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Abstract

This study empirically investigates how shocks to monetary policy measures (short-term nominal interest rate and broad money supply) affect economic aggregates: output growth, price levels and nominal exchange rate. The study is carried out for Pakistan using quarterly data covering the period from 1980 to 2009. In doing this, Johansen's (1988) co integration technique and vector error correction model are applied to explore the long-run relationship among the variables. We find significant evidence on the existence of a long-run stable relationship between our monetary measures and economic aggregates. The impulse response functions (IRFs) are computed to examine the response of each macroeconomic variable to a standard deviation shock to monetary measures. The IRF graphs reveal a price puzzle in closed as well as in open economy model. However, an initial appreciation of exchange rate is observed, indicating the overshooting hypothesis phenomenon for Pakistan.

JEL Classification: C3; E4; E5
Keywords: Monetary Policy, Economic Aggregates, VECM, Impulse Response Function

1. Introduction

Since the seminal work by Friedman (1963), the role of monetary policy in stabilization of macroeconomic aggregates is still an inconclusive issue. Besides the development on theoretical grounds, a substantial body of empirical literature contributed to the ongoing debate by providing significant evidence on how does monetary policy affect output growth, prices and exchange rate. No doubt, the adoption of floating exchange rate, the slogan of financial and trade liberalization and relatively more autonomy of central banks have further enhanced the significance of monetary policy. Therefore, both academics and policy makers are keen to understand how, when and to what extent the changes in monetary policy (both anticipated and unanticipated) affect economic aggregates.

In theory, the debate on monetary policy has evolved from policy ineffectiveness to the identification of the long-run and short-run impact of monetary policy. Monetary policy appears to be significantly effective for the short run and completely ineffective in the long run as viewed by monetarist school of thought. While with respect to the long-run neutrality of monetary policy both the New-Keynesian and classical school of thoughts have same views, the New-Keynesian economist believe that monetary policy may affect the output and inflation in short run as they presume the nominal wages are rigid at least in the short run. Moreover, rational expectation theory considers expectations as crucially important for analyzing the monetary policy (see, for further theoretical debates, Goodfriend, 2005).

Recent studies have much focused on how one can measure monetary policy and its innovations, particularly. Studies such as Bernanke et al. (2005), Bernanke et al. (1998), Eichenbaum et al. (1995), and Sims (1992) have significantly contributed in this context. These studies mainly utilize vector autoregressive methodology to measure the responsiveness of macroeconomic aggregates to monetary policy shocks. Although the findings of these studies provide significant evidence on the response of macro variables such as real economic activity, price level, and exchange rate to changes in monetary policy, there are number of measurement problems and various anomalies. These inconsistencies generally include price, exchange rate, and liquidity puzzles. To overcome these issues, researchers have made numerous attempts to develop much more advance estimation methods and shocks measuring techniques. Factor augmented vector autoregressive, known as FAVAR, developed by Bernanke et al. (2005) and structural factor augmented model proposed by Forni (2010) are examples of these advancements[1].

The functioning of monetary policy appears more complicated and challenging when we discussed in context of developing countries because most of the developing countries face lack of organized financial markets and have weak channels of transmission. The unorganized financial markets mechanism and weak channels of transmission may responsible to the inconsistent relationship of monetary policy with macroeconomic aggregates. Regarding empirical evidence, there is a small amount of studies which focus on developing countries. Thus, we relatively know less how economic aggregates such as output, prices and exchange rates respond to monetary policy shocks in developing countries. However, the understanding of the role of monetary policy in real and nominal sector of the economy is of great significance not

[1] Despite an extended empirical research and intensified methodological applications, the findings are inconclusive at best (see for further details Bjornland (2009)).

only to academics but also policy makers because in developing countries the market mechanism and the level of transparency significantly differ from developed countries.

Differing from the studies which largely focus on developed countries, the prime aspire of this study is to examine the significance of monetary policy for a developing and relatively small open economy namely Pakistan. Specifically, we first explore how and to what extent monetary policy helps three major macroeconomic variables viz. output growth, price level and nominal exchange rate in converging towards the long-run equilibrium. We next turn to examine how these variables respond to one standard deviation shock to monetary measures (i.e., short-term nominal lending rate and broad money supply). Specifically the study tests the following two hypotheses:

H_0^1 = there is long-run co-movement between macroeconomic aggregates and monetary policy

H_0^2 = there is significant convergence of macroeconomic aggregates towards steady state

To carry out our empirical investigation we first test the order of integration of the variables by estimating augmented Ducky-Fuller unit root test proposed by Ducky and Fuller (1981) with and without including trend in the specifications. After confirming the order of integration we test for long-run association among the variables. In so doing, we apply Johansen's (1988) cointegration process to test the possible co-integration vectors. To examine to direction of the short- and long-run causation and speeds at which the variables converge to its long-run equilibrium position we estimate vector error correction model (hereafter VECM). Finally, to investigate how macroeconomic aggregates respond to one standard deviation shocks to monetary measure, we estimate impulse response functions (hereafter IRFs) based on VECM. Throughout our empirical analysis our approach is to first estimate a bivariate model of closed economy as a baseline model and then gradually we include other variables and finally extend our model to open economy by incorporating bilateral nominal exchange rate and international commodity prices. This approach enables us to examine how the response of underlying variables to monetary measures changes when we include more information in the model. Furthermore, it allows us to do a comparison between close economy and open economy models.

The empirical literature on this issue for Pakistan is very limited not only in applying new methodologies but also in terms of diversifying aspects. Qayyum (2002) computes the monetary condition index (MCI) for Pakistan based upon the estimated weights to the measures of monetary policy such as interest rate and exchange rate. However, the application of MCI for Pakistan is questionable as MCI index is more useful in absence of supply shocks but the supply shocks are dominant in case of Pakistan. Therefore, the results of the study may not reliable[2]. Another study by Aga et al. (2005) uses six months Treasury bill (T-bill) rates as a measure of monetary policy and used VAR technique for empirical examination. Besides the short time span, the study has estimated a VAR model using variables at their level even though some of the variables are integrated of order one (non-stationary at levels) which not only leads to the efficiency loss but also calls into question the validity of the results. Finally, recently Khan (2008) has made an attempt to investigate the impact of unanticipated changes in monetary policy on output and inflation estimating structure VAR (SVAR). The study uses nominal shocks in

[2] Although Khan and Qayyum (2004) provide empirical evidence of superiority of the MCI over Bernanke and Mahivo (1998) measure of monetary measure while measuring the macroeconomic impact of monetary policy for Pakistan, Bernanke and Mihov's measure of monetary policy is better theoretically as it uses more financial variables which plays an important role in monetary policy formulation.

SVAR as a proxy for unexpected changes in monetary policy. However, this measure suffers with the problem of lake of theoretical rationales.

Our study significantly differs from above cited studies in following three ways. First, we utilize more recent sample period focusing on quarterly data rather than annual. The use of quarterly data enables us not only to harvest the gain of higher degree of freedom but also to use a deeper lags to identify a well-specified model without losing the informational credibility of the sample. Secondly, unlike the previous studies we take great consideration of the time-series properties such as non-stationary behavior of the variables before utilizing in estimation. Finally, we prefer VECM approach over the SVAR because SVAR does not account for the long-run association. We also take into account the world oil prices by including the world commodity price index as a control variable in our investigation.

The estimates on the co-integration test provide significant evidence of the existence of a long-run relationship among our macroeconomic aggregates and both measures of monetary policy used in the study. Estimating the VECM models we find that coefficient of error term is negative and statistically significant in most of the cases as required for convergence toward equilibrium. Overall, the findings of the study are in line with the conventional wisdom as impulse response functions of exchange rate exhibit declining pattern after a positive shock to money supply. This implies the absence of exchange rate puzzle. On contrary, price puzzle is observed after giving a positive shock to monetary policy.

The rest of the study is organized as follows. Section 2 reviews the existing empirical literature and highlights the strengths and weaknesses of their methodologies. Empirical methodology, data sources and the definition of the variables are given in Section 3. Section 4 presents our empirical findings. Finally, Section 5 concludes the study.

2. Literature Survey

Since Friedman's (1963) seminal work on the association between monetary policy and national income, how the output of economy response to monetary policy is still a debate among academics and researchers. Theoretical framework has been improved considerably from money demand function and Fisher's (1977) equation to rational expectations hypothesis. There is general consensus that monetary policy is effective in the short run but the views vary on the long-run effectiveness of monetary policy (Bernanke et al. 1995). The relationship between output and interest rate is a representation of investment-saving (IS) curve which describes a negative relationship between output and interest rate. Moreover, the relationship between consumer price index (CPI) with its lagged values and manufacturing output portrays the Phillips curve[3].

