SBP Working Paper Series

No. 80 November, 2016

Assessing Monetary Policy Effectiveness in Rich Data Environment

Muhammad Nadim Hanif

Javed Iqbal

STATE BANK OF PAKISTAN

SBP Working Paper Series

Editor: Muhammad Nadim Hanif

The objective of the SBP Working Paper Series is to stimulate and generate discussions on different aspects of macroeconomic issues among the staff members of the State Bank of Pakistan. Papers published in this series are subject to intense internal review process. The views expressed in these papers are those of the author(s) not State Bank of Pakistan.

Price per Working Paper (print form)

Pakistan:	Rs 50 (inclusive of postage)
Foreign:	US$ 20 (inclusive of postage)

Purchase orders, accompanied with cheques/drafts drawn in favor of State Bank of Pakistan, should be sent to:

Chief Spokesperson,
External Relations Department,
State Bank of Pakistan,
I.I. Chundrigar Road, P.O. Box No. 4456,
Karachi 74000. Pakistan.

Soft copy is downloadable for free from SBP website: http://www.sbp.org.pk

For all other correspondence:

Postal: Editor,
SBP Working Paper Series,
Research Department,
State Bank of Pakistan,
I.I. Chundrigar Road, P.O. Box No. 4456,
Karachi 74000. Pakistan.

Email: wps@sbp.org.pk

ISSN 1997-3802 (Print)
ISSN 1997-3810 (Online)

Published by State Bank of Pakistan, Karachi, Pakistan.
Printed at the SBP BSC (Bank) – Printing Press, Karachi, Pakistan.

Assessing Monetary Policy Effectiveness in Rich Data Environment

Muhammad Nadim Hanif and Javed Iqbal

Research Department, State Bank of Pakistan

Abstract

We assess impact of monetary policy actions upon inflation in a country while considering changes in global commodity prices in rich data environment. We apply Factor Augmented Bayesian Structural Vector Autoregression (FABSVAR) methodology of Bernanke et al (2005) upon Pakistan's monthly data for July 1992-June 2015. Unlike Bernanke et al (2005), we combine variables of similar nature in groups to extract factors. We think putting all sorts of variables in one group impairs the factor extraction. Moreover, rather than working only with the response of variable of interest (inflation in this study) to shocks in factors under consideration (which, consist of different interest rates, monetary aggregates, exchange rates in this study) we propose use of eigenvector to obtain Impulse Response Functions (IRFs) of shock to individual variables in a factor. We find significant and desired impact of monetary policy decisions upon inflation in Pakistan. Administered prices, however, are found to have no response to interest rate changes in the country, which is understandable. By analyzing IRFs of inflation in Pakistan to shocks in interest rate we do not observe any price puzzle. It is simply because we consider the relevant variables omitted in previous studies reporting price puzzle in Pakistan.

Keywords: Monetary policy, inflation, econometric modeling, interest rates

JEL Classification: E52, E31, C50, E43

Acknowledgements

The authors are thankful to Ali Choudhary, Muhammad Jahanzeb Malik, and two referees for their useful comments on earlier draft of this study.

Contact for correspondence:
Javed Iqbal
Joint Director, Research Department
State Bank of Pakistan
I.I. Chundrigar Road
Karachi 74000, Pakistan.
Email: javed.iqbal6@sbp.org.pk

Non-technical Summary

Monetary policy is the process by which the monetary authority of a country regulates supply of money and/or interest rate to achieve sustainable economic growth in low inflation environment. Do monetary policy actions results in desired outcome? Since Sims (1992), vector autoregression (VAR) approach has been a standard method to assess monetary policy effectiveness. However, VAR is rarely useful if we need to employ more than six to eight variables. The sparse information set used in VAR approach to monetary policy analysis sometime leads to counter intuitive findings such as price puzzle. Suggested solutions (like considering the omitted variables) require estimation of monetary policy effects (upon inflation) in rich data environment.

Factor Augmented Vector Autoregression (FAVAR) methodology of Bernanke et al (2005) is used to exploit rich data environment. By incorporating a large number of variables in terms of their combined factor, FAVAR model gives better results as compared to standard VAR model. Existing practice in FAVAR modeling is i) to combine all sorts of variables in one group to extract a factor, and ii) estimate IRFs of variable of interest to shock to factor (and not to the variables in the factor).

This study suggests a better way of combining variables (of similar nature like 'all types of interest rates') in groups to extract factors. Putting all variables under consideration (interest rates, monetary aggregates, exchange rates etc) in one group is found to impair the factor extraction. In addition, by using weights obtained in factor extraction process, we propose a mechanism to estimate IRFs of individual variable (like policy interest rate) to see impact of shock (to individual variable) upon variable of interest (like inflation).

We use Pakistan's case to empirically implement what we suggest above. Based upon estimated Factor Augmented Bayesian Structural Vector Autoregression (FABSVAR) model, while using group wise factors (instead of one factor from all sorts of variables), we observe that the direction and the magnitude of IRFs of variable of interest to shocks to different factors/variables are intuitive and consistent with the main stream macroeconomic literature. Against the finding of a) some past studies, and b) results from a standard VAR model in this study; we do not observe price puzzle in case of Pakistan when we apply FABSVAR model to assess effectiveness of monetary policy over the period of July 1992-June 2015. Innovations in State Bank of Pakistan's monetary policy related variables do influence inflation outcome in the country in desired manner.

1. Introduction

Monetary policy is the process by which the monetary authority of a country (State Bank of Pakistan, in this study) regulates supply of money and/or interest rate to achieve sustainable economic growth in low inflation environment. In the current monetary policy framework, inflation and economic growth rate targets are announced annually by Planning Commission, Government of Pakistan. SBP reviews its monetary policy every alternate month to see if it needs to make adjustment in interest rate (and/or to take any other relevant policy measure(s)) to guide the economy towards achieving inflation target without being prejudice to the target for real economic growth. How best a central bank achieves the given targets depends upon the structure of underlying economy and the macroeconomic environment in which it operate. In this paper we study the effects of monetary policy upon inflation in Pakistan by using Factor Augmented Bayesian Structural Vector Autoregression FABSVAR). Use of factor augmentation allows us to exploit maximum available information in VAR modeling which otherwise is constrained to 6-8 variables. We can see such examples of constrained estimation of VAR modeling for assessing monetary policy effectiveness from the empirical literature (of developed as well as developing countries) including Sims (1992) and Khan (2008).

Agha et al. (2005) estimated various VAR model (with six variables) of Pakistan to see the effect of monetary policy on inflation (and found that monetary contraction leads to decrease in domestic demand which leads to decrease in price level). They needed to exclude external sector variables in one of their exercise due to degree of freedom problem in VAR modeling and considered a closed economy model. Omitting relevant variable(s) could lead to results as in Javid and Munir (2010). They applied SVAR model on six macroeconomic variables of Pakistan to assess the effects of monetary policy on inflation and output growth. They found that a positive shock to interest rate leads to persistent rise in the price level (over 48 month horizon) and they termed it as an evidence of the existence of price puzzle in Pakistan over the period they studied.

Observation of price puzzle type results in estimated VAR modeling is counter intuitive and requires resolution of the issue behind such findings. Suggested solutions require estimation of monetary policy effects (upon inflation) in rich data environment. Sims (1992) suggested fully capturing the information necessary, in the line to theoretical framework, to estimate a VAR model. Balke and Emery (1994) suggested that we should introduce such variables into the system that contain information about future inflation and/or supply side representatives that are not already contained in the generally estimated VARs. Christiano et al. (1996) argued that the price puzzle is resolved when commodity prices are included in such empirical VAR modeling. We know we cannot use more variables in a VAR model due to 'degrees of freedom' problem (Bernanke et al 2005 and Gupta et al 2010).

To overcome the dimensionality problem in standard VAR modeling, Bernanke et al. (2005) proposed an econometric methodology known as Factor Augmented Vector Autoregressive (FAVAR) model. In FAVAR modeling, we augment our VAR model with one or more factors (principal components) of a group of as large number of variables as we need. We can then have IRFs of variable of interest, say inflation, to a shock to factor(s). So, FAVAR modeling facilitates use of a few factors (along with other main determinants of the variable of interest) instead of large number of (other relevant) variables. In order to see the effect of monetary policy in USA, Bernanke et al. (2005) extracted a few factors from a group of 120 variables. They compared the results of FAVAR model with those from simple VAR model (excluding the factors) and concluded that there was no price puzzle in the results from FAVAR model. In case of Pakistan, Munir and Qayyum (2014) applied the FAVAR model and found no evidence of prices puzzle.

Notwithstanding the success of FAVAR methodology in use of larger set of information compared to standard VAR approach, we find two areas where we can improve the application of FAVAR modeling.

