

Original Article

Investigating Long-run Relationship between Money, Income and Price for Bangladesh: Application of Econometrics and Cross Spectra Methods

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Abstract

This study examines the long-run causation between the three major macroeconomic variables namely real GDP, money supply and price level in the Bangladesh context. The results obtained by applying time series econometric techniques reveal that unidirectional causation exists between real GDP and prices. The study also suggests that causation runs from money supply to prices but price level does not causes money supply. However, co-integration analysis ascertains long run relationship between these three variables. Moreover, in order to decompose Granger causality between real GDP, money supply and prices in the frequency-domain, Lemmens et al. (2008) method of cross spectra analysis has been used which imply that money supply granger causes real GDP over the short-run, but in the long run, money supply Granger causes prices, not real GDP. [*Journal of Science Foundation, January 2016;14(1):17-25*]

Keywords: Real GDP; money supply; price level; co-integration; granger causality; frequency-domain

I. Introduction

Over the last few years, modeling the relationships between income, money supply and price level have been aroused as one of the main important issue for economists, researchers and particularly to the policymakers to ensure the effective macro-economic stabilization policies. A good number of approaches have been developed which allows exploring the causality lies behind the connection between these variables. The quantity theory of money argues that money is an exogenous variable. Cagan (1965) argues that money supply exhibits both endogenous and exogenous properties. The monetarist view implies a short-run trade-off between real and nominal magnitudes, with money supply impacting prices alone in the long-run. The rational expectations school would rule out short-run as well as long-run causality from anticipated money supply to income. The different Keynesian models, emphasizing rigidities, lead to theoretical short-run or short-run as well as long-run causation from money supply to output depending upon whether the structural rigidities are short-term or long-term. Which of these positions best describes the Bangladesh macroeconomic scenario can only be determined by empirical methodologies that are capable of distinguishing between causality in the short-run and the long-run.

Although there is disagreement among economists on the roles of money, income and prices as well as their interrelationship, these variables are considered very important for macroeconomic performances and have been extensively investigated in both, theoretical and empirical literature for both developed and developing countries. Their causal relationships have been an active area of investigation in economics particularly by Sims (1972) when he developed a test of causality and found unidirectional causality from money to income for United States as claimed by the Monetarists. Afterwards, Lee and Li (1983) found bidirectional causality between income and money and unidirectional from money to prices for Singapore. Joshi and Joshi (1985) support their claim from the evidence of Indian economy. However, Khan and Siddiqui (1990) have found of unidirectional causality from income to money and bidirectional between money and prices in Pakistan.

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Abbas (1991) has performed causality test between money and income for Asian countries and found bidirectional causality in Pakistan, Malaysia and Thailand.

At the same line of research Ramachandra (1986) has found money causes real income and price level, price level causes real income and nominal income causes money. Miller (1991) found that their co-integration results are sensitive to the monetary aggregates while Friedman and Kuttner (1992) and Miyao (1996) claimed these results are sensitive to the sample periods used. Stock and Watson (1993) exploits non-normalized assumptions to identify vector co-integrating relationship. Hossain (2005) supports their claim by investigating Indonesian economy. Herwartz and Reimers (2006) have analyzed dynamic relationships and found homogeneity between prices and money, particularly for high inflation countries. Saatcioglu and Korap (2008) reveal monetary aggregates are endogenous for the long-run evolution of prices and real income for Turkish economy. Chimobi and Uche (2010) find that money supply Granger causes both output and prices. However, Sharma, Kumar and Hatekar (2010) indicate that output and prices do not Granger cause money supply reflecting exogeneity of money supply. Therefore, for monetary policy stance it is imperative to understand the temporal dimensions of income, money and price causal relationship.

In spite of immense body of literature, there has been miniature evidence for the long-run relationship between these three important macroeconomic variables, in the context of Bangladesh economy. Moreover, existing literature do not decompose causality by different time horizons. This paper seeks to redress this gap by examining the long-run as well as short-run direction of causality between these three variables. Additionally, Cross Spectra method will be employed to identify how these causal relationships evolve over different temporal horizons.

