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Abstract

Asymmetries in fiscal policies cannot be captured by linear time series models. In order to examine the asymmetry responses of output in different phases of the business cycle, Markov Regime Switching (MRS) model is an alternative technique that is used to achieve the obsjective. The main objective of this study is to empirically explore the effects of fiscal shocks (spending and taxes) on Pakistan's overall economic activity GDP while utilizing the Markov Switching MS-VAR model. The model is characterized to allow for the variation in mean, coefficients and in error variances. The study results show that the effect of shocks and the size of multipliers vary across regimes confirming the asymmetric behavior of fiscal policy transmission mechanism. Moreover, the impact of positive spending shock has a stronger effect on output in the recession as compared to boom. One surprising result of the study is that the tax shock increases the output both in recession and boom. Lastly, spending and revenue behave a-cyclically.

Keywords: MSVAR model, fiscal policy, nonlinear effect, economic activity

JEL Classification Codes: C11; C32; E62

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1. Introduction

The monetary policy during the Great Recession reached its limits and was unable to answer the ongoing recession. Thereafter the fiscal policy has used a tool to find a solution for a slump in economic activity. The available literature is inconclusive on the effects of changes in fiscal shocks on aggregate economic activity along with its transmission mechanism. The different theoretical models might explain the different effects of fiscal policy on aggregate economic activity at different times. This might be due to the asymmetric response of the economy to fiscal shocks as a result of whether the economy is in boom or recession.

The effect of fiscal policy on private demand is a question in the academic literature of macroeconomics. Keynesian and Classical economists have different views regarding expansionary fiscal policy (Hoppner & Wesche, 2001). Keynesians believe that an increase in government expenditure positively affects private demand, which results in a “crowding-in” effect. On the contrary, Classical suggests that fiscal expansion decreases the private-sector output through crowding out and thus sedates the economy. Classical believes that when government finances expenditure through public debt, the public expects future taxes which induce the labor to increase supply and hence lower the real wages and consumption as well as aggregate economic activity.

With the given perspective, the discretionary fiscal policy is the ultimate tool to beat the recession and stimulate the aggregate demand, however, the empirical question arises that how fiscal shocks affect the output over the business cycle. Answering this question will help the policymakers in planning their stabilization strategies. Which policy induces real economic activity more; tax cut policy or a positive spending shock remains a debatable topic between classical and Keynesians for years. The recent financial crises regenerate the interest of the economist in this debate. Policymakers try to find whether fiscal stimulus packages before and after recession times should have the same effect or not.

Linear Models to examine the effect of fiscal policy instruments on economic activity ignore the potential asymmetry in business cycles. The statistical approach of identifying whether an economy is in a phase of recession or expansion is started by Hamilton (1989). Thereafter, this statistical approach was adopted by many academic studies, especially for business cycle research.

In contrast to the threshold indicator, the Markov switching technique uses all the information limited in the fiscal policy dynamics (Krolzig H-M, 1997, 1998; Hamilton, 2008; Favero & Monacelli, 2005; Hoppner, & Wesche, 2001). The use of Markov switching for modeling fiscal policy dynamics is theoretically justified as the shifts in states fit the policy maker's decision rule which is caused by the shift in fiscal policy (Fialho & Portugal, 2005).

There are four identification approaches through which we can empirically examine the asymmetric impact of fiscal instruments on aggregate output. The four identification approaches to identify fiscal shocks include the structural approach, the recursive approach, the event study approach and the sign restrictions approach. However, these approaches examine only the linear impacts of fiscal shocks on aggregate economic activity but did not have the power to analyze the asymmetric responses (nonlinear). These asymmetric responses have the ability to identify the nature of the effects of fiscal shocks in periods of recessions and booms. The various identification approaches are supposed to answer the following questions. Does fiscal policy behave symmetrically in all situations? Or there is some asymmetric behavior of fiscal shocks over business cycles? Which one fiscal policy (spending or tax) is more effective to stimulate aggregate economic activity in a recession? And lastly, whether decision-makers adopt Keynesian (countercyclical), non-Keynesian (acyclical) or adopt a combination of policies to business fluctuations?