First, Bernanke et al. (2005), Munir and Qayyum (2014) and other followers of this methodology combine all sort of variables (those which may have positive and those which may have negative correlation with the variable of interest) in one group for factors extraction. Combining variables with pair-wise negative correlation in one group weakens the extracted factor(s) as representative(s) of the group. Combining all sorts of variables in one group also deprives factor of any interpretation and renders IRF of any variable of interest (to shock in factor) meaningless. We propose (and demonstrate) formation of more than one groups from the available information based upon the prospective relationship of the variables in the groups with the variable of interest (inflation in our study). In this way we combine only those variables within a group which have positive correlation amongst themselves. From each group we can extract at least one factor (explaining most of the variation in the group) and use in the FAVAR methodology of Bernanke et al. (2005). Such factor(s) are better representative of the group they are extracted from and have clear relationship with the variable of interest in the FAVAR model. They will have their own (economic) interpretation and thus IRFs of relevant variables of interest to shocks in such factors are going to be meaningful.

Second, in the FAVAR model the shock can be given to and impulse response functions can be estimated only for those variables which are included in the modeling strategy, that is the factor(s) and other main variables of interest. We cannot obtain IRFs of shocks to individual variables in the group(s) from which we extract the factors. In practice, researcher and/or policy maker may be interested in shock to a specific variable which is not modeled explicitly in the FAVAR setting but is included as one of the variables in a group. We propose (and demonstrate) a way to obtain IRFs of variable of interest (like inflation in our case) to shocks to the individual variable of set of variables from which factor is extracted within the estimated FAVAR set up. We can see the impact of shocks to the individual variable[1] on the variable of interest through its 'weight' in the respective factor[2].

In this study we demonstrate the above two contributions to the FAVAR literature using Pakistan economy data and found 'price puzzle' resolved as envisaged while we thought to use rich information environment to assess impact of central bank's policies upon inflation outcome in the country. This is what we believe is a significant result, particularly when we know a number of studies (based upon limited information approach) reported price puzzle for the case of Pakistan.

In the next Section we elaborate the FAVAR methodology in connection with our contributions to apply it. Data used and the way variables of interest are modeled is also explained in this Section. In Section 3 we have presented our findings. The last Section is for concluding remarks.

2. Data, Modeling and Methodology

For the purpose of assessing the impact of monetary policy upon inflation in Pakistan, we have used monthly time series data set of relevant policy variable (like discount rate), growth in monetary aggregates (including private sector credit growth and change in government borrowing from banking system), and fluctuations in exchange rate (Pak rupee per foreign currency unit) in addition to Pakistan's large scale manufacturing index growth[3], and global commodity prices changes (including

[1] Which is not directly used in estimation of FAVAR model.
[2] Which is directly used in estimation of FAVAR model along with other macroeconomic variables.
[3] As a proxy for Pakistan's GDP.

crude petroleum oil price fluctuations). Details pertaining to data used in this study have been provided in the Table 1 (Appendix B).

The data span for this study is July 1992 to June 2015. Pakistan embarked upon financial sector restructuring and reforms program during early 1990s (Hanif, 2003). That is one of the reasons of selecting July 1992 as starting period for this study. Moreover, this is the period for which we have consistent monthly time series available for our main variables of interest like inflation, administered prices' inflation, food inflation and core inflation. Unlike Bernanke et al. (2005) and Munir and Qayyum (2014), we have combined variables of 'similar nature' in a group to extract factor(s). Combining only the variables of 'similar nature' in a group saves us from impaired factor extraction. Munir and Qayyum (2014) attempted to reduce such impairment by standardizing the individual variables before taking them to make a factor. But standardization actually causes loss of some information and that standardization does not correct the impairment in the factor(s) due to combining variables with negative pair-wise correlation. We have divided monetary policy related time series in two different groups, interest rate group and monetary aggregate group to obtain interest rate factor and monetary factor respectively. Exchange rate factor is extracted separately from the group comprised of relevant exchange rates[4]. All the individual variables have been seasonally adjusted (except interest rates) using X-12 ARIMA approach before forming a group for factor extraction. Stationarity of all the individual variables is established using Augmented Dickey Fuller test.

Existing literature on monetary policy's impact upon inflation in Pakistan relate inflation in Pakistan with interest rates, monetary aggregates, exchange rate, and general economic activities in the country (see for example Agha et al (2005), Khan (2008), Munir and Qayyum (2014)). Following suggestions from Sims (1992), Balke and Emery (1994) and Christiano et al. (1996) we consider global commodity prices (crude petroleum oil price, food price index, and index of 'non-food-non-energy' goods' prices) also to assess effectiveness of monetary policy upon inflation outcome in Pakistan.

A joint econometric analysis to estimate the effects of monetary policy and exchange rate dynamics on inflation in a rich data environment is unfeasible in a frequentist framework. A VAR model which is one of the most successful, flexible and easy way for multivariate analysis; cannot be useful for set of more than 6 to 8 variables due to degrees of freedom problem. As a mean of reducing this dimensionality problem, we have employed factor analysis using a factor-augmented VAR (FAVAR) as proposed by Bernanke et al (2005). Before pursuing our goal to analyze the impact of a large set of macroeconomic variables (global prices, interest rates, monetary aggregates, exchange rates, and domestic economic activity) on inflation on Pakistan we would like to summarize FABSVAR modeling and the extension we have made in the same to obtain single variable's IRFs after running factor augmented vector autoregression.

Let Y_t be M×1 vector of selected macroeconomic variables, (say M2, real GDP, and inflation) which are inter-related within an economy. Like in numerous VAR based past empirical studies, there is additional economic information (including policy interest rate, market interest rates, exchange rate with different countries, global prices of different commodities which a country imports or exports) not included in Y_t but may be relevant to model the dynamics of the series in Y_t. Let X_t be N×1 vector of time series which contains many stationary time series variables.

[4] This group actually demonstrates how useful it is to combine variables of similar nature to extract factor to represent the group. See footnote 8.

Following the standard approach to establish the relationship between these 'large set' of macroeconomic variables we might desire to proceed by estimating VAR, a Structural VAR or other multivariate time series model using data for the Y_t and X_t together. To handle dimensionality problem we can summarize the set of macroeconomic variables (X_t) by a K × 1 vector of unobserved factors, F_t, where *K* is less than or equal to *N*.

Hence in VAR setup we use F_t instead of X_t along with Y_t. Assume that the joint dynamics of (F_t, Y_t) are given by:

$$\begin{bmatrix} \mathrm{F_t} \\ \mathrm{Y_t} \end{bmatrix} = \emptyset(\mathrm{L}) \begin{bmatrix} \mathrm{F_{t-1}} \\ \mathrm{Y_{t-1}} \end{bmatrix} + \mathrm{v_t} \qquad (1)$$

Where $\emptyset(\mathrm{L})$ is a lag polynomial of finite order d and $\mathrm{v_t}$ is error term with mean zero and covariance matrix $\sum$.

Equation (1) is a VAR model in (F_t, Y_t). The above system reduces to a standard VAR in Y_t if the terms of $\emptyset(\mathrm{L})$ that relate Y_t to F_{t-1} are all zero; otherwise, it is referred to as Factor-Augmented Vector Autoregression (FAVAR). Equation (1) cannot be estimated directly because the factors F_t are unobservable. If we can interpret the factors F_t in addition to observed macroeconomic variables as representing forces that potentially affect the target variable, we can make inferences about the unobserved factors as well as observed variables within the group from we extract factors in relation to economic time series of interest. Suppose that the number of informational time series (X_t) N is large and greater than the number of factors (K+M<<N), then we assume that relationship between the set of variables X_t , the unobservable factors F_t and the observed variables Y_t is represented by an observation equation of the form;

$$\mathrm{X_t'} = \Lambda^{\mathrm{f}}\mathrm{F_t'} + \Lambda^{\mathrm{y}}\mathrm{Y_t'} + \mathrm{e_t'} \qquad (2)$$

where Λ^{f} is an N×K matrix of factor loadings, Λ^{y} is N×M is a matrix of coefficient and $\mathrm{e_t}$ is a N×1 vector of error terms with mean zero and will be assumed either weakly correlated or uncorrelated (Bernanke et al, 2005).

We use two-step principal component approach, which provides a non-parametric way of uncovering the space spanned by the common components, C_t. In the first step, the common components are estimated using the first K principal components of X_t, which is a part of space covered by C_t and denoted by $\hat{F}_t$. In principal component analysis, a set of variables is transformed linearly and orthogonally to an equal number of new uncorrelated variables such that the total variance is unchanged (Lee, 2007). In practice, we pick the first K principal components as it explains the most of the total variance. In our study K=1[5]. In the second step, the FAVAR, equation (1) is generally estimated by ordinary least squares, with F_t replaced by $\hat{F}_t$. This procedure has the advantages of being computationally simple and easy to implement as discussed in Bernanke et al. (2005)[6].