To investigate the long-run relationship between Real Gross Domestic Product (GDP), Money Supply (MS) and Price level (CPI), yearly time series data over the period 1972 to 2013 have been used. All series are expressed in logarithm. Data on real GDP and CPI have been collected from the Bangladesh chapter of the World Bank economic indicator data. Due to unavailability of CPI data from year 1972 to 1985 have been taken from Bangladesh bureau of statistics for government employees only. The measure of money supply used is the broad one, which consists of currency held by non-bank public and demand deposit held at the monetary sector (Narrow money; M1), and time deposits held at commercial banks. Data on money supply has been collected from the quarterly bulletin published by the Central bank named Bangladesh Bank.

II. Methodology

II A. Econometric Tools

The Augmented Dickey–Fuller (1981) unit root test has been applied to detect the stationarity of the three macroeconomic variables to avoid the problem of spurious regression and to meet the requirements of stationarity properties of the time series data. Moreover, since non-stationary economic time series may produce stationary relationships if they are cointegrated and even if the residuals of the three variables do not contain unit roots, the econometric relationship among the variables could be co-integrating, so unit root analysis has been subjected to individual series. To determine the existence of a long - run relationship between real GDP, money supply and prices a cointegration test is carried out. In the present study the Engle and Granger (1987) two step procedures for modelling the relationship between cointegrated variables has been employed. Granger Causality (GC) tests are employed and Schwarz Information Criterion has been used to determine the numbers of lagged terms to test the hypotheses related to:

(i) Is it the money supply that causes price movements or is it the price movements that cause money supply for the Bangladesh economy? i.e.

$$MS_t = \sum_{i=1}^n \alpha_i CPI_{t-i} + \sum_{j=1}^n \beta_j MS_{t-j} + u_{1t}$$

$$CPI_t = \sum_{i=1}^n \gamma_i CPI_{t-i} + \sum_{j=1}^n \beta_j MS_{t-j} + u_{2t}$$

(ii) Is it GDP that causes the money supply or is it the money supply that causes GDP for the

Bangladesh economy? i. e. $GDP_t = \sum_{i=1}^n a_i MS_{t-i} + \sum_{j=1}^n b_j GDP_{t-j} + u_{3t}$

$$MS_t = \sum_{i=1}^n c_i MS_{t-i} + \sum_{j=1}^n d_j GDP_{t-j} + u_{4t}$$

III B: The Cross Spectra methodology

Analysing time series in frequency domain i.e. spectral analysis could be helpful in supplementing the information obtained by time-domain analysis (Granger, (1969) and Priestley, (1981)). In this study, the bivariate Granger Causality test over the spectrum proposed by Lemmens et al. (2008) has been employed which is based on Pierce (1979), and termed as Pierce's spectral GC measure. The idea behind the mechanism is that, if X_t and Y_t be two stationary time series of length T , the goal is to test whether X_t Granger causes Y_t at a given frequency λ . Pierce's measure for GC (Pierce,1979) in the frequency domain is performed on the series, u_t and v_t , derived by filtering the X_t and Y_t as univariate ARMA processes (Lemmens et al, 2008) i.e

$$\Theta^x(L)X_t = C^x + \Phi^x(L)u_t \dots\dots\dots (1) \quad \& \quad \Theta^y(L)Y_t = C^y + \Phi^y(L)v_t \dots\dots\dots (2)$$

Where $\Theta^x(L)$ and $\Theta^y(L)$ are autoregressive polynomials, $\Phi^x(L)$ and $\Phi^y(L)$ are moving average polynomials and C^x and C^y potential deterministic components. The obtained innovation series u_t and v_t , which are white-noise processes with zero mean, possibly correlated with each other at different leads and lags. Let $S_u(\lambda)$ and $S_v(\lambda)$ be the spectral density functions, or spectra, of u_t and v_t at

$$\text{frequency } \lambda \in]0, \pi[, \text{ define by } S_u(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_u(k) e^{-i\lambda k} \dots\dots\dots (3)$$

$$\text{And } S_v(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_v(k) e^{-i\lambda k} \dots\dots\dots (4)$$

where $\gamma_u(k) = \text{Cov}(u_t, u_{t-k})$ and $\gamma_v(k) = \text{Cov}(v_t, v_{t-k})$ represent the autocovariances of u_t and v_t at lag k . The idea of the spectral representation is that each time series may be decomposed into a sum of uncorrelated components, each related to a particular frequency λ^2 . The area under $S_u(\lambda)$ and $S_v(\lambda)$, between any two frequencies λ and $\lambda + d\lambda$, gives the portion of variance of u_t and v_t respectively, due to cyclical components in the frequency band $(\lambda, \lambda + d\lambda)$.

