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MEASURING THE EFFECTS OF MONETARY POLICY: A FACTOR-AUGMENTED VECTOR AUTO REGRESSIVE APPROACH

Kulsoom Bibi and Ahsan ul Haq Satti[1]

Abstract

Monetary policy performs a significant role in regulating the inflationary burden of a country. This study attempts to evaluate effects of monetary policy on a wide range of different macroeconomic variables. Vector Autoregressive (VAR) and Factor Augmented Vector Autoregressive (FAVAR) approaches are employed by using data of 145 variables from November 2003 to December 2018 on monthly frequency. For FAVAR approach, results are estimated with Principal Components Analysis (PCA), and with Partial Least Squares - Structural Equation Modelling (PLS-SEM) methods. The results of VAR and FAVAR approaches are compared to identify the approach with the more plausible results. The FAVAR results are appeared to be more consistent with economic theory as this approach comprised of a large data set. Whereas, the VAR delivers improbable results due to mis-specified information. FAVAR model both with PCA and PLS-SEM method shows the reduction of price puzzle whereas results estimated with VAR approach shows price puzzle appeared strongly. Both of these approaches support theory of money neutrality.

Key words: Monetary policy, Factor-Augmented Vector Auto Regressive Approach, Price Puzzle, Money Neutrality

JEL Classification: E52, E58, C40

1. INTRODUCTION

In most of the empirical research of macroeconomic issues, VAR models have been used extensively as these were introduced by Sims 1980 for such purposes. Since Bernanke and blinder (1992), an extensive literature has been developed using vector autoregressive models for measuring the effects of monetary policy on macroeconomic variables. These models usually provide empirically reasonable measurements for the responses of chief variables to the innovations in monetary policy both from a theoretical exercise to theoretical models. The key characteristic of this approach is that it only requires the identification of monetary policy shocks and does not require the identification of remainder of the variables used in macroeconomic model.

With the purpose of measuring the effects of monetary policy innovations, VAR approach appears to deliver a lot of important structural information. Logically, this approach does not dearth for criticism. Because most of the researchers have disagreed about the appropriate strategy for the identification of policy shocks.

[1] Authors are respectively MPhil student and faculty in Department of Economics and Finance, Pakistan Institute of Development Economics, Islamabad, Pakistan (Email of corresponding author: ahsansatti@pide.org.pk)

Alternative identification schemes may produce different conclusions about the timing and shape of the responses of macroeconomic variables.

Quite a lot of criticisms of the VAR approach center around the little amount of information or only the subset of total information. This censure makes this approach as low-dimensional VAR due to degrees of freedom problem as the number of variables to be added are usually less than 10. Therefore, the use of VAR models for measuring the effects of monetary policy postures a major constraint as the information sets which are actually used by the central bank literally follows hundreds of macroeconomic series. This mis specified information or sparse information sets lead to at least three potential problems.

First is the lack of information. The information sets used by the Central or Policy maker are much larger than the information sets covered by these models, i.e. all the information is not reflected in SVAR/VAR models. Due to this, the problem of price puzzle arises, a predictable finding of VAR analysis when we adopt a monetary policy in a contractionary way results in the short-run rise in prices.

Second problem which arises using sparse information sets is of impulse responses. The impulse response functions merely calculated for the included variables[2] (Bernanke et al., 2005) generally constitute a small subset of information which the policy maker or Central bank care about. In standard VAR analysis, the inclusion of variables severely limited to problem of degrees of freedom. Therefore, if these approaches are taken under consideration to uncover the effects of the monetary policy innovations, the policy shock is likely to be contaminated.

Finally, SVAR/VAR models require to represent some theoretical constructs based on specific variables. For instance, the concept of 'real activity' is not be represented by a single series such that GDP or IPI, or any other observable measure. Moreover, any observable measure is likely to be contaminated by measurement error issues as the concept of real activity may be the combination of multiple macro-economic series. Unfortunately, the inclusion of relevant variables in standard VAR analysis is severely limited to degrees of freedom problem.

Based on the developments of dynamic factor models, Bernanke, Boivin and Eliasz (2005) proposed an econometric methodology in which it becomes possible to condition VAR approach to assess the policy change on larger information sets without giving up the statistical advantages of limiting the analysis to smaller number of data series. This approach is called as "Factor Augmented Vector Autoregressive Approach" which combines the standard VAR analysis with

[2] It's an obstruction in the implementation of standard VAR approaches for identification of shocks of monetary policy as these are low dimensional. However, to preserve the df problem, Standard VAR approach can hardly tackle more than 6 to 8 variables. (Bernanke et al., 2005)

factor analysis. It means a large number of macroeconomic series can successfully be summarized by a smaller number of estimated indexes.

Emphasizing liberalization in 1990, a substantial revolution occurred in the financial and monetary sector in Pakistan. In order to shift towards market-based and indirect monetary management, a number of alterations have been made in the policies, thereafter. After liberalization, the expediency and competence of the monetary policy remained unexplored. Hence, it is of worth to explore – how effective the monetary policy is and also, how the shockwaves are transmitted to the monetary policy?

As most of the studies have used data driven FAVAR approaches to measure the effects of monetary policy. None of the above studies have reported theory driven Structural Equation Modelling for measuring the effects of monetary policy. In this study, we consider the estimations and properties of FAVAR with principal components analysis, a data driven practice, and FAVAR with Structural Equation Modelling, a theory driven practice, in which factors are estimated by outer weights of Confirmatory Factor Analysis. These methods are then applied to the issues raised above. This study attempts to measure the effects of monetary policy by comparing both data- driven and theory driven techniques.

Rest of the paper is organized as follows. Section 2 discusses the related work. Section 3 portrays the data description and the proposed methodology. Section 4 demonstrates the empirical results on the effects of policy change on macro-economic variables. Section 5 covers the concluding remarks and the policy recommendation.

2. LITERATURE REVIEW

The subject of measuring monetary policy effects has been sightseen for years. Since 1980, to scrutinize the effects of monetary policy, two approaches VAR and SVAR have become the standard approaches. After the pioneered work of Sims (1980, 1992) and Bernanke and Blinder (1992), many researchers (Peersman and Smets (2001), Miyao (2002), Castelnuovo and Surico, (2009) provide a decent overview of the implication of VAR models in measuring the monetary policy innovations on macroeconomic data sets. Some relevant early explorations include Balke and Emery (1994), Bagliano and Favero (1998), Kim and Roubini (2000), Giordani (2004).