---

[5] Details of estimation of principal components are given in Appendix A. Why we have taken K=1 is discussed in section on empirical results in detail.

[6] Bernanke et al (2005) discussed some identifications of model (1)-(2) especially restrictions which are necessary to identify the uniqueness of factors and associated loadings against any rotation. Since factors are obtained entirely from the observation equation (2), and identification of the factors is standard. In this case we can choose either to restrict loadings by $\Lambda^{f\,'}\Lambda^f/N = I$ or restrict the factors by $F'F/T = I$.

In order to have meaningful IRFs in VAR type analysis, shocks in different variables in the model need to be independent. To ensure independence of the shocks, we will be using Cholesky decomposition or in other words we will be estimating factor augmented structural VAR or FASVAR model. Expecting the improvement in the accuracy of the impulse response functions, we have estimated the factor augmented SVAR model using Bayesian approach. In case of SVAR modeling, even with moderate number of variable, we know that the usual (maximum likelihood) estimators may not have desirable properties. However, in case of the Bayesian SVAR approach we can expect improved accuracy of estimated impulse response functions (Canova, 2007 and Robertson, 2000). This is what is known as Factor Augmented Bayesian Structural Vector Autoregression (FABSVAR). Popularly used IRFs in the literature are those based upon one SD shocks; and are quite useful academically. As discussed in Hanif et al. (2016), IRFs of 1 percentage point shock (instead of one SD shock) are relatively easy to interpret and communicate for policy debates. In this study we have used IRFs generated by 1 percentage point shock because such IRFs are also useful in comparison of two different IRFs.

While implementing FABSVAR approach, as outlined above, we can obtain the impulse responses of all variables by giving shock to any of the variables in the VAR setup, including the factors. However, to the best of our knowledge, no study has discussed IRFs of variable of interest (like inflation in our case) to shocks to the individual variable(s) of set of variable from which factor is extracted. The reason of it being ignored is simply that such individual variable(s) are never a part of FAVAR model being estimated. In this study, we have proposed and used a way to obtain IRFs of variable of interest to shocks to the individual variable(s) in the group from which factor is extracted within the estimated FAVAR set up. We can see the impact of shocks to the individual variable(s) on the variable of interest through their factor (which is directly used in FAVAR setup along with other macroeconomic variables) as follows. A factor is a weighted average of all individual variables (detail is given in the Appendix A) and can be written as;

$$F_t = V_1 X_{1t} + V_2 X_{2t} + \cdots + V_N X_{Nt} \qquad (3)$$

Where $V_1, V_2, \ldots V_N$ are components of eigenvector associated with factor F_t. In equation (3) we can see that if we increase a variable X_{1t} by 1 unit then F_t will increase by V_1. In this way if we give one unit shock of variable X_{1t} its mean we are giving V_1 unit shock to F_t which is directly used in VAR setup. In VAR model (1) we can calculate response of target variable by giving any shock to factor. By adopting the standard procedure of IRF calculation and instead of one unit shock, we propose to use V_1 shock[7] to factor F_t, to obtain response of target variable by giving one unit shock to X_{1t}. This is the IRF which one should be interested in rather than that of overall factor (F_t) which contains relevant but too much information.

3. Empirical Results

Following theoretical underpinnings and empirical literature on Pakistan economy (Agha et al. (2005), Khan (2008), Munir and Qayyum (2014), Hanif (2014)) we have considered a set of relevant macroeconomic variables to assess the impact of monetary policy actions upon inflation in Pakistan. We have used FABSVAR modeling to trace the effect of monetary policy innovations upon inflation in the country. We have given all the models we have estimated in Table 2 (of Appendix B). First we estimate simple VAR model considering global commodity prices as completely exogenous in the system. Then comes (monetary) policy variables (like monetary aggregates and/or interest rates), then

[7] V_s is the component of eigenvector associated with the factor and it is the weights of s^{th} variable in factor equation (3)

exchange rate and real economic activity. Inflation is modeled in the manner if it is impacted by all the variables in the system from global commodity prices to (monetary) policy related variables, exchanges rates to economic activity in the country. Simple VAR model consists of global oil prices inflation (GOLI), global food inflation (GFDI), State Bank of Pakistan's discount rate (DISR), broad money supply growth in Pakistan (MGPK), appreciation/depreciation in US dollar rate in terms of Pak Rupee (ADDR), changes in large scale manufacturing production index (LSMI) and consumer price inflation (CPII). We name this as Model 1 and use this to compare with what we suggest and estimate in this study. Then we estimate FABSVAR model in which we put all the variables pertaining to monetary authority's actions and exchange rate behaviour in one factor – factor of Pakistan's money supply, interest rates and exchange rates (FIME). This is the approach (of putting all the variables in one factor) used in Bernanke et al.(2005) while developing the factor augmented VAR methodology and is followed by Munir and Qayyum (2014) for the case of Pakistan. We name this as Model 2 and use this as well to compare with what we suggest and estimate in this study. Contrary to Bernanke et al. (2005) and Munir and Qayyum (2014) we do not use any of the variables already in the group (from which we extract factor), in the VAR setup to avoid double representation in the modeling. Moreover, combining all sorts of variables in same factor forces use of standardization in which we may lose some basic information regarding the variables standardized.

We suggest to combine those variables in one factor which have positive correlation amongst themselves (like various monetary aggregates) rather than combining all sort of variables which may have opposite movements (like monetary aggregates and interest rates). We divide our variables into groups and estimate factors from each group separately. Interest rate group consists of DISR, overnight interest rate (ONIR) which is money market rate, and weighted average lending rate (WALR) which is representative of (effective) rates of interest actually charged upon lending operations in the commercial banks in Pakistan. Monetary group includes MGPK, credit to private sector growth (CPSG) and changes in credit to government sector (CGSG). Exchange rate group includes the exchange rates of all those 23 countries which are significant trading partners with Pakistan (on the lines of estimation of nominal effective exchange rate (NEER) of Pakistan)[8]. Therefore in FABSVAR to trace the effect of monetary policy innovations upon (overall) inflation in Pakistan (Models 3 in Table 2 of Appendix B), instead of single factor we include three factors. We compare the results of our model (Model 3) with those from Model 1 and Model 2.

Before going to the estimated results, here we would like to discuss the number of factors and lag length (of the variables) for the VAR model estimation. How many factors to be included in VAR models to capture the maximum information is of course an important practical question. Since we are using Principal Component approach to extract factors, we can have as many factors as number of variables in the set. There is no point in using all the factors in the VAR as this will not solve the dimensionality problem[9] which prompted the need and use of FAVAR modeling. So the factors in the VAR model have to be less than N. That is $K<<N$. Different empirical studies have used different K. Bernanke et al. (2005) and Munir and Qayyum (2014) used up to 5 factors. Gupta et al. (2010) used 2 factors in their study. There is surely a tradeoff between increasing the efficiency of VAR modeling in using higher number of factors and facing the degrees of freedom problem in the estimation. Since we

[8] It is an interesting observation that the factor extracted using first PC from a set of (change in) exchange rates most relevant to Pakistan (in fact, all those which are in the basket for computation of NEER for the case of Pakistan) is very close to (log difference of) NEER (see Figure 1 in Appendix C). This closeness gives us confidence in using factors extracted from various groups of 'similar nature' variables (rather than combining all sorts of variables in one group, factor of which represents none).
[9] Maximum number of PCs equals the number of variables in the group. Using of all factors in VAR is equal to using the actual variables in the group and this is not a solution to dimensionality problem.

are using factors extracted from different groups containing positively correlated variables instead of factors extracted from a combined group (of all the relevant variables ignoring their correlation coefficients), we choose to use only 1 factor from each group of variables of interest. We choose the one which explains most of the variation in its group. The Akaike Information Criterion (AIC) is used in selecting the appropriate lag length (in such a way that no or minimum serial correlation is left in the stochastic error term). Since we are using monthly data the maximum lag length we use is 13.

3.1 Estimated BSVAR model (Model 1)

FAVAR model in equation 1 can be reduced to standard VAR model if we assume that all those values of $\emptyset$(L) in equation (1) which relates Y_t to F_t are zeros. As stated above Model 1 is estimated in the following ordering: GOLI, GFDI, DISR, MGPK, ADDR, LSMI and CPII. Figure 1 (Appendix D) shows the accumulated impulse response functions (up to 36 months) of inflation in Pakistan to one unit shock to each variable in the estimated BSVAR model (Model 1). From Figure 1 (Appendix D), it can be seen that a 100 basis point positive shock to discount rate increases inflation up to 2 percentage points in one year and it does not converge. Impact of 1 percent shock to change in exchange rate upon (overall) inflation does not converge as well. Shock to LSMG has almost no effect on inflation in the country. Some studies interpret results like increase in inflation after positive shock to interest rate as price puzzle in Pakistan (for example Javid and Munir , 2010, Hayat and Hanif, 2016). This could be due to lack of information necessary to estimate such VAR model (as noted in Sims, 1992) like global commodity prices (as pointed out specifically by Christiano et al, 1996).