In theory, exchange rate not only responds to monetary policy significantly but also plays an important role in monetary policy formulations. The standard exchange rate model by Dornbusch (1976) explains the appreciation in nominal exchange rate as a response of contractionary monetary policy. Below we review empirical studies that examine the impact of monetary policy on economic aggregates.

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[3] The equation does not incorporate expectations therefore it cannot be regarded as expectations augmented Phillips curve (see, for further details, Clarida et al. (1999)).

2.2 Review of Empirical Literature

Forni et al. (2010) assess the dynamic exogenous effect of monetary policy by employing standard recursive scheme through a dynamic structural factor model for USA covering the time period 1973:3-2007:10. Their empirical analysis is based on the variables which are used by Stock and Watson (1998). There are 16 static factors chosen based on Bai and Ng (2002) criterion. They argue that the factor analysis model is superior to FAVAR proposed by Bernanke et al. (2005) because it helps in eliminating the puzzles in monetary policy analysis. They find that a positive shock to Federal Funds Rate (FFR) leads to an appreciation of real exchange rates. This confirms overshooting hypothesis of Dornbusch (1976). Computing impulse response graphs they show the absence of price puzzle. Further, they argue that industrial production falls, although temporary, to a large extent with a humped shaped response.

Bjornland (2008) examine the response of macroeconomic economic aggregates to monetary policy by including exchange rate in macroeconomic variable set. He used quarterly data over the period 1993-2004. The study use Cholesky ordering and Kim and Roubini (2000) identification to determine the order of the variables. He shows that there is a temporary increase in the interest rate which normally takes four quarters to converge to its normal path. However, the analysis does not provide any evidence of the exchange rate puzzle or price puzzle.

Ansari et al. (2007) explores the relationship between money income and prices by estimating VECM. They use narrow and broad money as measures of monetary policy. Using quarterly data, they document that for any divergence from long-run equilibrium; output will increase by 6% to adjust to its long-run equilibrium point. Furthermore, they show that a positive shock to money leads to adjustment in output after 5 quarters. However, the study did not mention the order of integration which is pre-requisite for co-integration analysis. Furthermore, the authors did not mention how they choose the order of variables while computing the IRFs, thus the results of the IRFs are likely to be biased.

Bernanke et al. (2005) introduced a combination of VAR model and factor model to capture large information set which a simple VAR analysis is unable to incorporate. They use a diffusion indexes develop by Stock and Watson (2002) to estimate the factors by utilizing a balanced panel of 120 monthly macroeconomic series (1959:1-2001:8). They argue that the FAVAR is more capable of delivering large information based upon small set of estimated factors. A recursive structure is assumed with identifying assumption of no contemporaneous response of unobserved factors to monetary policy shocks[4]. The comparison of 3-variable VAR with two FAVAR specifications reveals the fact that standard VAR results show a significant price puzzle and inconsistent production response with the long-run money neutrality. However, the FAVAR approach improves the results as price puzzle disappears after one year, real activity declines, monetary aggregates fall and exchange rate appreciates for USA. As in Forni et al. (2010), since the study did not distinguish between number of static factors and structural shocks, a large number of economic restrictions are imposed to reach the identification. Moreover, the restrictions are imposed on IRFs of static factors instead of IRF of variables.

[4] Monetary policy variable is last in the variable ordering.

Holtemoller (2004) investigates the relationship between macroeconomic variables such as output, prices and money supply for Euro area. The study covers the sample period 1984-2001. Specifically, he estimates money demand function by incorporating short-run along with long-run rate of interest. Co-integrating vectors has been identified through Johansen's (1995) approach and the long-run causation relationship is identified through the VECM. He reports three cointegrating vectors. Although his results are strongly significant, one cannot ignore the fact that the selection of the right vector is a critical issue in case of more than one cointegrating vectors. Moreover, the long-run as well as short-run interest rates and money supply are potential measures of monetary policy which are used in the same equation without addressing the issue of multicollinearity.

Jang and Ogaki (2004) examine the relationship between monetary policy shocks and Dollar/Yen exchange rate, prices and output level for USA. The empirical analysis is carried out, following the model of Jang (2000), through structural VECM and VAR by employing long-run and short-run restrictions on the model. They use seven macroeconomic variables in their empirical investigation. These variables include domestic and foreign output levels, domestic prices, domestic and foreign interest rates, real exchange rate, whereas monetary variables include FFR and non-borrowed reserves (NBR). They find that an appreciation of exchange rate is the result of a contractionary monetary policy. This confirms the overshooting hypothesis and is also in line with the uncovered interest rate (UIP) theory. Furthermore, they find that output in domestic and foreign country significantly decreases due to the long-run neutrality restrictions with an exception of USA where a decline in output becomes negligible after four years. Finally, a fall in price is observed as a result of tight MP. While, estimating VECM and VAR with short-run restrictions for variables in their levels they fail to accept the UIP condition, they find strong evidence in support of the existence of price puzzle.

Berument (2007) provides the empirical estimates of monetary policy in a small open economy namely Turkey, by utilizing the monthly data from 1986:05-2000:10. The study has introduced a new monetary policy instrument which is the spread between central Bank's interbank interest rate and depreciation of the domestic currency to deal with liquidity, price and exchange rate puzzles. Non-policy variables included in the model are national income, CPI, commodity price index, and money. The application of recursive VAR system and IRF towards a positive shock to spread yields a decline in industrial production but this declining trend is not persistent. They also show that the negative response of prices and exchange rate to interest rate spread eliminates price and exchange rate puzzles, respectively. Although the study appears to be successful in eliminating the famous puzzles, it is based on a narrow time span.

Fullerton et al. (2001) utilize error correction model to study the behavior of exchange rate for Mexican peso for the period 1976-2000. The variables included in the model are nominal ER, CPI, liquid international reserves, money supply and real GDP as non policy variables while one month and 3-month T-Bill rates as policy variables. Their empirical analysis based on the balance of payment framework and monetary model of exchange rate does not provide any support to the established theory. However, balance of payment framework with one month T-bill rate is marginally better than the monetary model.

Wong (2000) empirically investigates the impact of monetary policy on macroeconomic variables by applying time-varying parameter model for USA over the period 1959:1-1994:12. The combination of different macroeconomic aggregates included in the study are NBR as a measure of monetary policy, IPI, CPI, FFR, total reserves and commodity price index. Output and prices are assumed to have lagged effect but FFR and reserves are considered to have contemporaneous effect. The rolling VAR has been estimated with maximum three lags. The empirical results suggest an increase in output with a contractionary shock to monetary policy. The output is more responsive to shocks during the periods when the central bank adopts inflation controlling policy, whereas it is less responsive when the central bank aims at promoting economic growth. Overall, the plots of IRF indicate the presence of price puzzle.

Despite a large amount of literature on the monetary policy, there is no consensus on the measure of monetary policy. Bernanke and Mihov (1998) develop a VAR based methodology to measure and assess the impact of MP on macroeconomic variables. The measure of MP is derived from an estimated model of Central Bank's Operating procedures and the market for commercial bank reserves which makes it more consistent than the previously used instruments of monetary policy. Policy variables are the FFR, borrowed reserves and NBR while the non-policy variables are real GDP, GDP deflator, and spot commodity prices. The model has been estimated for different time periods of post 1965-1996 for USA. The exogenous policy shocks are computed through a standard VAR method by applying Generalized Methods of Moments (GMM) in which the policy variables are placed at last in variable ordering. The IRFs indicate an increase in output as a response to expansionary MP, a slower but persistent rise in the prices. However, their results considerably vary across different measure of monetary policy. Although the study attempts to capture all the possible measures of MP but at the end it fails to notify which measure is relatively more efficient.

In 1995, Eichenbaum et al. analyze the ER transmission mechanism of monetary policy for period 1974:1-1990:5. They use three measures of monetary policy which are commonly used in the literature. These measures are FFR, NBR and the narrative measure of Romer and Romer (1989). They estimate a multivariate VAR model by using the ordering of the variables suggested by Wold. The estimates on IRFs reveal that contractionary monetary policy leads to a significant and continual decline in US interest rate, sharp and persistent appreciation of US exchange rate which is contradictory with overshooting hypothesis.

