Exchange Market Pressure and Monetary Policy[1]

Sayera Younus*

Abstract

The paper examines empirically the impact of monetary policy on exchange market pressure (EMP) in Bangladesh. EMP is measured as the sum of percentage change of international reserves and percentage change of nominal exchange rate. The sum of domestic credit to the private sector and the government sector is used as the measure of monetary policy. Domestic credit is considered the variable directly controlled by policy makers. This paper also examines the impact of changes in real income, the money multiplier, and foreign inflation rate on the EMP. Because Bangladesh is a small open economy, Taka/Dollar and Taka/Rupee nominal exchange rates are used to estimate separate EMP models. Quarterly data from 1976:2 to 2003:1 are used to examine Girton and Roper's (1977) monetary model of the EMP based on Engle and Granger's (1987) two-step single-equation error correction model (ECM). Impulse response functions (IRFs) and variance decompositions (VDCs), derived from a vector error correction model (VECM), are also used to examine the robustness of the impact of monetary policy, foreign inflation (U.S. and India), domestic real income, and money multiplier on EMP. The estimated coefficient of domestic credit derived from the ECM shows that domestic credit has a significant and negative impact on EMP. The IRFs and VDCs derived from the VECM also indicate that monetary policy, measured by the domestic credit, has a significant impact on EMP. The response of EMP due to shock to domestic credit is significant and negative as expected. This implies that the monetary authority in Bangladesh reduces exchange market pressure by either reducing foreign reserves or depreciating domestic currency.

1 The views expressed in this paper are those of the author and do not in any way represent those of the Bangladesh Bank

* Deputy Director, Research Department, Bangladesh Bank, Head Office, Dhaka.

I. Introduction

Effective management of foreign exchange is very important to achieve tolerable inflation and a desired level of economic growth for a country. The intention of this paper is to examine the impact of monetary policy on exchange market pressure (EMP), and determine how the central bank of Bangladesh deals with EMP by depreciating the exchange rate, by losing foreign exchange, or by using a combination of the two.

The monetary approach to the balance of payments is based on the assumption of fixed exchange rate, while the monetary approach to exchange rate determination is based on perfectly flexible exchange rate. In practice, many countries have neither a fixed exchange rate nor a perfectly flexible exchange rate. In order to overcome the limitations of the traditional monetary approach to the balance of payments and exchange rate determination, Girton and Roper (1977) developed the concept of exchange market pressure, which can be used in a fixed exchange rate regime, a flexible exchange rate regime and a managed float exchange rate regime. In the fixed exchange rate regime, the change of the exchange rate will be zero, while in flexible exchange rate regime, the change of international reserves will be zero, and in the managed float, the exchange market pressure is absorbed by either currency depreciation, or reserves losses, or a combination of the two. Girton and Roper (1977) defined EMP as the sum of the percentage change in the nominal exchange rate appreciation and percentage change in international reserves.

This study uses Girton and Roper's (1977) exchange market pressure (EMP) model rather than monetary approach to balance of payments or the monetary approach to exchange rate determination model to examine the exchange market pressure in Bangladesh. This is the first study that uses Girton and Roper's (1977) EMP model in Bangladesh to examine the exchange market pressure measured by the sum of the percentage change in exchange rate appreciation and the percentage change in the international reserves scaled by the monetary base. The traditional monetary approach uses either the exchange rate or international reserves as a dependent variable. This study uses sophisticated econometric techniques, such as Engle and Granger's (1987) single-equation error correction model (ECM) and a vector error correction model (VECM) to estimate the exchange market pressure. These techniques allow us to capture the non-stationarity properties in individual series. The existing literature on exchange market pressure does not use these techniques.

An analysis of exchange market pressure (EMP) model is appropriate for Bangladesh because it had experienced managed, pegged but adjustable flexible exchange rate regimes since the country's inception in 1971 until May 31, 2003. On May 31, 2003 the government of Bangladesh introduced a floating (managed) exchange rate system.

Following independence, Bangladesh's currency, the Taka, was pegged to U.K.'s pound sterling, which was at that time the intervention currency. In order to control capital flight, the Government of Bangladesh imposed restrictions on foreign exchange. In the controlled exchange regime, a secondary market developed to satisfy the excess demand for foreign currency. In the secondary market, the foreign currency price was much higher than the official exchange rate. In May 1975, a major step toward effective exchange management took place with a massive devaluation (by 37%) of the Taka. Since then, the central bank of Bangladesh pursued a policy of depreciating the Taka to improve the balance of payment deficits. It is worthwhile to mention here that in order to reduce balance of payment deficits Bangladesh devalued her currency about 130 times over a thirty-year period.

In 1985, the intervention currency was changed to U.S. dollar. This change was made because most of the official trade in Bangladesh was performed with the U.S. dollar rather than the pound sterling. In order to determine the strength of Taka against foreign currency, the index of real effective exchange rate (REER) index was introduced in 1985. Since then, the nominal exchange rate of Taka in relation to the U.S. dollar was determined daily by monitoring REER index, the U.S. dollar being the intervention currency. Under the 'structural adjustment program' and the 'financial sector reform program' 'Taka' was declared convertible on the current account beginning March 24, 1994. Finally, the Bangladesh government introduced a floating exchange rate system on May 31, 2003.

In order to examine how the monetary authority in Bangladesh handles exchange market pressure, this study estimates two-exchange market pressure models. One model uses the Taka/Dollar nominal exchange rate and the other uses Taka/Rupee nominal exchange rate to construct EMP. The U.S. and India are the major trading partners of Bangladesh. At the same time, India is a significant competitor of Bangladesh. It is generally believed that in the developing countries currency devaluation is not a very popular policy tool to reduce exchange market pressure due to the possibility of higher debt burden and its impact on the domestic price level. It is a crucial issue to investigate empirically whether the monetary authority in Bangladesh reduces EMP by depreciating the domestic currency or losing international reserves or a combination of the two·

II. Theoretical Background

Exchange market pressure arises due to a disequilibrium between the growth rates of domestic supply of, and demand for, money. An excess supply of money creates an excess domestic demand for goods and services, which in turn increases demand for foreign goods and services, and results in reserves flowing out of the domestic money market. Girton and Roper (1977) argue that an excess supply of money relative to demand will result in some combination of currency depreciation and an outflow of foreign reserves. Following the models by Kim (1985), and Shiva and Bahmani-Oskooee (1998), a variant of the Girton-Roper model is outlined below:

$$M^d = kPY\text{................}(1)$$

$$M^s = A(R+D)\text{.........}(2)$$

$$P = EP^*\text{......................}(3)$$

$$M^d = M^s\text{......................}(4)$$

Equation (1) represents the demand for nominal balances where P stands for the domestic price level and Y is real income, k is a fraction of nominal income that people want to hold as cash. Equation (2) is a nominal money supply equation. The money supply is the sum of the net foreign assets (R), the foreign component of the monetary base, and the domestic assets (D), the domestic component of the monetary base, multiplied by the money multiplier (A=M2/Monetary Base). Equation (3) represents a purchasing power parity condition where E is the nominal exchange rate, which is defined as the domestic currency per unit of foreign currency, P* is the foreign price level.[2] Equation (4) represents a money market equilibrium identity where money demand equals money supply.