3.2 Estimated FABSVAR model (Model 2)

In the following we are going to use rich information environment in an attempt to yield a plausible picture of the effects of monetary policy upon inflation. We know that we cannot include more variables in BSVAR model estimated above due to degrees of freedom problem. So we use FABSVAR approach by including all the variables related to monetary aggregates, interest rates and exchange rates in one group. Rather than using only one interest rate (policy rate preferably) as in Model 1, here we have included three types of interest rates: DISR, ONIR and WALR. Similarly, from the monetary aggregates we have used MGPK, CPSG, and CGSG. In case of exchange rates we have included exchange rates of 23 countries which are part of Pakistan's NEER estimation, being our significant trading partners. We extract first principal component of this group as its factor (which explains most of the variability of the group). We denote this as factor of interest rates, monetary aggregates and exchange rates (FIME). FABSVAR model is estimated by placing variables in the following order: GOLI, GFDI, FIME, LSMI and CPII.

Figure 2a (Appendix D) shows the accumulated response of inflation after one unit shock to all variables in the FABSVAR (Model 2). One unit shock to FIME has (strictly) positive effect on inflation which approaches 4 percentage points in 36 months. Results of this shock cannot be convincing since the factor extracted from a group consisting of both positively correlated variables (like monetary aggregates) and negatively correlated variables (like interest rates) with inflation. One reason could be that the estimation of such factor is biased to that group of variables which have relatively stronger correlation amongst themselves – like the exchange rates in this case – compared to other variables in the group. It is evident from absence of some intuitive explanation of any of the individual IRFs of almost all the variables in FIME (Figure 2b, Appendix D). It seems if it is the IRFs of inflation to exchange rate related shock that dominates.

We propose to estimate factor augmented VAR model in such a manner that separate factors are used for representation of groups containing only positively related variables within each group (irrespective of correlation of the group with the variable(s) of interest).

3.3 Estimated FABSVAR models with different factors for different groups/types of variables

Now we explore how interest rate changes, growth in monetary aggregates and changes in different exchange rate parities impact (overall) inflation in Pakistan while considering other relevant macroeconomic determinants of inflation in Pakistan like global commodities prices' movements and growth in real economic activities (Model 3 in Table 2 of Appendix B). Based upon estimated FABSVAR model with group wise factors we can say that direction and magnitudes of IRFs of variables of interest (say, inflation) to shocks to different factors/variables are intuitive and consistent with the main stream macroeconomic literature. We do not see significant price puzzle in the estimated FABSVAR Model 3 for Pakistan economy. We think this is because we utilize the relevant information set (as against Model 1) and that too without clubbing all the policy-type variables in one group to generate factors (as against Model 2 in this study and in Munir and Qayyum, 2014).

Based upon estimated FABSVAR model with group wise factors we find that 1 percent shock to change in exchange rate factor has highest positive impact on inflation in Pakistan (Figure 3a, Appendix D). Impact of 1 percent shock to change in exchange rate upon overall inflation is more than double in just first 12 months and accumulates to (its peak) 5 percent in 36 months. Lowest, rather almost nil impact upon inflation in Pakistan is that of changes in real economic activities. This finding is similar to those of Riazuddin (2008) where he found a no link between inflation and economic growth in Pakistan. 1 percent shock to interest rates' factor has overall negative impact on inflation in the country and here we solve the price puzzle reported by various studies for the case of Pakistan. Initially it is slightly positive (0.5 percent) and enters negative quadrant after 13 months (as we know here are lags in the monetary policy effects). 1 percent shock to interest rates' factor reduces inflation by above 5 percent in the country in 36 months. This 'overall' effect needs to be disentangled. In this study we have proposed a way to estimate impulse response functions (to a shock to the factor) of all the variables in the group (from which we extract factor). We have plotted individual variables' IRFs in figures named with b as alpha part of figure's number (like Figure 3b in Appendix D for Model 3). From Figure 3b (Appendix D), we can see that shock to discount rate (DISR) has highest negative impact (near 2 percent in 36 months). We can also see that shock to change in Pak Rupee and US dollar parity (ADDR) has significant positive impact on inflation in Pakistan – almost 3 percent in 36 months.

In the following we see impact of monetary policy innovations and exchange rate movements upon various subgroups of interest in the overall basket of CPI in Pakistan.

We start from exploring if interest rate(s) has any impact upon inflation in (the index of the basket of) administered prices. Intuitively, there should be no impact upon administered prices' inflation as the name suggests. These prices are administered by the government of Pakistan and are mostly related to fuel, energy and allied goods/services. Pakistan being an energy importer country, these prices should be more linked with international commodity prices and exchange rate. In order to have IRFs of inflation to various innovations of interest we estimate FABSVAR of following: GOLI, GFDI, ONIR, FMON, FEXR, LSMI and APII. We can see from Figure 4a (Appendix D) that the highest response of APII is to shocks to changes in factor of exchange rate and then comes the effect from shocks to global commodity prices. One can think of response of APII to 1 percent shock in FEXR as high. The fact is when we draw individual IRFs of inflation to (positive) shock to, say, change in US dollar exchange rate we see that (Figure 4b, Appendix D) APII increases by almost 1 percentage point in first 9 months. 1 percent positive shock to global crude oil price changes causes more than 5 percentage points rise in inflation in administered prices in Pakistan within 2 years. Almost similar is the response of APII to (1 percent positive) shock in global food prices after 2 years. Only difference is that the impact of shock to global food prices is relatively sluggish in the early period compared to that of shock in global crude oil prices change (which is quicker as the government of Pakistan usually pass on the impact of oil price changes to domestic users after 1 month). Policy interest rate has least (and in fact zero) effect upon APII in Pakistan which is not surprising.

When it comes to free market prices' inflation, we estimate the following FABSVAR model: GOLI, GFDI, FINR, FMON, FEXR, LSMI and NAPI. What we find from Figure 5a (Appendix D) is that the highest response of NAPI is to GFDI. It seems intuitive and is straightforward: food items carry more than one-third weight in free-market prices basket of consumer goods/services in Pakistan. 1 percent positive shock to global food inflation causes up to 7 percentage points rise in inflation in non administered prices in Pakistan in three years. This may be high because this may include not only the direct effect (of changes in global food inflation to inflation in Pakistan) but also indirect effect in non-food-non-administered prices' inflation due inflation in domestic food prices (caused by GFDI). From Figure 5a (Appendix D) we can see that 1 percent shock to factor of monetary aggregates does have but very mild (almost 1 percentage point) effect in NAPI. And so (mild) are the effects of individual variables in the group from where we extracted the factor of monetary aggregates (Figure 5b, Appendix D). 1 percent positive shock to factor of exchange rates' changes causes around 2 (4) percentage points rise in inflation in non administered prices within 1(3) year. As expected (due to lags in monetary policy effects) 1 percentage shock to factor of interest rates causes almost no impact upon non administered prices' inflation until 18 months. After this it starts showing up the negative effect which reaches 4 percentage points during 18-36 months. And so are the patterns of effects of individual variables (DISR, ONIR, and WALR) in the group from where we extracted the factor of interest rates (Figure 5b, Appendix D).

Food group is most significant and important group in CPI basket. For its importance we can see that weight of food group in CPI basket of 2007-08 is 34.85 percent and about 40.34 percent in baskets of 1995 and 2001 (Hanif et.al 2016). Food inflation affects poor more compared to rich as poor spend higher share of their income on food items (Hanif 2012). We estimated the accumulated impulse responses from following FABSVAR model: GOLI, GFDI, FINR, FMON, FEXR, LSMI and CPFI.

Contrary to general perception that food inflation may not be getting effected by monetary authority's actions, we can see from Figure 6a (Appendix D) that 1 percent shock to interest rate factor has significant negative impact upon food inflation in Pakistan. When we disentangle this for each of the variables in the group from where we extracted the interest rate factor, we can see that shock to Pakistan's policy interest rate results in almost 4 percent decline in food inflation in the country. Similarly, 1 percent positive shock to monetary factor has also positive significant impact upon food inflation in Pakistan. Impact of 1 percent shock to exchange rate factor upon food inflation is 4 percent in 28 months which is combined responses of all exchange rates in the study while accumulated response of exchange rate (US$) changes converge to 2 percent increase in food inflation in 30 months (Figure 6b, Appendix D). Shock to global food inflation has highest positive response on domestic food inflation (around 6 percent within 2 years) as compared to other variables in the model. Not surprisingly, shock to large scale manufacturing growth (LSMI) has no impact on food inflation (Figure 6a, Appendix D). May be, if we construct an index for agriculture production in Pakistan and estimate the FABSVAR used in this study, we can observe some effects to food inflation from supply side (production).