3. Empirical Methodology, Data and Variable Definition

This section discusses the methodology, variable definition and source of data. We divide the section into further two sub-sections. Section 3.1 presents the estimation methods. First we describe the unit root test, then we turn to discuss the cointegration technique and finally, we specify our VECM. In Section 3.2, we discuss data and present the definition of variables used in empirical investigation

3.1 Estimation Methods

Under univariate analysis, non-stationary behavior of macroeconomic variables can be easily dealt with by differencing. However, the problem of non-stationary is more complex in the multivariate analysis. The non-stationary behavior of time series data results a spurious regression which can be confronted by the application of cointegration analysis. In Engel and Granger (1987), the application of cointegration analysis requires the series to be integrated of the same order.

Therefore, at the first step of estimation, each variable is tested to determine its order of integration (stationary/non-stationary). Specifically, we test to determine whether the variable is stationary at level (I(0)), or at first difference (I(1)). If the variables appear to be stationary, then there is no need to carry out the co-integration analysis. On the other hand, the presence of unit root leads us to apply the cointegration test to identify the number of cointegrating vectors.

The presence of unit root has been assessed through two methods: informal and formal. The informal way is the descriptive method for analyzing the behavior of time series through computing Autocorrelation Functions (ACFs) and Partial Autocorrelation Functions (PACFs) of the series. Although this method helps in evaluating and analyzing the behavior, one cannot fully rely on the statistical significance and the empirical validation of the evidence. Hence, studies apply more robust and empirically valid test for testing the order of integration.

Following the previous studies, this study uses augment Dickey-Fuller test proposed by Dickey and Fuller (1981) to examine whether the series follow unit root or not. The general practice to implement the ADF test is to follow the most general form of ADF test and then move to the specific form based upon the obtained outcomes of test in each stage. The ADF statistic is used to test the null hypothesis of unit root against the alternative of no unit root. The more negative value of the ADF statistics implies the strong rejection of the null hypothesis (Gujarati, 2003).

The following two specifications, with trend and without trend, are estimated:

$$\Delta X_t = \mu + \gamma X_{t-1} + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t \tag{1}$$

$$\Delta X_t = \mu + \gamma X_{t-1} + \delta t + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t \tag{2}$$

where μ denotes a drift term, Δ is the first difference operator, t is a linear time trend, and the term ε_t is the stochastic error term. Equations (1) and (2) present the ADF specifications without and with trend, respectively. The coefficient of interest is γ. If γ significantly differs from one, there is no unit root in the underlying series.

The optimum lag length for estimating the ADF equation is selected by following a general to specific approach proposed by Cambell and Perron (1991). In this process, one should start with a relatively long lag-length m^* and apply t-statistic to test the statistical significance of lagged coefficient. The equation should be re-estimated with (m^*-1) lags. The procedure should be repeated until the t-statistic on the last lagged term is statistically significant.

In the next step, we identify the cointegrating vectors. That is, we test whether there is any long-run association among the variables. In general, the components of a vector X_t are said to be co-integrated of order d, b denoted by $X_t \sim CI\ (d, b)$ if

* All components of X_t are integrated of order d; and
* There exists a vector β = $(\beta_{1,}, \beta_2 \ldots\ldots\ldots..\beta_n)$ such that the linear combination $\beta X_t = \beta_1 X_{1t} + \ldots. + \beta_n X_{nt}$ is integrated of order $(d - b)$ where$b > 0$.

For n non-stationary variables there can be $n-1$ linearly independent co-integrating vectors. The number of co-integrating vector is called co-integrating rank of X_t. Co-integration implies that deviations from equilibrium are stationary even though the series themselves are non-stationary and have infinite variance (Engle and granger, 1987).

In literature, two methods namely Engle and Granger (1987) two-step methodology and Johansen's (1988) one step maximum likelihood estimator are commonly used for testing cointegration. However, the recent empirical work on cointegration analysis prefers Johansen's procedure, particularly in multivariate case as the Engle-Granger method is only appropriate for two variable cases (Enders, 2010)[5]. Johansen's method is based on the relationship between the rank of matrix and its characteristic roots (Enders, 2010). For multivariate analysis,

$$\Delta x_t = \Pi(x_{t-1}) + \sum_{i=1}^{p-1} \Pi_i \ \Delta x_{t-i} + BZ_t + \varepsilon_t \tag{3}$$

where

$\Pi = -\left(1 - \sum_{i=1}^{p} A_i\right)$ And $\Pi_i = -\sum_{j=i+1}^{p} A_j$, x_t is a k-vector (n × 1) of I(1) variables[6]. Z_t is a d-vector (n × 1) of deterministic variables, the matrix B contains the exogenous variables that are excluded from the cointegration space, p is the maximum lag, ε_t is assumed to be k-vector (n × 1) of Gaussian error term, and Π_i's are (n × n) matrices of coefficients to be estimated by maximum likelihood estimator.

The rank of Πdetermines number of independent co-integrating vectors:

* If rank (Π) = n, then all series in vector x_t are I (0), hence co-integration is irrelevant
* If rank $(\Pi) = 0$, then all elements of Π are zero (null matrix), this implies that no combination of variables in Π are stationary therefore variables in x_t are not co-integrated. Hence a VAR in first differenced form is applied
* If rank $(\Pi) = r$ such that$0 < r < n$, then the model has r cointegrating vectors. For a unique value of Π there is a single cointegrating vector and Πx_{t-1} is the error Correctio term.

To estimate the rank of Π, there are two test statistics proposed by Johansen (1988) namely Trace (λ_{trace}) and maximum (λ_{max}) eigenvalue statistics. The test will determine the number of characteristic roots which are insignificantly different form unity.

$$\lambda_{trace}\ (r) = -T \sum_{i=r+1}^{n} ln\ (1 - \hat{\lambda}) \tag{4}$$

$$\lambda_{max}\ (r, r+1) = -Tln(1 - \hat{\lambda}_{r+1}) \tag{5}$$

$\hat{\lambda}$ is ith largest eigenvalues obtained from the estimated Π matrix , T is the number of observation and $r = 0, 1, \ldots., n-1$. λ_{trace} test the null hypothesis that the number of distinct cointegrating vector is less than or equal to r against a general alternate hypothesis ($r = n$). More specifically,

Null hypothesis (H_0): there are at most p cointegrating vector or $r \leq p$

Alternate hypothesis (H_1): $r = n$

where r is the number of cointegrating vector while n is variables in X_t. To determine the number of cointegrating, we can proceed sequentially from $r = 0$ to $r = n-1$. If the null hypothesis of r = 0 at most is accepted then testing stops there by concluding no co-integration. Otherwise the testing procedure continues until the null hypothesis of at most p cointegrating is accepted.

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[5] In case of more than two variable there is no systematic procedure for the separate estimation of multiple co-integrating vectors

[6] In our study x_t contains LIPI, LCPI and exchange rate, i.e. $x_t = \begin{bmatrix} LIPI \\ LCPI \\ LER \end{bmatrix}$

λ_{max} statistic tests the null that number of cointegrating is r against a specific alternate of r + 1 cointegrating vector under the following hypothesis:

Null hypothesis (H_0): there are p cointegrating vector or $r = p$

Alternate hypothesis (H_1): $r = p + 1$

The results of the cointegration test are very sensitive to the lag-length of the variables. Therefore, Akaike's Information Criterion (AIC) and Schwarz Information Criterion (SC) are employed to select the optimum lag length. The prime objective here is to choose the lag length which gives disturbances without any autocorrelation (white noise).

As in Engle and Granger (1987), the dynamic behavior of a set of integrated variables can be empirically analyzed through vector error correction (VECM) models which are the reduced form time series models. The selected model is based on the backward looking behavior of output, prices and exchange rate. The study employs a bi-variate closed economy model as in Sims (1980) and Chiristiano et al. (1999) which is then extended to a multivariate and open economy model to measure the relationship between macroeconomic aggregates – output, prices and exchange rate – and monetary policy. In matrix notation, the VECM can be written as follows:

$$\Delta X_t = \beta_0 + \beta_1 t + \Pi \Delta X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \sum_{i=1}^{p-1} \phi_i \Delta Y_t + e_t \quad (6)$$

where t = 1, 2, …, T, $X_t = n \times 1$ vector of n endogenous $I(I)$ variables included in the VECM. These variables include IPI, CPI and exchange rate. $Y_t = n \times 1$ vector of exogenous $I(I)$ variables such as broad money, money market lending rate and international commodity prices index. $\beta_0 = n \times 1$ vector of intercepts. $\beta_{1,} \Gamma_i$ and ϕ_i,= $n \times n$ matrices of coefficients. $e_t = n \times 1$ vector of error terms distributed as iid and fulfills the Gaussian properties of zero mean and constant variances. Π = matrix of parameters such that one element is non-zero. Moreover, Δ is the difference operator and all the variables are in log form except interest rate.