A large body of literature is available in Pakistan investigates the effects of fiscal policy on aggregate economic activities. By examining the impact of discretionary fiscal policy on macroeconomic variables such as output, employment, and inflation (Ismail & Hussain, 2012) finds that although the fiscal policy is discretionary while having no significant impact on major macroeconomic variables. The transmission mechanism is identified via estimating the fiscal reaction function (Khalid, Malik & Sattar 2007) and found a pro-cyclical response of fiscal policy to the business cycle fluctuations. The role of dynamic fiscal shocks on aggregate output is examined by (Shaheen &

Turner 2010) while utilizing an SVAR model with (Blanchard & Perroti, 2002) type identification. The study finds a significant role of government spending and taxes in explaining the changes in output. Some other (Subhani, 2010; Javid & Arif, 2009) examine the effect of a fiscal variable on aggregate economic activity, but a very little or no literature is found particularly in Pakistan that analyzes the impact of regime-dependent fiscal shocks on aggregate output.

Based on the aforementioned backdrop, the given study is an attempt to explore the time-varying effects of fiscal policy on the aggregate economic activity of Pakistan while utilizing the Markov Switching Vector-Autoregressive (VAR) model. More specifically the study aims to identify the high and low growth periods endogenously while measuring the asymmetric impact of fiscal policy on aggregate economic activity.

The section that follows discusses the previous literature, while section three is about data and study methodology. Descriptive analyses, interpretation of results and regime wise evaluation of impulse responses are provided in section four. Finally, section five concludes the study.

1. Literature Review

The fiscal policy effectiveness is assessed in the context of discretionary fiscal policy and economic stabilization. In the Keynesian framework, private demand is positively influenced by the expansionary fiscal policy while following the assumption of price rigidity, excess capacity, and liquidity constraint for households and firms. Supply-side models of rational expectation and Ricardian equivalence hypothesis are the non-Keynesian effects of fiscal policy. Crowding out effects in the IS-LM model is larger if the investment is more sensitive to money demand and less sensitive to the interest rate. An expansionary fiscal policy increases the domestic interest rate and as a result, the inflow of foreign capital is larger in the context of (Mundell, 1963) which assumes capital mobility. A contractionary fiscal policy has the effect of a decrease in interest rate which in turn depreciates the currency. This depreciation of currency resultantly offset the contractionary effect of fiscal policy by raising the exports fully with fixed prices and partially with flexible prices. The inflow of capital will not tend to increase the interest rate in case of a fixed exchange rate and fixed prices in response to the expansionary fiscal policy. The result is no crowding-out effect.

Linear models are incapable to capture the asymmetric effect of fiscal policy instruments on the aggregate output of the economy. The statistical approach that whether the economy is in the phase of recession or expansion is started by (Hamilton, 1989). Thereafter, this statistical approach was adopted by many academic studies, especially for business cycle research. There is a wide range of theoretical and empirical literature on Vector-Auto Regression (VAR) that investigated and inspected the consequences of fiscal shocks on the macro economy, it does not work if the objective is to investigate the asymmetric responses of output to shock in fiscal instruments In which state of the business cycle the economy is can be explained via the non-linear responses.

In time series analysis, the introduction of Markov regime-switching models is due to (Hamilton, 1989). The Markov switching VAR model was popularized by (Krolzig, 1997) that replicated the Hamilton MS (2)-AR (4) (two regimes) model for US and German business cycles. Since the researchers have little information about the time of parameter shifts. Therefore, it is necessary to model structural changes through Markov regime-switching regression and makes rational implications about the significance of the parameter shifts. The above-mentioned problem is avoided as Markov switching endogenously determines the shift in the regime. In contrast to the threshold indicator, the Markov switching technique uses all the information limited in the fiscal policy dynamics (Krolzig, 1997, 1998; Hamilton, 2008; Favero & Monacelli, 2005). The use of Markov switching for modeling fiscal policy dynamics is theoretically justified as the shifts in states fit the policy maker's decision rule which is caused by a shift in fiscal policy. Chibi, Benbouziane, and Chekouri, (2014), used the MS-VAR model and found that fiscal policy i.e. expenditure and taxes behave differently across regimes of recession and expansion. Further, the finding of the study suggests that fiscal policy is pro-cyclical