Substituting (1) and (2) into (4) we get

$$kPY = A(R+D)\text{..........}(5)$$

Replacing P by EP*, we get

$$k(EP^*)Y = A(R+D)\text{.......}(6)$$

In terms of percentage change and rearranging terms, equation (6) can be rewritten as:

$$r - e = -d + p^* + y - a\text{.......}(7)$$

2 An (*) asterisk indicates foreign variable;

Where, r = the percentage change in international reserves;
e = the percentage change in the nominal exchange rate depreciation;
d = the percentage change in domestic credit;
p* = the percentage change in the foreign price level;
y = the percentage change in domestic real income; and
a = the percentage change in the money multiplier;

The left-hand side of the equation (7) represents the exchange market pressure variable, while the right-hand side represents the variables that may have significant impact on exchange market pressure. Equation (7) states that an increase in the exchange market pressure due to an increase in the domestic credit decreases EMP either by losing reserves or by depreciating currency. However, an increase in domestic real income, or foreign price level, or money multiplier also increases exchange market pressure.

Girton and Roper (1977), Connolly and Silveira (1979), and Shiva and Bahmani-Oskooee (1998) propose to include a variable Q = (e/r) to see whether the monetary authority responds to absorb exchange market pressure either by the exchange rate depreciation or losing foreign reserve. A significant and positive coefficient of Q implies that the monetary authority absorbs more pressure by the exchange rate depreciation, while a significant and negative Q implies that more pressure is absorbed by reserve losses. An insignificant coefficient implies that the monetary authority is not sensitive to components of EMP. The coefficient of Q is important in the sense that it allows us to see whether a country follows a traditional monetary approach to balance of payments or exchange rate determination model or Girton and Roper's (1977) exchange market pressure model where they use the sum of the growth rates of nominal exchange rate and the growth rate of the international reserves as an EMP variable.

III. Literature Review

Several studies deal with exchange market pressure and monetary policy including Girton and Roper (1977), Connolly and Silveira (1979), Hodgson and Schneck (1981), Kim (1985), Wohar and Lee (1992), Mah (1998), Bahmani, and Shiva (1998), Mathur (1999), Pollard (1999), Pentecost, Hooydonk and Poeck (2001) and Tanner (2001).

Girton and Roper (1977) derive an EMP model for Canada. They use the sum of the growth rate of the nominal exchange rate and growth rate of international reserves scaled by the monetary base as a dependent variable. As an independent variable, the growth rate of domestic credit scaled by the monetary base is used as a measure of domestic monetary policy. The growth rate of the U.S. monetary base is used to represent the foreign monetary variable. They also use growth rate of domestic income and foreign income as explanatory variables. The growth rate of the sum of a four-year distributed lag of GNP is used as an income variable. Girton and Roper (1977) assume that the purchasing power parity condition holds and the interest rate differential between Canada and the U.S. is zero. They estimate the model using annual data for the period 1952 to 1974. All the equations are estimated using Cochrane–Orcutt's method to adjust for serial correlation. Girton and Roper (1977) use three measures of foreign monetary policy (M_1, M_2 and the monetary base). They find all the variables statistically significant with the expected signs. To examine whether the monetary authority is sensitive to the components of exchange market pressure (i.e., EMP is more absorbed by the nominal exchange rate or international reserves), Girton and Roper (1977) construct a variable Q= (e/r). The estimated coefficient of Q turns out to be not-significant. This implies that the monetary authority is not sensitive to components of EMP, which supports the monetary approach to exchange market pressure.

Connolly and Silveira (1979) apply Girton and Roper's (1977) EMP model to explain Brazilian data. Like Girton and Roper (1977), Connolly and Silveira (1979) assume purchasing power parity and construct the EMP variable as the sum of the growth rates of the nominal exchange rate and international reserves. The international reserves variable is scaled by the monetary base. Domestic credit scaled by the monetary base is used as the monetary policy variable, the U.S. wholesale price index is used as foreign inflation, and the three-year moving average of real GDP is used as an income variable. All variables are in the growth rates. Like Girton and Roper (1977), Connolly and Silveira (1979) estimate the model using a Cochrane-Orcutt iterative technique and annual data for the sample period 1955 to 1975 and 1962 to 1975. In the latter sample period, Brazil imposed fewer restrictions on its exchange rate. The estimated results from the latter sample period perform well, all the variables are statistically significant with the expected sign. In the sample period from 1955 to 1975, only the coefficient of domestic credit is significant. They also estimate a model using international reserves as a dependent variable for both sample periods. In the sample period 1955 to 1975, domestic credit and domestic income are statistically significant, while foreign inflation is not. In the sample period from 1962 to 1975 domestic income is the only significant variable. Finally, they include a variable Q= (e-1)/(r-1) to measure whether the monetary authority is sensitive to components of

EMP. The coefficient of Q turns out to be not-significant implying that the monetary authority is not sensitive to components of EMP.

Hodgson and Schneck (1981), using quarterly data, estimate Girton and Roper's (1977) monetary model of the exchange market pressure for seven advanced economies (Canada, France, West Germany, Belgium, the Netherlands, Switzerland, and the United Kingdom). For the United Kingdom, the sample period covers 1964:2 to 1976:1 and for the rest of the countries from 1959:2 to 1976:1. The EMP model for each country includes domestic credit, domestic and world money multipliers, domestic and world inflation rates, the domestic forward exchange rate, and world international reserves as explanatory variables. Hodgson and Schneck (1981) use the spot exchange rate and domestic international reserves as the EMP variable. All variables are in growth rates. The weights for the world variables are calculated as the ratio of the individual money stocks to the world money stocks. The world is defined as the seven countries in the sample plus the United States, Japan and Italy.

The equation is estimated using two stage least squares (2SLS). The coefficient of the domestic rate of inflation is significant for Canada only, while the coefficients on domestic and world income are significant only for France. The coefficient of the growth rate of domestic money multiplier is significant for Germany, Belgium, the Netherlands and Switzerland. The coefficient of the growth rate of the world money multiplier is insignificant for all the countries. The coefficient on the growth rate of world reserves is significant for France and Belgium, and the coefficient of the growth rate of the world credit is significant only for the Netherlands. The coefficient of home domestic credit is significant for all countries except for France and Switzerland. The coefficient on the rate of change in the forward exchange rate is significant and positive for Belgium, the Netherlands and Switzerland. A structural stability test for each country shows that there is considerable instability between domestic credit and the EMP, which may be due to mis-specification in the monetary equation or shift in the structure due to institutional changes. They do not find a one-to-one negative relationship between domestic credit and EMP. Therefore, they conclude by saying that there may be factors other than the monetary variable that affect EMP.

Kim (1985) estimates Girton and Roper (1977) version of EMP model for Korea using monthly data from March 1980 to July 1983. Korea's domestic credit is used as the monetary policy variable. The trade-weighted average of Korea's major trading partners' wholesale price index is used as the foreign price variable. Korea's real wage income is used as a domestic income variable. The sum of net foreign assets and the Korean Dollar/Won exchange rate is used as EMP variable. The estimated results, using OLS, show that all the coefficients are statistically significant with the expected sign except for the foreign rate of inflation. The results support the monetary model of EMP. To see whether monetary authority absorbed EMP by the exchange rate depreciation or the international reserves, a new variable Q = (e-1)/(r-1) is constructed and added in the model. However, the coefficient of Q turns out to be non-significant, implying that the monetary authority is not sensitive to components of EMP.