The time path of the cointegrating variables is influenced by the extent of any deviation from long run equilibrium as well as by their separate self feedback pattern plus stochastic shocks and exogenous variables. The long-run behavior of the system depends on the rank of Π. Granger representation theorem shows that if X_t is integrated of order r then one can write $\Pi = \alpha\beta^{/}$ where matrix β contains matrix of r cointegrating vector. The matrix α known as the speed of adjustment measures how quickly ΔX_t reacts to deviation from equilibrium (Engle and Granger (1987)).

After estimating the VECM, finally, we compute the IRFs to examine the response of macroeconomic aggregates to one standard deviation shock to monetary measures. In two variables case (say X and Y) the coefficient $\emptyset_i$ can be used to generate the effects of ε_{yt} and ε_{zt} shocks on the entire time path of Y_t and Z_t sequences with the elements of $\emptyset_i$ as impact multipliers. The accumulated effects of unit impulses in ε_{yt} and/or ε_{zt} can be obtained by the appropriate summation of the coefficients of the IRF. The set of coefficients in $\emptyset_i$ are called IRF. The plot of coefficients in $\emptyset_i$ (IRF in other words) represents the behavior of a series in response to various shocks (Enders, 2010).

3.2 Data and Definition of Variables

To examine the response of macroeconomic aggregates to monetary policy we use quarterly data for Pakistan over the period from 1980-2009 except for exchange rate series. Pakistan moved from fixed exchange rate system to managed exchange rate therefore, for the model where exchange rate is used the time period starts form 1990Q1-2009Q2. All the data except broad money are obtained from the International Financial Statistics (IFS) database published by International Monetary Fund (IMF). Data on money supply are taken from Statistical Bulletins of Pakistan published by State Bank of Pakistan (SBP). All the variables are in log form except short-term interest rate. The response variables such as IPI and CPI are taken in real form while all the other variables such as exchange rate, money market rate, money supply are in nominal form. All the variables are on annual basis with millions of Pak Rupee as unit of measurement. World commodity prices index does not have data for the full length of sample period, therefore, few values of the said variable are interpolated by applying the two year moving average formula.

Following the prior studies we use two alternative measures of monetary policy namely broad money supply and short-term interest rate. Bernanke (1992) and Sims (1998) argue that short-term interest rate is a superior measure of monetary policy and it should be preferable over money supply. However, in our empirical investigation we utilize both measures with an aim to do the comparison between both the said measures. Moreover, we use money supply as a measure of monetary policy as in Pakistan it has been used to formulate the monetary policy. However, recently the monetary authority in Pakistan is giving relatively more weightage to short-term interest rate. In additional, Berument (2003) suggests that broad money is a better indicator of monetary policy in a small open economy.

The variables are defined as follow:

* Industrial Production Index (LIPI): the index captures the current economic activity. It consists of mining and quarrying, manufacturing and electricity, and gas and water. The indices are computed by Laspeyres' formula. The index refers to production of major primary commodities for many developing countries (IFS, 2010).
* Consumer Price Index (LCPI): the index is most widely used measure of inflation. It illustrates changes in the cost of acquiring a fixed basket of goods and services by the average consumer (IFS, 2010)
* World Commodity Price Index (LCOMP): it is included in the model to capture the oil price shocks and other supply side factors which influence output and inflation as suggest by Bernanke et al. (1995).
* Exchange Rate: exchange rate is expressed in domestic currency (Pak Rupee) per unit of foreign currency (US$) and the study uses "ae" definition of IFS series.
* Money Market Rate (SR): money market rate is used to instrument monetary policy. It is defined as the rate on short-term lending between financial institutions (IFS, 2010).
* Money Supply (Broad Money): broad money, generally termed as M2, is used as another measure of monetary policy. It comprises of currency in circulation, demand deposit, time deposit, other deposits (excluding IMF A/C, counterpart) and resident's foreign currency (SBP, 2009).

4. Empirical Findings

We start our empirical investigation by plotting each series against time. The plot of each series is presented in Figure 1. All the series exhibit an increasing trend. Next, the nature of each series is checked by computing the ACFs and PACFs. ACFs are the gross correlation between $(\boldsymbol{x})_t$ and$(\boldsymbol{x})_{t-k}$ (Enders, 2010). The shaded area in the graph shows 95% confidence interval. The spikes outside the shaded area indicate the number of significant spikes. There are numbers of significant spikes for each variable which indicate association of current values with the previous quarter values, referring to the serial correlation problem or non stationary behavior of the series.

Although one can get the idea about the nature of the series by plotting ACFs or PACFs, it is essential to be ensured about the stationary/non-stationary behavior of the series. To achieve this, we employ ADF test. Table 1 presents the estimates on ADF tests.

Following general to specific approach, the optimal lag lengths are selected for the ADF equations. Specifically, we start with a maximum 8 lags as our data is quarterly and presume that this length is enough to mitigate the problem of autocorrelation. However, we also estimate the ADF equations with other lag lengths to check the robustness of the estimates at different lags. The results are given in Table 1. The optimal lag length is market by asterisk in the table.

The estimates do not provide any significant evidence to reject the null of unit root for level series. However, the first difference of the series appears stationary at the 5% level of significance. These findings are robust across different lag lengths used in the estimation[7]. Thus, we conclude that the variables are integrated of order one.

Next, to examine the long-run association we estimate the Johansen's cointegration test. Table 2 reports the results. Since the results of the cointegration are very sensitive to the lag length we select the optimal lag length by applying AIC and BIC. Further, we ensure that the estimated model has white noise disturbances. We start by estimating a bivariate model for each of our response variable. In next step, we extend the bivariate model to multivariate model by incorporating other control variables. One should note that when we include exchange rate in the specifications our model represents the case of open economy[8].

The results in Table 2 provide evidence that there is a single cointegrating vector between IPI and short-term interest rate, implying that both variables have co-movement in the long run. This piece of evidence is robust to the inclusion of other variables in the specifications. Our results suggest that there is only one cointegrating vector regardless we estimate model for close or open economy. The existence of the one cointegrating vector at different specifications of the model confirms the validity of our results.

When we turn to examine the long-run association between short-term interest rate and the second response variable, LCPI, similar to the case of IPI, we accept the null hypothesis of one cointegrating vector at the 1% level of significance. Comparing the model with other macroeconomic determinants for LCPI such as LIPI, the Johanen's test identifies the presence of one linear combination of I(1) variables which is I(0). In the next step, adding LER and LCOMP in to the system we shift from a closed economy to an open economy model. Trace statistics

[7] The results of ADF test for first difference are not given here, however, are available from authors upon results.

[8] Although we use response variables as control variables as well, we estimate separate model for each response variable to test for integration.

reject the alternate hypothesis; estimated eigenvalues signify the presence of one cointegration relationships in both cases.

Third goal variable considered by this study is bilateral nominal exchange rate between PAK rupee and US dollar. Adopting the previous strategy, the model is extended form bi-variate to multivariate model. The estimated eigenvalues show that short-term rate of interest and exchange rate emerge to have one linear combination of variables that is I(0). The trace statistic rejects the alternate hypothesis of more than one cointegrating vector at 5% level of significance. Further, when the model is comprised of LCPI and LIPI, the estimated eignevalue points out one linear combination of I (1) variables which is stationary.

As mention earlier, we use an alternative measure of monetary policy namely broad money supply as well. The results of the cointegration tests with this measure are given in Table 3. In general, the findings are consistent with the results reported in Table 2. However, in two of the cases we find two cointegrating vectors instead of one. In case of more than one cointegrating vectors, the general practice is to select the cointegrating vector which has highest eigenvalue because it is most associated with the stationary part of the model (Rashid, 2009)[9]. Following this, we select first conintegration vector as it has the highest value. The alternate measure of monetary policy (money supply) appears to have one cointegration vector with all the three equations with the exchange rate as dependent variable based upon the trace statistics at 5% critical value.

After confirming the presence of the long-run relationship, we estimate VECM for each model to examine the direction of the response and the speed of adjustment towards the long-run equilibrium.

The long-run relationship is captured by error correction term which appears to be statistically negatively significant for the first bivariate model, where we regress industrial production on money market rate. The negative sign of the coefficient associated with error term is in line with the adjustment process, suggesting that IPI converges to its long-run equilibrium. Specifically, the coefficient of error term is 0.021 which implies that any disequilibrium in industrial production will be adjusted at the rate of 2.1% in one quarter. However, when we add LCPI in the specifications, then the speed of adjustment significantly increases to 7.6%.