The evidence of fiscal stabilization in Ireland (1987-1989) and Denmark (1983-1986) are found by (Hellwig & Neumann, 1987; Giavazzi & Pagano, 1990). The responsible factor for stabilization is wealth effect which maintains that higher real interest rate causes capital gains which encourage consumption. Similarly, people tend to import durable goods as the exchange rate appreciates and cause a consumption boom. Some studies found inconsistent Keynesian regimes in the sub-sample period.

While estimating the fiscal policy feedback rules for Japan, the United Kingdom and the United States (Ito, Watanabe & Yabu2007) find that the fiscal policy regime is not fixed in Japan. These results imply that the Japanese government has adopted either the Ricardian or non-Ricardian fiscal policy regime. The results for the UK and US were in sharp contrast with Japan. Similarly while examining the effect of fiscal policy on Algerian economic activity (Chibi, Benbouziane, & Chekouri, 2014) by utilizing the MS-VAR model maintain that fiscal policy in Algeria behaves asymmetrically during different phases of the business cycle. The study also found that in the short run during recession economic activity is stabilize more effectively by government spending policy than tax policy.

The take away from the available literature is that the dynamic effect of fiscal instrument on economic activity, may be changing across the economies depending on the circumstances. The aggregate economic activity may respond differently to shocks in fiscal instrument in different phases of the growth. The assessment of the asymmetric responses of aggregate economic activity to fiscal shocks cannot be detected via conventional linear VAR model. This needs the utilization of more rigorous econometric technique to investigate the existence of this kind of fiscal policy making. Fiscal policy plays an active role in order to achieve the twin goals of macroeconomic stabilization and economic growth in a developing economy like Pakistan (Sattar, 2014). Moreover, in conducting the fiscal policy the stabilization and magnitude of instruments of fiscal policy are also influenced by political pressure, wars across borders, natural disaster and governance issues.

2. Methodology

2.1. Markov Switching VAR Model

The relationship between the fiscal instrument (i.e. tax revenue and expenditure) may be subject to a regime shift in a single or multi-equation system if the parameters in the relationship change according to the state or regime the economy is in at each time period. The use of the MS-VAR model is justified in the following lines:

Most often it is observed that the fiscal instrument such as taxes and expenditure is strongly correlated with the business cycle, so an endogenous shift of the variables is quite reasonable. Secondly, the fiscal instrument may behave differently during different phases of the business cycle i.e. during expansion and recession or during excessive growth. In other words, the fiscal policy may affect economic activity in a non-monotonic way. Lastly, it is argued that fiscal policy affects an individual's expectations and decisions rule due to which fiscal policy react nonlinearly to the changing aspects of the private sector.

A standard nonlinear VAR (switching model) in which the fiscal instrument affect aggregate economic activity can be written in general form as follows:

$$y_t = \mathrm{v}(s_t) + \sum_{j=1}^{M} A_j(s_t)\, y_{t-j} + u_t \tag{1}$$

where u_t is assumed a Gaussian innovation process, conditional on the regime s_t: i.e. $u_t \sim NID(0, \sum_{(s_t)})$

In the framework of Hamilton, the unobservable variable s_t follows a first-order two-state Markov process with transition probabilities given as follows:

$$\Pr(s_{t+1} = 0/s_t = 0) = P^{00} \tag{2}$$
$$\Pr(s_{t+1} = 1/s_t = 0) = 1 - P^{00} = P^{01} \tag{3}$$
$$\Pr(s_{t+1} = 1/s_t = 1) = P^{11} \tag{4}$$
$$\Pr(s_{t+1} = 0/s_t = 1) = 1 - P^{11} = P^{10} \tag{5}$$

where

$$\sum_{j=1}^{M} p_{ij} = 1 \; for\ all\ j \in \{1 \ldots \ldots M\} \tag{6}$$

i.e. $P^{00}+P^{01} = 1$ and $P^{11}+P^{10} = 1$The above 2-state Markov process is written in matrix notation as follows:

$$\mathrm{P} = \begin{bmatrix} P^{00} & P^{10} \\ P^{01} & P^{11} \end{bmatrix} \tag{7}$$

It is assumed here that each element of this matrix i.e. p_{ij} is less than one so that the regime is persistent rather absorbent[2].