Wohar and Lee (1992) estimate a modified version of Girton and Roper's (1977) EMP model for Japan using annual data for the period 1959 to 1991. The sum of the yearly change of net foreign reserves as a percent of high-powered money and the yearly growth rate of the market exchange rate of yen per U.S. dollar is used as an EMP variable. The yearly change of central bank net credit as a percent of high-powered money is used as a monetary policy variable. The yearly growth rate of domestic money multiplier is calculated as the quotient of the money supply and high–powered money. The yearly growth rate of the U.S. monetary base is used as a foreign money supply variable. The yearly growth rate of the Japanese permanent income is calculated from the three-year moving average of the Japanese GNP in 1985 prices. A three-year moving average of the U.S. GNP in 1985 prices is used as a foreign permanent income variable. The differential between the domestic inflation and foreign inflation rate adjusted by the exchange rate and the differential between the lending rate of Japan and the U.S. are used to see the channel through which foreign disturbances transmit to the domestic economy.

Unlike other studies (for example, Girton and Roper, 1977, Kim, 1985), Mah (1998) estimates a dynamic specification of the EMP model for Korea for the sample period 1980:1 to 1993:1. In the dynamic model, Mah (1998) includes lagged and current value of all independent variables, while the semi-dynamic model includes a lagged dependent variable as a regresor. Akaike's final prediction error criterion is used to select the lag length of the independent variable in the dynamic model. A maximum lag length up to eight is checked and a lag order of three is chosen for the estimation. The sum of the trade-weighted effective exchange rate and percentage change in international reserves of the monetary base is used as EMP variable.[3] As independent variables, Mah (1998) uses trade-weighted foreign wholesale price index, domestic real income and the money multiplier. The industrial production index of Korea is used as the

3 The weights are U.S.: 0.47, Japan: 0.38, Germany: 0.07, Canada: 0.04, and U.K. 0.04

domestic real income variable. The money multiplier is calculated dividing M2 by the base money.

Mah (1998) examines the stationarity property of the individual series and finds that all the model variables are stationary. A Hildreth-Lu search method is used to estimate the dynamic and semi-dynamic model. The estimated results of the dynamic model perform better than the semi-dynamic model. In the dynamic model, all coefficients are statistically significant with the expected sign, while in the semi-dynamic model all coefficients are significant other than foreign inflation and domestic income.

Shiva and Bahmani-Oskooee (1998), using a modified version of the Girton and Roper (1977) EMP model, examine whether the central bank of Iran engages in black market activity. In 1979, a period of exchange control due to excess demand for foreign currency, a black market for foreign exchange developed in Iran. The exchange rate in the black market rose from 70 rials per dollar in 1979 to 1630 rials per dollar in 1993 (Shiva and Bahmani-Oskooee, 1998, p.97). Therefore, the central bank decided to unify the black market exchange rate with the official exchange rate in 1993. The rial depreciated substantially due to the removal of foreign exchange controls and reached 7000 rials per dollar in May 1995. This forced the central bank to implement exchange controls again at a fixed rate of 3000 rials per dollar. To check whether the central bank in Iran engaged in black market activity (buying foreign currency, while dumping domestic currency), Shiva and Bahmani-Oskooee (1998) estimate Girton-Roper EMP model using a black market exchange rate and the official exchange rate for the sample period 1959 to 1990.

First, using the black market rate, EMP is regressed on domestic credit, foreign inflation (U.S.), real domestic income, and the money multiplier. A $Q = (e-1)/(r-1)$ variable is included to examine whether the monetary authority absorb more pressure by the black market exchange rate or losses of international reserves. Shiva and Bahmani-Oskooee (1998) find all estimated coefficients are statistically significant with the expected signs except for the foreign inflation. The coefficient of Q is negative and statistically significant implying that the central bank in Iran is not engaged in black market activity because the EMP is mostly absorbed by losing reserves.

Second, using the official exchange rate, the EMP model is estimated using all the variables described earlier. They find a statistically significant and negative coefficient on the domestic credit and the money multiplier. However, the coefficients of foreign inflation and real domestic income are not significant. Using the official exchange rate, they find a statistically significant and positive coefficient on Q. This implies that more of the pressure is absorbed by the official exchange rate.

Shiva and Bahmani-Oskooee (1998) also estimate an equation using international reserves as the dependent variable. The results are much better when international reserves are used as a dependent variable. This time, foreign inflation becomes significant together with domestic credit and the money multiplier. Therefore, they conclude that the traditional monetary approach to balance of payments performs better in case of Iran than Girton and Roper's (1977) exchange market pressure model.

Mathur (1999) estimates a modified version of the Girton and Roper's (1977) EMP model for India using monthly data 1980:1 to 1998:7. Mathur (1999) modified Girton and Roper's (1977) EMP model by including a variable, the change in the expected rate of appreciation of the nominal exchange rate. Mathur (1999) uses the sum of the rate of change of the exchange rate and the rate of change of the international reserves as a proportion of money as an EMP variable. The growth rates of domestic credit, the foreign monetary base, domestic and foreign income and the change in the expected rate of appreciation are used as the explanatory variables for India's EMP model. The nominal effective exchange rate (NEER) is used as an exchange rate variable. The NEER is a weighted average of the bilateral nominal exchange rate of the home country in terms of the foreign currencies. The NEER is calculated using bilateral total trade weights. The number of countries used to construct the NEER is 36. To generate the data on the expected rate of appreciation, Mathur (1999) uses three forecasting methods: the random walk model, Box-Jenkins methodology, and a vector autoregression (VAR). The OECD group of countries is used as a rest of the world. A 'total OECD' and 'OECD major seven' are used as world variables. The narrow money (M_1) index of the 'OECD total' and the 'OECD seven' are used as a world money variable. In order to calculate the index of M_1, weights are derived from the averages of the monthly M_1 figures from 1990 for each country converted to dollars using the 1990 purchasing power parity. The weights for the world's income variable are constructed using GDP from industry and GDP from purchasing power parity.

A set of diagnostic tests shows the absence of multicollinearity, autocorrelation and homoscedasticity. Therefore, OLS is used to estimate the models. Mathur (1999) first estimates the original Girton and Roper (1977) model for the two sets of world variables. The estimated results are not impressive. None of the coefficients are significant except for domestic income. Mathur (1999) also tries to estimate the model by dividing the sample period into two-sub periods. The results do not improve. In the sub-sample periods, domestic real income remains only significant variable.

Mathur (1999) also uses six modified versions of the Girton and Roper (1977) model including the forecasting results from the three methods of forecasting. The estimated results from OLS show improvement over Girton and Roper's (1977) original model. The coefficients of domestic credit and domestic income appear to be statistically significant with the expected negative and positive signs respectively for all the six variants of the modified Girton and Roper (1977) model. The coefficient of the expected rate of appreciation also appears to be significant for all the equations except one.

Tanner (2001) estimates an exchange market pressure (EMP) model using monthly data from 1990 to 1998. A vector autoregression (VAR) approach is used to estimate the EMP model for Brazil, Chili, Mexico, Indonesia, Korea, and Thailand.

Unlike other studies Tanner (2001) constructs EMP variable in the following way:

$$EMPe_t\text{-}r_t = \delta_t\text{-}m_t,$$
$$\delta_t = D_t/M_{t-1}$$
$$m_t = M_t/M_{t-1}\text{-}\pi_t$$

Where, e_t represents the rate of growth of the nominal exchange rate, r_t=R_t/M_{t-1}, M_t is nominal money at time t, R_t is international reserves, $_t$ is the rate of inflation, D_t is domestic credit, r_t is the rate of growth of the international reserves scaled by monetary base, and $_t$ is the rate of growth of the domestic credit scaled by monetary base.

