test that was applied in both with and without time trend specification for identifying the stationarity properties in TS are presented separately in table-2 (see annex). The estimated results show that the null hypothesis, H_0, (have unit roots) can not be rejected for all the variables in question, that is, p_t, $m1_t$, e_t, $DEPOINT_t$, and p^f_t are non-stationary in levels forms for both the cases of with and without time trend (i. e., they became stationary only after first differencing) except three variables $m2_t$, y_t and $(y\text{-}y^*)_t$. It is to be noted that $m2_t$ is seen as non-stationary only when we test with no time trend fit but even in the same fit the

[6] The test statistic is not distributed according to a standard t-distribution. Dickey and Fuller (1976) have tabulated the distribution of the statistic, which, however, varies depending on whether the model is estimated with or without a constant and a trend. Later, the critical values have been tabulated by Mackinnon (1991 and 1996) using the technique of Monte-Carlo simulations response surface.

Phillips-Perron (PP) Statistic could not reject the null of unit roots where the PP statistic value is shown in parentheses.

For the variable y_t we found that it is non-stationary in no time trend fit but stationary in the fit with time trend but when we considered the PP statistic that could not reject the null of unit root. The variable $(y\text{-}y)^*_t$ is found to be stationary in both the fits of no time trend and with time trend but the null of unit root is rejected at a very low level of significance for both fits (10 percent level). Thus, after observing the difference in unit root test results of ADF and PP statistics, finally these variables were also included in the co-integration analysis. All these variables were identified as stationary in the first difference which means that they are integrated of order one, I(1), in level forms. The immediate implication following from the unit root tests of TS data set is that any dynamic specification of the model in the levels of the series (such as the partial-adjustment model, frequently found in the literature) is likely to be inappropriate, and may be plagued by problems of spurious regression. However, we may be guided towards an error-correction form if the series of the model are co-integrated. So the next step is to establish a co-integrating relationship between these non-stationary variables in the model.

5.4 Estimation of Co-integrating Relationship and Long-Run Behavior of the Determinants of Price Inflation in Bangladesh

After the confirmation from the unit root test (above) that all of the variables of interest are having unit roots showing the presence of non-stationarity in their TS data and also after determining their order of integration which were one, I(1), we have forward to the tests for co-integration. The idea of co-integration is to determine if the stochastic trends in all the variables that contain unit roots have long-run co-integrating relationship between them. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series (which have the same order of integration) may be stationary. If such a stationary linear combination exists, the non-stationary TS are said to be co-integrated. The stationary linear combination is called the co-integrating equation and may be interpreted as a long-run equilibrium relationship among the variables. In the original Engle and Granger approach to co-integration it is established that if the μ_t,s are stationary, differences between the x_t series ultimately die out and the variables x_t are thought to exist in a longrun balance.

In order to test whether there exists co-integrating relationships among non-stationary variables in the model we have applied the Johansen (1988, 1991 and 1995) and Johansen and Juselius (1990, 992) multivariate co-integrating methodology which jointly determine empirically the number of r (maximum k-1) co-integrating vectors from a vector of k endogenous variables in the model along with coefficients of the variables and the adjustment parameters. Johansen procedure is based on the technique of reduced rank regression where r is the rank of the original vector of variables with order k * r. Generally, a set of non-stationary variables which (must) have same order of integration (all considered as endogenous in Johansen procedure) is said to be co-integrated if a linear combination of their individual integrated series, which are I(d), is stationary. Intuitively, Johansen's method follow VAR-based coi-ntegration test. Consider a VAR of order p:

$$x_t = A_1 x_{t-1} + \text{-----------} + A_p x_{t-p} + By_t + \mu_t \qquad (16)$$

where x_t is a k-vector of non-stationary I(1) variables, y_t is a d-vector of deterministic variables (such as a constant, or a constant and time trend etc.) and μ_t is a vector of errors (innovations). We can rewrite this VAR as (after taking first difference):

$$\Delta x_t = \Pi x_{t-1} + \sum_{i=0}^{p-1} \Gamma_i \Delta x_{t-i} + By_t + \mu_t \qquad (17)$$

where $\Pi = \sum_{i=0}^{p} A_i - I$; and $\Gamma_i = \sum_{j=i+1}^{p} A_j$

Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank $r < k$, then there exists α and β matrices with order $k * r$ each with rank r such that $\Pi = \alpha\beta$ and $\beta^* x_t$ is I(0) ; r is the number of co-integrating relations (the rank) and each column of β is the co-integrating vector. The elements of α are known as the adjustment parameters (as explained below) in the VEC model. Johansen's method is to estimate the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank ($r < k$) of coefficient matrix Π.

5.5 Estimation Results of Co-integrating Relations between the Price Level and Its Various Determinants

In our empirical estimation the Johansen procedure is applied to a fourth order VAR (with maximum lags four) to test for co-integration in mainly two sets of equations (equation-9a and 15a). In our deterministic trend component specification in co-integrating equations we choose case-3 (linear trend assumption) that is, we assumed that the level series of endogenous variables have linear deterministic trends but the co-integrating equations have only intercepts (constants) [7]. That choice is based on our experience from the unit root tests which have shown that the critical values of ADF Statistics for all the variables were improving when we consider a time trend and also they are stationary in first difference (integrated of order one). Again, we observed that inclusion of time trend in the VAR did not make any significant effect on the value of Trace statistic or maximum eigenvalue statistic in determining the co-integrating relationships. The results are presented in Tables- 3 to 6 (see annex).