The cross spectrum represents the cross covariogram of two series in frequency domain. It allows determining the relationship between two time series as a function of frequency. Let $S_{uv}(\lambda)$ be the cross

$$\text{spectrum between } u_t \text{ and } v_t \text{ series, defined as, } S_{uv}(\lambda) = C_{uv}(\lambda) + iQ_{uv}(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{uv}(k) e^{-i\lambda k} \dots\dots\dots (5)$$

where $C_{uv}(\lambda)$ is called co-spectrum and $Q_{uv}(\lambda)$ is called quadrature spectrum are respectively, the real and imaginary parts of the cross-spectrum and $i = \sqrt{-1}$. Here $\gamma_{uv}(k) = \text{Cov}(u_t, v_{t-k})$ represents the cross-covariance of u_t and v_t at lag k . The co-spectrum $C_{uv}(\lambda)$ between two series u_t and v_t is the covariance between two series u_t and v_t that is attributable to cycles with frequency λ . The quadrature spectrum looks for evidence of out-of-phase cycles (Hamilton, 1994). The cross-spectrum can be estimated

$$\text{non-parametrically by, } \hat{S}_{uv}(\lambda) = \frac{1}{2\pi} \left\{ \sum_{k=-M}^M w_k \hat{\gamma}_{uv}(k) e^{-i\lambda k} \right\} \dots\dots\dots (6) \text{ with } \hat{\gamma}_{uv}(k) = \hat{COV}(u_t, v_{t-k}),$$

for $k = -M, \dots, M$. Eq. (6) is called the *weighted covariance estimator*, and the weights w_k are selected as,

² The frequencies $\lambda_1, \lambda_2, \dots, \lambda_N$ are specified as follows: $\lambda_1 = 2\pi/T, \lambda_2 = 4\pi/T, \dots$

The highest frequency considered is $\lambda_N = 2N\pi/T$, where $N \equiv T/2$, if T is an even number and $N \equiv (T-1)/2$, if T is an odd number (Hamilton, p.159, 1994).

the Bartlett weighting scheme i.e. $1 - |k|/M$. The constant M determines the maximum lag order considered. The spectra of Eq. (3) and (4) are estimated in a similar way. This cross-spectrum allows to compute the coefficient of coherence $h_{uv}(\lambda)$ defined as,

$$h_{uv}(\lambda) = \frac{|S_{uv}(\lambda)|}{\sqrt{S_u(\lambda)S_v(\lambda)}} \dots\dots\dots (7)$$

Coherence can be interpreted as the absolute value of a frequency specific correlation coefficient. The squared coefficient of coherence has an interpretation similar to the R-squared in a regression context. Coherence thus takes values between 0 and 1. Lemmens et al. (2008) have shown that, under the null hypothesis that $h_{uv}(\lambda) = 0$, the estimated squared coefficient of coherence at frequency λ , with $0 < \lambda < \pi$ when appropriately rescaled, converges to a chi-squared distribution with 2 degrees of freedom³, denoted by χ_2^2 i.e. $2(n-1)\hat{h}_{uv}^2(\lambda) \xrightarrow{d} \chi_2^2 \dots\dots\dots (8)$

with $n = T / (\sum_{k=-M}^M w_k^2)$. The null hypothesis $h_{uv}(\lambda) = 0$ versus $h_{uv}(\lambda) > 0$ is then reject if $\hat{h}_{uv}(\lambda) > \sqrt{\frac{\chi_{2,1-\alpha}^2}{2(n-1)}}$ with $\chi_{2,1-\alpha}^2$ being the $1 - \alpha$ quantile of the chi-squared distribution with 2 degrees of freedom.