The growth rates of domestic credit and the interest rate differential between domestic and U.S. interest rates are used to examine the impact of the monetary policy on the exchange market pressure. The response of the EMP is positive and significant as expected due to shock to domestic credit for all countries except for Korea. The response of EMP Korea is statistically significant and negative. The response of the EMP due to shock to the interest rate differential is weaker than that of the shock to domestic credit. The response of EMP due to a shock to the interest rate differential is statistically significant and negative for Indonesia, Thailand, Brazil and Mexico.

From the above review of literature, the monetary model of exchange market pressure seems to be appropriate for both developed and developing countries. The present study uses the same model for Bangladesh, a developing country, to examine the impact of monetary policy on the Girton and Roper's version of EMP. This study also investigates the factor sensitivity of the EMP with respect to reserves and nominal exchange rate by introducing a new variable Q (=e/r).

IV. Model Variables

Quarterly data from 1976:2 to 2003:1 are employed to estimate Engle and Granger's (1987) two-step single equation error correction model (ECM) and a vector error correction model (VECM) containing the following variables:

d = percentage change of domestic credit scaled by the monetary base;

e = percentage change of nominal exchange rate (Taka-Dollar or Taka-Rupee);[4]

r = percentage change of international reserves scaled by the monetary base;

p_i^* = percentage change of foreign consumer price index (India and the U.S.);

y = percentage change of industrial production;

mm = percentage change of the money multiplier;

Q_i = (e/r) = Q_i is included to examine whether monetary authority is sensitive to components of EMP.

Seasonally adjusted data are used for all the variables except for the exchange rate. All the variables are in log-differenced form. A description of the variables is given in detail in the data appendix.

V. Econometric Methodology

Before estimating the model, the statistical properties of each variable are analyzed. A series of Dickey-Fuller (1981) unit root tests are used to examine each series up to two unit roots. Log level data are used to run the test for the presence of one unit root, while first differenced data are used to run the test for the

[4] The U.S. and India's exchange rate are included because the USA and India are the two major trading partners of Bangladesh. i=1(USA) and 2(India).

presence of a second unit root, given that the first unit root is present. Two sets of the unit root tests are performed using the Taka/Dollar and the Taka/Rupee exchange rates. The augmented Dickey-Fuller (ADF) unit root tests suggest that the log of the domestic credit scaled by the monetary base, the log of the foreign (the U.S. or India) price level, the log of real output, and the log of money multiplier contain one unit root and therefore need to be differenced once to attain stationarity. The composite value of EMP in level also fails to reject the null hypothesis of unit root for both Taka/Dollar and Taka/Rupee exchange rate.

According to Engle and Granger (1987), an equation estimated with differenced data will be mis-specified if the variables are cointegrated and cointegration is ignored.[5] Therefore, cointegration among the I (1) variables is tested using the techniques developed by Johansen (1988) and Johansen and Juselius (1990).

This paper uses a two-step procedure suggested by Engle and Granger (1987) to estimate the model. In this approach, first, a long-run equilibrium EMP model in log levels is estimated by ordinary least square (OLS). Then the lagged value of the calculated residuals from step one is used in an error correction model. This lagged value of the residual specifies the short-run dynamics of the second model; the coefficient on the lagged residual is the speed of adjustment. The significance of the coefficient of the lagged residual implies that the variables are cointegrated. The larger the coefficient is, the greater the responses of the variables to fill the gap of the deviation from long-run equilibrium (Enders 1995).

Error Correction Model (ECM)

Two sets of equations are estimated in this paper. First, two U.S. variables and four domestic variables are used to estimate the model (growth rate of Taka/Dollar exchange rate and growth rate of domestic international reserves are used to construct EMP) and three domestic variables (domestic credit, real income, money multiplier) and a foreign variable (U.S. inflation) are used to estimate the long-run equilibrium model and a short-run dynamic model. Engle and Granger's (1987) two-step procedure is used to estimate the model. In the first step, a long-run equilibrium model is estimated with OLS using log levels of the variables. In the second step, the lag value of the residual derived from the first step is used in the second equation to estimate the short-run dynamic model. The same procedure is repeated with the second set of equations containing growth rate of Taka/Rupee

5 Variables are cointegrated if each variable is I(d), but a linear combination of the variables is I(d-b), b>0.

exchange rate and domestic international reserves to construct EMP. India's inflation, and same three domestic variables are used as independent variable.

Following Girton and Roper (1977) a new variable Qi (=e/r) is also included in the model to examine whether the monetary authority in Bangladesh is sensitive to the components of EMP.

A significant positive coefficient of Qi will imply that the monetary authority in Bangladesh responds to EMP by depreciating currency. A significant and negative coefficient of Qi will imply that the monetary authority in Bangladesh responds to exchange market pressure by reserve losses. In that case, the central bank sells foreign currency instead of currency depreciation. The insignificance of the Qi will imply that the EMP is not sensitive to its components. The results from the short-run dynamic models are reported in Tables 1 and 2.

Table-1 shows the estimated results from Engle and Granger's (1987) two-step single equation model containing U.S. variables. The coefficient of the growth rate of the domestic credit is significant at 1% level. The coefficient of domestic credit (-0.96) implies that a 10% increase in the domestic credit causes the exchange rate to depreciate by (e=-0.96*10=)-9.6%, or a loss of reserves by (r=-0.96*10=)-9.6%, or a combination of the two.

The coefficient of the lagged value of the error term also appears to be significant. A significant error correction term implies that the variables are cointegrated. However, the coefficients on U.S. inflation and real income and money multiplier are not significant, which implies that U.S.'s inflation and domestic real income and money multiplier do not have an impact on EMP in Bangladesh. The results remain the same when estimating the model adding a new variable Q1. Q1 is added to see whether EMP is sensitive to its components. The coefficient of Q1 turns out to be insignificant, implying that the monetary authority is not sensitive to the components of EMP. They adjust both, international reserves and the exchange rate to reduce EMP.

This paper estimates the model using the Taka/dollar nominal exchange rates as a dependent variable. The estimated coefficients are all insignificant when Taka/dollar exchange rate is used as a dependent variable. This paper also estimates the model using international reserves as a dependent variable. In that case, the coefficient of domestic credit is statistically significant and negative at 1% level.

Table-2 shows the estimated single equation results using India's variables. The coefficient of domestic credit is negative and significant at 1% level. India's inflation and error correction terms are also significant at 5% and 1% levels, respectively, with the expected signs. A significant and positive coefficient of India's inflation implies that an increase in the India's inflation increases foreign exchange market pressure in Bangladesh and a significant error correction term implies that the variables are cointegrated. However, the money multiplier and real income are not statistically significant. The results do not change when the Q2 variable is added to the model. The coefficient of Q2 turns out to be insignificant.

This paper also estimates the model using Taka/Rupee exchange rate and the international reserves as dependent variables. The estimated coefficients from using Taka/Rupee exchange rate are all non-significant, while the estimated coefficients from international reserves as a dependent variable have two significant coefficients. Domestic credit is statistically significant and negative at 1% level, while India's inflation is statistically significant and positive at 5% level.[6]

Vector Error Correction Model (VECM)

In order to see the robustness of the results from the ECM, this paper derives impulse response function (IRFs) and variance decomposition (VDCs) from vector error correction models (VECM) using both exchange rates: Taka/Dollar and Taka/Rupee. The VDCs show the portion of the variance in the forecast error for each variable explained by innovations to all variables in the system. This study is mostly interested in the portion of the forecast error variance of exchange market pressure that is explained by shocks to the domestic credit (d), foreign price levels (p_i*), domestic real income (y), and the money multiplier (mm). If these factors explain a significant portion of the forecast error variance in the EMP then we can say these factors have significant impact on EMP.