The main issue faced by application of these approaches is that the models constructed from these two approaches are basically low dimensional because of the fact that a wide range of variables cannot be incorporated in the model. Very limited variables are being contained in VAR analysis which does not show all the relevant and necessary information which the policy maker and central bank care about. So, the problem of misspecification of information comes into being. (Castelnuovo and Surico, 2009) argued that due to sparse information problem,

the results of measurement of monetary policy innovations would then be blemished. As the VAR models sporadically exhibit some contentious or debatable results that's why these models have been criticized, specifically, after adoption of contractionary monetary policy. Due to which the problem of price puzzle exists. One major explanation of the price puzzle is that central bank contains a large body of information sets which cannot be captured by simple VAR analysis. Sims (1992) introduced the problem of price puzzle very first time. The second problem which is associated here is that the results which may be obtained by VAR analysis are appeared to be biased.

Bernanke et.al (2005) explained that VAR (structural vector autoregressive) models are extensively applied, for the indication of sound effects of monetary policy innovations on economy but these models do not reveal the complete information which the policy maker and central bank consider. These models become low dimensional because of sparse information sets, arising price puzzle. To overcome this issue, FAVAR models are being preferred to capture the information as much as possible using monthly data from 1959 to 2001 of U.S. economy and concludes that results specify some validation for the opinion that price puzzle arises because of the abolition or elimination of conditioning information. Rusnak et al. 2010 concludes that the foremost rationale of price puzzle is associated with the forward-looking models, the central banks followed, and the response to the expected forthcoming inflation changes by increasing the rate of interest.

The use of GDP which is not assumed to control the potential level of economy in the VAR system may cause the results appeared to be biased causing price puzzle. Addition of commodity prices and output gap are appeared to be very significant to mitigate price puzzle.

A factor augmented vector autoregressive models[3] are widely used in the framework of monetary policy and to address the problem of price puzzle.

3. DATA AND METHODOLOGY

The data set which is used in this study consists of 148 macroeconomic series with monthly frequency. The sources of data are State Bank of Pakistan, International Financial Statistics and Khi-Stocks. Time span for the collected data

[3]On inflation and industrial production, to measure the effects of exogenous changes or innovations in unconventional and conventional tools, VAR model is used frequently. Although, to precise the whole information which is enclosed in a large data set of time series into a small factor numbers, and then put these factors into the VAR model which is called FAVAR model. This action is taken to run through the external economic developments. Results suggest that on financial and economic stabilization, unconventional monetary policy has played a significant role. (Fiorelli & Meliciani, 2019)

is from November 2003 to December 2018. The selection of the opening point of data depends on the availability of data from respective sites. The data is collected from the following broad categories i.e. Output, Prices, External Sector, Money, Capital Market and Interest rate.[4]

There are a lot of limitations for the selection of data in Pakistan. This study used Industrial Production Index (IPI) instead of GDP. As the frequency is monthly and GDP is not provided on monthly basis but on annual frequency, that's why we work with IPI instead of GDP. Data on unemployment and employment is also not available at monthly frequency but on twelve-monthly frequency with too many missing observations so this study does not take account of these variables in analysis. SBGI and SBSI cannot be used for measuring the sound effects of monetary policy on the capital market as the State Bank has stopped constructing index since June 2008 and the time span for this study is starting from November 2003 so collecting data for approximately 5 years is of no use. We then used market capitalization of industries of different sectors listed on KSE-100. The data has been processed from the following steps.

First is that the series used in this study are seasonally adjusted as all the series are on monthly frequency so seasonality can exist in all series. The transformation of data is contingent on the features of series. Logarithmic transformation is best to secure linearity as most of the series shows exponential growth (Luetkepohl and Xu, 2009).

For FAVAR model, to obtain the factors which are free from policy instrument, the whole data set is decomposed into fast moving and slow-moving variables. Slow moving variables are those which do not respond quickly after giving shock to the monetary/financial policy variable rather they appeared to respond after a lag whereas the fast-moving variables are those which quickly respond with the shock in policy variable say, interest rate or discount rate.

In categorization of variables, Prices and production sector are included in the former category however capital market, interest rates, exchange rates are included in the category of fast-moving variables as these variables respond rapidly (Bernanke et al., 2005). The first phase of FAVAR is to club a large data set into different factors by making principal components to reduce dimensions in which correlated variables are grouped based on the intensity of correlation. In the second phase, we worked through the VAR analysis.

VARs can definitely explains monetary policy as the changes in the monetary policy instruments that are not explained by the variables which are included in the model are interpreted as the exogenous changes in policy or the 'policy shocks' so VARs (developed by Sims, 1972) can explain monetary policy shocks

[4] Data can be accessed from authors on request

to economic conditions and extensively policy shocks are used to identify what are the policy effects on the economy (Evans & Kuttner, 1998).

3.1 FAVAR Framework and Estimation

Suppose that Y_t is the *P X 1* vector for different observable macroeconomic variables which are expected to drive dynamics of economy. For the time being, it is not necessary to stipulate that whether our crucial interest is in the recognition of structural relationships of these variables or in estimating Y_t. As suggested by the standard VAR approaches, Y_t may include different observable measures of real economic activity. Along with this, Y_t may also include a policy indicator. The traditional approaches to measure the influences of monetary policy on real economy includes estimating SVAR, VAR or some other additional multi variable time series models using data only for Y_t.

Though, in many studies[5], to model the dynamics of these series, the relevant additional economic information may not be included in Y_t. Now, assume that X_t is the *Q X 1* vector which comprises many different time series variables where *Q* is larger than *P* i.e. $Q > P$ and Y_t is considered as a subset of X_t. Additionally, it is assumed that F_t is the *K X 1* vector of factors which are unobserved that capture the additional information contained in X_t whereas $Q > K$. The unobserved factors are considered to capture the additional information or variations in unobserved credit conditions, price pressures or the most inspired concept like 'economic activity' that can be represented by a wide variety of macroeconomic variables but not reflected by only one or two series.