The coefficient of coherence in Eq. (7) gives a measure of the strength of the linear association between two time series, frequency by frequency, but does not provide any information on the direction of the relationship between two processes. Lemmens et al (2008) have decomposed the cross-spectrum (Eq.5) into three parts: (i) $S_{u \leftrightarrow v}$, the instantaneous relationship between u_t and v_t ; (ii) $S_{u \Rightarrow v}$, the directional relationship between v_t and lagged values of u_t ; and (iii) $S_{v \Rightarrow u}$, the directional relationship between u_t and lagged values of v_t , i.e., $S_{uv}(\lambda) = [S_{u \leftrightarrow v} + S_{u \Rightarrow v} + S_{v \Rightarrow u}]$

$$= \frac{1}{2\pi} \left[\gamma_{uv}(0) + \sum_{k=-\infty}^{-1} \gamma_{uv}(k)e^{-i\lambda k} + \sum_{k=1}^{\infty} \gamma_{uv}(k)e^{-i\lambda k} \right] \dots\dots\dots (9)$$

The proposed spectral measure of GC is based on the key property that u_t does not Granger cause v_t if and only if $\gamma_{uv}(k) = 0$ for all $k < 0$. The goal is to test the predictive content of u_t relative v_t to which is given by the second part of Eq. (9), i.e. $S_{u \Rightarrow v}(\lambda) = \frac{1}{2\pi} \left[\sum_{k=-\infty}^{-1} \gamma_{uv}(k)e^{-i\lambda k} \right] \dots\dots\dots(10).$

The Granger coefficient of coherence is then given by, $h_{u \Rightarrow v}(\lambda) = \frac{|S_{u \Rightarrow v}(\lambda)|}{\sqrt{S_u(\lambda)S_v(\lambda)}}$. Therefore, the Granger coefficient of coherence takes values between zero and one. Granger coefficient of coherence at frequency

λ is estimated by $\hat{h}_{u \Rightarrow v}(\lambda) = \frac{|\hat{S}_{u \Rightarrow v}(\lambda)|}{\sqrt{\hat{S}_u(\lambda)\hat{S}_v(\lambda)}}$, $\dots\dots\dots (11)$ with $\hat{S}_{u \Rightarrow v}(\lambda)$ as in Eq. (6), but

³ For the endpoints $\lambda = 0$ and $\lambda = \pi$, one only has one degree of freedom since the imaginary part of the spectral density estimates cancels out.

with all weights $w_k=0$ for $k \geq 0$. Under the null hypothesis $\hat{h}_{u \Rightarrow v}(\lambda) = 0$, the distribution of the squared estimated Granger coefficient of coherence at frequency λ , with $0 < \lambda < \pi$ is given by $2(n'-1)\hat{h}_{uv}^2(\lambda) \xrightarrow{d} \chi_2^2$; where n is now replaced by $n' = T / \left(\sum_{k=-M}^{-1} w_k^2 \right)$. Since the w_k s', with a positive index k , are set equal to zero when computing $\hat{S}_{u \Rightarrow v}(\lambda)$, in effect only the w_k with negative indices are taken into account. The null hypothesis $\hat{h}_{u \Rightarrow v}(\lambda) = 0$ vs $\hat{h}_{u \Rightarrow v}(\lambda) > 0$ is then rejected if $\hat{h}_{u \Rightarrow v}(\lambda) > \sqrt{\frac{\chi_{2,1-\alpha}^2}{2(n' - 1)}}$ (12)

Afterward, we compute Granger coefficient of coherence given be Eq. (11) and test the significance of causality by making use of Eq. (12).

III. Results and Discussions

III A. Econometric time series analysis

There exist high correlation between GDP, Money and CPI (results are not presented here). The magnitude of correlation lies between 0.77 to 0.94. The Augmented Dickey-fuller test to detect the stationarity (applied for both level and first differences) with and without trend is presented in Table 1.

Table 1: Augmented Dickey- Fuller (ADF) unit root test results

| | Levels | | First Differences | |
|----------|-----------|--------------|-------------------|--------------|
| | τ_c | $\tau_{c,t}$ | τ_c | $\tau_{c,t}$ |
| Ln(RGDP) | 3.07* (0) | 1.62 (0) | --- | 4.27* (0) |
| Ln(MS) | 3.84* (4) | 2.97* (4) | --- | |
| Ln(CPI) | 5.03* (0) | 0.82 (2) | --- | -2.98* (0) |

Note: τ_c and $\tau_{c,t}$ are the test statistic for ADF test with constant and with constant & trend respectively. The critical values for ADF test are -3.60, -2.94 and 2.61 at 1%, 5% and 10% level of significance respectively. Number of maximum allowable lags is in bracket which is determined by Schwarz information criteria

The unit root test results given in Table 1 indicates that the unit root null hypothesis are rejected for all the variables in their levels when including only constant in the model, but when including trend and intercept in the test equation, the ADF results show that the unit root hypothesis can be rejected only for MS. When first difference is considered real GDP and CPI series provide stationary of these variables like GDP and CPI are trend-stationary).