The IRFs show the dynamic response of each variable in the system to shocks from each variable in the system. If the response of the exchange market pressure is significant and negative due to shocks to domestic credit and money multiplier then we can say that domestic credit and money multiplier have a significant impact on EMP. On the other hand, we expect a significant and positive impact of

6 This paper also estimates the model with OLS using growth rates (excluding error correction terms) of U.S. and India's variables with and without the Q_i variable. This time only the domestic credit variable appears to be significant at 5% level with the expected sign in the U.S. equations. In the India's equations, domestic credit and India's inflation appear to be significant at the 5% level with the expected negative and positive signs respectively.

domestic real income and foreign inflation on the EMP. If the response of EMP is significant and positive we can say that an increase in the domestic real income and the foreign inflation would increase EMP.

Hafer and Sheehan (1991) argue that VAR results can be very sensitive to the choice of lag length. Therefore, Akaike's Information Criterion (AIC) and Schwartz's Information Criteria (SIC) are used to select the lag length for the VECM model. Lag orders of one through eight are tested.[7] A lag order of four produces the minimum AIC and SIC in each case. Q-statistics are used to see if VECM residuals in each equation are white noise at this minimum AIC and SIC. The Q-statistics show white noise residuals for each equation at lag order four. Therefore, a lag of four is used to derive VDCs and IRFs from the VECM. To see the robustness of the results, a lag of eight is also used to estimate the model. This paper reports the estimated results using optimal lag 4 in upper portions of Tables 3 and 4 and estimated results using lag 8 in the lower portions of Tables 3 and 4.

To estimate VDCs and IRFs, orthogonalization of the VECM residuals is required. Cholesky decomposition is used to orthogonalise the residuals. The Cholesky decomposition requires the variables to be ordered in a particular way such that variables placed higher in the ordering have a contemporaneous impact on all variables lower in the ordering, but the variables lower in the ordering do not have a contemporaneous impact on the variable higher in the ordering.

Therefore, it is important to decide a proper ordering of the variables. The Cholesky ordering of the variables for this study is: p_i^*, mm, d, y, and EMP.[8] The foreign inflation variable is placed first in the ordering according to small country assumption; foreign inflation is exogenous. Placing foreign inflation higher in the ordering implies that foreign inflation has a contemporaneous impact on money multiplier, domestic credit, domestic real income, and EMP, while these variables have no contemporaneous impact on foreign inflation. EMP is place last in the order allowing all other system variables to have a contemporaneous impact on EMP. This assumption is consistent with previous single-equation studies that treat EMP as an endogenous variable, while treating all other system variables as exogenous.

The money multiplier is assumed to remain constant within a given quarter. Hence, the money multiplier is placed above other domestic variables. This assumption allows the money multiplier to have a contemporaneous impact on

7 A maximum lag length of eight is used to preserve degrees of freedom.

8 This paper also estimates VECM models adding the Qi variable, but the IRFs and VDCs of EMP due to shocks to Q_i are never significant.

other domestic variables, but domestic variables have no contemporaneous impact on the money multiplier. As a policy variable, domestic credit is placed above real income in the ordering. This allows monetary policy to have a contemporaneous impact on real income. However, policy decisions respond with a lag to changes in real income.[9]

Variance Decomposition (VDCs) of Exchange Market Pressure (EMP) using Taka/U.S. Dollar Nominal Exchange Rate

In order to know the impacts of a shock, VDCs for time horizons of 4, 6, 12, 16 and 20 are computed. The estimates of the forecast error variance are considered significant if the point estimate is at least two times as large as the standard error. Twenty-five hundred Monte Carlo simulations are used to calculate the standard errors. Because this study is most concerned with the forecast error variance in the exchange market pressure (EMP) explained by the foreign (U.S. and India) price level, money multiplier, domestic credit, and real income, VDCs of EMP derived from using the VECM model are reported in Tables 3 and 4. Table-3 shows the VDCs derived from estimating VECM model using Taka/U.S. dollar nominal exchange rate, and Table-4 shows the VDCs derived from estimating VECM model using Taka/India's Rupee nominal exchange rate.

Table-3 indicates that domestic credit can explain a significant portion of the forecast error variance in EMP at time horizons 4, 8, and 12, while estimating at lag length 4 using Taka/Dollar exchange rate. The forecast error variance explained by the domestic credit at time horizon 12 is 30.56%. None of the other variables are significant. The results change if we change the lag length. At lag 8, the forecast error variance explained by domestic credit is significant at time horizons 4, 8, 12, 16, and 20. Domestic credit is the only significant variable regardless of the lag length.

Variance Decomposition (VDCs) of Exchange Market Pressure (EMP) using Taka/India's Rupee Nominal Exchange Rate

Table 4 shows the variance decomposition of EMP due to shock to foreign inflation, money multiplier, domestic credit, and real income estimated for VECMs at lags 4 and 8. The Taka/Rupee exchange rate is used to construct EMP.

---

9 This study also estimates VECM by switching the order between domestic real income and money multiplier and domestic credit and money multiplier. Major policy conclusions do not change due to switching the ordering between real income and money multiplier and switching the ordering between domestic credit and money multiplier.

In order to know the magnitude of the shock, variance decompositions at time horizons 4, 8, 12, 16, and 20 are reported. The upper portion of Table-4 shows that domestic credit can explain a significant portion of the forecast error variance in EMP at time horizons 4 and 8, when estimating the VECM at lag 4. The forecast error variance explained by domestic credit at time horizon 8 is 34.42%. None of the other variables explain a significant portion of the forecast error variance in the EMP. These results hold if we change the lag length to 8. At lag 8, domestic credit can explain a significant portion of the forecast error variance of EMP at all time horizons.

Impulse Response Function (IRFs) of the Exchange Market Pressure (EMP) using Taka/Dollar Nominal Exchange Rate

The IRFs show the dynamic response of each variable in the system to shock from each variable in the system. The Cholesky ordering of the variables for this study is: pi*, mm, d, y and EMP.[10] A two-standard-deviation confidence interval is reported for each IRF. A confidence interval containing zero indicates lack of significance. The confidence interval for each IRF is computed from twenty-five hundred Monte Carlo simulations. The IRFs of EMP due to shocks to foreign price level, money multiplier, domestic credit, and real income are shown in Figures 1 to 4. In Figures 1 and 3 the optimal lag length of four is used to derive the IRFs estimating the VECM using Taka/Dollar and Taka/Rupee exchange rates. To see the robustness of the results, the IRFs derived from VECM using lag length 8 are also estimated and reported in Figures 2 and 4.

In Figures 1 and 2, the Taka/Dollar exchange rate is used to construct the EMP variable. Figure-1 shows the IRFs of EMP due to shocks to domestic credit, U.S. inflation, real income and the money multiplier.[11] In Figure-1, the response of EMP due to shock to domestic credit is significant and negative initially, remaining significant up to time horizon 13, and becomes insignificant thereafter. The IRFs of EMP due to socks to U.S. inflation is insignificant initially, becomes significant and negative at time horizon 7, and remains significant thereafter. The impulse response function of EMP due to shock to the U.S. inflation appears with the wrong sign. None of the other variables are significant in Figure-1. As Figure-2 shown, the results remain the same when the lag length is increased to 8.[12]

---

10 i=1(USA) and 2(India).

11 VECMs with Q1 and/or Q2, included also estimated. The IRFs of EMP due to shocks to Q1 and Q2 were never significant.

12 At lag 8, the response of the EMP due to shock to income becomes significant only for the 5th quarter and the response of EMP to a shock to U.S. inflation is significant for time horizons 6 to 9.