The monetary model literature suggests that for the case of pure monetary model of inflation a co-integrating (or long-run) relationship may be found between prices (p_t), real money holdings ($m1_t$, or $m2_t$), nominal exchange rate (e_t), price expectation (Δp_{t-1}) and the level of real income, y_t. But we may also expect to find a similar co-integrating relationship between growth of prices (Δp_t), deviation of monetary growth over output growth ($\Delta m1_t - \Delta y_t$), the deposit rate of interest (DEPOINT$_t$), the rate of exchange rate depreciation (Δe_t), and price expectation (Δp_{t-1}) in case of monetary growth model of inflation. Similarly, the simple growth theoretic model of inflation suggests the presence of a co-integrating relationship in terms of growth between prices, domestic money holdings, output, exchange rate depreciation and the opportunity cost of alternative asset holdings.

Another variant of the inflation model known as Phillips Curve or real activity or output gap model which also suggests that a co-integrating (or long-run) relationship may be found between inflation (π_t), growth of actual output over potential output ($\Delta y_t - \Delta y^*_t$), price expectation ($\Delta p_{t-1}$) and the exchange rate depreciation (Δe_t). We therefore, are obliged to examine all these possibilities. The order of integration tests indicate that focus should be on the I(1) series for general price level, money, income, interest rates and the exchange rate, but since Δp_t seems to be a stationary series then by definition it will not be co-integrated with other series. However, even though the statistics seems to conclusively reject non-stationarity for inflation we initially allow for the possibility that there are biases in the critical values of statistics and include Δp_t in the co-integration analysis. Note that the idea that money holdings do not play a role in the

[7] In the case of tests for co-integration the critical values for the tests statistics differ according to the number of variables, k, in the co-integrating regression as well as the assumptions regarding the intercept and deterministic trend component (five different specifications are available).

determination of actual rate of inflation may not generally be true, rather the co-integration result simply implies that there is no long-run equilibrium relationship between money holdings and price inflation.

We first choose to test for the possibility of co-integrating relationships between the variables captured in the monetary model (equation 9a) by running a series of bivariate co-integrating regressions[8]. We did the same for the other three models such as the monetary growth model, the growth theoretic model and the output gap model separately. For all four models, we have found the existence of a bi-variate co-integrating relationships between price level and the variables of interest such as $m1_t$, y_t, Δp_t, e_t, Δe_t, $DEPOINT_t$, p^f_t and $(y\text{-}y^*)_t$. In all the bi-variate co-integrating relationships, the critical values of the maximal eigenvalue statistics and trace statistics easily (strongly) reject the null hypothesis of no (zero) co-integrating vector in favor of a single co-integrating vector in each case at the 5 percent levels of significance and even in some bi-variate cases the null hypothesis of no co-integration is rejected at the one-percent level of significance. The existence of bi-variate co-integrating relations implies that there were long run equilibrium relationships between price level and each of the variables in interest seperately such as $m1_t$, y_t, Δp_t, e_t, Δe_t, $DEPOINT_t$, p^f_t and $(y\text{-}y^*)_t$. The variables broad money ($m2_t$) and foreign price level (p^f_t) have shown no long run equilibrium relationships with the inflation rate.

In the next step we tested 4 major co-integrating equations; the pure monetary model of inflation, the monetary growth model, the growth theoretic model and the output gap model separately to estimate the multivariate co-integrating relationships following the Johansen and Juselius method. In all cases the critical values of the maximal eigenvalue statistics and trace statistics easily (strongly) reject the null hypothesis of no (zero) co-integrating vector in favor of a single co-integrating vector in each case at both the 1-percent and 5-percent levels of significance. These imply that there were longrun stationary relationships between the price level or the inflation rate and the independent variables captured in our theoretical specification; put another way, the price level in the Bangladesh economy expressed in (p_t) is significantly influenced by the level of scale variable y_t, (real income) and also by the expected rate of inflation (Δp_{t-1}), the level of exchange rate (e_t), rate of depreciation of exchange rate (Δe_t), money supply ($m1_t$), deposit interest rate ($DEPOINT_t$), the foreign price level (p^f_t) and the level of the gap or deviation of actual to potential GDP or output $(y\text{-}y^*)_t$.