Table 2: Co-integration test results

| Engle-Granger co-integration test | | | |
|--|----------------|---------------|--------------|
| | Tau-statistic | z-statistic | p-values |
| DRGDP | -10.62 | -56.54 | 0.00 |
| DMS | -9.31 | -53.76 | 0.00 |
| DCPI | -11.12 | -62.21 | 0.00 |
| Unit root test(Null hypothesis: common unit root process) | | | |
| Levin, Lin & Chu t* statistic: | -17.47 | | 0.000 |
| Unit root test Null: Unit root (assumes individual unit root process) | | | |
| ADF - Fisher Chi-square statistic | 83.7240 | | 0.000 |
| PP - Fisher Chi-square statistic | 58.6329 | | 0.000 |

Table 2: Co-integration test results (Continued)

| | | | |
|--|-----------------|-------------|--------------|
| LM, Pesaran and Shin W-statistic | -16.0722 | | 0.000 |
| Lag order: 0 | | | |
| Johnson co-integration coefficients | | | |
| Ln(constant) | Ln(DMS) | Ln(DCPI) | |
| 9.5 | -1.11 (2.77) | 0.82 (0.85) | |

Notes: number inside parentheses next to each coefficient is the standard error. The critical values for ADF tests are -1.94, -2.58 and -1.62 for 5%, 1% and 10% respectively. Reported first four P-values represent Mackinnon (1996) p-values.

The Johansen procedure was used to test for the existence of a long-run relationship between real GDP, MS and CPI, i.e. a co-integrating relationship. Table 2 provides the results of the cointegration tests. The test results indicate co-integrating relationship at 5 percent significance level. Hence, the long-run equilibrium relationship can be expressed as:

$$\text{Real GDP} = -0.33\text{MS} + 2.29\text{CPI} + 136276.6$$

After establishing the long run relationship of the variables, the direction of causation between money and prices are to be investigated. The Granger Causality tests to examine the pair wise relation between variables are presented in Table 3.

Table 3: Granger Causality Tests results

| Null hypothesis | Observations | F-statistics | Probability |
|----------------------------------|--------------|--------------|-------------|
| MS Does not Granger Causes RGDP | 41 | 1.32 | 0.27 |
| RGDP Does not Granger Causes MS | 41 | 2.01 | 0.16 |
| CPI Does not Granger Causes RGDP | 41 | 2.84 | 0.13 |
| RGDP Does not Granger Causes CPI | 41 | 7.45 | 0.005 |
| CPI Does not Granger Causes MS | 41 | 2.69 | 0.12 |
| MS Does not Granger Causes CPI | 41 | 12.11 | 0.0003 |

The Granger Causality test results from Table 3 revealed a unidirectional causation between money and prices for Bangladesh. The direction of causation between money supply and prices runs from money supply to price. On the other hand, there is no reverse causation from price movements to money supply. The reasons behind this scenario are that, in one hand government is borrowing from the banking system which contributed to inflation. On the other hand, financial markets are not well developed and their influence in the economy as a whole is not strong enough. Moreover, the majority of the people do not have adequate knowledge and much confidence in the financial markets. Hence, it seems that the main alternative to holding money is spending on goods and services and therefore causes the movement in prices. The results also reveal that, there is no reverse causation noted from prices to income. Finally, no much amount of causation was found between real GDP and money supply.

III B. Cross Spectra Analysis

All the three differenced series of RGDP, MS and CPI have been filtered using ARMA models to obtain the innovation series. The frequency (λ) on the horizontal axis can be expressed into a cycle or periodicity of T months by $T = 2\pi / \lambda$ where T is the period. After ARMA filtering the series and adjusting for lags, there remaining 39 observations. Therefore, $N=13$ cycles of different frequencies, with the shortest possible cycle of 3 months and longest cycle of $13*12=156$ months can be considered.