Impulse Response Function (IRFs) of Exchange Market Pressure (EMP) using Taka/India's Rupee Nominal Exchange Rate

Figures 3 and 4 show the IRFs of EMP due to a shock to the domestic credit, foreign inflation, real income and money multiplier when Taka/Rupee exchange rate is used. Figure-3 shows the response of EMP due to shocks to domestic credit, foreign inflation, and the money multiplier estimated at lag 4 using Taka/Rupee nominal exchange rate. In Figure-3, the response of EMP declines sharply due to shock to domestic credit and remains negative and significant for the rest of the periods. The response of the EMP due to innovation to India's inflation is significant and positive for the first two quarters, which becomes insignificant thereafter. None of the other variables appears to be significant in Figure-3. As Figure 4 shows, the results remain the same when the lag length of 8 is used.

Analysis of the results from ECM and VECM:

The results derived from VECM are better than single equation ECM because VECM takes into account endogeneity of the variables where a single-equation ECM considers each right-hand side variable as exogenous. This potentially creates a simultaneity bias in the coefficients. The results from VECM are more reliable because it takes into account the simultaneity problem.

The significance of the coefficient of domestic credit in terms of 't' ratio from ECM and IRFs and VDCs from VECM show that domestic credit has a significant impact on EMP for both exchange rates. However, domestic real income is never significant for any case.[13]

The estimated coefficient of foreign inflation (India) from ECM and IRFs estimated at lag 4 show significant and positive impacts on EMP. The response of EMP due to shock to the U.S. inflation is significant and negative. However, the coefficient of the U.S. inflation from ECM and VDCs of EMP due to shock to U.S. inflation is not significant. The estimated coefficient of the money multiplier is never significant either using Taka/Dollar or Taka/ Rupee exchange rate·

VI. Conclusion

This paper provides evidence supporting the claim that domestic credit has a significant and negative impact on exchange market pressure using either the

[13] At lag 8, the response of EMP due to shock to income becomes significant only for the 5th quarter.

Taka/U.S. Dollar or the Taka/India's Rupee exchange rate. Domestic credit has a significant impact on EMP in each model estimated. We do not find evidence of the impact of domestic real income on EMP for either of the two cases. The impact of the money multiplier on EMP is not significant in any of the cases. However, the IRFs estimated in this paper show a significant and positive response of EMP due to a shock to India's inflation and significant and negative impact due to shock to the U.S. inflation. The ECM also supports the significant and positive coefficient of India's inflation. However, the coefficient of EMP from ECM and VDCs of EMP due to shock to the U.S. inflation does not support the significant impact of the U.S. inflation on EMP. The coefficient of Q_i is never significant in the VDCs or IRFs. This implies that the monetary authority in Bangladesh responds to EMP by depreciating currency and losing international reserves. This is true for both exchange rates (Taka/U.S. Dollar or Taka/India's Rupee). Therefore, as a policy prescription, we can say that the monetary model of exchange market pressure can be used to determine the level of intervention needed to achieve an exchange rate target for Bangladesh.

Table 1 : Dependent Variable: EMP (Taka, vis-a-vis U.S. Dollar)

Independent Variable	r-e	r-e		r-e
Constant	-9.38	-9.35	-4.85	4.52***
	(-1.57)	(-1.56)	(-0.79)	(3.49)
d	-0.96***	-0.96***	-0.94***	0.01
	(-6.53)	(-6.52)	(-6.22)	(0.46)
p_1*	0.0008	-0.03	-0.07	0.06
	(0.00)	(-0.03)	(-0.06)	(0.29)
y	-0.10	-0.12	-0.07	0.03
	(-0.48)	(-0.57)	(-0.30)	(0.81)
mm	0.47	0.48	0.48	0.01
	(1.51)	(1.54)	(1.51)	(0.25)
Q_1	-	-1.45	-	-
		(-0.43)		
Lagged e-hat	-64.15***	-64.74***	-61.63***	2.52
	(-3.18)	(-3.19)	(-2.96)	(0.58)
adj-R^2	0.34	0.33	0.31	0.005

(***) Implies significant at 1% level, while (**) implies significant at 5% level.

Table 2 : Dependent Variable: EMP (Taka, vis-a-vis India's Rupee)

Independent Variable	r-e	r-e	r	e
Constant	-25.58***	-25.92***	-25.62***	-0.02
	(-2.81)	(-2.81)	(-2.89)	(0.44)
d	-1.06***	-1.05***	-1.06***	0.003
	(-7.05)	(-6.97)	(-7.21)	(0.07)
p_2*	2.79**	2.80***	2.66**	-0.12
	(2.78)	(2.78)	(2.72)	(-0.41)
y	-0.01	-0.008	-0.04	-0.02
	(-0.06)	(-1.51)	(-0.19)	(-0.42)
mm	0.53	0.54	0.44	-0.09
	(1.67)	(1.68)	(1.42)	(-0.90)
Q_2	-	0.53	-	(0.26)
Lagged e-hat	-47.75***	-47.64***	-54.54***	-6.79
	(-2.42)	(-2.40)	(-2.83)	(-1.10)
Adj-R2	0.34	0.33	0.35	0.07

(***) Implies significant at 1% level, while (**) implies significant at 5% level.

Table 3 : Variance Decomposition of Exchange Market Pressure using Taka/Dollar nominal exchange rate and Cholesky ordering as: p_1*, mm, d, y and EMP.

VECM Lag	Time Horizon	p_1*	mm	d	y
4	4	1.24	4.04	41.33**	2.02
		(4.19)	(6.54)	(11.75)	(4.06)
	8	10.21	3.29	36.71**	4.24
		(12.03)	(8.20)	(13.32)	(5.61)
	12	21.42	2.86	30.56**	5.84
		(17.14)	(8.52)	(13.51)	(6.13)
	16	29.48	2.16	25.53	6.58
		(19.16)	(8.08)	(13.39)	(6.37)
	20	33.83	1.63	22.13	6.75
		(19.98)	(7.66)	(13.30)	(6.52)
8	4	2.44	1.92	33.88**	3.62
		(5.18)	(5.85)	(12.17)	(5.75)
	8	13.66	1.41	34.34**	10.89
		(11.66)	(6.39)	(13.35)	(10.17)
	12	16.63	5.24	34.81**	11.49
		(13.35)	(9.17)	(13.72)	(10.81)
	16	17.44	6.47	32.69**	12.99
		(14.37)	(9.94)	(13.42)	(11.46)
	20	16.96	6.04	32.18**	12.68
		(14.79)	(9.75)	(13.47)	(11.59)

Notes: Figures in the parenthesis are Monte Carlo simulated standard errors. The point estimates are considered significant if the point estimates are at least twice as large as their standard errors.

Table 4 : Variance Decomposition of Exchange Market Pressure using Taka/Rupee nominal exchange rate and Cholesky ordering: p_1*, mm, d, y and EMP.