However, for two variables, broad money ($m2_t$) and foreign price level (p^f_t), the coefficient signs were not theoretically acceptable in the co-integrating relations and also they were not statistically significant and therefore, those variables were excluded from our analysis of multivariate co-integrating relationships. The possible reason of such absence of co-integrating relation of broad money with inflation might be that in the context of Bangladesh, the major component of broad money is the quasi money (almost 80 percent of broad money). In fact, quasi money is basically term deposits which is used for such activities that usually could not be affected by consumer price index effectively. The absence of a co-integrating relation between the foreign price level and inflation might be due to the fact that any important change in Bangladesh's import price index is mainly caused by the devaluation or depreciation of the

[8] As in juselius (1992) and Dureval (1998), the co-integrating analysis is conducted for each sector (monetary, labor and external) separately, for a number of reasons. In the first place, the data sample is not large enough to examine systems with as many as seven variables. Secondly, as Juselius (1992) notes, it becomes increasingly difficult to interpret the co-integrating space as the number of variables added in the VAR grows. Even though the co-integration analysis is conducted for four different models separately, the analysis is still able to capture most of the economically meaningful bi-variate long-run relations that might affect prices and the variables of interest. Moreover, we also established two separate functions for monetary model and output gap model that includes all the seven variables to see if there exists co-integrating relations among all the variables of interest.

exchange rate and not due to change of international price and in fact, the latter price has proved to be more stable for most of the Bangladesh's importables[9].

Several important remarks could be developed from the results of co-integrating relations. **First**, if we look at tables-3 to 6 it can be observed that in the pure monetary model, the coefficient value for the explanatory variable y_t is stronger than the coefficient of narrow money supply which means that the hypothesis that the price inflation in Bangladesh is essentially a monetary phenomenon is not a very robust hypothesis. The same result can be seen in the growth theoretic model where the coefficient of output growth is much stronger than the coefficient of narrow money growth. Furthermore, in the monetary growth model we can see that the variable $(\Delta m1 - \Delta y)_{t,,}$ that is the rate of monetary growth over real output growth has also long run co-integrating relation with price which is also consistent with the results of pure monetary model in the sense that any monetary growth in excess of real output growth is responsible for price inflation in Bangladesh.

Second, one common phenomenon is strongly evident in the estimation result of every co-integrating relation is that the price expectation variable (here one-period lagged price level) has a substantial role in price formation in Bangladesh which means price level in Bangladesh is downward sticky and very rigid to adjustment by any policy. **Third**, the role of the level of exchange rate or depreciation of the exchange rate in price inflation is very important as can be seen from the very high coefficient values in every co-integrating relation for four different inflation models. **Fourth**, the explanatory variable, opportunity cost of holding money as proxied by deposit interest rate (which is also directly responsible for the speculative demand for money) has shown co-integrating relation with price inflation only in the monetary growth model and growth theoretic model and it's coefficient value is not very strong. The reason is simple: interest rate has not been determined by the market forces for a long time in Bangladesh and also its role as an opportunity cost of holding money is not very strong because there are few alternative financial assets for a typical household.

And **finally**, we can observe from the output gap model that there exists a strong long-run co-integrating relation of price with deviation of actual output over potential output with a high coefficient value[10]. In the same model the price expectation variable shows that a three-quarter lagged price level strongly explains the inflation rate in the present quarter. So in the context of Bangladesh the expectation augmented Philips Curve type real activity model (output gap model) is also powerful to explain the long run equilibrium relationship between output gap and price level which again supports the argument that inflation in Bangladesh is not purely a monetary

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[9] One of the important imports is petroleum and petroleum products (POLs) whose share is more than 10-percent of total imports. Although the POLs' international price is highly fluctuating but its local supply price is administered by the government and has been adjusted occasionally. Moreover, the weight given to POLs is very small (about 4%) in CPI. Thus it has a very limited influence (i.,e., weak pass-through effect) on the CPI.

[10] We use the Hodrik-Prescott (HP) Method. For an economy that experiences a relatively stable growth trend with minor fluctuations over the business cycle the HP filtering technique is an efficient device. In the Bangladesh context this filter may probably give a good estimate of historical trend output. The HP filter is a linear, two-sided filter that computes the smoothed series by minimizing the squared distance between trend and the actual series, subject to an adjustment factor (λ), a penalty coefficient, on the second difference of the smoothed series. The latter parameter controls the smoothness of the series by setting the ratio of the variance of the cyclical component and the variance of the actual series. In our calculation we used the standard value of 100 for λ as recommended by Burns and Mitchell (1946) for annual data. We also calculated HP trend by giving the value of λ=50 but finally left because the HP trend line provided by λ =100 seemed more normal.

phenomenon. Rather, it is basically generated by excess growth of monetary variables, especially money supply, compared to the real output growth.

Furthermore, the adjustment coefficients or feedback parameter values (α matrix) of different co-integrating variables gives an indication of whether the feedback parameter values were sufficiently strong to determine the variables of interest such as m_t, y_t, Δp_t, e_t, Δe_t, r_t, ($DEPOINT_t$), and $(y\text{-}y)^*_t$. in a endogenous fashion. In Tables-4 and 5 (in both the growth-based models) it can seen that the dependent variable, the price level, is likely to be endogenously determined by its direct determinants. The implications of the high α values are that the fluctuations of the inflation rate have been corrected (timely or sufficiently) by the appropriate adjustments of m_t, y_t, Δp_t, e_t, Δe_t, $DEPOINT_t$, and $(y\text{-}y)^*_t$ which means that any adjustment policy through changing those variables on behalf of the central bank has important impact in inhibiting the price rise than the automatic correction of price itself by its past values.