Some central banks are more interested in understanding impact of monetary policy upon core (rather than overall) inflation in the country simply because core inflation measure excludes items with volatile prices, generally food and energy. We have attempted to estimate a FABSVAR model for core (non-food non-energy) inflation in Pakistan. The model we estimated is similar to what we used in case of NAPI except inclusion of global non-food non-energy prices' inflation. The model we estimate here is in the following order: GOLI, GFDI, GNFE, FINR, FMON, FEXR, LSMI and NFEI. A positive shock of 1 percent to exchange rate changes has the highest impact (3.5 percent) on core inflation in Pakistan in 36 months (Figure 7a, Appendix D). Then comes the impact upon core inflation in the country from shocks to global food price inflation and global core inflation. 1 percent shock to monetary aggregates' factor results 1.5 percent increase in core inflation in the country. From Figure 7a (Appendix D) we can also observe that interest rate factor have no significant impact on core inflation up around first one and half year and then we see negative impact of 1 percentage point shock to interest rate factor upon core inflation in the country. Similar is the behaviour of DISR, ONIR and WALR (Figure 7b, Appendix D). This is simply because of long lags in monetary policy transmission and that core inflation is persistent in Pakistan (Hanif et al, 2014). The part of IRF in positive quadrant is very low in size and is statistically insignificant. Thus we do not find evidence of price puzzle in Pakistan.

4. Conclusion

In this study we analyze the effects of monetary policy actions on inflation in Pakistan by using FABSVAR methodology. By incorporating a large number of variables in terms of their combined factor, FAVAR model gives some useful results as compared to standard VAR model as found in Bernanke et al. (2005) and Munir and Qayyum (2014). We suggest a better way of combining variables (of similar nature like 'all types of interest rates') in groups to extract factors - as putting all variables under consideration (interest rates, monetary aggregates, exchange rates etc) in one group impairs the factor extraction. In addition, by using weights obtained in factor extraction, we propose a mechanism to estimate impulse response function of shock to individual variable (like policy interest rate) to see impact on variable of interest (like inflation).

By applying estimated FABSVAR model to exploit rich data environment we see direction and magnitude of IRFs of variable of interest to shocks to different factors/variables are intuitive and consistent with the conventional wisdom. Against the findings of studies based upon standard VAR modeling; we do not observe price puzzle in case of Pakistan when we exploit wider set of information to assess effectiveness of monetary policy during the last couple of decades. In our work we see desired impact of monetary policy innovations upon overall inflation as well as upon changes in price indices of various subgroups (in the CPI basket of Pakistan). Policy interest rate, however, has no effect upon administrative prices inflation in the country, which is intuitive. Such prices are actually influenced by exchange rate dynamics as well as global commodity prices' changes.

References

Agha, A. I., N. Ahmed, Y.A. Mubarik and H. Shah, (2005), "Transmission Mechanism of Monetary Policy in Pakistan", SBP Research Bulletin 1(1), pp.1–23.

Balke, N. S. and K. M. Emery, (1994), "Understanding the Price Puzzle", Federal Reserve Bank of Dallas, Economic Review, Fourth Quarter.

Bernanke, B. S., J. Boivin and P. Eliasz, (2005), "Measuring the Effects of Monetary Policy: A Factor Augmented Vector Autoregressive (FAVAR) Approach", Quarterly Journal of Economics, Vol. 120, pp. 387-422.

Canova, F., (2007), "G-7 Inflation Forecasts: Random Walk, Philips Curve or What Else?" Macroeconomic Dynamics, 11, pp. 1-30.

Christiano, L.J., M. Eichenbaum and C. Evans, (1996), "The Effects of Monetary Policy Shocks: Some Evidence from the Flow of Funds", Review of Economics and Statistics, 78, pp.16–34.

Fernald, J., M.M. Spiegel and E.T. Swanson, (2014), "Monetary Policy Effectiveness in China: Evidence from a FAVAR model, Journal of International Money and Finance, 49, pp. 83-103.

Gupta, R., M. Jurgilas and A. Kabundi, (2010), "The Effect of Monetary Policy on Real House Price Growth in South Africa: A Factor-Augmented Vector Autoregression (FAVAR) Approach", Economic Modeling, 27, pp. 315-323.

Hanif, M. N., (2003), "Restructuring of Financial Sector in Pakistan", Journal of the Institute of Bankers Pakistan, January, pp. 43-74.

Hanif, M. N., (2014), "Monetary Policy Experience of Pakistan", MPRA Paper 60855, http://mpra.ub.unimuenchen.de/60855/.

Hanif, M.N., J. Iqbal and I.N. Khan, (2016), "Global Commodity Prices and Inflation in a Small Open Economy", Working Paper 76, State Bank of Pakistan.

Hayat, Z. and M.N. Hanif, (2016), "Assessing the Role of Money versus Interest Rate in Pakistan", Working Paper 79, State Bank of Pakistan.

Javid, M. and K. Munir, (2010), "The Price Puzzle and Monetary Policy Transmission Mechanism in Pakistan: Structural Vector Autoregressive Approach", Pakistan Development Review, 49(4): Part II, pp. 449–460.

Khan, M.H., (2008), "Short Run Effects of an Unanticipated Change in Monetary Policy: Interpreting Macroeconomic Dynamics in Pakistan", Working Paper 22, State Bank of Pakistan.

Lee, S. (2007), "Structural Equation Modeling: a Bayesian Approach", Chichester: Wiley.

Munir, K. and A. Qayyum, (2014), "Measuring the Effects of Monetary Policy in Pakistan: A Factor-Augmented Vector Autoregressive Approach", Empirical Economics, 46, pp.843–864.

Riazuddin, R., (2008), "An Exploratory Analysis of Inflation Episodes in Pakistan", The Lahore Journal of Economics (Special Edition), pp.63-93.

Robertson, J., (2000), "Central Bank Forecasting: An International Comparison", Federal Reserve Bank of Atlanta, Economic Review, Second Quarter, pp. 21-32.

Sims, C., (1992), "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy", European Economic Review, 36, pp.975-1000.

Stock, J. H. and M. W. Watson, (1998), "Diffusion Indexes", Working paper 6702, National Bureau of Economic Research.

Stock, J. H. and Watson, M. W., (1999), "Forecasting Inflation", Journal of Monetary Economics, 44, pp.293-335.

Appendix A

Principal Component Analysis

Following Stock and Watson (1998, 1999), we use principal components to estimate the factors F_t in the dynamic factor model in equation (1). This method is numerically robust and computationally efficient, and is econometrically consistent for the latent factors F_t under the standard technical conditions discussed in Fernald et al. (2014). Following are simple steps for estimation of factor from principal component analysis.

Let ω_t is a variance covariance matrix of all variables in $X_t = [X_{1t,} X_{2t,} \ldots, X_{Nt}]$. We calculate the eigenvalues of ω_t and then eigenvector corresponding to each eigenvalue.

Let $A = [A_{1,} A_{2,} \ldots, A_N]$ be a set of eigenvalues and $V_1 = [V_{11,} V_{12,} \ldots, V_{1N}]$, $V_2 = [V_{21,} V_{22,} \ldots, V_{2N}]$ and $V_N = [V_{N1,} V_{N2,} \ldots, V_{NN}]$ are eigenvectors corresponding to $A_{1,} A_{2,} \ldots, A_N$ respectively. The principal components (factors) are obtained as

$$F_{1t} = V_{11}X_{1t} + V_{12}X_{2t} + \cdots + V_{1N}X_{Nt}$$

$$F_{2t} = V_{21}X_{1t} + V_{22}X_{2t} + \cdots + V_{2N}X_{Nt}$$

and so on

The factor obtained by the largest eigenvalue is the most representative of variables in X_t in the sense of explaining highest part of the total variance.