The transition equation represents the joint dynamics of $\boldsymbol{Y_t}$ and $\boldsymbol{F_t}$ is as follows:

$$\begin{bmatrix} \boldsymbol{F_t} \\ \boldsymbol{Y_t} \end{bmatrix} = \boldsymbol{\gamma(L)} \begin{bmatrix} \boldsymbol{F_{t-1}} \\ \boldsymbol{Y_{t-1}} \end{bmatrix} + \boldsymbol{\varepsilon_t} \qquad (1)$$

In matrix notation, it is represented as

$$\begin{bmatrix} f_{1t} \\ f_{2t} \\ \vdots \\ f_{Kt} \\ y_{1t} \\ y_{2t} \\ \vdots \\ y_{Pt} \end{bmatrix} = \begin{bmatrix} \gamma_{11}(L) & \gamma_{12}(L) & \cdots & \gamma_{1(K+P)}(L) \\ \gamma_{21}(L) & \gamma_{22}(L) & \cdots & \gamma_{2(K+P)}(L) \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{K}(L) & \gamma_{K2}(L) & \cdots & \gamma_{K(K+P)}(L) \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{(K+P)1}(L) & \gamma_{(K+P)2}(L) & \cdots & \gamma_{(K+P)(K+P)}(L) \end{bmatrix} \begin{bmatrix} f_{1t-1} \\ f_{2t-1} \\ \vdots \\ f_{Kt-1} \\ y_{1t-1} \\ y_{2t-1} \\ \vdots \\ y_{Pt-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{Kt} \\ \vdots \\ \varepsilon_{(K+P)t} \end{bmatrix}$$

Where $\gamma(L) = \gamma_1(L) + \gamma_2(L) + \cdots + \gamma_p(L)$ is a matrix of a lag polynomial having finite order *p* where γ_j ($j = 1,2,\ldots, p$) and a matrix of $((K + P) * (K + P))$

[5] (Hassan, 2015)

matrix of coefficients and ε_t is a *((K +P) X 1)* error term vector which is having zero mean and covariance matrix $\sum\varepsilon$.

Equation (1) is the basic model of FAVAR. It can also be considered as a reduced form of linear rational expectation model because it includes unobserved and observed variables both. If all the terms which are included in $\gamma(L)$ that narrates the relation of Yt to $Ft-1$ becomes zero then this model (1) can be regarded as standard vector autoregressive model otherwise it indicates FAVAR model.

It is because of the fact that standard VAR model nests in the FAVAR model, so equation authorizes for an easy assessment of VAR results and also offers a system of measuring the marginal contribution of additional information which is contained in Ft. If the equation (1) is estimated as standard VAR analysis i.e. with the omitted but the actual system is a FAVAR then it leads to biased results of coefficients of VAR and also biased estimates of impulse response coefficients.

As equation (1) includes unobserved factors Ft so its estimation cannot be done directly. Along with the observed variables Yt, we can also interpret the unobserved variables Ft as the conventional strengths which determines the changing aspects of the real economy. Suppose the association between unobservable factors Ft, observed variables Yt and informational time series is signified by an observation equation which is of form:

$$X_t = \Omega^f F_t + \Omega^y Y_t + \mu_t \qquad (2)$$

Where,

Y_t is the *P X 1* vector for observed variables

F_t is the *K X 1* vector of unobserved factors

Ω^f is the *Q X K* matrix of factor loadings (the relationship of each variable to its respective factor)

Ω^y is the *Q X P* matrix of coefficients

In matrix form, it can be written as:

$$\begin{bmatrix} x_{1t} \\ x_{2t} \\ \vdots \\ x_{Qt} \end{bmatrix} = \begin{bmatrix} \Omega^{f11} & \Omega^{f12} & \dots & \Omega^{f1K} \\ \Omega^{f21} & \Omega^{f22} & \dots & \Omega^{f2K} \\ \vdots & \vdots & \ddots & \vdots \\ \Omega^{fQ1} & \Omega^{fQ1} & \dots & \Omega^{fQK} \end{bmatrix} \begin{bmatrix} f_{1t} \\ f_{2t} \\ \vdots \\ f_{Kt} \end{bmatrix} =$$

$$\begin{bmatrix} \Omega^{y11} & \Omega^{y12} & \dots & \Omega^{y1P} \\ \Omega^{y21} & \Omega^{y22} & \dots & \Omega^{y2P} \\ \vdots & \vdots & \ddots & \vdots \\ \Omega^{yQ1} & \Omega^{yQ2} & \dots & \Omega^{yQP} \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{Kt} \end{bmatrix} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \vdots \\ \mu_{Qt} \end{bmatrix}$$

and with zero mean and covariance matrix $\sum\mu$ is the *Q X 1* vector of error terms which is either uncorrelated or having a small degree of cross-correlation, depending on which estimation technique is being used i.e. principal components analysis or likelihood methods.

Equation (2) shows that F_t and Y_t both can be correlated generally, and act for common forces that determine dynamics of X_t. The equation (2) without the observable factors can be termed as 'dynamic factor model'.

3.2 The Motivation behind the FAVAR structure: An Example

It is a solemn fact that central bank monitor hundreds of different macroeconomic series for the formulation of policy which provides motivation for taking a large data set under consideration. In this section, a standard macro-economic model is considered which is generally used to capture the fluctuations in monetary policy.

Consider the following simplified backward-looking macroeconomic model. [6]

$$\pi_t = \delta\pi_{t-1} + k(y_{t-1} - y_{t-1}^n) + s_t \quad (3)$$

$$y_t = \varphi y_{t-1} - \psi(D_{t-1} - \pi_{t-1}) + d_t \quad (4)$$

$$y_t^n = P y_{t-1}^n + \eta_t \quad (5)$$

$$s_t = \alpha s_{t-1} + \gamma_t \quad (6)$$

$$D_t = \beta\pi_t + \gamma(y_t - y_t^n) + \varepsilon_t \quad (7)$$

$$X_t = \Omega\,(\, y_t^n, s_t\,,\ \pi_t\,,\ y_t\,, D_t) \quad (8)$$

Equation 3 is the Philips curve or AS equation. Equation 4 is the IS curve or aggregate demand equation. Equation 7 and 8 indicate that the potential output and cost-push shocks are the 1st-order auto-regressive processes. Equation 7 indicates that D_t is the nominal interest rate which is set by the state bank and εt is distributed normally with zero mean and unit variance. Equation 8 is showing the rich set of information which is reflected by macroeconomic indicators Xt.