5.6 Dynamic Relationship between Price Level and m_t, y_t, Δp_t, e_t, Δe_t and $(y\text{-}y)^*_t$: Vector Error Correction (VEC) Models

As explained above, the presence of a co-integrating relation forms the basis of the Vector Error Correction Model (VECM) specification. More precisely, the VECM specification is built in such a way that controls for co-integrating relations among the co-integrating variables. For example, in our case, the lagged residuals (errors) from the estimated co-integrating vectors would be introduced as an argument (i. e., short run adjustment in correcting the errors) in the dynamic equation of VEC Model capturing the shocks, say changes in demand for money, on changes in the other variables of the model such as the y_t, Δp_t, e_t, Δe_t, $DEPOINT_t$ and $(y\text{-}y)^*_t$ or a shocks generated in the opposite direction. The co-integrating relationships reveal the factors that affect the long run level of demand for money. However, in the short run, deviations from these relations could occur as a result of shocks to any of the relevant endogenous variables. Thus, after testing for co-integration, a VECM is estimated for each of the four models.

The VECM is conditional on co-integrating vectors and thus, specified as to regress the first (time) difference of each non-stationary endogenous variable at time-t on one period lag (at time t-1) of the co-integrating equation/vector (s) and the lagged (at time-t-i) first (time) differences of all of the endogenous variables in the system. In fact, when we impose number of co-integrating vectors as restrictions among the endogenous variables in the VAR, we move to VEC model whosegeneral form is:

$$\Delta x_t = c_0 + \sum_{i=0}^{p-1} \gamma_i \, \Delta x_{t-i} + \lambda_i \, ECT_{t-i} + \omega_t \qquad (18)$$

In our case of four alternative inflation models the forms of VECs will be as follows:

Pure Monetary Model: $\Delta p_t = c_0 + \sum_{i=0}^{p-1} \gamma 1_i \, \Delta m1_{t-i} + \sum_{i=0}^{p-1} \gamma 2_i \, \Delta(\Delta p_{t-i}) + \sum_{i=0}^{p-1} \gamma 3_i \, \Delta y_{t-i} + \sum_{i=0}^{p-1} \gamma 4_i \, \Delta e_{t-i} + \lambda_i \, ECp_{t-i} + \omega 1_t$

Monetary Growth Model: $\Delta(\Delta p_t) = c_0 + \sum_{i=0}^{p-1} \gamma 1_i \, \Delta(\Delta m1 - \Delta y)_{t-i} + \sum_{i=0}^{p-1} \gamma 2_i \, \Delta(\Delta p_{t-i}) + \sum_{i=0}^{p-1} \gamma 3_i \, \Delta(\Delta e_{t-i}) + \sum_{i=0}^{p-1} \gamma 4_i \, \Delta DEPOINT_{t-i} + \lambda_i \, ECp_{t-i} + \omega 2_t$

Growth Theoretic Model : $\Delta(\Delta p_t) = c_0 + \sum_{i=0}^{p-1} \gamma 1_i \, \Delta(\Delta m1_{t-i}) + \sum_{i=0}^{p-1} \gamma 2_i \, \Delta(\Delta p_{t-i}) + \sum_{i=0}^{p-1} \gamma 3_i \, \Delta(\Delta y_{t-i}) + \sum_{i=0}^{p-1} \gamma 4_i \, \Delta(\Delta e_{t-i}) + \sum_{i=0}^{p-1} \gamma 5_i \, \Delta DEPOINT_{t-i} + \lambda_i \, ECp_{t-i} + \omega 3_t$

Output Gap Model: $\Delta p_t = c_0 + \sum_{i=0}^{p-1} \gamma 1_i \Delta p_{t-i} + \sum_{i=0}^{p-1} \gamma 2_i \Delta(y-y)^*_{t-i} + \sum_{i=0}^{p-1} \gamma 3_i \Delta(\Delta e_{t-i}) + \sum_{i=0}^{p-1} \gamma 4_i \Delta DEPOINT_{t-i} + \lambda_i ECp_{t-i} + \omega 4_t$

Where EC is the error correction term (generated from the co-integrating equation) capturing the disequilibrium or deviation that arise between the level of money supply and money demand in monetary model of inflation, deviation between growth rate of money and growth rate of real output in the monetary growth model. The parameter λ is the speed of adjustment (in case of short run imbalances) in bringing about the equilibrium that is, removing the deviation. For example, in case of the output gap model, the disequilibrium between potential GDP and actual income (Y_t-Y_t^*) and in the monetary model of inflation disequilibrium between money supply and money demand (M_t^s-M_t^d) are removed or adjusted by short run variation of interest rates, expected rate of inflation, changes of foreign prices and the rate of currency depreciation at the rate of λ. In fact, in the VEC all the variables in the model are endogenously determined and the parameter λ is the speed of adjustment or the parameter of error correction.