Figure 1 presents the result of Granger coefficient of coherence for causality against the frequency. Fig A shows that at 5% level of significance, money supply Granger causes output at higher frequencies reflecting short-run cycles. The causality running from money supply to output is significant between frequencies corresponding to 3-4 months cycles and then between frequencies corresponding 6-10 months cycle. The

Granger coefficient of coherence suggests that the causality running from money to output between frequencies corresponding to 3-4 months cycles is relatively weak compared to frequencies corresponding 6-10 months cycles. The peak of Granger coefficient of coherence is reached at the frequency corresponding to 8-9 months. However, the results in figure A indicate that at 5% level of significance, money supply does not Granger causes output at frequencies corresponding to more than a year. Based on the results obtained in fig A, we can say that money supply provides significant predictive power for future output movement within a year, but money supply does not appear to be an indicator of interest for future output movement for more than a year.

In figure B, Granger coefficient of coherence for causality running from money supply to prices has been presented. Fig B suggests that the estimated Granger coefficient of coherence rises at frequency corresponding to 3 months cycles, but at these frequencies the coefficient of coherence is not significant at 5% level. However, fig B suggests that the Granger coefficient of coherence is significant at 5% level at lower frequencies. At frequencies corresponding to 18 months cycle to 156 months cycle, we find money supply significantly Granger causes prices. This reflects that money supply Granger causes prices over the business cycle frequencies and also in the long-run.

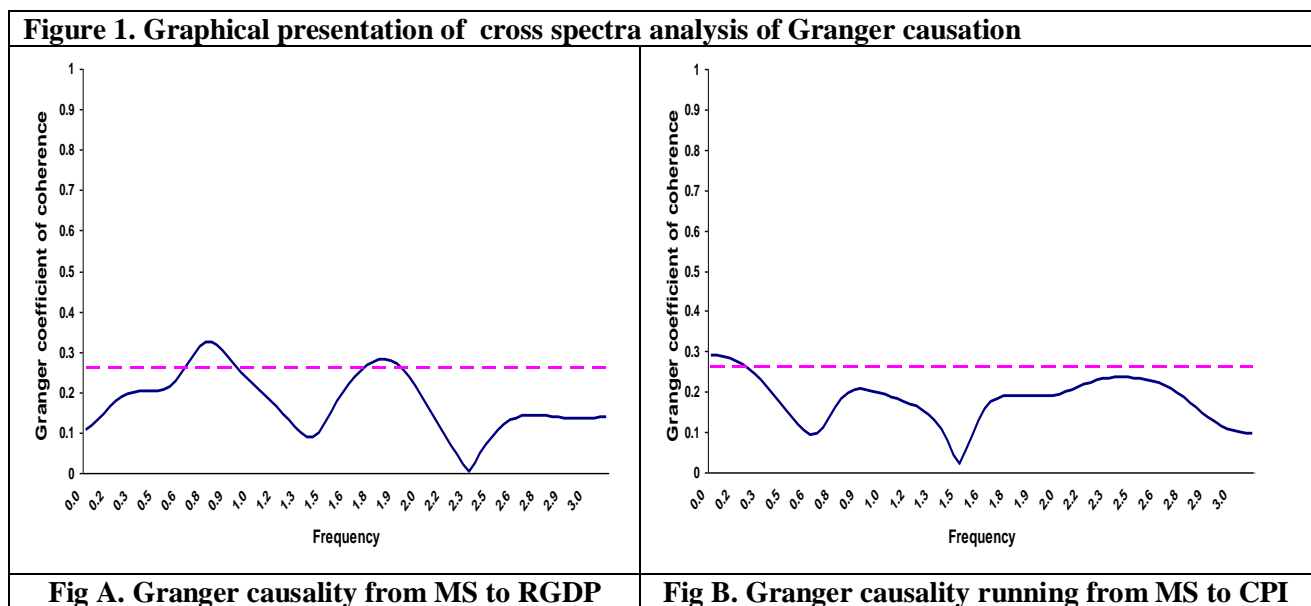
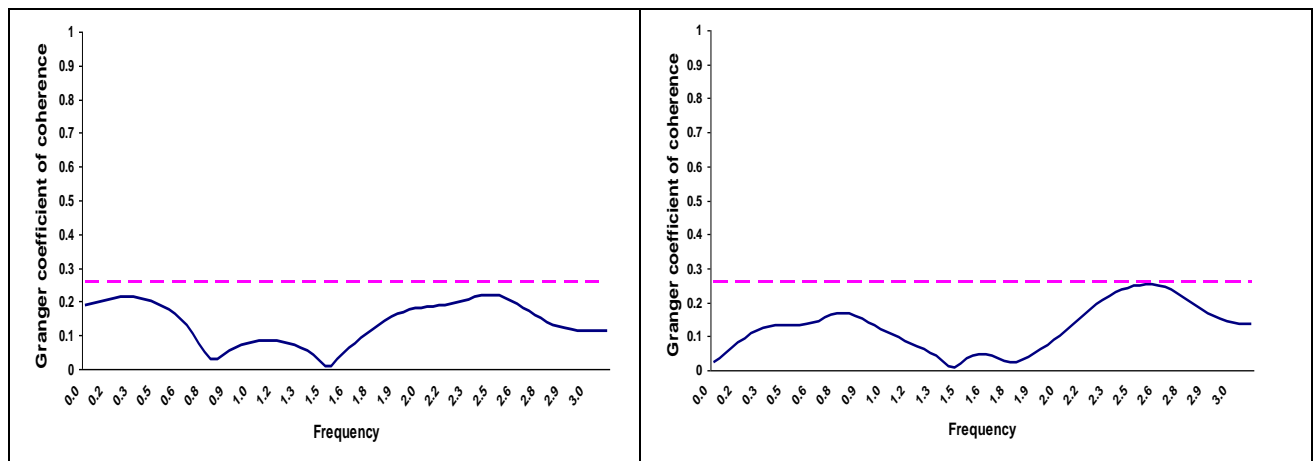