Appendix B

Table 1: List of Variables

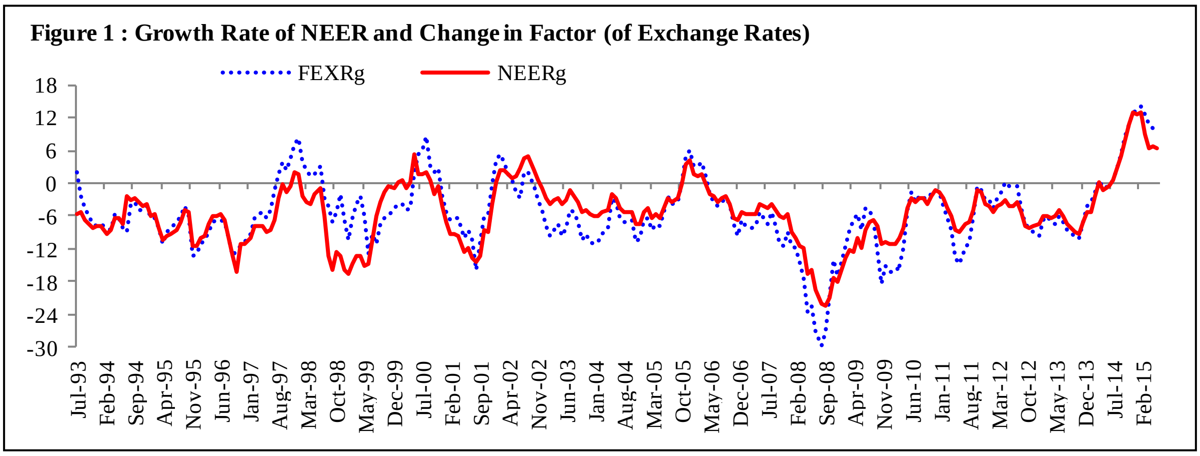
Variable		Description	Source
CPII		Consumer price index (inflation) – overall (487 commodities in the basket)	PBS[1]
CPFI		Consumer price inflation – food (139 commodities in the basket)	PBS[1]
NFEI		Consumer price inflation – non-food/non-energy (331 commodities in the basket)	PBS[1]
APII		Consumer price inflation – administered (30 commodities in the basket)	PBS[1,@]
NAPI		Consumer price inflation – non administered (457 commodities in the basket)	PBS[1,@]
MGPK		Broad money (M2) growth	SBP[2]
ADDR		Appreciation/depreciation of nominal exchange rate (Pak Rupee per US dollar)	SBP[2]
	WALR	Weighted average lending rate	SBP[2]
FINR[a]	ONIR	Overnight interest rate (money market rate)	SBP[2]
	DISR	Discount rate (policy rate)	SBP[2]
	MGPK	Broad money (M2) growth	SBP[2]
FMON[b]	CPSG	Credit to private sector (growth)	SBP[2]
	CGSG	Credit to government sector (growth)	SBP[2]
FEXR[c]		Factor of 23 exchange rates	IMF[3,]
FIME		Factor of Pakistan's 3 interest rates, 3 money aggregates, and 23 exchange rates	SBP[2], IMF[3,]
LSMG		Pakistan's large scale manufacturing index growth	PBS[1]
GOLI		Inflation in global spot crude oil average US$ price of Brent, WTI[#] and Dubai Fateh	IMF[3,]
GFDI		Change in global food price index	IMF[3,]
GNFE		Change in global non food non energy prices index	IMF[3,]

1: Pakistan Bureau of Statistics.
2: State Bank of Pakistan.
3: International Monetary Fund.
a: authors' calculation of factor of three interest rate variables - DISR,WALR and ONIR.
b: authors' calculation of factor of monetary variables - MGPK, CPSG and CGSG.
c: author's calculation of factor of exchange rate of all those 23 countries which are trading partners of Pakistan and are part of NEER calculation, i.e. UK, Belgium, France, Germany, Italy, Netherlands, Spain, Norway, Sweden, Switzerland, Canada, Japan, Turkey, Australia, Saudi Arabia, UAE. India, Korea, Malaysia, US, Singapore, Thailand and China.
@: Administered price index is compiled by Research Department of SBP on the basis of prices data of PBS. It includes following items from CPI basket: wheat, sugar, electricity, piped gas, kerosene oil, petrol, high speed diesel, compressed natural gas, liquid petroleum gas (cylinder), car tax (800cc to 1300cc), train fares, railway platform ticket, postal envelop (domestic and Saudi Arabia), telephone charges, (local as well as intercity). TV license fee, government college/university fee.
#: West Texas Intermediate.

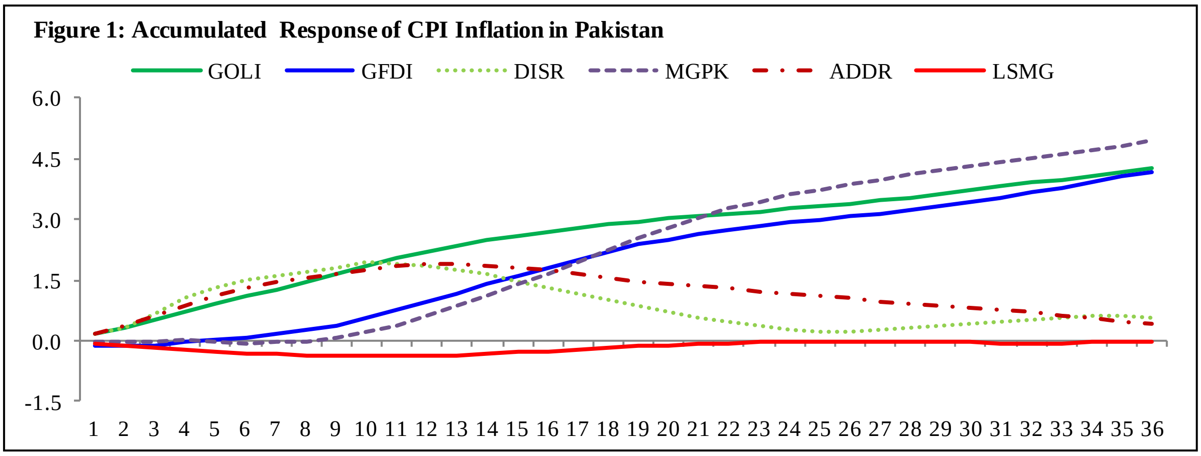
Table2: Model specification to assess the impact of Monetary Policy and Exchange rate policy upon inflation in Pakistan

Model No.	Global Inflation			Policy Variables			Other Determinants of Inflation in Pakistan			Factors				Domestic Price Measure				
	GOLI	GFDI	GNFE	DISR	ONIR	WALR	MGPK	ADDR	LSMG	FIME	FINR	FMON	FEXR	CPII	APII	NAPI	CPFI	NFEI
1	✓	✓		✓			✓	✓	✓					✓				
2	✓	✓							✓	✓				✓				
3	✓	✓							✓		✓	✓	✓	✓				
4	✓	✓			✓				✓			✓	✓		✓			
5	✓	✓							✓		✓	✓	✓			✓		
6	✓	✓							✓		✓	✓	✓				✓	
7	✓	✓	✓						✓		✓	✓	✓					✓

Appendix C



Appendix D



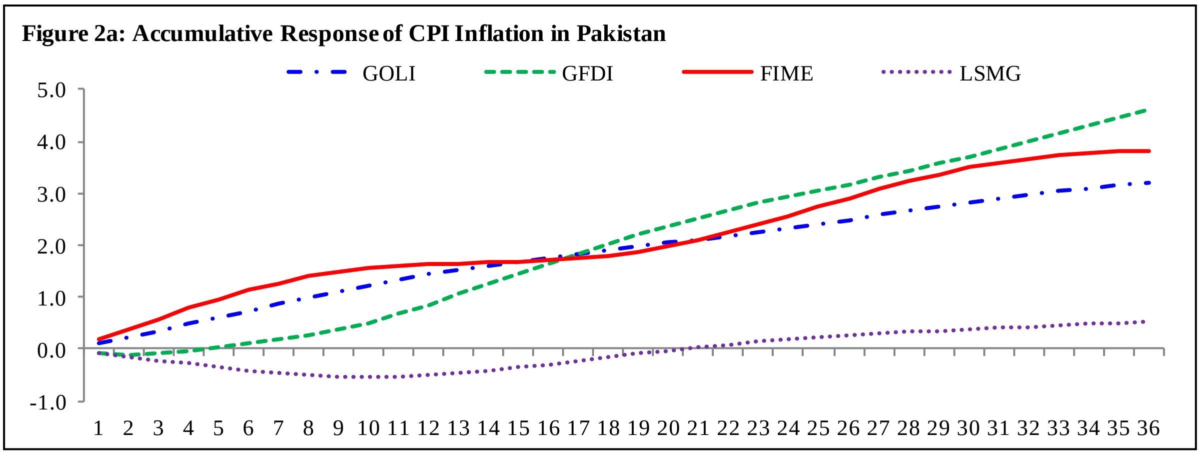


Figure 2a: Accumulative Response of CPI Inflation in Pakistan
GOLI
GFDI
FIME
LSMG
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