[2] Once the system reaches a regime, it stays there infinitely.

Equation (2) through (5) records the probabilities of being in either of the two regimes conditioning in the previous period. For instance, the probability of high growth regime in time t given that the economy was in a high growth regime in the previous period (s_t = 1) is $P(s_{t+1} = 1/s_t = 1)$ which is a constantP^{11}. Equally, the probability of a high growth regime on time t, given a low growth in the previous period is a constantP^{01}.

2.2. The Model

We have three variables in our model, the seasonally adjusted series of GDP at constant prices, total government expenditure and the net revenue variable (total tax revenues minus transfers including interest payments on government debt). The data span is from the first quarter of 1973 to the fourth quarter of 2014 (quarterly data)[3].

The mean equation of the MS-VAR model in their reduced form is specified as follows.

$$X_t = F_0(s_t) + F_1(s_t)X_{t-1} + \dots\dots\dots + F_M(s_t)X_{t-M} + \sigma(S_t)u_t, \quad u_t \sim N(0, \Sigma(s_t)), \tag{8}$$

where X_t= $(\Delta t_t,\ \Delta y_t,\ \Delta g_t)$ is a vector of endogenous variables described above. $F_0(s_t)$ is a vector of constant, and $F_m(s_t)$ is a matrix of coefficients where m ϵ $\{1, \dots \dots, M\}$. Moreover, in the latent variable i.e. s_t = 1, 2, ……, S which represents the regime in period t; S is the number of regimes. Thus the VAR in the above system can be considered as two VARs one that holds for when s_t = 0 and one that holds for s_t = 1.

The MS-VAR model is composed of two components i.e. the Gaussian VAR model and the Markov chain. The first component is characterized by the conditional data generating process whereas second is the regime generating process. The estimation of both the component is based on the maximum likelihood, estimate. Specifically, the model parameter is obtained by the expectation-maximization (EM) algorithmic rule, proposed by (Hamilton, 1990). Starting from the

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[3] Since MS-VAR models are more parameter consuming technique so it requires higher frequency. To increase the number of observation we quarterize the annual series to quarterly series by following Chow and Lin (1971) approach. The detailed of this approach are provided in Appendix-B.

initial estimates of the hidden information, this method iteratively produces a joint distribution which in turn increases the probability of observed information.

The EM algorithm maximizes the incomplete-data log-likelihood through the iterative maximization of the expected complete-data log-likelihood, conditional upon the observable data. Given the observed data and some initial estimates of the parameters in the model, the EM algorithm begins by calculating the smoothed state probabilities. After smoothed state and transition probabilities, the expected complete data log-likelihood function is constructed which is the "E", expectation part of the algorithm. The "E" part is then maximized to obtain an updated parameter estimate which is the "M", maximization part of the algorithm. Based on this updated estimate, again the smoothed probabilities are calculated and are substituted back into the expected likelihood function. This procedure is repeated until convergence (in the parameter estimates or the likelihood function) is obtained.

In linear VAR models how the endogenous variables responds to a unit, exogenous shocks are examined through impulse response functions. The regime dependent impulse response function introduced by (Ehrmann, Ellison, & Valla2003) is built-in MS-VAR models. to analyze the impact of regime-dependent innovations on endogenous variables that are also subject to regime shift. The regime dependent residuals terms i.e $(S_t)u_t^t$, $(S_t)u_t^y$, $(S_t)u_t^g$ of this MS-VAR are generally correlated (their regime dependent variance-covariance matrix Ω_u is not diagonal) so these reduced-form residuals have little economic significance. To avoid this problem, the reduced form model is transformed into a structural model by pre-multiplying a (k×k) matrix A to both sides of equation (8).

$$A(s_t)\, X_t = A(s_t)\, F_0(s_t) + A(s_t)\, F_1(s_t) X_{t-1} + \dots\dots\dots + A(s_t)\, F_M(s_t)\, X_{t-M} + \mathrm{B} e_t \tag{9}$$

In order to retrieve the actual VAR for parameter estimates from the reduced form then an identification problem arises.