In matrix form, equation from 3 to 8 can be written as:

[6] (Linde, 2000) inspected how sensitive the backward-looking model accompany with the Tylor rule (as equation 7 in the current study) is for determining the influences of monetary policy. It is concluded that robustness of the model is significant and monetary policy shocks should be checked in an equilibrium framework.

$$\begin{bmatrix} p & o & o & o & o \\ o & \alpha & o & o & o \\ o & \alpha & \delta & k & -k \\ o & o & \psi & \varphi & -\psi \\ \gamma\psi & \beta\alpha & (\beta\alpha+\gamma\psi) & (\beta k+\gamma\varphi) & -(\beta k+\gamma p) \end{bmatrix} \begin{bmatrix} y_t^n \\ s_t \\ \pi_t \\ y_t \\ D_t \end{bmatrix}$$

$$v_t = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ \gamma & 1 & -\gamma & \beta \end{bmatrix} \begin{bmatrix} d_t \\ \varepsilon_t \\ \eta_t \\ \gamma_t \end{bmatrix}$$ (matrix of error terms)

As we know, X_t is the combination of Y_t and F_t depends on which variables are directly observed and which are not. If we assume to estimate all the variables directly by the policy maker and central bank, then its mean that equation 8 will be terminated. But this argument cannot be supported because in real, whole information set can be observed directly by the central bank but not by the policy maker. Only a subset of that information can be perceived by the policy maker. Let suppose a policy maker cannot observe potential output and policy shock directly so these variables are treated in the category of unobserved. $F_t = y^n$, s_t and $Y_t = \pi_t$, y_t , R_t. Specifically, a more plausible assumption is that central bank and the policy maker can only expect to observe the policy instrument D_t.

According to the FAVAR approach, there is no limit on the inclusion of useful factors as intended by Sims 1980. In the standard vector autoregressive approach, we are concerned only with those specifications that become helpful in identification of shocks of monetary policy and not with the other unobservable factors whereas FAVAR estimation technique allows the imposition of all the additional restrictions in the model estimation.

3.3. Estimation

Eq. (1) can be calculated by a standard VAR approach but as the F_t is unobservable so it is impossible. FAVAR approach is a two-step procedure in which first step is of principal components analysis which postulates a non-parametric (a way of not involving the estimation of parameters) way to disclose the space extend over by factors of X_t which is denoted in equation (1) as $C(F_t, Y_t)$. Another chief feature of this technique is that it allows to treat with data analytically to overcome its anomalies. Many studies have argued that X_t may comprise of quarterly and monthly data both over and above that series in which data includes many missing values or discontinuity. (Bernanke and Boivin, 2003).

In this approach, we estimate the common factors by using principal components $(K + P)$ of X_t denoted as $c(F_t , Y_t)$. During estimation of the first step, this fact is not blemished that Y_t is observed. As the $c(F_t , Y_t)$ is a linear

arrangement of its components, finding f_t is to determine the remaining part of $c(F_t, Y_t)$ which is not explained by Y_t. In second step, the FAVAR equation (1) is estimated by OLS method where Ft is replaced by ft. Impulse responses of the relevant variables also calculated which tells about the convergence to the mean value.

In Pakistan, central bank discount rate appears to be a policy instrument. Hence, the change in discount rate is considered as shock in monetary policy as depicted by Bernanke, Boivin, and Eliasz (2005). In Pakistan the instrument of monetary policy i.e. discount rate D_t as an observable variable which is the only one variable in the given vector Y_t viz. $Y_t = D_t$. Except this, all other variables are considered as unobservable. So, only D_t the policy instrument, and a huge set of macroeconomic indicators i.e. X_t is observed. A recursive procedure is used to identify the shocks of monetary policy, all those factors which are appearing in the equation (1) react with a lag to a variation in D_t (instrument of monetary policy).

3.4 Identification of VAR

The recursive assumption makes use of the Cholesky Decomposition of the variance covariance matrix of the estimated residuals; a simple algorithm for splitting a symmetric positive definite matrix into the product of a lower triangular matrix and its conjugate transpose. In the VAR process, the Cholesky Decomposition suggests a strict causal ordering of the variables. The variable ordered last responds contemporaneously to all the other variables, while none of these variables respond contemporaneously to the variable ordered last. The next to last variable responds contemporaneously to all variables except the last, whereas only the last variable responds contemporaneously to it.

An identification assumption in VAR studies of the monetary transmission mechanism is that monetary policy shock is orthogonal to the variables in the policy rule, in the sense that economic variables in the central bank's information set do not respond contemporaneously to the realizations of the monetary policy shock. This implies that some variables are exogenous to the policy shock. We follow the Cholesky Decomposition scheme in which the policy variable i.e. discount rate, is ordered last and treat its innovations as the policy shocks.

3.5 Structural Equation Modelling

To enumerate SEM model, we start with a theoretical framework by constructing CFA (confirmatory factor analysis) and the second step is structural regression model. The basis of SEM is more specifically on theoretical constructs, which are signified as latent factors. The regression coefficients are mandatory to observe the relationship between theoretical constructs within the factors.

3.5.1 Confirmatory Factor Analysis

When the relationships between different constructs are tested and quantified

on the basis of pre- existing structure referred to as CFA. Within SEM, confirmatory factor analysis (CFA) acts as a measurement model because it is a step taken to predict how the latent factors are measured by observed indicators. It tells that how good the model fits the data. It is also exploited to verify the correlation among the latent variables.

As in the current study, six latent variables are introduced such as output, prices, money, interest rate, capital market and external sector. We come up with suitable results by taking under consideration transmission mechanisms of monetary policy which tells us how changes in the money market feed into the real economy.

As there are 6 latent variables. Each latent factor has different number of manifest indicators. Like external Sector is appeared to be first latent variable which is measured by 19 different observed variables. These 19 variables are further clubbed into three main categories i.e. Exchange rates (ER), Imports (M) and Exports (X). Money is the second latent variable having three observed variables of demand deposits, saving deposits and M0. Third latent variable is of prices which is represented by 16 variables further clubbed into two sub categories of Consumer Price Index (CPI) and Wholesale Price Index (WPI). Variables from 23-31 are included in CPI and from 32-37 are in WPI. Fourth latent variable is interest rate characterized by four manifest variables i.e. govt. bond yield (GB), KIBOR, 6-months Treasury bills (TB) and discount rate (DR).

Fifth latent construct is output which is measured by 31 different observed variables. These 31 indicators are clubbed into 3 main categories of IPI, Production of Agricultural products (AP) and Minerals (Min). From the variables list, variables from 56, 57, 65, 66, 70 and 71 are included in AP. Variables from 42, 43, 46, 50, 54, 55, 59-62, 67, 68 and 72 are included in IPI and from 44, 45, 47-49, 51-53, 58, 63, 64 and 69 are included in Min. The sixth latent variable is of capital market measured by market capitalization of 73 industries from 27 sectors of KSE-100 . Choice of data of capital market depends on the availability of data from respective sectors.