From our VEC model estimation results we can draw several important conclusions; first, the error correction term is significant (at the 1-percent error level) in our specification of monetary growth model and the growth theoretic model, as implied by the Granger representation theorem. In the present context Granger representation theorem would imply that if there was any short-run deviation of money demand from money supply (long-run equilibrium in the money market), and in case of monetary growth model, deviation between growth rate of money and growth rate of real output, it was automatically removed by appropriate change or adjustment of $m1_t$, y_t, Δp_t, e_t, Δe_t, and $DEPOINT_t$. In more general terms, the significance of EC terms implies that the error-correction mechanism works effectively to reduce the disequilibrium between the money supply and money demand (for monetary model) so that the price level will adjust to the new equilibrium. In the pure monetary model the EC term is significant at the 10-percent level thus the error correction process is at works.

However, there are several features to be analyzed. **First**, in the pure monetary model some of the adjustment coefficients of lagged values of explanatory variables were not significant such as the coefficients of $m1_t$ at 1, 2 and 3 quarter lag but at 4th quarter lag it became significant at the 10-percent level. For, the variable Δp we can see that it is significant at 10-percent level at 3rd and 4th quarter lags (see table-7). In two other models: monetary growth model and growth theoretic model, the adjustment coefficients of explanatory variables were mostly significants at 1-percent and 5-percent level in different lagged values. The value of ajdusted R^2 is reasonably good for both monetary growth model and growth theoretic model which is 0.61 and for the pure monetary model it is relatively low (only 0.42).

Second, we obtained a negative sign of EC term (coefficient of co-integrating vector) in three VEC equations (table-7 and 8) which means that if the money demand is distorted away from money supply (from long run money market equilibrium point of view) then the distortion was automatically removed by appropriate change of price level or adjustment of m_t, y_t, Δp_t, e_t, Δe_t, r_t ($DEPOINT_t$) p^f_t and $(y-y)^*_t$ and brings equilibrium. That is what would be expected as a policy of short run adjustment through monetary policy such as the interest rate policy or through trade policy such as the exchange rate policy. In case of monetary growth model the sign of the EC coefficient is positive which implies that any monetary growth in excess of output growth was automatically removed by the downward adjustment of price level or adjustment of $m1_t$, y_t, Δp_t, e_t, Δe_t, and $DEPOINT_t$ and brings equilibrium.

Third, in the case of output gap or Phillips curve model we obtained that the coefficients of EC terms are not significant, which implies that any short run deviation of actual output from the potential output, was not automatically removed by appropriate change or adjustment of $y_{t,}$ $\Delta p_{t,}$ $e_{t,}$ and Δe_t. that is, the EC mechanism did not work effectively to reduce the imbalances between the actual and potential output, and hence, the price level could not be adjusted in the long run.

Fourth, the statistically significant error-correction terms in three models implies that lagged values of the $m1_{t,}$ $y_{t,}$ $\Delta p_{t,}$ $e_{t,}$ $\Delta e_{t,}$ and $DEPOINT_t$ can be used as a guideline for present or future policy direction of monetary sector equilibrium adjustment (in pure monetary model) or for real sector equilibrium adjustment in order to match real output growth with monetary growth (in monetary growth or growth theoretic models) to stabilize the price level. **Fifth**, the significance of coefficient values of various lagged endogenous variables (both the dependent and explanatory variables, see tables-7, and 8) implies that all those variables were actively playing role in bringing long-run equilibrium in the monetary sector or the real sector through changing their lagged values which is called the short-run adjustment mechanism. **Sixth**, in general, the coefficients on the error correction terms are small, indicating that prices, output and various rates of return in Bangladesh's monetary sector or real sector adjust slowly to its long-run equilibrium and therefore, the feedback effect on price level is also slow. However, in VEC specification-3 and 4 the estimated coefficients of the EC terms are large implies a more rapid adjustment mechanism at work in correcting monetary disequilibrium.

To summarize, the results shown in the error correction (EC) specification of monetary growth model (table-8) do support the hypothesis that the short-run adjustments among the variables are fairly characterized by correct EC representations with the statistical significance and that could be interpreted as the evidence of conventionally expected relationship among the price level, supply of money, output balance and rate of return and prices such as $m1_{t,}$ $y_{t,}$ $\Delta p_{t,}$ $e_{t,}$ $\Delta e_{t,}$ and $DEPOINT_t$. Furthermore, growth theoretic model and to some extent the pure monetary model also represent appropriate EC mechanism with relatively slow adjustment speed at work.

6. Conclusion and Policy Implications

The purpose of the present study was to demonstrate the actual inflationary process and to identify the determinants of inflation in the economy of Bangladesh. To this end, first we have observed the fact that Bangladesh has relatively low inflation experience during the past decade as compared to some South Asian countries, and the trend rate had gradually declined in the early years of the new milleneum. To identify the factors behind such low inflation performance we used broadly two dominant economic models: the monetary model and the real activity or output gap model. We have accommodated a numbers of variables chosen accordingly to the broad theoretical models and seggregated these into four different models: three versions from the basic monetary model and one version from the output gap model. We tested all these four models econometrically by using quarterly data of Bangladesh economy. The idea established through the econometric results is that to investigate the real causes of inflation of Bangladesh both the broad models are useful individually and suggested that both sets of factors are relevant in explaining the price behavior of the Bangladesh economy.