The variance-covariance matrices of structural shocks and reduced-form residuals are related as follows.

$$\textstyle\sum_i = E(B_i u_i u_i' B_i') = B_i\, E(u_i u_i') B_i' = B_i \mathrm{I} B_i' = B_i B_i'. \tag{10}$$

It is assumed that structural shocks are unrelated to each other due to which the variance-covariance matrix of structural form residuals becomes an identity matrix. while $\sum_{(st)}$ is the variance-covariance matrix of reduced form residuals. The symmetric property of variance-covariance matrix) imposes K(K+1)/2 restriction on the identity $\sum_i = B_i B_i{}'$. We apply the Cholesky type restriction to a vector of endogenous variables in which the matrix of contemporaneously related variables is restricted to a lower diagonal matrix. This Cholesky type restriction orders the spending variable first which is the most exogenous variable in our case to most endogenous such as taxes and GDP.

How endogenous variables respond when one standard deviation shock is given to the k-th disturbance at time t is expressed in the below equation.

$$\frac{\partial E_t y_{t+h}}{\partial u_{k,t}} \Big|_{S_{t=\cdots\ldots=S_{t+h}=i}} = \theta_{ki,h} \tag{11}$$

According to Erhmann et al. (2003), the impulse responses are as follows.

$$\widehat{\theta_{k\iota,0}} = \widehat{B}_\iota \varepsilon_0 \tag{12}$$

$$\widehat{\theta_{k\iota,h}} = \sum_{j=1}^{\min(h,p)} \hat{A}_{ji}^{h-j+1} \widehat{B}_\iota \varepsilon_0 \tag{13}$$

3. Data and Results

The study uses quarterly data of GDP (y_t) in real terms, government expenditure (g_t) and net taxes (nt_t). All the data are real variables and are seasonally adjusted and arebeing transformed into log-difference form for estimation purposes. In Pakistan, data series are available annually[4] so, first of all, we converted the data into quarterly series by (Chow & Lin, 1971).

In modeling Markov switching models the initial step is to test non-linearity in the variables in order to confirm whether the Markov regime-switching model is appropriate or not. The likelihood ratio test is not valid because of the presence of nuisance parameters when

[4] The econometric method that is utilized in this paper required longer time series data, therefore we use an authentic quarterization technique to have loger time series in hand.

testing the null hypothesis of linearity[5]. This problem was recognized by (Hamilton, 1998) in his influential work on Markov switching models. However (Hansen, 1996) cured this problem in detail.

Hansen pointed out that due to the unidentified nuisance parameters P_{00} and P_{11} under the null hypothesis, the quasi-log-likelihood function becomes flat which produces two problems i.e. no unique maximum and local optimum or inflection point. Under such circumstances, the usual tests (likelihood ratio, Lagrange multiplier, Wald tests) asymptotic distributions are non-standard. Therefore Hansen (1996) proposed a standardized likelihood ratio test which accounts for such problems. The Hansen standardized LR is applied in this research to test for nonlinearity. The results (see Table 1, Appendix-A)[6] indicate that the null of one state is rejected in all cases against two states. Thus the Hansen test provides evidence for the two-regime shifting representation in modeling the relationship between these two variables.

To avoid miss speciation of the model i.e. to decide which parameters are regime dependent once a second regime is recognized. Following (Krolzig, 1997), "bottom-up" procedure and successively a general specification of the MS-VAR are tested against each other, comprising MSIH(2)-VAR(1) and MSIAH(2)-VAR(1) against the initial illustration of MSI(2)-VAR(1). To fix the suitable specification between alternative models assuming the constant number of regimes, the LR test is used and the log-likelihood values of the different specifications are given in table 3 (see appendix-A). On the basis of this bottom-up strategy, the selected specification is MSIAH(2)-VAR(1). The two modeled regimes are thus low growth regime, in which the mean and volatility are larger and high growth regime in which the mean and volatility are low.