4. RESULTS AND DISCUSSION

As mentioned in the literature, addition of relevant information helps to reduce price puzzle. We begin by comparing the results of standard three variable VAR based on Industrial production index, Consumer price index, and Discount rate with FAVAR model estimated with principal components to see whether the addition of information improves the results. Therefore, the first model is standard VAR model which includes three variables IPI, CPI and DR. Second model is FAVAR model which includes a policy variable ‘discount rate’ considered as observed variable, vector of unobserved variables and the three factors. The last model is inaugurated by PLS-SEM method in which six

latent variables are derived by the given observed variables through the outer weights of confirmatory factor analysis and then VAR analysis are being applied on those latent constructs.

4.1 Results estimated from FAVAR and VAR models

Figures given below shows the impulse response functions of benchmark FAVAR and standard VAR model. To inspect the response , we give one standard deviation positive shock to discount rate and see the results.

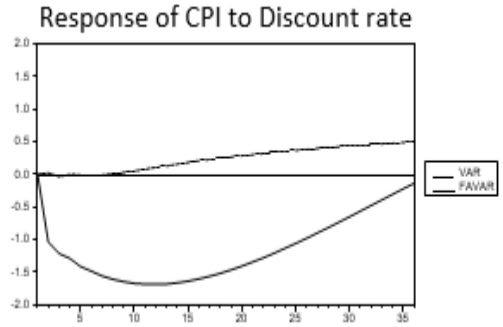

Figure 1: Impulse Response of One S.D. shock in Discount rate on Consumer Price Index

Figure 1 shows the impulse responses of one standard deviation shock in discount rate on discount rate and on non-policy variables. The response of prices due to the shock in interest rate displays resilient presence of price puzzle i.e. due to rise in interest rate, money supply declines. As the money supply is negatively correlated with prices, so prices should decline but the impulse response function of CPI demonstrates the shock does not converge in 36 months horizon. The presence of price puzzle is also narrated in Pakistan by Khan and Ahmed (2008), Agha et al., (2005) and Javid and Munir (2010).

The benchmark FAVAR model shows no presence of price puzzle in Pakistan as the shock in discount rate shows decrease in prices with the contractionary monetary policy. This is the strong evidence that the inclusion of information removes price puzzle. FAVAR model depicts results which are consistent with theory. In Pakistan, as related to output prices are more flexible and the transmission mechanism of monetary policy to prices is faster than output.

According to Estrella (2015), monetary policy effects often measured with VAR analysis whereas the imperfection in using VARs is such that the information used is not enough, unexpected contractionary monetary policy leads to the appearance of price puzzle, that is the rise in inflation in impulse response. Bernanke et al., (2005), Munir and Qayyum (2012) delivered the results in the light of FAVAR that as the large sets of information enclosed almost all the data looked for measuring the effects of monetary policy, so the chances regarding appearance of price puzzle declines.

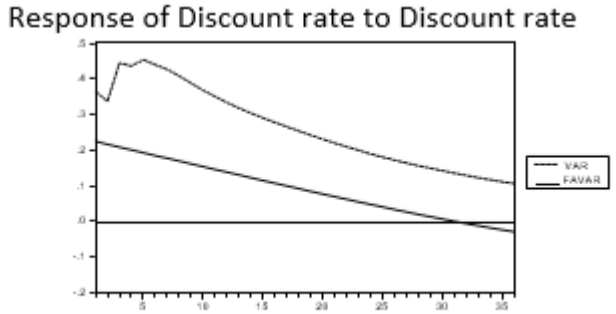

Figure 2: Impulse Response of One S.D. shock in Discount rate on Discount rate

Figure 2 depicts the response of one S.D. shock in discount rate on discount rate. The FAVAR model depicts results which are appeared to be consistent with theory. As we have taken time horizon of 36 months i.e. 3 years, the shock in discount rate converges after 31 months in FAVAR model and displays declining trend for 36 months horizon.

The standard VAR model shows that the discount rate reflects its own shock. Initially, the shock increases till 5th month and shows its maximum then displays declining trend throughout the given horizon. The shock does not die off in 36 months horizon i.e. it takes greater than 36 months to die off which shows inconsistency with theory.

This would also suggest that VAR model render the estimation less precise as compared to FAVAR model. This comparison suggests that the FAVAR approach is successful at extracting pertinent information from a large data set of macroeconomic indicators.

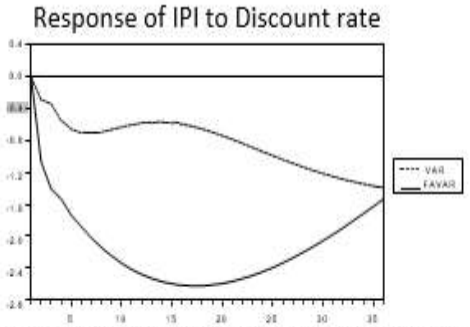

Figure 3: Impulse Response of One S.D. shock in Discount rate on Industrial Production Index

Figure 3 shows how the industrial production changes when we give a positive shock to discount rate. The standard VAR model shows declining trend till 7th period then start converging for a little and after 15th period, it again shows declining trend. The shock does not show any sign of strong convergence in the given time horizon of 36 months and keep showing declining movements. Based on these results, the response is very persistent but inconsistent with long-run

money neutrality. It is important to note that the information included was irrelevant or not enough which would render the VAR results less precise but the estimate should remain unbiased.

The IRF of FAVAR model depicts the strong evidence of money neutrality in long-run. The shock in discount rate initially shows declining trend till 19th period. From 20th period onwards, it shows reviving trend which depicts consistency with theory of long run money neutrality[7]. This suggests that the information contained in FAVAR model is useful beyond that already contained in standard VAR. This comparison suggests that the FAVAR approach is successful at extracting pertinent information from a large data set of macroeconomic indicators.

4.2 Dynamic Effects of Monetary Policy on Various Variables

It is a common fact that the FAVAR approach with principal component analysis can construct impulse response functions for all the variables included in the system i.e. for any element of Xt. This may deliver more comprehensive information and gives more absolute check on the empirical plausibility of the results. The next figure reports the effects of unforeseen changes in monetary policy through impulse response functions.