The four versions of inflation models established the fact that both the monetary factors like the lagged narrow money supply, devaluation of local currency, price expectations and the interest rate and the real variables like real GDP growth or trend of output gap are the factors responsible for or are mitigating the current inflationary process in Bangladesh. Error correction model has strongly represented the short run adjustment dynamics in the price adjustment process in Bangladesh with both the level and lagged coefficient values of different variables of interest with high statistical significance. However, the estimated equations may be used as ad-hoc, in that they are not based on a economy-wide general equilibrium model.

To conclude, a continuously rising money growth can provoke a price spiral in the long run and the monetary growth experience over the last 3-4 years in Bangladesh can be claimed to exert a sizable inflationary pressure that is yet to be manifested. This should be taken seriously while setting the monetary target. The findings of our empirical study can contribute effectively in the formulation of monetary policy. The econometrically significant determinants found in our empirical inflation model can play an important role in forecasting the future inflation rate and thus contribute to the design of the monetary program.

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Table – 2 : Unit Root Test : ADF Test Statistics (Period 1973-2002)

Variables	Variables in Levels		Variables in First Differences	
	ADF Statistics (No time trend)	ADF Statistics (With time trend)	ADF Statistics (No time trend)	ADF Statistics (With time trend)
I	II	III	IV	V
p_t	-0.30	-2.62	-4.42***	-4.42***
dp_t	-4.42***	-4.42***	-	-
$m1_t$	-0.67	-2.30	-4.42***	-4.43***
$dm1_t$	-4.42***	-4.43***	-	-
$m2_t$	-3.57** (-1.91)	-0.91	-3.11** (-18.85***)	-4.61***
$dm2_t$	-3.11** (-18.85***)	-4.61***	-	-
y_t	-0.13	-4.83*** (-3.31*)	-5.72***	-5.69***
$(y-y)^*_t$	-3.42*	-3.57*	-6.03***	-6.04***
DEPOINT	-1.60	-0.88	-9.38***	-9.58***
e_t	-0.96	-1.27	-3.95***	-4.20***
de_t	-3.95***	-4.20***	-	-
$d(m1_t - y_t)$	-6.53***	-6.57***	-	-
$d(m2_t - y_t)$	-39.82***	-39.91***	-	-

Notes : (a) The definition of Variables are same as given in the text. All lower case variables are in log form

(b) Optimal lag lengths for autocorrelation correction is determined by the Akaike Information Criterion (AIC)

© *, **, and *** indicates significance at 10%, 5%, and 1% level respectively

(d) Values in the 2nd, 3rd, fourth and fifth columns represent the t-values of the Augmented Dickey-Fuller (ADF) Statistics, with critical values based on the response surface in MacKinnon (1991).

(e) The ADF Statistics (Critical t-values) are testing a null hypothesis of the presence of a unit root in each variable against an alternative hypothesis of a stationary root.

(f) Each Regression in columns 3rd and fifth contains a constant and a time trend variable and Regression in columns 2nd and fourth are estimated with constant and without time trend variable

(g) The figures in parentheses are the values of Phillips-Perron Test Statistics and are given only when the Statistic values are differents from the values of ADF Test Statistics in identifying the Unit Root case.

Pure Monetary Model of Inflation

Table – 3 : Co-integration Analysis of Price Level CPI_t (p_t) with real GDP (y_t), inflation expectation (Δp_{t-1}), exchange rate (e_t), and narrow money supply ($m1_t$)

Eigenvalues	0.44	0.27	0.09	0.07
Hypotheses	r = 0	r ≤ 1	r ≤ 2	r ≤
Trace Statistics (Lambda Trace)	118.95**	55.26**	20.70	10.77
95% Critical Values	68.52	47.21	29.68	15.41
Maximum Eigen-Statistic	63.70**	34.56**	9.93	7.87
95% Critical Values	33.46	27.07	20.97	14.07

Standardized Co-integrating Coefficients (or Eigenvectors)

p_t	y_t	Δp_{t-1}	$m1_{t-4}$	e_t
1.00	-0.52	0.73	0.46	2.90
(0.51)	(1.07)	(0.43)	(0.52)	

Standardized Adjustment Coefficients (Alpha Coefficients)

p_t	y_t	Δp_{t-1}	$m1_{t-4}$	e_t
0.02	0.12	0.08	0.04	0.06

The VAR includes 4 lags on each variable, a constant term and a linear deterministic term. The ** and * denote significant at 1% and 5% level respectively. The critical values for the trace statistics are from Hansen-Juselius (1995) and the critical values for Lambda Max are taken from Osterwald-Lenum (1992). The figures in parenthesis are the standard errors of the coefficient estimates for independent variables.