3.1. Results of Markov Regime Switching

We estimated different specifications of the MS-VAR model and choose the best fit on the basis of the maximum value of likelihood given in table 4 i.e. MSIAH (2)-VAR (1) model for analysis. The coefficients of the MS-VAR(1) model in the recessionary phase are

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[5] The detail discussion on this is given in Hansen (1996)

[6] To run the (Hansen, 1996) Matlab codes, MATLAB 7.9.0 (R2009b) is used.

negative and its volatility is also higher. On the other hand, the second regime catches the expansion phase of the fiscal instrument with a positive sign and lower volatility. It is also seen from Table 3 that the probability of staying in regime 1 is higher $\Pr(s_{t+1} = 0/s_t = 0)$ is 0.8043 as compared to the probability of staying in regime 2 $\Pr(s_{t+1} = 1/s_t = 1)$ that is 0.6236 which proposes that regime 1 is more persistent as compared to regime 2. The associated smoothed probabilities which are used to obtain a forecast about the regime for future periods are given in figure 1 in Appendix-A.

By analyzing the lag coefficients of the endogenous variables, we can observe that shock in government spending and GDP in the *t-1* period produce a positive effect on government spending and GDP in period *t*. Similarly, the autoregressive coefficient of lag 1 for taxes produces a positive but insignificant effect on taxes in period *t*. The coefficient of the control variable also suggests some inference about the transition probabilities of switching the two growth states. A positive and significant estimate of a_1 indicate that the likelihood of being staying in a low growth-high variance state is increasing. Similarly, since the estimate of $b_1$is positive and significant also suggests that the chances of switching from one regime to another are high.

The smoothed probabilities are based upon all sample period information for a regime at time t while the filtered probabilities are conditional on information up to time *t*. The plot of the smooth regime probability tells us at which point in time all the series follow the same behavior which is either all the series are increasing (regime 2) or decreasing (regime 1).

3.2. Regime wise Impulse Response Analysis

In the subsequent section, the study is aimed to analyze the results through impulse response functions regime wise. All the impulse responses in regime 1 and 2 are displayed in figures 2 and 3 in the appendix-A.

Observing figure 1 in regime 1 (when the economy is in low growth regime), we could see that one-unit shock in government spending (or Pakistani rupee) having a multiplier effect on the output of about 0.65 in the first period (first quarter). In the 5^{th} period, the multiplier decreases to about 0.50 and thereafter decreases continuously in the long run. By observing the response of output to a unit shock in government spending in second regime, it could be deduced that in the initial periods (up to 3rd quarter) output response negatively, response remain positive up to 12th quarter with the highest positive multiplier of about 0.70 in the 5th period but become negative again thereafter. One conclusion drawn from this analysis is that the effect of shocks and the size of multipliers varies across regimes confirming the asymmetric behavior of fiscal policy transmission mechanism. Moreover, the impact of positive spending shock has a stronger effect on output in the recession as compared to boom. Other impulse responses in the two regimes should be explained in the same way.

Figure 2 shows how output responses to a unit shock in taxes in both regimes. In the low growth regime, tax shock positively affects the output at impact period, the positive effect decreases up to the 6th quarter and thereafter an everlasting increasing impact on output. Similarly, in the high growth regime output again increasing in response to tax shock until the 45th quarter and then generate a negative impact. This surprising non-Keynesian impact of tax spurs on business cycle fluctuation maybe because of the low tax to GDP ratio in Pakistan.

As far as figure 3 of regime 1 and 2 is concerned, the fiscal policy in Pakistan neither behaves according to Keynesian view nor Anti-Keynesian as in response to one-unit shock in output, revenue and spending first decreases in both the regimes while increases after some time periods. In fact, spending and revenue behave cyclically.