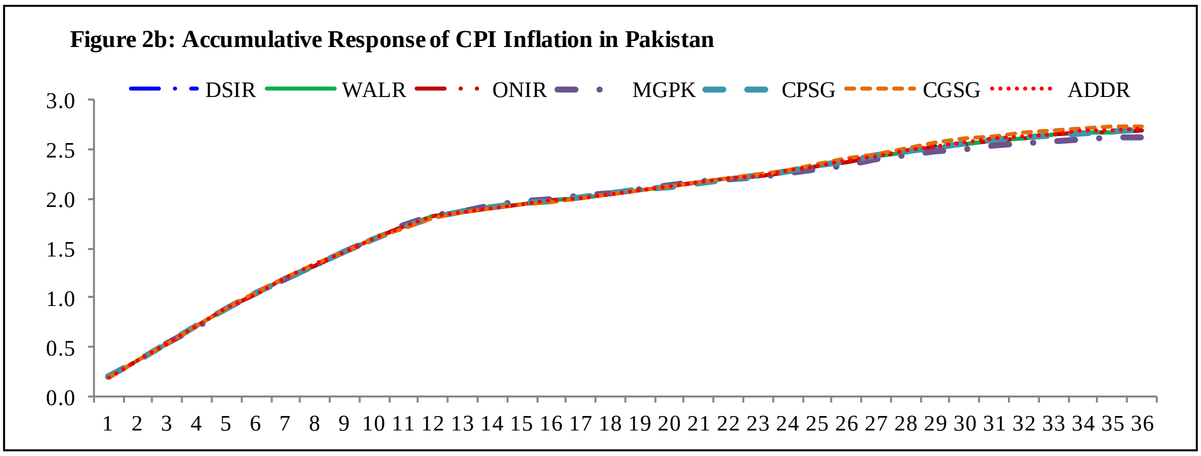


Figure 2b: Accumulative Response of CPI Inflation in Pakistan
DSIR
WALR
ONIR
MGPK
CPSG
CGSG
ADDR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

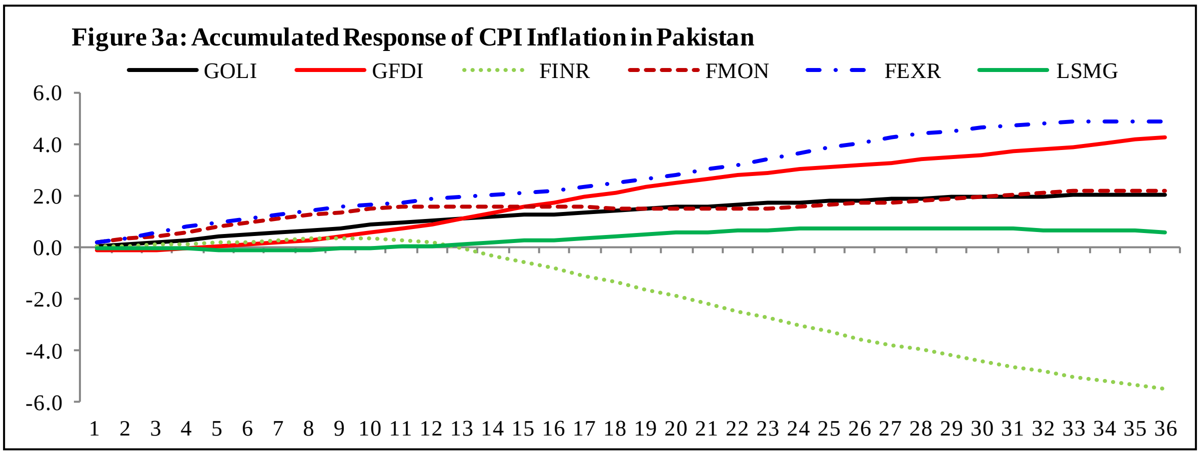


Figure 3a: Accumulated Response of CPI Inflation in Pakistan
GOLI
GFDI
FINR
FMON
FEXR
LSMG
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

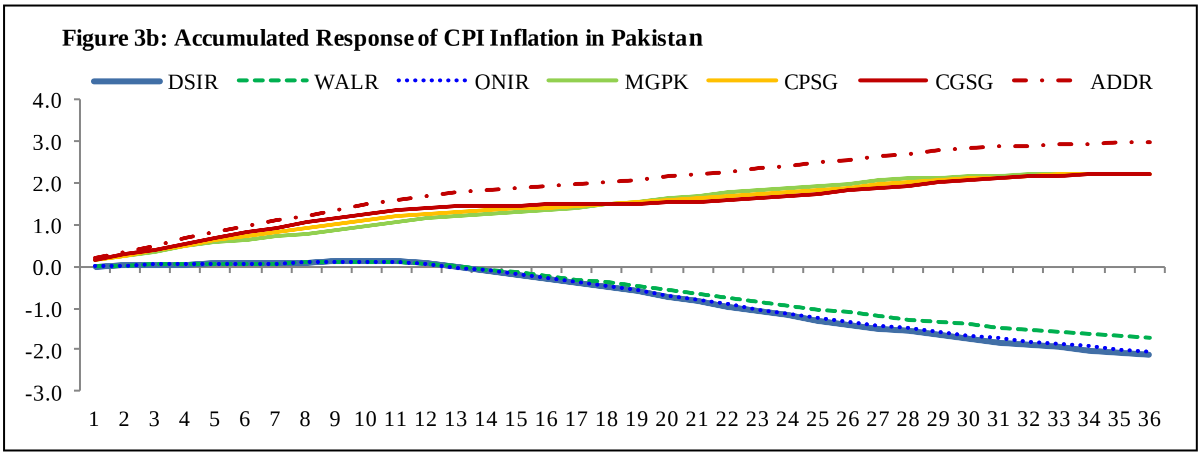


Figure 3b: Accumulated Response of CPI Inflation in Pakistan
DSIR
WALR
ONIR
MGPK
CPSG
CGSG
ADDR

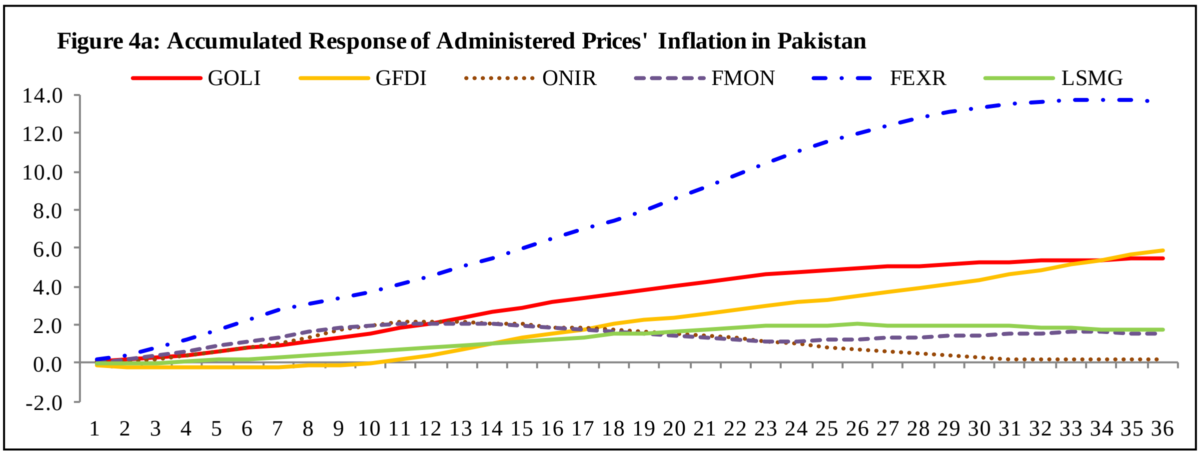


Figure 4a: Accumulated Response of Administered Prices' Inflation in Pakistan
GOLI
GFDI
ONIR
FMON
FEXR
LSMG

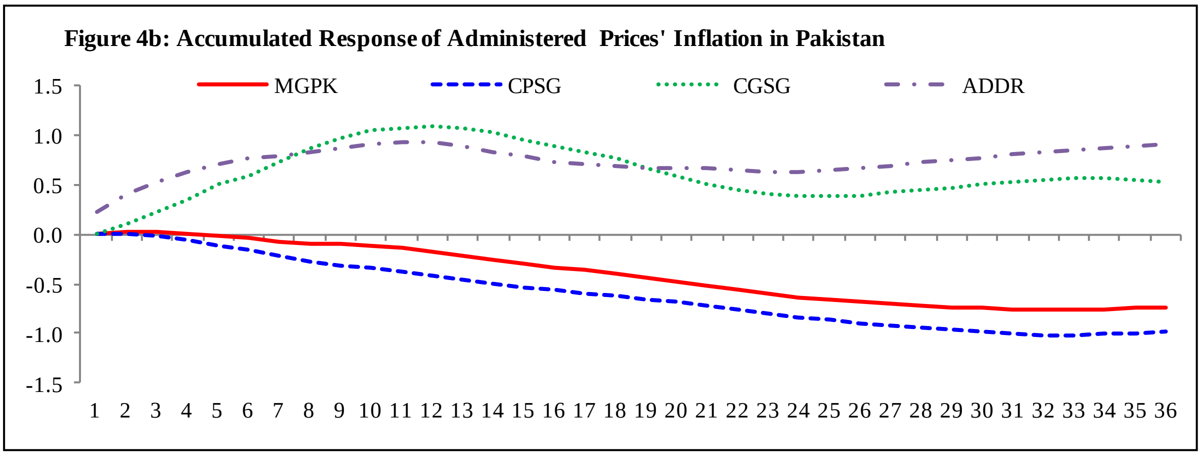


Figure 4b: Accumulated Response of Administered Prices' Inflation in Pakistan
MGPK
CPSG
CGSG
ADDR