Monetary Growth Model of Inflation

Table – 4 : Co-integration Analysis of Inflation rate ΔCPI_t (Δp_t) with narrow money growth over GDP growth ($\Delta m1_t - \Delta y_t$), inflation expectation (Δp_{t-1}), exchange rate depreciation (Δe_t), and with deposit interest rate ($DEPOINT_t$)

Eigenvalues	0.42	0.26	0.16	0.10
Hypotheses	r = 0	r ≤ 1	r ≤ 2	r ≤ 3
Trace Statistics (Lambda Trace)	127.54**	67.68**	35.55*	16.39*
95% Critical Values	68.52	47.21	29.68	15.41
Maximum Eigen-Statistic	59.86**	32.13*	19.16	12.15
95% Critical Values	33.46	27.07	20.97	14.07

Standardized Co-integrating Coefficients (or Eigenvectors)

Δp_t	$(\Delta m1_t - \Delta y_t)$	Δp_{t-1}	$DEPOINT_t$	Δe_t
1.00	0.26	0.83	0.34	0.22
	(0.05)	(0.06)	(0.03)	(0.06)

Standardized Adjustment Coefficients (Alpha Coefficients)

Δp_t	$(\Delta m1_t - \Delta y_t)$	Δp_{t-1}	$DEPOINT_t$	Δe_t
1.22	3.06	0.002	0.04	3.72

The VAR includes 6 lags on each variable, a constant term and a linear deterministic term. The ** and * denote significant at 1% and 5% level respectively. The critical values for the trace statistics are from Hansen-Juselius (1995) and the critical values for Lambda Max are taken from Osterwald-Lenum (1992). The figures in parenthesis are the standard errors of the coefficient estimates for independent variables.

Growth Theoretic Model of Price Behavior

Table – 5 : Co-integration Analysis of Price Growth (Δp_t) with narrow money growth ($\Delta m1_t$), GDP growth (Δy_t), inflation expectation (Δp_{t-1}), exchange rate depreciation (Δe_t), and with deposit interest rate ($DEPOINT_t$)

Eigenvalues	0.37	0.31	0.17	0.15
Hypotheses	r = 0	r ≤ 1	r ≤ 2	r ≤ 3
Trace Statistics (Lambda Trace)	139.72**	89.73**	49.13*	29.33
95% Critical Values	94.15	68.52	47.21	29.68
Maximum Eigen-Statistic	49.99**	40.59**	19.80	17.37
95% Critical Values	39.37	33.46	27.07	20.97

<u>Standardized Co-integrating Coefficients (or Eigenvectors)</u>

Δp_t	$\Delta m1_t$	Δy_t	Δp_{t-1}	$DEPOINT_t$	Δe_t
1.00	0.01	0.15	0.85	0.03	0.15
	(0.06)	(0.04)	(0.04)	(0.02)	(0.04)

<u>Standardized Adjustment Coefficients (Alpha Coefficients)</u>

Δp_t	$\Delta m1_t$	Δy_t	Δp_{t-1}	$DEPOINT_t$	Δe_t
1.67	0.48	1.26	0.01	0.07	5.12

The VAR includes 6 lags on each variable, a constant term and a linear deterministic term. The ** and * denote significant at 1% and 5% level respectively. The critical values for the trace statistics are from Hansen-Juselius (1995) and the critical values for Lambda Max are taken from Osterwald-Lenum (1992). The figures in parenthesis are the standard errors of the coefficient estimates for independent variables.

Output Gap Model of Inflation (Phillips Curve Model)

Table – 6 : Co-integration Analysis of Price Level CPI_t (p_t) with deviation of actual real GDP over potential GDP ($y_t - y^*_t$), inflation expectation (Δp_{t-1}), and with the depreciation of nominal exchange rate (Δe_t)

Eigenvalues	0.36	0.31	0.22	0.01
Hypotheses	r = 0	r ≤ 1	r ≤ 2	r ≤ 3
Trace Statistics (Lambda Trace)	114.92**	66.27**	26.35**	0.09
95% Critical Values	47.21	29.68	15.41	3.76
Maximum Eigen-Statistic	48.65**	39.92**	26.25**	0.09
95% Critical Values	27.07	20.97	14.07	3.76

Standardized Co-integrating Coefficients (or Eigenvectors)

p_t	$(y_t - y^*_t)$	Δp_{t-3}	Δe_t
1.00	0.62	0.64	1.26
	(0.13)	(0.15)	(0.44)

Standardized Adjustment Coefficients (Alpha Coefficients)

p_t	$(y_t - y^*_t)$	Δp_{t-3}	Δe_t
0.001	1.10	0.004	0.24

The VAR includes 5 lags on each variable, a constant term and a linear deterministic term. The ** and * denote significant at 1% and 5% level respectively. The critical values for the trace statistics are from Hansen-Juselius (1995) and the critical values for Lambda Max are taken from Osterwald-Lenum (1992). The figures in parenthesis are the standard errors of the coefficient estimates for independent variables.