VECM LAG	TIME HORIZON	P_2*	MM	D	Y
4	4	4.11	0.45	38.59**	1.65
		(4.61)	(3.32)	(12.01)	(4.06)
	8	6.13	1.80	34.42**	2.73
		(7.98)	(5.22)	(15.10)	(6.16)
	12	7.44	2.40	32.31	2.99
		(9.45)	(6.30)	(16.87)	(7.24)
	16	8.20	2.72	31.15	3.11
		(10.26)	(6.90)	(17.89)	(7.87)
	20	8.67	2.91	30.47	3.17
		(10.76)	(7.26)	(18.53)	(8.27)
8	4	4.60	0.27	43.60**	1.20
		(6.37)	(3.68)	(12.66)	(4.54)
	8	4.79	2.67	45.70**	5.53
		(8.84)	(6.48)	(15.59)	(9.14)
	12	6.39	1.97	42.88**	7.15
		(11.00)	(6.65)	(16.63)	(10.84)
	16	9.87	1.69	39.22**	7.91
		(13.02)	(7.26)	(16.98)	(11.23)
	20	12.62	1.44	37.49**	7.98
		(14.40)	(7.59)	(17.25)	(11.23)

Notes: Figures in the parenthesis are Monte Carlo simulated standard errors. The point estimates are considered significant if the point estimates are at least twice as large as their standard errors.

Figure 1 : Responses of EMP due to shocks to d, mm, p_1*, and y estimated at lag 4 using Taka/Dollar exchange rate and Cholesky ordering: p_1*, mm, d, y and EMP.

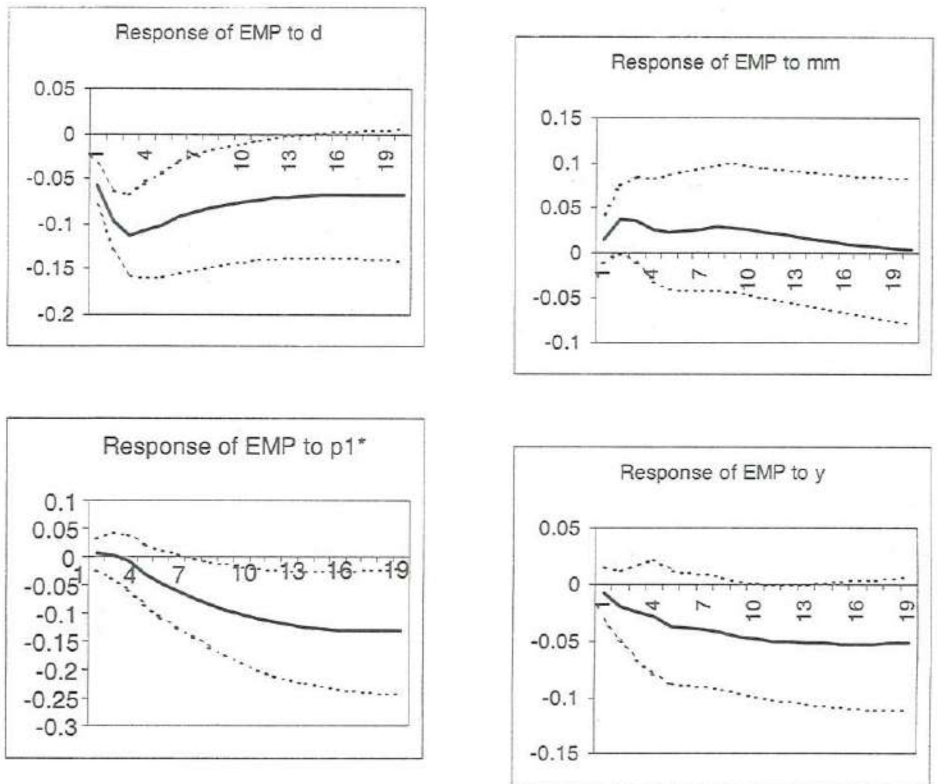


Figure 2 : Responses of EMP due to shocks to d, mm, p_1*, and y estimated at lag 8 using Taka/Dollar exchange rate and Cholesky ordering: p_1*, mm, d, y and EMP.

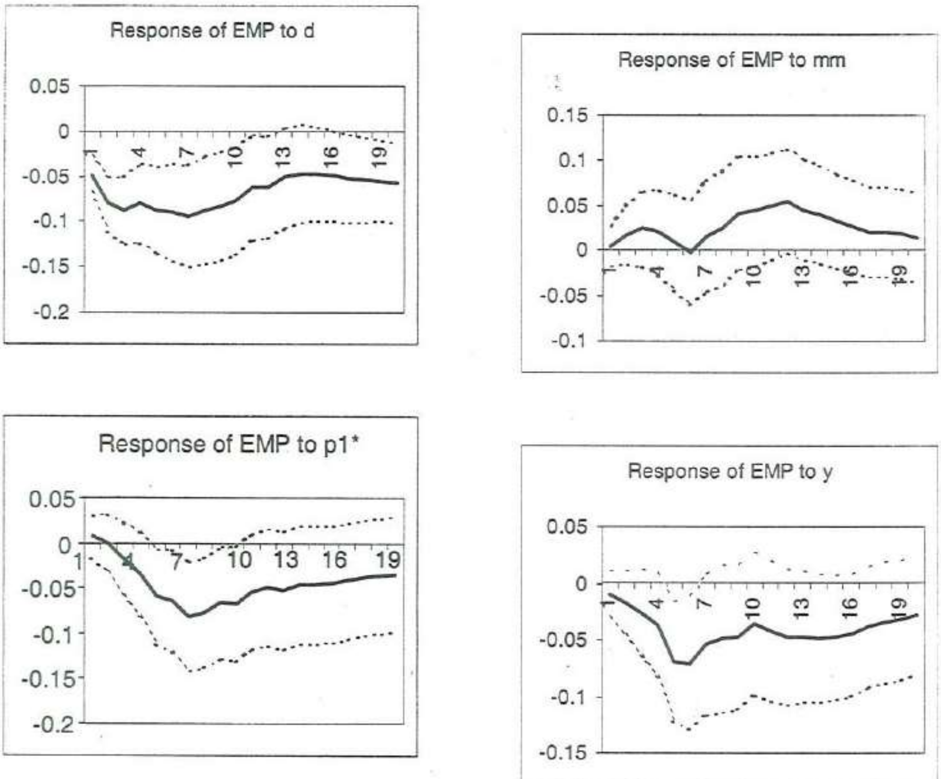


Figure 3 : Responses of EMP due to shocks to d, mm, p_2*, and y estimated at lag 4 using Taka/India's Rupee exchange rate and Cholesky ordering: p_2*, mm, d, y and EMP.