The estimates on the speed of adjustment have dramatically improved in the case of open economy model. For instance, the disequilibrium in industrial production is now corrected by rate of 56.2% in one quarter, while an addition of LCOMP into the model further increases the adjustment speed to 68.42% with a statistical significance of one percent. This suggests that the adjustment process of industrial production to disequilibrium is relatively fast in the open economy.

The above model with the same order of variables has been regressed by using an alternative measure of monetary policy (broad money). The speed of adjustment is remarkably high for base line model as 76% percent adjustment in disequilibrium will be adjusted by the current value of IPI at one percent level of significance. Contrary to the first measure, the rate of convergence declines with the addition of more information into the model. This finding suggests that when the monetary policy is measured by short-term interest rate it is more effective for open economy, whereas the measures of money supply has significant role in closed economy. This finding

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[9] For further detail, see Johansen and Juselius (1992).

makes somehow sense as theoretically the interest rate plays significant role in external capital flows along with its internal effectiveness, whereas money supply is relatively more effective tool to make adjustment in domestic accounts.

For LCPI, the long-run relationship appears to be statistically significant. The positive coefficient of error correction term (0.081%) specifies that the prices should decrease to reach to its equilibrium position. It is interesting to note that the inclusion of LIPI to the model yields statistically negatively significant estimates on error term. This implies that the short-run interest may affect price levels through its effects on industrial output. Next, we include exchange rate into the model to represent an open economy framework. Based upon one cointegration vector, the long-term equilibrium relationship appears to be statistically negatively significant at one percent level of significance. A 1.6% pace is identified by the error correction term with which the disequilibrium will be corrected by LCPI. However, the extension of the model by including LCOMP further improves the speed of adjustment to 3.2%. It is evidence that prices respond more and the pace of movement to equilibrium point has increased by moving from closed economy to open economy model.

The model of LCPI is empirically tested for long-run equilibrium relationship by using the alternative measure of monetary policy as well. In a biavriate closed economy situation, there is negative and statistically significant long-run relationship as identified by the error correction term. The system converges to its long-rum equilibrium position at the rate of 5.7% per quarter. The open economy, adding LCOMP, once again increases the ability of prices to adjust to the long-run equilibrium.

For the third dependent variable, exchange rate, the error correction term appears negative and statistically significant. However, the magnitude of the coefficient indicates that the system converge to its long-run equilibrium by a marginal rate. Including LIPI to the model we find that the adjustment speed has increased to 17% while the addition of LCPI further enhances the process of adjusting (30%) towards long-run equilibrium position. These results suggest that the both industrial production and prices have a significant role to play in adjustment mechanism.

Regarding the money supply as a measure of monetary policy, we find that the speed of adjustment is 8.04% for model of exchange rate and money supply. In addition, the inclusion of LCPI in the exchange rate model enhances the speed of adjustment to 25.0% in one quarter. Further, when we include LIPI in the system, the estimates provide evidence that any deviation from the equilibrium is adjusted to the long-run equilibrium position with the rate of 33% per quarter.

Last but not least, we compute the IRFs to examine the response of IPI, CPI and exchange rate to a standard deviation shock to monetary measures. Similar to the case of cointegration and VECM estimation, we start from a model of close economy (bivariate case) then extend the model to open economy by incorporating exchange rate and international commodity prices index. One of the major problems in IRFs is the sensitivity with respect to variables ordering in the system. Therefore, following the empirical literature such as Forni et al. (2010) Bernnake et al. (2005), Bjournland (2008) and Holtemoller (2004), the study assume a recursive structure of ordering for the closed economy in which policy variables are ordered last. This implies that macroeconomic aggregates do not respond contemporaneously to monetary policy innovations but monetary policy might react towards any news from macro aggregates within the period. This is consistent with the transmission mechanism of monetary policy as highlighted by empirical studies such as Svensson (1997). In the closed economy, the variables are ordered as follows: $LIPI_t$ $LCPI_t$ and SR_t.

In open economy model, the exchange rate is placed last in the order of variables as suggested by Eichenbaum et al. (1995). It ensures a lagged response of monetary policy towards any change to exchange rate shocks but this identification results in a delayed exchange rate response to monetary policy (Bjornland, 2008). Kim and Roubini (2000) propose a contemporaneous interaction between monetary policy and exchange rate to solve the problem of exchange rate puzzle. The present study employed Kim and Roubini (2000) methodology and introduced exchange rate and monetary policy interaction of contemporaneous impact (by reversing the place in variable ordering for IRF). Since Pakistan is a small open economy, international prices are assumed exogenous for the economy. In other words, central Bank does not have international prices in its information set (Juang et al., 2003). Therefore LCOMP are placed after the ER. The variables oredering in the open economy is$LIPI_t$ $LCPI_t$ SR_t LER_t and $LCOMP_t$.

The IRFs for the closed economy by using money market rate and broad money as measures of monetary policy are presented in Figures 2 and 3, respectively. In the bilateral model, shock to SR appears to have a negative impact on LIPI with a margin positive start. The overall impact is comprised of downward and upward fluctuations of LIPI curve with a declining trend. It is interesting to note that the inclusion of the variables in the baseline model neither changes the initial nor the long-run response of LIPI to a standard deviation shock to money market rate. These findings are consistent with results of prior studies such as Forni at al. (2010) and Bjornland (2008), who also report a negative response of output to monetary policy shocks. The response of LIPI remains negative with respect to short-term interest rate shocks even for a multivariate closed economy model.

LCPI respond positively which provide the evidence of the existence of price puzzle. Similar evidence is reported by Sims (1992). However, our findings are in contrast to Ogaki et al. (2003), who find that there is no price puzzle[10].

The inclusion of exchange rate and LCOMP improves the response of LIPI towards positive monetary policy innovations as depicted in the figure. A positive shock to money market rate decreases the IP at a sharp rate before it starts increasing. This fact is in line with the findings of Bernnake et al. (1998) and Forni et al. (2010) that there is a decline in output after positive shock to FFR. On contrary, in the open economy model, a sharp and abrupt increase in price level is observed after a shock to MP. This point outs price puzzles (Leeper et al. (1992) and Bernanke et al. (1992)). Sims (1992) suggested that price puzzle can be tackled by including the international commodity prices but in our case the inclusion of international prices does not provide any significant help in eliminating the puzzle. Yet, our finding is consistent with Eichenbaum et al. (1999), who argue that the inclusion of international commodity prices does not improve the responsiveness of prices towards monetary policy innovations.

The initial response of exchange rate to monetary policy innovation is zero as can be observed from the figure. However, later on it appreciates followed by depreciation, confirming the overshooting hypothesis of Dornbusch (1976). This suggests that a contractionary monetary policy would lead to an appreciation in the nominal exchange rate before it depreciates in the long run. However, we find the evidence of exchange rate puzzle when we include international commodity price in the model.

[10] However, he used different technique namely SVAR.

The results for the alternative measure of monetary policy are consistent with the baseline model as depicted by IRFs. In the bivariate closed economy models the positive shock to broad money supply appears to increase the LIPI at first and then there is a decline in the production proceeded to an increase again. When the model is transformed into an open economy by incorporating exchange rate and then LCOMP, the response of LIPI remains similar to our earlier results. The results are in line with Berument (2003) and Ansari et al. (2007), who also found a positive response of GDP towards positive shock to money supply. Contrary to the money market rate measure of monetary policy, there is no evidence of price puzzle in the open economy. These findings are similar to Juang et al. (2003) and Forni(2010), and Bernanke et al. (2005). Similarly, exchange rate appears to appreciate (decrease) in response to a positive shock to monetary policy and then depreciates. This confirms the overshooting hypothesis of Dornbusch (1976) and provides no evidence of any exchange rate puzzle[11].

Collectively, the results suggest that there is significant interaction between real and monetary side of the economy in Pakistan. We find a clear support to accept both the hypothesis as the statistical significance of error correction term refers to the convergence to the long-run equilibrium of industrial production, prices and exchange rate with both measures of monetary policy. Similarly there is a significant response of the macroeconomic aggregates to shocks to monetary policy.

5. Conclusions and Recommendations

The study was carried out to empirically analyze the nature of the response of macroeconomic aggregates such as real economic activity, prices, exchange rate to shocks to monetary policy for Pakistan during the period from 1980:Q1-2009:Q2. The ADF test is used to test the time series properties of the variables. The cointegration relationship is observed by applying Johansen's coinetgration technique. We also estimate the VECM to estimate the speed of adjustment towards long-run equilibrium. Finally, we compute IRFs to examine the response of the macroeconomic aggregates to one standard deviation shocks to monetary measures.