4.2.1 Impulse Responses of Prices

The results of impulse response functions generated by FAVAR model of the sub-classifications of prices to get a clearer picture of the effects of monetary policy on prices.

With the positive increase in the monetary policy shock, CPI: General initially shows declining trend, reaches its minimum value till 10th period then starts reviving trend and the shock converges till 36th period. CPI: House Rent illustrates decreasing trend till 15th period then start reviving and the shock converges to mean line zero in 36 months horizon showing no evidence of price puzzle. The response of CPI: Food Beverages and Tobacco is a little bit different because the graph declines in the start then increases rapidly and converges but does not touch the mean line in the given months horizon. The impulse response function of CPI: Education with the positive shock in policy variable illuminates no convergence in the given horizon and remains below the mean line of zero. The response of CPI: Apparel Textile and Footwear also shows falling trend, then commenced reviving tendency. Based on the above mentioned results, it can be said that monetary policy takes different time lags to transmit to consumer prices. As FAVAR model signifies no evidence of price puzzle still the persistency and consistency of consumer prices may vary.

[7] VAR analysis are very common and widely used in the field of empirical macroeconomics to identify the real effects of monetary policy. A positive shock in interest rate or contractionary monetary policy produces a large negative effect on GDP which diminishes and then be wiped out in long-run which is in the favour of long-run neutrality of money. (Gambetti, 1999 & Uhlig, 2005)

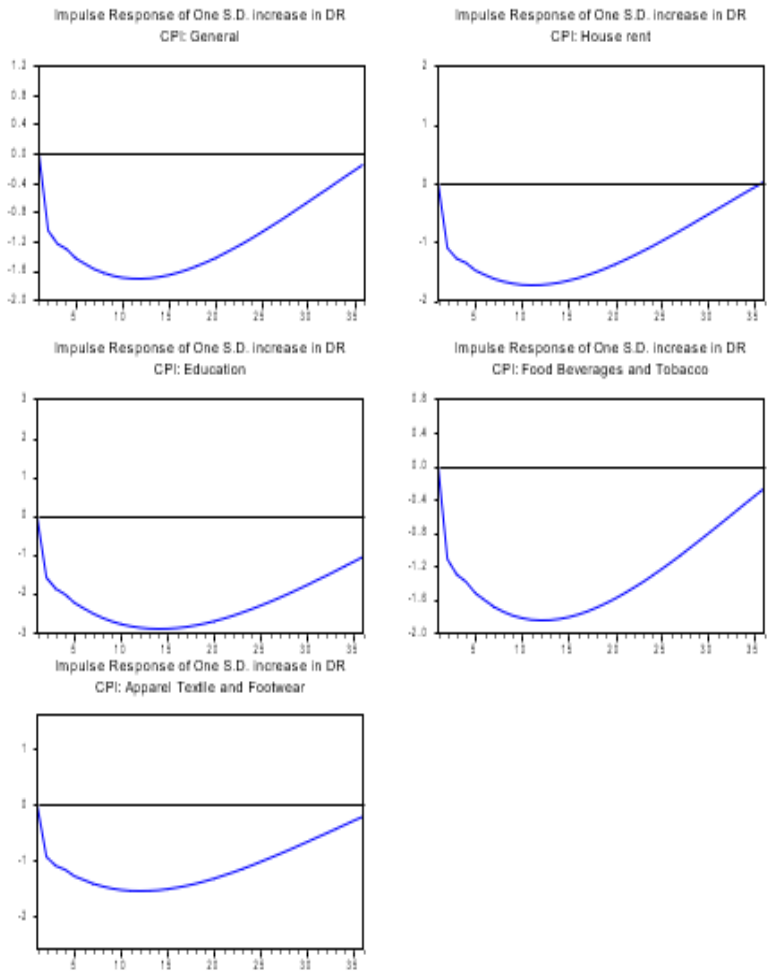

Figure 4: Impulse Responses Generated from FAVAR with Three Factors and DR Estimated by Principal Components

4.2.2 Impulse Responses of Output

Figure 5 represents the results of impulse response functions generated by FAVAR model of the sub-classifications of output to get a clearer picture of the effects of monetary policy on output.

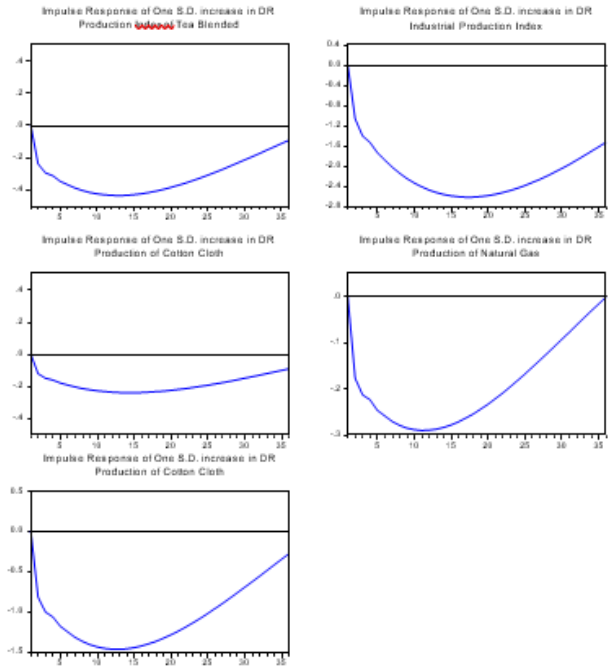

Figure 5: Impulse Responses Generated from FAVAR with Three Factors and DR Estimated by Principal Components

With the positive increase in the monetary policy shock, production index of tea blended shows declining trend, reaches its minimum value till 15th period then starts reviving trend. Industrial Production Index illustrates decreasing trend till 20th period then start reviving and the shock does not

converge in 36 months horizon. The response of production of cotton cloth is a little bit different because the graph shows almost smooth trend. The impulse response function of Natural Gas with the positive shock in policy variable illuminates highly decreasing trend. The response of Production of Cotton Cloth also shows falling trend, then commenced reviving tendency after 15th period. Based on the above-mentioned results, it can be said that monetary policy takes different time lags to transmit to Output. As FAVAR model signifies money neutrality still the persistency and consistency of among various groups are different.

4.2.3 Impulse Responses of External Sector and Money

Figure 6 represents the results of impulse response functions generated by FAVAR model to get a clearer picture of the effects of monetary policy on these variables.