4. Summary and Policy Recommendation

There are many ups and downs in Pakistan's economy since its inception. This study is intended to examine the different relationships in the business cycle phases. The study employed MS-VAR to empirically explore the effects of fiscal shocks (spending and Taxes) on Pakistan's macroeconomy (GDP). The study estimated different specifications of the MS-VAR model among which the best fit model was chosen for analysis. The results confirm the business cycle asymmetries i.e. fiscal shocks behave differently over the business cycle. The study results show that the effect of shocks and the size of multipliers vary across regimes confirming the asymmetric behavior of fiscal policy transmission mechanism. Moreover, the impact of positive spending shock has a stronger effect on output in the recession as compared to boom. One surprising result of the study is that tax shock increases output both in recession and boom. Lastly, spending and revenue behave acyclically.

The results of the study conclude that spending policy during a recession is more effective as compared to tax policy in the context of stabilization strategies. Knowledge of the regime-switching relation between the fiscal instrument and economic activity may provide important policy implications. Policymakers can set the appropriate policies depending on whether the financial instrument has adverse or favorable effects on economic activity in a state of recession or boom.

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Annexure A

Table 1: Results of Likelihood Ratio Test

	Hansen's LR Test	P-Value M=0	M=1	M=2	M=3	M=4
GDP	2.5342	0.016	0.015	0.014	0.011	0.003
Spending	2.6534	0.088	0.082	0.067	0.081	0.057
Taxes	1.8989	0.106	0.104	0.108	0.12	0.14

Table 2: Results of Two-Regime MS-VAR Model

Coefficients	Δspending	Δtaxes	ΔGDP
Regime-dependent means			
Mean($s_t = 0$)	-0.036181	-0.756890	-0.437270
	(-0.0065)	(-.4203)	(-0.1821)
Mean($s_t = 1$)	0.767584	1.247934	0.023325
	(.3439)	(0.4288)	(0.00778)
Coefficients			
$\Delta spending(-1)$	0.977801	1.730688	0.218928
	(.3948)	(.2073)	(0.0846)
$\Delta taxes$(-1)	0.002117	-0.121612	0.004954
	(0.3887)	(-2.3436)	(0.5952)
$\Delta GDP(-1)$	0.637715	4.667273	0.402002
	(0.1715)	(2.1878)	(0.1552)
Regime-dependent variances			
$\sigma^2(s_t = 0)$	3.86	7.26	6.35
$\sigma^2(s_t = 1)$	2.35	2.69	2.55
Log-likelihood			
Transition function			
Transition variable/parameter	**interest rate**	**interest rate**	**interest rate**
a_0	2.073	1.73	0.128
	(0.15)	(1.33)	(.02)
a_1	2.283	1.29	2.326
	(0.80)	(0.32)	(0.59)
b_0	5.064	5.53	5.504
	(0.31)	(0.27)	(1.48)
b_1	10.42	1.21	0.04
	(2.13)	(0.91)	(0.95)
P_{ij}	State 1	State 2	
State 1	0.8043	0.3764	
State 2	0.1957	0.6236	
Duration of regime	5.87	2.35	
Final Log-Likelihood	2413.8284		

Note: standard error is given in parenthesis.

Table 3: Different Specification and their Transition Probability Matrix

Transition Probability Matrix		Expected Duration of Regime	
		State 1	State 2
MSI(2)-VAR(1)	$\begin{bmatrix} 0.97 & 0.17 \\ 0.03 & 0.83 \end{bmatrix}$	16.84	2.62
MSIH(2)-VAR(1)	$\begin{bmatrix} 0.95 & 0.11 \\ 0.05 & 0.89 \end{bmatrix}$	19.43	8.89
MSIAH(2)-VAR(1)	$\begin{bmatrix} 0.94 & 0.09 \\ 0.06 & 0.91 \end{bmatrix}$	18.41	11.18