We find that there is a significant co-movement between the macroeconomic aggregates such as IPI, CPI and nominal exchange rate. The estimates of error correction term provide evidence that the industrial production adjusts at faster speed relative to prices and exchange rate over the examined period. Furthermore, the short-term interest rate has relatively stronger effects on output as compared to broad money supply, whereas, prices and exchange rate adjust more quickly to their long-run equilibrium when money supply is used as a measure of monetary policy.

When money market rate is used as monetary policy, the graphs of IRF provide the evidence of price and exchange rate puzzles. By contrast, when broad money supply is used as a measure of monetary policy, no evidence of exchange rate puzzle is witnessed. This finding is in line with the Dornbusch (1976) overshooting hypothesis.

The findings of analysis suggest that the interest rate oriented monetary policy is more effective when the monetary authorities have objective to enhance the output growth of the economy. However, if the objective is to control the inflation, then the broad money supply is a more

[11] Bjornland (2008) and Forni et al. (2010) also find an appreciation of ER in response to a positive shock to MP.

appropriate instrument. Furthermore, our findings suggest that the monetary policy has a significant role in stabilizing both real and nominal sector of the economy.

Although the findings of the study support the existing theoretical and empirical work, there are some caveats associated with this analysis. For instance, the recent literature (e.g., Forni (2010) and Bernanke et al. (2005)) employs methodologically rich techniques and a large set of information to model the dynamics of MP. This helps in tackling the problem of various anomalies associated with monetary policy analysis.

Table 1: Estimates from ADF test

Variables	Model	No. of Lags				Conclusion
		6	4	2	1	
LIPI	Drift and Trend	-2.350	-1.762 [a]	-2.524	-8.199	Non-Stationary
	Drift	-1.407	-1.352 [a]	-1.132	-2.010	Non-Stationary
LCPI	Drift and Trend	-1.936	-2.415 [a]	-1.350	-1.764	Non-Stationary
	Drift	0.950 [a]	1.198	1.584	1.303	Non-Stationary
LER	Drift and Trend	-1.671	-1.807	-1.826	-1.819 [a]	Non-Stationary
	Drift	-0.925	-0.868	-0.859	-0.862 [a]	Non-Stationary
LCOMP	Drift and Trend	-1.523	-1.975 [a]	-1.266	-1.693	Non-Stationary
	Drift	-2.110	-1.869	-2.223 [a]	-3.035	Non-Stationary
R	Drift and Trend	-2.031	-1.805	-2.194 [a]	-3.017	Non-Stationary
	Drift	-2.110	-1.869	-2.223 [a]	-3.035	Non-Stationary
LM	Drift and Trend	-2.137	-3.128 [a]	-2.323	-1.552	Non-Stationary
	Drift	-0.424	-0.644 [a]	-0.530	-0.500	Non-Stationary

Note: ‘a’ represents optimum lag length selected by the Akaik Information Criterion (AIC)

Table 2: Results for Cointegration Test and VECM
(Policy Variable: Short-term Interest Rate)

Model specification	No.(Lags)	Rank	Q_r	Eigenvalue	ECT	No.(Lags)
Model-1. Dependent Variable: LIPI						
LIPI, R	114(4)	1	2.658	0.2094	0.0208*** (0.000)	114(4)
LIPI, LCPI, R	112(6)	1	11.104	0.1836	-0.0762*** (0.000)	114(4)
LIPI, LCPI, LER, R	115(3)	1	28.062	0.1638	-0.5622*** (0.000)	116(2)
LIPI, LCPI, LER, LCOMP, R	115(3)	1	47.082	0.2452	-0.6842*** (0.000)	116(2)
Model-2. Dependent Variable: LCPI						
LCPI, R	117(1)	1	0.439	0.1601	0.0008* (0.052)	109(9)
LCPI, LIPI, R	114(4)	1	9.934	0.1823	-0.0199** (0.000)	111(7)
LCPI, LIPI, LCOMP, R	116(2)	1	22.975	0.4584	-0.0157*** (0.000)	116(2)
LCPI, LIPI, LER, LCOMP, R	115(3)	1	47.082	0.2452	-0.032*** (0.000)	111(7)
Model-3. Dependent Variable: LER						
LER, R	78(7)	1	1.0381*	0.1752	-0.0038** (0.017)	78(7)
LER, LIPI, R	78(4)	1	12.7371*	0.2521	-0.1682*** (0.001)	78(6)
LER, LIPI, LCPI, R	78(4)	1	25.1796*	0.4194	-0.2978*** (0.002)	78(6)

Notes: this table displays the estimates for short –run interest rate as measure of monetary policy. lags in 2nd column refers to the number of lags for CIV while lags in 7th column are for estimation of vector error correction term. Qr is the LR trace statistic. *** , **, * denote the significance at the 1 % , 5%, 10% levels, respectively.

Table 3: Results for Cointegration Test and VECM
(Policy Variable: Broad Money Supply)

Model specification	No.(Lags)	Rank	Qr	Eigen value	ECT	No.(Lags)
Model-1. Dependent Variable: LIPI						
LIPI, LM	116(2)	1	0.0004	0.3743	-0.7595*** (0.000)	116(2)
LIPI, LCPI, LM	113(5)	1	9.033	0.2365	-0.3795*** (0.000)	113(5)
LIPI, LCPI, LER, LM	116(2)	1	28.742	0.5715	-0.3571** (0.000)	113(5)
LIPI, LCPI, LER, LCOMP, LM	115(3)	2	27.761	0.2286	-0.4549*** (0.000)	113(5)
Model-2. Dependent Variable: LCPI						
LCPI, LM	109(9)	1	0.4011	0.1343	-0.0573*** (0.002)	113(5)
LCPI, LIPI, LM	113(5)	1	9.0338	0.2365	-0.1524*** (0.003)	110(8)
LCPI, LIPI, LCOMP, LM	114(4)	1	20.1580	0.3805	-0.1441 (0.033)	112(6)
LCPI, LIPI, LER, LCOMP, LM	115(3)	2	27.7615	0.2286	-0.2207** (0.007)	112(6)
Model-3. Dependent Variable: LER						
LER, LM	78(11)	1	2.526	0.1578	-0.0804** (0.019)	78(4)
LER, LIPI, LM	78(2)	1	9.806	0.2813	-0.2486*** (0.000)	78(5)
LER, LIPI, LCPI, LM	78(4)	1	26.798	0.3336	-0.3298*** (0.000)	78(6)

Notes: this table displays the estimates for money supply (M2) as measure of monetary policy. lags in 2nd column refers to the number of lags for CIV while lags in 7th column are for estimation of vector error correction term. Qr is the LR trace statistic. *** , **, * denote the significance at the 1 % , 5%, and 10% level, respectively.