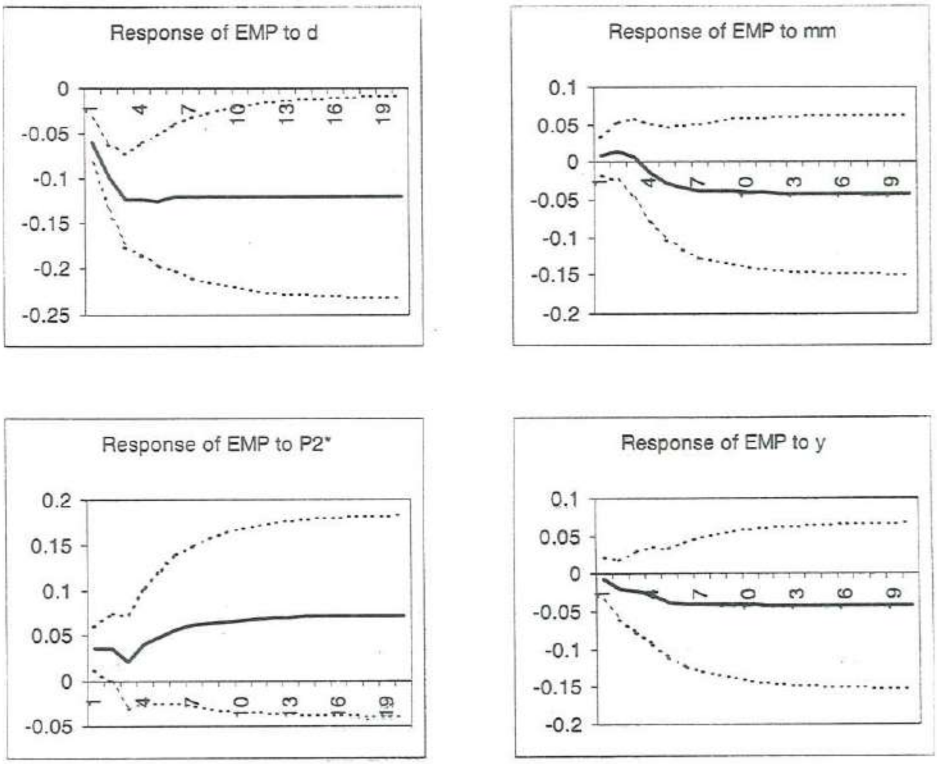
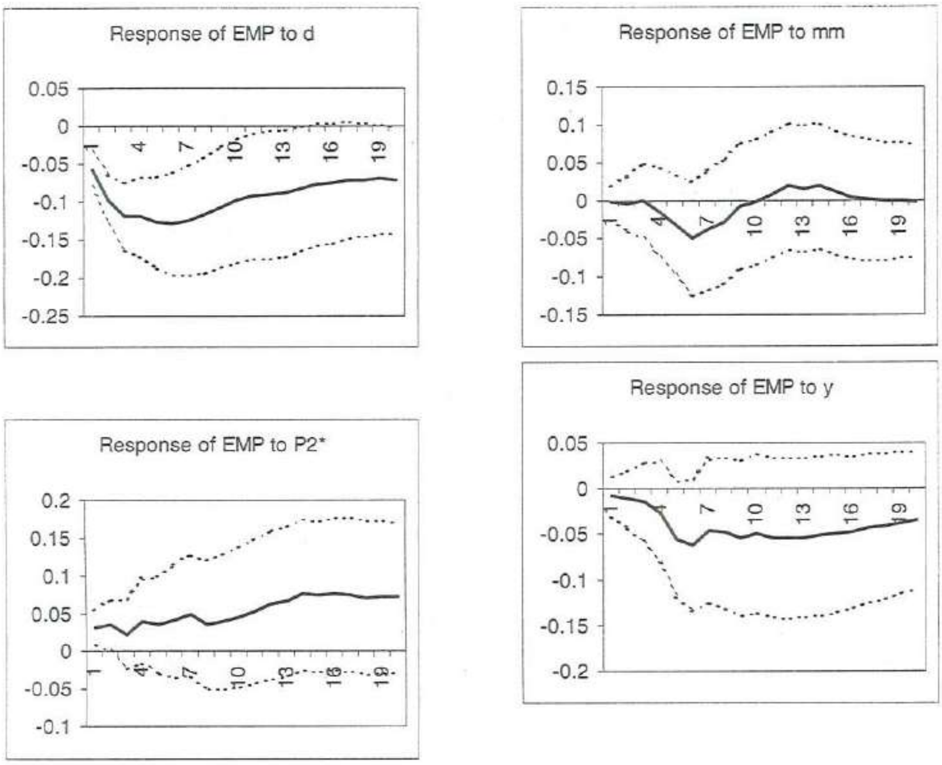


Figure 4 : Responses of EMP due to shocks to d, mm, p_2*, and y estimated at lag 8 using Taka/India's Rupee exchange rate and Cholesky ordering: p_2*, mm, d, y and EMP.



Variable List

The data period for this paper is from 1976:2 to 2003:4. All data are adjusted from IMF, International Finanical Statisties (ITS) CD-ROM. The seasonally unadjusted data are seasonally adjusted using the XII Prvcedure in SAS. Variables used in paper are described in the following:

Foreign Inflation (pi*) (1995=100) = the percentage change of foreign (India and the U.S.) consumer price index. The percentage change of CPI is used as a foreign inflation variable.

Real Income (y) (1995=100) = the percentage change of real income is used as the real income (y) variable.

International Reserves (r) (in Million Taka) = the percentage change of foreign assets (r) of the monetary authorities are used as an international reserves variable.

Domestic Credit (d) (in Million Taka) = the percentage change of central bank domestic credit to the government and the private sector is used as a monetary policy variable.

Exchange rate (e) = the percentage change of the nominal exchange rate (Taka/Dollar and Taka/Rupee). Here, Taka/Rupee rate is the cross rate derived from dividing Taka/Dollar by Rupee/Dollar nominal exchange rate.

Money Multiplier (mm) = the percentage change of the money multiplier (mm); the money multiplier is calculated dividing M2 by the monetary base.

Q=(e/r) = Q is calculated dividing the percentage change of the exchange rate by the percentage change of the international reserves.

References

1. Bahmani-Oskooee, M.; Shiva, Reza, "A Method of Detecting Whether a Central Bank Engages in the Black Market for Foreign Exchange: Evidence from Iran," Economics Letters, Vol.60, (1998), pp.97-103.
2. Connolly, Michael; Silveira, Jose, Dantas, D., "Exchange Market Pressure in Postwar Brazil: An Application of the Girton-Roper Monetary Model,"American Economic Review, Vol.69, n3, (1979), pp.448-454.
3. Dickey, David; Fuller, W. A., "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," Econometrica, 49, (1981), pp.1057-72.
4. Engle, Robert E.; Clive W.J. Granger, "Cointegration and Error Correction: Representation, Estimation, and Testing," Econometrica, 55, (March 1987), pp.251-76.
5. Girton, Lance; Roper, Don, "A Monetary Model of Exchange Market Pressure Applied to the Postwar Canadian Experience," American Economic Review, Vol.67, Issue3, (1977), pp.537-548.
6. Hodgson, John, S.; Schneck, Ronald, G. "Stability of the Relationship between Monetary. Variables and Exchange Market Pressure: Empirical Evidence," Southern Economic Journal, Vol.47, n4, (1981), pp.941-58.
7. Johansen, Soren; Juselius, Katerina, "Maximum Likelihood Estimation and Inference on Cointegration with Application to The Demand for Money," Oxford Bulletin of Economics and Statistics, 52, (1990), pp.169-209.
8. Kim, Inchul, "Exchange Market Pressure in Korea: An Application of the Girton-Roper. Monetary Model: Note," Journal of Money, Credit and Banking, Vol.17, n2, (1985), pp.258-263.
9. Mah, Sheen, Jai, "Exchange Market Pressure in Korea: Dynamic Specifications,"Applied Economics Letters, Vol.5, (1998), pp.765-768.
10. Mathur, Priya, "An Exchange Market Pressure Model for India," Indian Economic Review, Vol.XXXIV, n2, (1999), pp.127-148.
11. Pentecost, J. E.; Hooydonk, V. C; Poeck, V. A., "Measuring and Estimating Exchange. Market Pressure in the EU," Journal of International Money and Finance, Vol.20, (2001), pp.401-418.
12. Pollard, Stephen, "Foreign Exchange Market Pressure and Transmission of International. Disturbances: The case of Barbados, Guyana, Jamaica, and Trinidad & Tobago," Applied Economics Letters, Vol.6, (1999), pp.1-4.
13. Tanner, Evan, "Exchange Market Pressure and Monetary Policy: Asia and Latin America in the 1990s," IMF Staff Papers, Vol.47, n3, (2001), pp.311-333.
14. Walsh, Carl. E, "Monetary Theory and Policy," The MIT Press, Cambridge, Massachusetts, London, England (1998).