Figure 5a: Accumulated Response of Non Administered Prices' Inflation in Pakistan

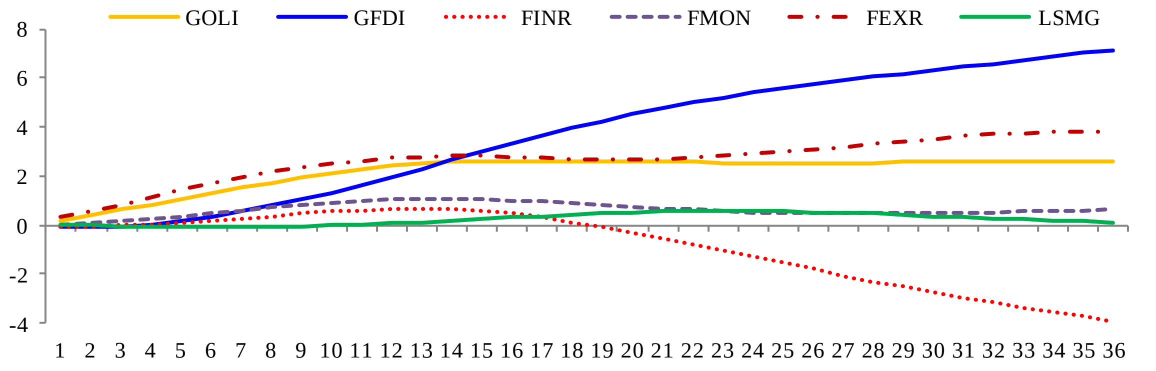


Figure 5b: Accumulated Response of Non Administered Prices' Inflation in Pakistan

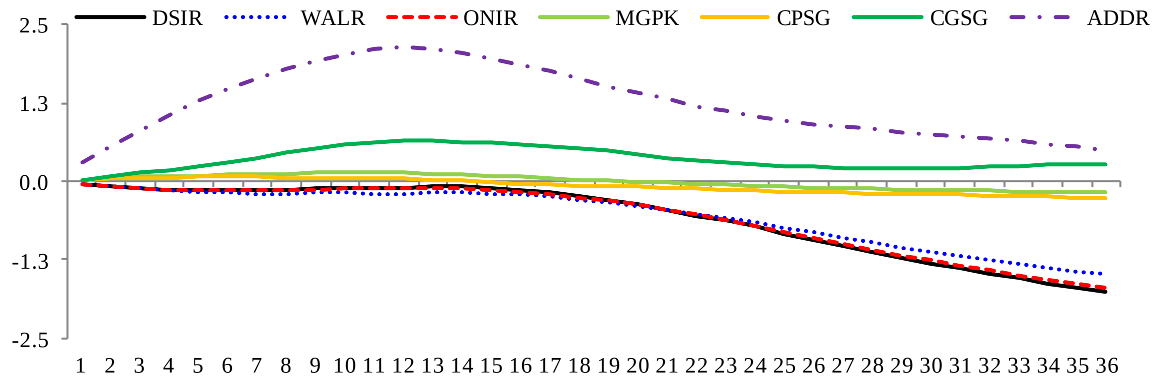


Figure 6a: Accumulated Response of Food Inflation in Pakistan

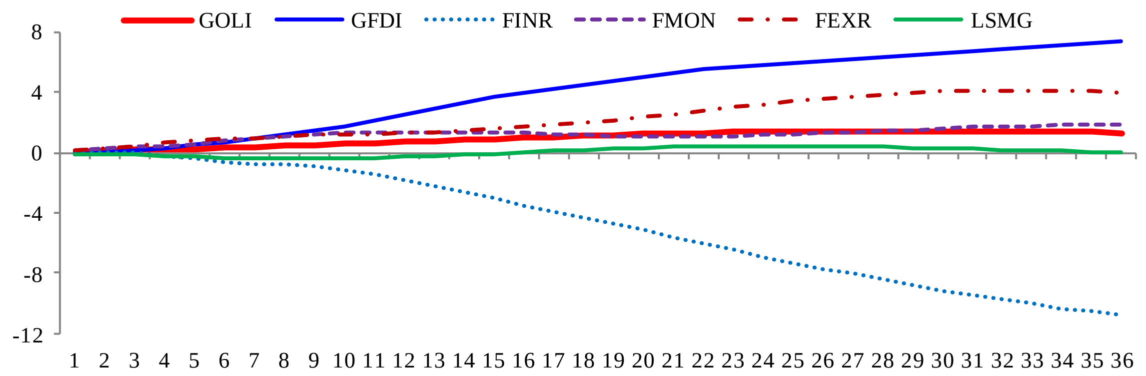


Figure 6b: Accumulated response of Food Inflation in Pakistan

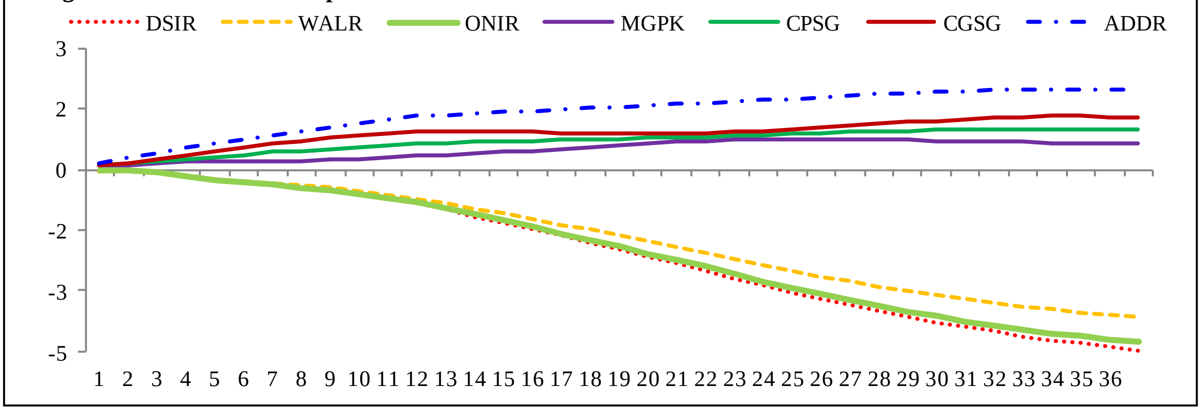


Figure 7a: Accumulated Response of CORE Inflation in Pakistan

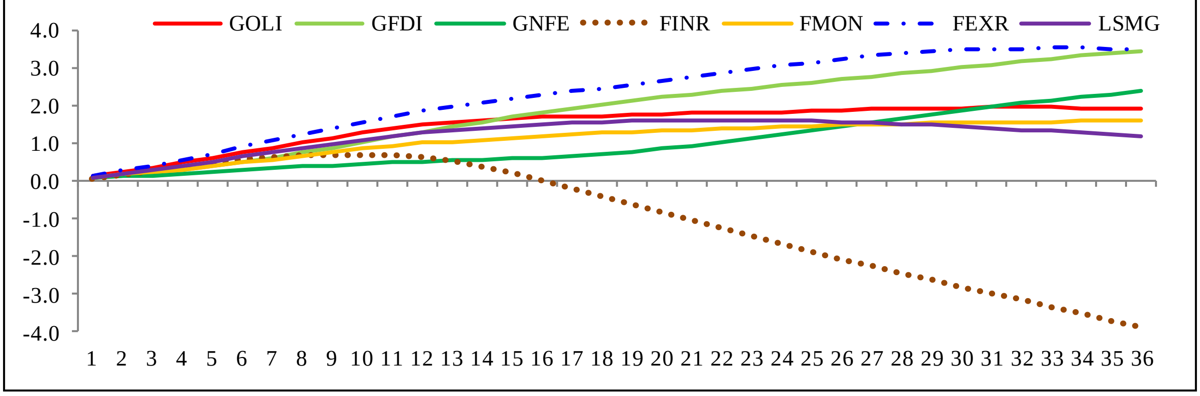


Figure 7b: Accumulated Response of CORE Inflation in Pakistan