Figure 1: Time Series Trends

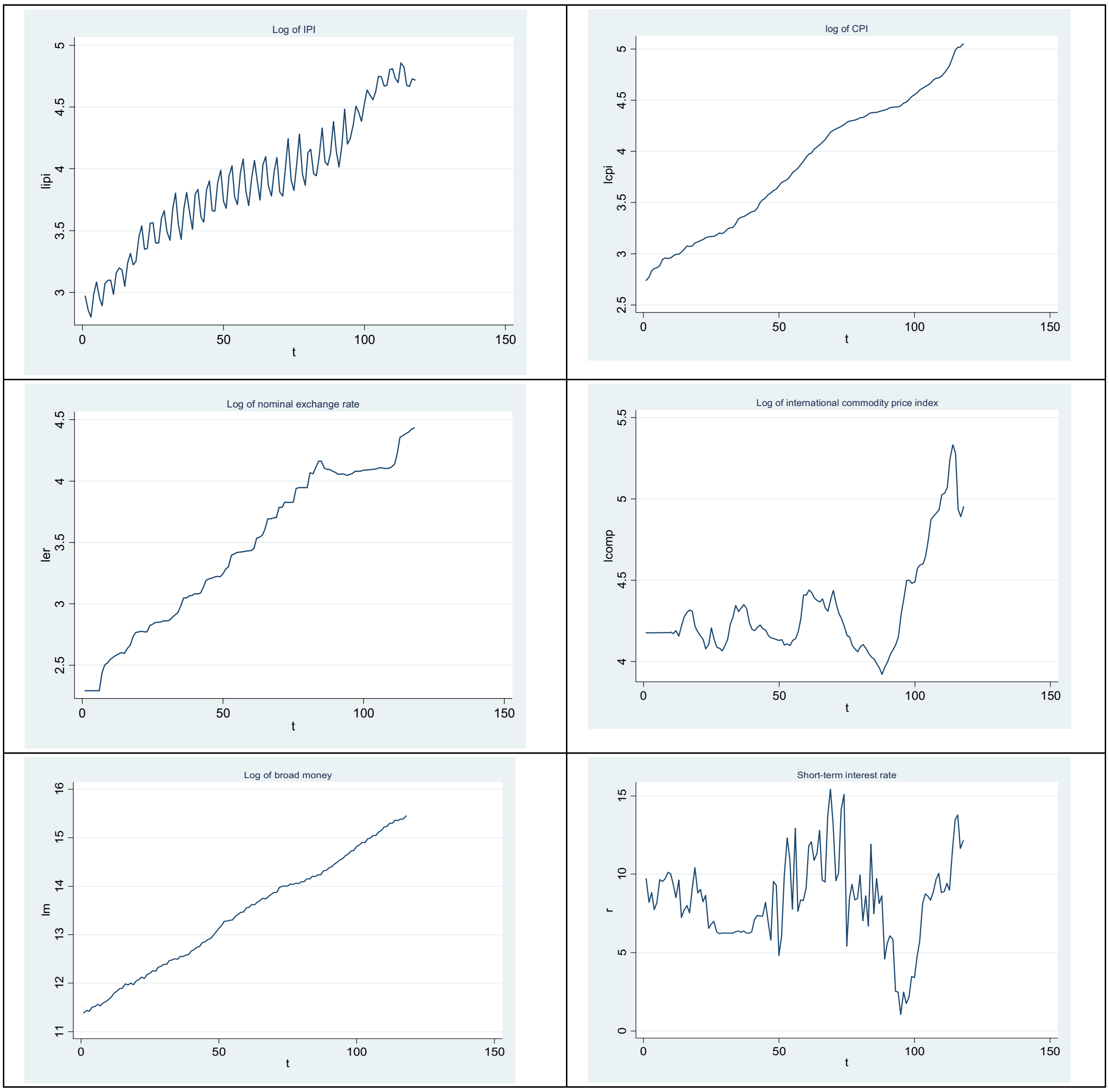
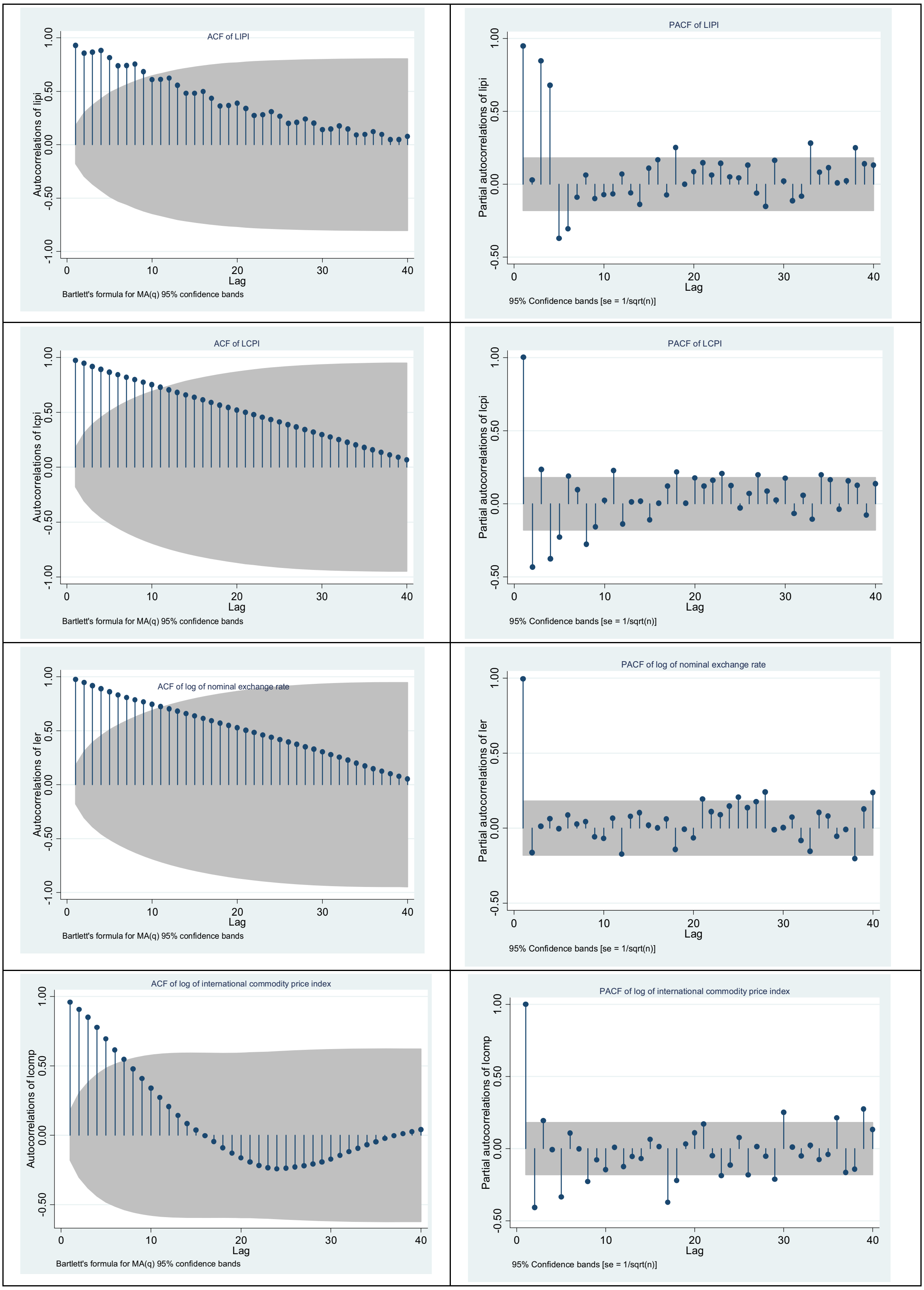


Figure 2: ACFs and PACFs



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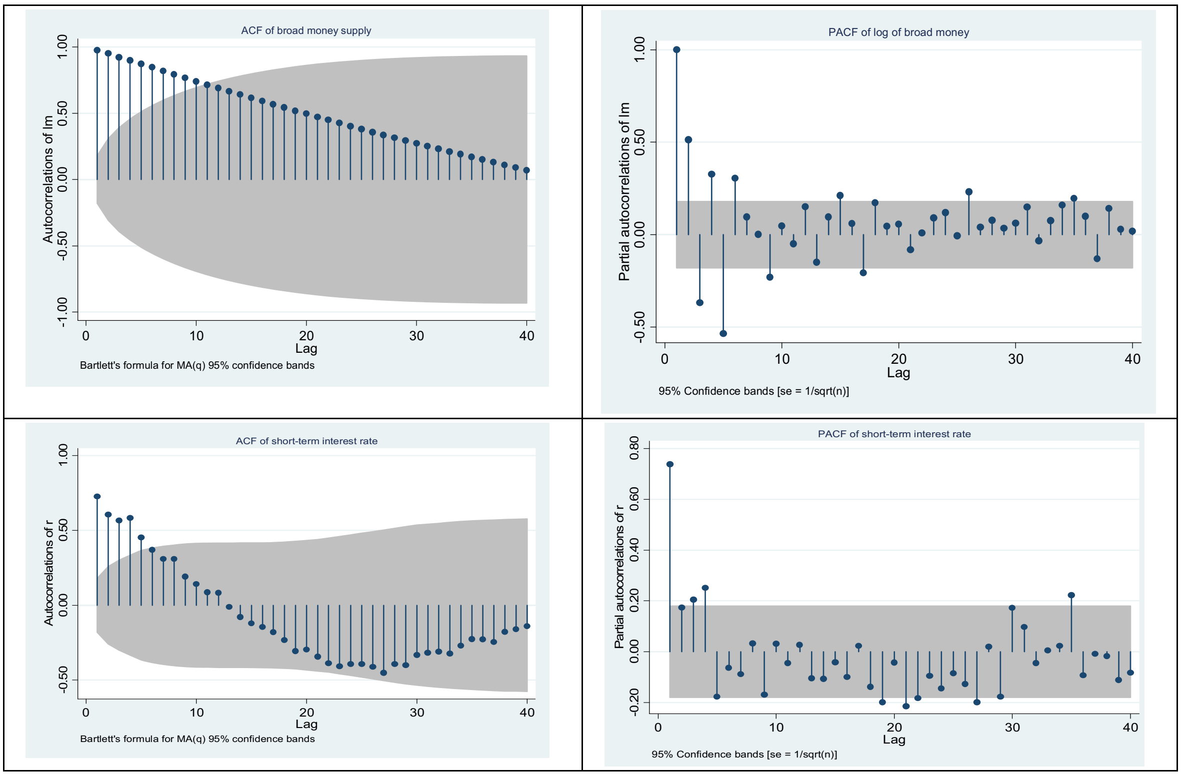