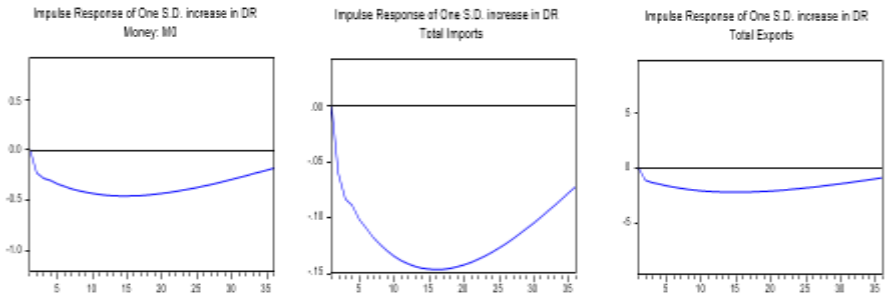

Figure 6: Impulse Responses Generated from FAVAR with Three Factors and DR Estimated by Principal Components

With the positive increase in the monetary policy shock, broad money M2 shows declining trend, reaches its minimum value till 16th period then starts reviving trend and the shock does not converge in 36 months horizon. Total Imports illustrates decreasing trend till 18th period then starts reviving. The response of Total Exports to the increase in discount rate also depicts decreasing tendency. Based on the above-mentioned results, it can be said that monetary policy takes different time lags to transmit to Output. Magnitude of transmission may also vary.

4.2.4 Impulse Responses of Capital Market

Figure 7 represents the results of impulse response functions of One S.D. positive shock in discount rate generated by FAVAR model to get a clearer picture of the effects of monetary policy on capital market.

With the positive increase in the monetary policy shock, Fauji Fertilizers Co. Limited responds positively for first two months but this response is not significant then there appears a declining trend till 8th period. At 8th period, the response of Fauji Fertilizers also reaches its minimum, then starts converging towards zero but the shock does not disappear in the given month horizon. The response of OGDCL due to increase in policy variable initially portrays the positive reaction then starts reviving after reaching its minimum value at 10th period. Abbot Laboratories appears to respond positively at its initial periods and then gradually decreases. Within 36 periods horizon, there is no complete convergence of the shock towards mean value. The last industry of Nishat Mills Limited demonstrates positive tendency in the beginning then shows declining trend till 10th period. As shown in the above figure, the response of Nishat Mills is also positive at its initial periods, reaches minimum till 10th period then starts reviving trend. The shock does not appear to be convergent in a given horizon but shows smooth tendency after 10th period. Based on the aforementioned results, it can be said that the magnitude of monetary policy shock differs and transmission takes different time lags.

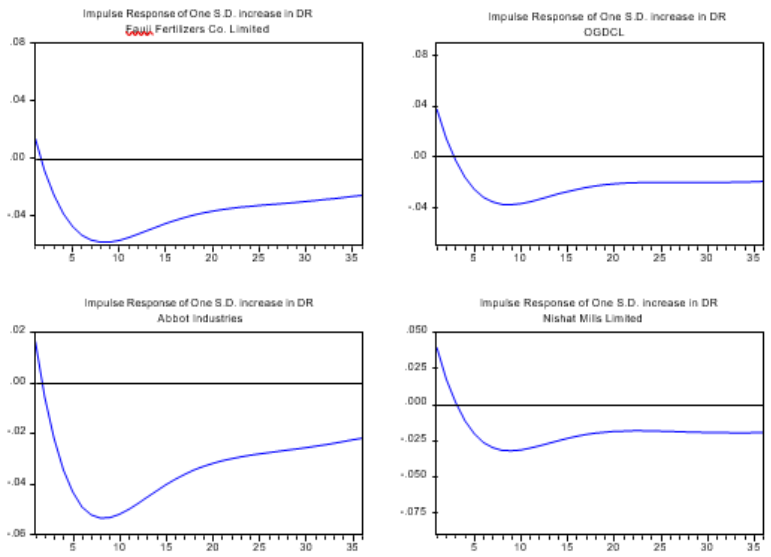

Figure 7: Impulse Responses Generated from FAVAR with Three Factors and DR Estimated by Principal Components

Table 1 depicts the influence of a shock in monetary policy to variance of forecast error of each individual variable at 6 months horizon. The second column indicates the R-square of regression of the given variables on the common components and it represents goodness of fit measures, a high R–square explains that the common components adequately summarize the information which is contained in the respective variable.

Table. 1 Variance Decomposition and R-Square

Variable	Variance Decomposition	R-Square
CPI: General	0.1432	0.9834
CPI: House rent	0.3813	0.9816
CPI: Education	0.2434	0.9546
CPI: Food Beverages and Tobacco	0.3845	0.9756
CPI: Apparel Textile and Footwear	0.3475	0.9548
Production Index of Tea Blended	0.0945	0.8429
Industrial Production Index	0.0532	0.7745
Production of Cotton Cloth	0.0524	0.7673
Production of Natural Gas	0.0456	0.7316
Production of Cotton Yarn	0.0724	0.8523
Money	0.1942	0.6783
Total Imports	0.1411	0.7951
Total Exports	0.2703	0.9118
Fauji Fertilizers Co. Limited	0.3327	0.9752
OGDCL	0.2885	0.8675
Abbot Laboratories	0.9173	0.9583
Nishat Mills Limited	0.6712	0.8402

The contribution of a monetary shock ranges from 0 to 91.7 percent. Precisely, the contribution of a policy shock for the sub-categories of prices ranges from 14.3 to 38.4 percent. The policy shock explains only 5.3 percent of industrial production index. In particular, the policy shocks explain 27.0 percent, 28.8 percent and 67.1 percent of total exports, OGDCL and Abbot laboratories. Looking at the 3rd column of the table, the R-square of the common component explains that most of the measures shows high values of R-square which explore the fact that those measures adequately summarize the information contained in that variable except M_0 whose R-square value is relatively low i.e. 67 percent which does not explain a sizeable portion of information contained in that variable. These results suggest that we should have more confidence in the impulse response functions of these variables except M_0.

4.3 FAVAR Model (PLS-SEM)

We computed the impulse response functions by one standard deviation shock in interest rate. Results appeared to be more reliable with theory in comparison with VAR model. The response of industrial production index to the positive shock in interest rate initially shows increasing trend till 6 months then decline. After 30 months, the shocks recover, and it shows reviving trend. Results of FAVAR model favors the money neutrality in case of Pakistan. The response of prices due to the shock in interest rate identifies the presence of price puzzle. FAVAR model shows results that are consistent with theory i.e. rise in interest rate decreases money supply which in turn decreases the level of overall prices. It signifies no presence of price puzzle in Pakistan.