Fig C presents the results for Granger causality running from output to money supply. The result indicates that at 5% level of significance output does not Granger causes money supply, at higher as well as at lower frequencies. Though, the Granger coefficient of coherence jumps at frequencies corresponding to 3 months cycles but does not cross the significance level. Therefore we cannot reject the null hypothesis of no causality running from output to money at 5% level of significance, at all the frequencies.

The result reported in Fig D clearly reveals that the null hypothesis of no Granger causality running from prices to money supply cannot be rejected at 5% level of significance, at all the frequencies. Though, at frequencies corresponding to 3 months cycles, the effects of prices on money supply were not strong enough to be statistically significant at 5% level of significance. .

**Fig C. Granger causality from RGDP to MS****Fig D. Granger causality running from CPI to MS**

Note: The critical value for the null hypothesis at the 5% level of significance is presented by dotted line.

The results evolving from this study suggests that in Bangladesh, money supply seems to provide reliable prediction power for future output movement within a year period but not in the long- run. The feedback running from income to money supply as well as from prices to money supply is not significant at any of the frequencies. The causality running from money supply to prices over the business cycle frequencies as well as in the long-run indicates that at these frequencies money supply seems to provide reasonable information regarding the movement of future prices in India. Therefore, money Granger causes output in short-run but over the business cycle frequencies and in the long-run it Granger causes prices. This finding highlights that the monetarist proposition works well in India. The finding of unidirectional causality running from money to output and money to prices indicates that money supply remains exogenous. The exogeneity of money supply indicates that monetary authority can use money supply as an effective monetary policy instrument.

IV. Conclusion

The salient features relevant to the three major macroeconomic variables of Bangladesh economy during the period 1972 – 2013 are presented. Unit root test and Johansen procedure have been carried for long-run equilibrium relationship. The Granger causality test reveals a uniform directional causation between the supply of money and prices movement. The results show that causal and reverse causal relations between money and output and money and prices vary across frequencies. The causality running from money to output remains a short-run phenomenon. The study also stipulates a unidirectional causality between money and prices, with causality running from money supply to prices, which can be regarded as a piece of empirical evidence supporting the monetarist claim. The unique contribution of the present study lies in decomposing the causality on the basis of time horizons and demonstrating that short run causality from money supply to output, long run causality from money supply to prices, as well as lack of long run causality from money supply to output, all co-exist. These results are consistent with nominal price rigidity in the short run, but full nominal price flexibility at the business cycle frequency as well as in the long run. On the other hand, output in the long run is likely to be determined by real factors rather than by nominal variables.

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