ACF of broad money supply
Autocorrelations of lm
Lag
Bartlett's formula for MA(q) 95% confidence bands
PACF of log of broad money
Partial autocorrelations of lm
Lag
95% Confidence bands [se = 1/sqrt(n)]
ACF of short-term interest rate
Autocorrelations of r
Lag
Bartlett's formula for MA(q) 95% confidence bands
PACF of short-term interest rate
Partial autocorrelations of r
Lag
95% Confidence bands [se = 1/sqrt(n)]

Figure 3: IRFs: Effects of Shocks to Short-term Interest Rate

LIPI LCPI LER

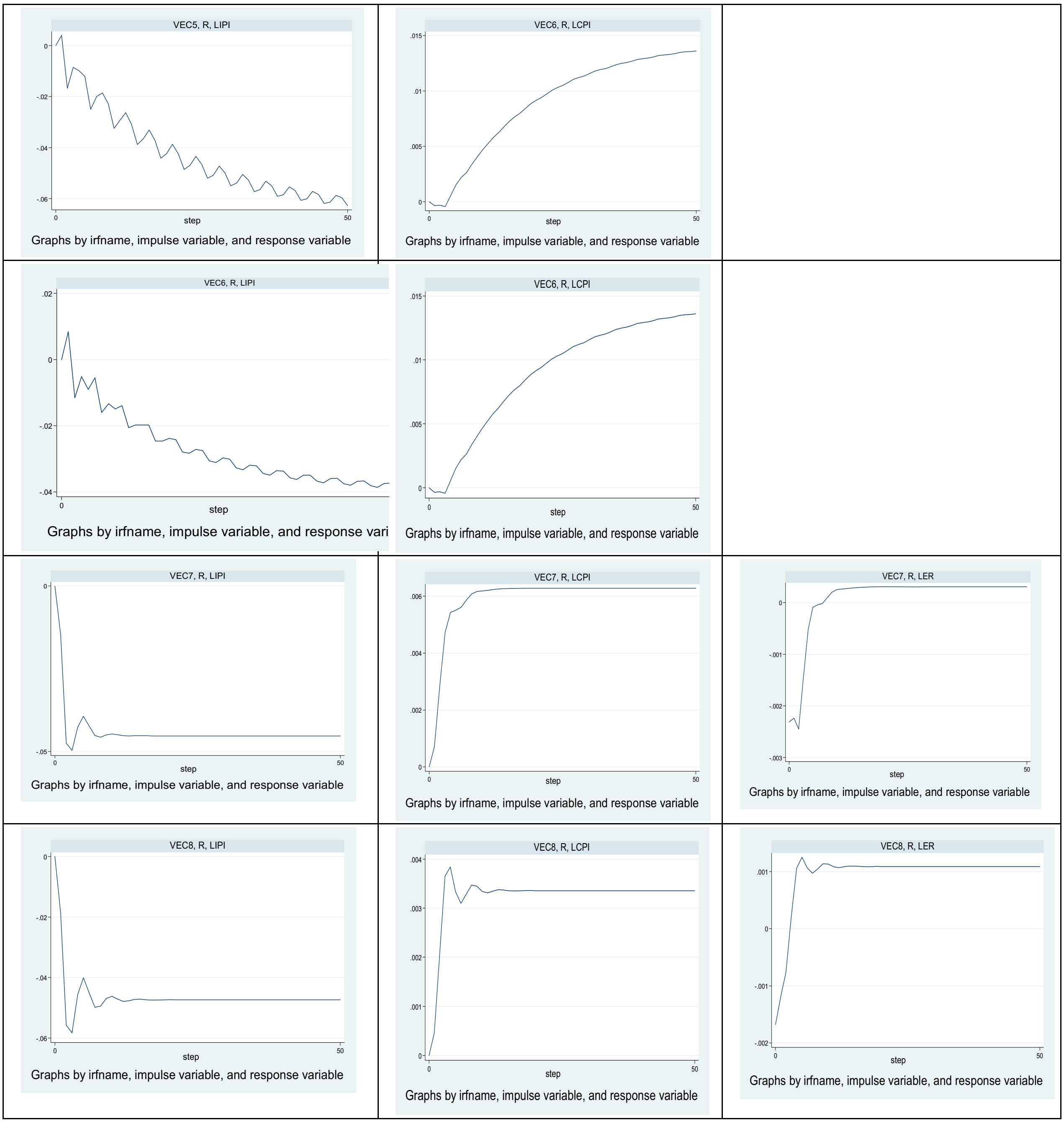
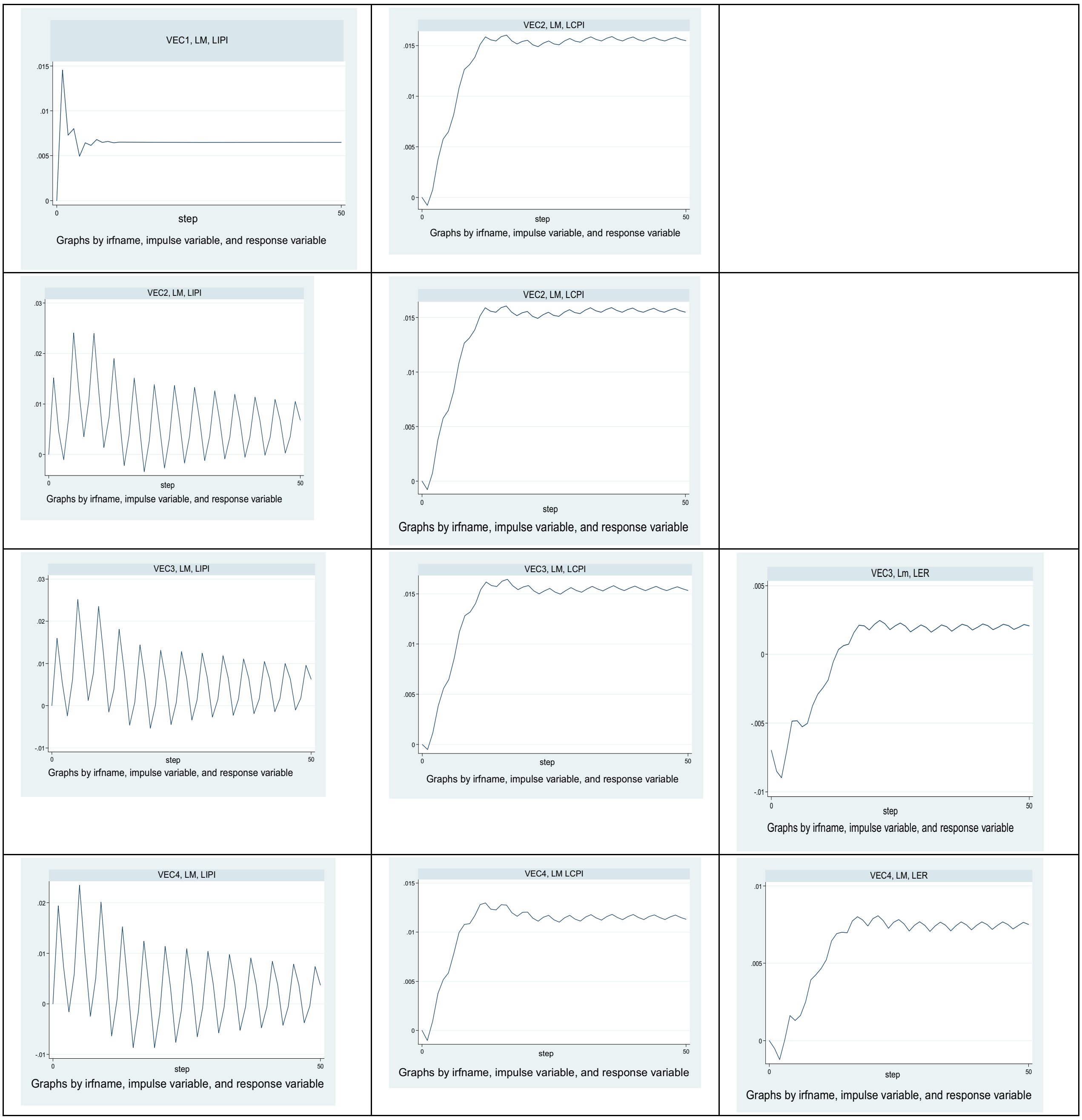


Figure 4: IRFs: Effects of Shocks to Broad Money Supply

LIPI LCPI LER



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