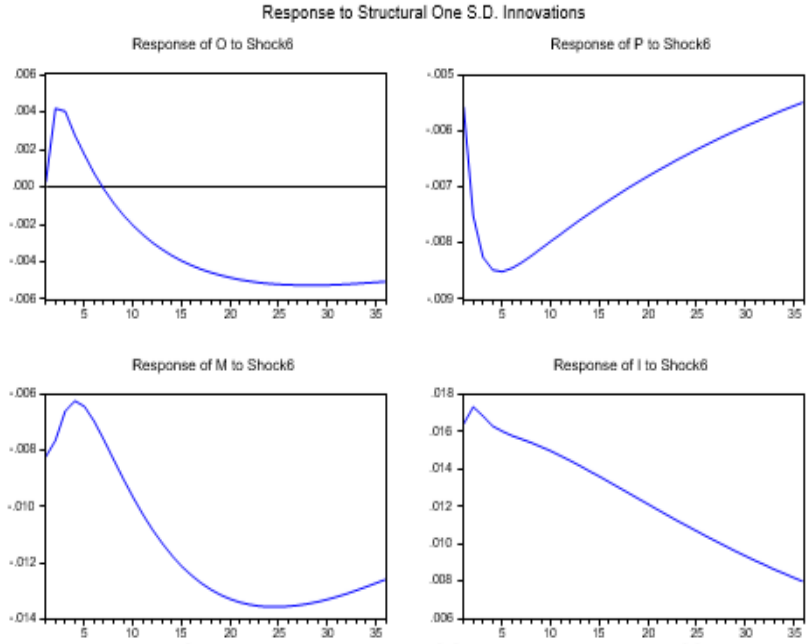

Figure 8: Impulse Responses Generated from FAVAR estimated by PLS-SEM

Liquidity effect is shown by changes in money stock due to variations in interest rate. Results of FAVAR model shows no evidence of liquidity puzzle in Pakistan as the positive shock in discount rate (policy variable) leads to decrease the stock of money in economy. In the beginning, the impulse response function shows declining trend till 24th period and then the shock recovers exhibiting reviving trend from 25th period.

4.3.1 Results of CFA

The values of Cronbach's alpha for each latent construct is greater than 0.90 except output. The value for output is 0.779 which is close to 0.80. The values of composite reliability for all the latent constructs are between 0.70 and 0.90 except interest rate (i.e. 0.667) which are acceptable and concludes that all the constructs are reliable on the basis of standardized outer loading of indicator variable, measurement error of indicator variable and variance of the measurement error.

The results of Average variance extracted indicate that the latent variable capital market explains more than half of a variance of its indicators as the value of AVE is 0.696 or 69.6% leading to reduction of errors. The second latent construct of external sector explains 0.525 or 52.5% of the variance of its indicators. The third latent construct which is of money explains 0.798 or 79.8% of the variance of its indicators specifies that convergent validity of money is quite high enough.

The value of AVE of the latent construct output is appeared to be 0.460 which is less than 0.50 showing that output does not explains 50 percent of the variance of its indicators which means on average more error remains in the indicator variables than the variance explained by the latent variable. The fifth latent variable is of prices and the value of AVE is 0.947 which means that 94.7% variance of indicator or observed variables is explained by the latent construct prices. This shows that convergent validity is quite high enough because the observed measures of latent construct prices are highly positively correlated. The last latent variable interest rate shows AVE value is 0.444 which shows interest rate does not explain more than half of a variance of its indicators. It also specifies the presence of error in indicator variables.

5. CONCLUSIONS

An understanding of the effects of monetary policy is crucial for authorities to achieve objectives of their policies. The current study has introduced a method for incorporating a broad range of conditioning information, shortened by a small number of factors, in otherwise standard VAR analyses. We have shown how to identify and estimate a factor-augmented vector autoregression (FAVAR) model by a two-step method based on estimation of principal components and secondly identifying and estimating FAVAR by theory-based

PLS-SEM approach.

Moreover, FAVAR allows us to discover the responses of a wide range of included variables to monetary policy shocks which provides a complete check on the plausibility of results and a clearer picture of effects of monetary policy. The major benefit of FAVAR approach is that it allows to find out the responses of all the variables included in the vector of unobserved variables which gives us a clearer picture of examining the effects of monetary policy.

The effects of monetary policy have been measured by the VAR and FAVAR models. The baseline VAR model has been compared with the benchmark FAVAR model. The major conclusions of the study are as follows:

The vector autoregressive model signifies the presence of price puzzle whereas FAVAR model estimated by two-step principal components approach depicts no evidence for price puzzle presence. FAVAR model estimated by PLS-SEM method also shows reliable results and no existence of price puzzle as impulse response function of CPI to the positive shock in discount rate indicates positive relationship between prices and contractionary monetary policy i.e. as money supply decreases, prices also declines.

In case of money neutrality, VAR model shows the response of IPI to the shock in discount rate is very persistent but inconsistent with the theory of long run monetary neutrality whereas FAVAR model with principal components approach approves the monetary neutrality. This is the evidence of using relevant information in FAVAR model. The results of FAVAR model estimated with PLS-SEM method also signifies that money is neutral in long-run but non-neutral in short run. Same results are depicted by (Gambetti, 1999). FAVAR model also suggests that the interest rate channel is the most effective channel in Pakistan.

In our monetary application of FAVAR methods, we find that overall the both of these methodologies approximately deliver the same results, although the PLS-SEM approach produce more reasonable results as these are theory driven results because weights through which factors are estimated are theory based. Furthermore, the results conclude that 'price puzzle' exists due to inclusion of irrelevant information or by excluding the relevant conditioning information.

The major policy implications which can be drawn from this study is:

- As the interest rate influences prices negatively, so, in Pakistan it is a good instrument for handling and controlling inflation.
- There is a scope to exploit more information in empirical macroeconomic modeling.

The objectives of this study are well achieved but still there is a venue for further research. For example, to investigate the properties of FAVARs by alternative estimation methods and identification schemes. Furthermore, to use the other definitions of money i.e. broad money may contribute a lot.

The current situation of Pakistan's economy is the challenging one. Government needs to control inflation. Therefore, in this regard, interest rates used as best tool of monetary policy for putting inflation under control.

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