Table – 7 : Vector Error Correction (VEC) Model : Short run Adjustments for the Price movement behavior (p_t), by real GDP (y_t), narrow money supply ($m1_t$), inflation expectation (Δp_t), deposit interest rate ($DEPOINT_t$) and exchange depreciation (Δe_t)

Co-integrating terms And Determinants of the Price Behavior	Δp_t Pure Monetary Model	Δp_t Output-Gap Model
ECT$(p)_{t-1}$	-0.02** (-1.69)	-
ECT$(p)_{t-1}$	-	-0.001 (-0.27)
Δy_{t-1}	-0.09 (-0.84)	-
Δy_{t-2}	-7.68** (-2.54)	-
Δy_{t-3}	-3.60 (-0.70)	-
Δy_{t-4}	-0.03** (-1.93)	-
$\Delta m1_{t-1}$	-0.07 (-1.03)	-
$\Delta m1_{t-2}$	-0.08* (-1.34)	-
$\Delta m1_{t-3}$	-0.03 (-0.42)	-
$\Delta m1_{t-4}$	-0.07** (-1.99)	-
$\Delta(y - y^*)_{t-1}$	-	-0.0001 (-0.26)
$\Delta(y - y^*)_{t-2}$	-	-0.0001 (-0.27)
$\Delta(y - y^*)_{t-3}$	-	-0.0001 (-0.46)
$\Delta(y - y^*)_{t-4}$	-	-0.0001**(-1.65)
$\Delta(y - y^*)_{t-5}$	-	-0.0001* (-1.32)
Δp_{t-1}	-0.04 (-0.60)	0.001 (0.01)
Δp_{t-2}	-0.002 (-0.001)	0.002* (1.36)
Δp_{t-3}	-0.002** (-1.96)	0.001 (1.02)
Δp_{t-4}	-0.001** (-1.98)	0.002** (1.94)
Δp_{t-5}	-	0.001 (1.15)
Δe_{t-1}	-0.17*** (-2.56)	-0.001** (-1.85)
Δe_{t-2}	-0.10* (-1.49)	-0.001* (-1.43)
Δe_{t-3}	0.06 (0.81)	-0.001 (-0.60)
Δe_{t-4}	-0.02** (-1.93)	-0.003 (-0.40)
Δe_{t-5}	-	-0.0001 (-0.17)
CONSTANT	0.28 (0.15)	-0.008 (-0.09)
R^2	0.42	0.38
SE	0.03	0.03
F(a,b)	1.92	2.56

***, ** and * shows co-integrating terms and partial adjustment coefficients are significant at 1%, 5% and 10% level respectively

Table – 8 : Vector Error Correction (VEC) Model : Short run Adjustments for the Price movement behavior (p_t), by real GDP (y_t), narrow money supply ($m1_t$), inflation expectation (Δp_t), deposit interest rate ($DEPOINT_t$) and exchange depreciation (Δe_t)

Co-integrating terms And Determinants of the Price Behavior	$\Delta(\Delta p_t)$ Monetary Growth Model	$\Delta(\Delta p_t)$ Growth Theoretic Model
$ECT(p)_{t-1}$	1.22*** (2.65)	-1.67*** (-2.74)
$\Delta(\Delta m1 - \Delta y)_{t-1}$	-0.31*** (-2.73)	-
$\Delta(\Delta m1 - \Delta y)_{t-2}$	-0.28*** (-2.59)	-
$\Delta(\Delta m1 - \Delta y)_{t-3}$	-0.20*** (-2.10)	-
$\Delta(\Delta m1 - \Delta y)_{t-4}$	-0.14*** (1.96)	-
Δy_{t-1}	-	-0.20** (-1.73)
Δy_{t-2}	-	-0.16* (-1.54)
Δy_{t-3}	-	-0.13* (-1.52)
Δy_{t-4}	-	-0.07* (-1.36)
Δy_{t-5}	-	-0.05** (-1.95)
$\Delta m1_{t-1}$	-	-0.06 (-0.46)
$\Delta m1_{t-2}$	-	-0.07 (-0.35)
$\Delta m1_{t-3}$	-	-0.16** (-1.
$\Delta m1_{t-4}$	-	-0.10** (-2.14)
$\Delta m1_{t-5}$	-	-0.17*(-1.52)
Δp_{t-2}	0.20*** (5.47)	-0.47*** (3.22)
Δp_{t-3}	0.31*** (3.45)	-0.69** (1.85)
Δp_{t-4}	0.68 (1.21)	-0.19 (-0.32)
Δp_{t-5}	0.21*** (2.12)	-0.13** (-2.02)
Δp_{t-6}	-	-0.28*** (-2.54)
$\Delta DEPOINT_{t-1}$	0.55*** (3.87)	0.09 (0.22)
$\Delta DEPOINT_{t-2}$	0.14*** (3.23)	0.56** (2.11)
$\Delta DEPOINT_{t-3}$	0.82* (1.45)	-0.41** (2.12)
$\Delta DEPOINT_{t-4}$	0.58 (1.04)	-0.76** (1.92)
$\Delta DEPOINT_{t-5}$	-	-0.34* (1.32)
Δe_{t-2}	-0.40*** (-4.54)	-0.44*** (-3.44)
Δe_{t-3}	-0.30*** (-2.96)	-0.40*** (-2.91)
Δe_{t-4}	-0.05 (0.42)	-0.12 (-0.85)
Δe_{t-5}	-0.29** (-1.42)	-0.14** (-1.98)
Δe_{t-5}	-	-0.13** (-2.12)
CONSTANT	0.29 (1.23)	0.10* (1.39)
R^2	0.61	0.61
SE	2.92	3.0
F(a,b)	3.88	2.97

***, ** & * shows co-integrating terms & adjustment coefficients are significant at 1%, 5% & 10% level respectively