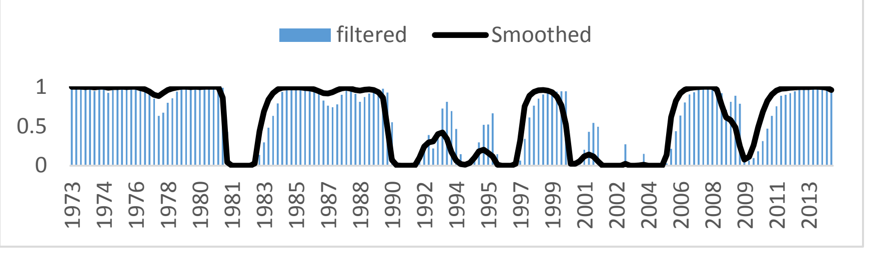


Figure 1: Two-Regime MS-VAR Model Filtered and Smoothing Probabilities

Figure 1: Impulse Response Functions to a unit shock on spending

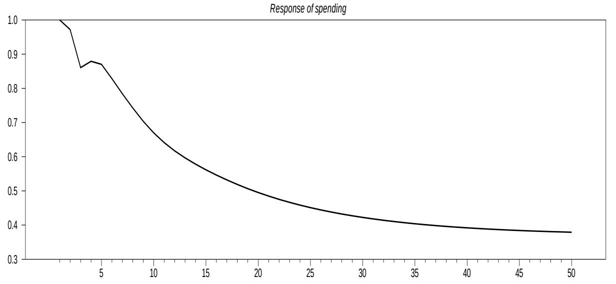


Figure 1: Impulse Response Functions to a unit shock on spending

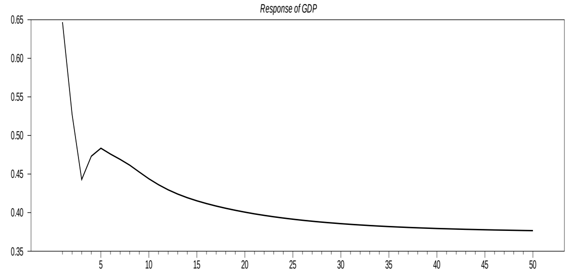


Figure 2: Impulse Response Functions to a unit shock on Taxes

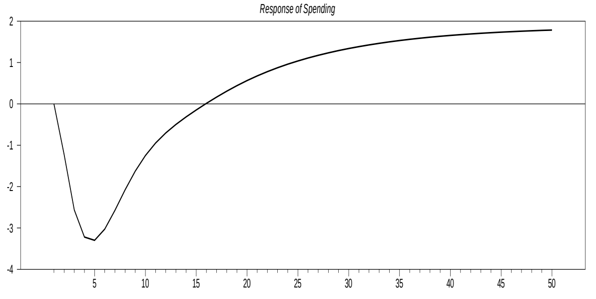


Figure 1: Impulse Response Functions to a unit shock on spending

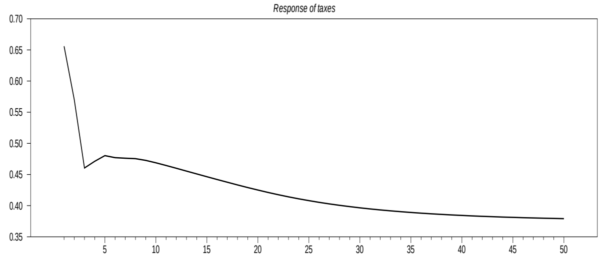


Figure 2: Impulse Response Functions to a unit shock on Taxes

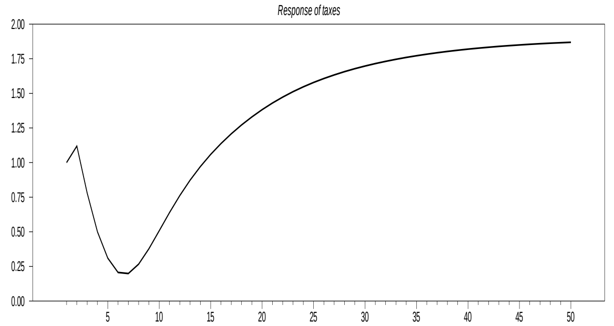


Figure 3: Impulse Response Functions to a unit shock on GDP

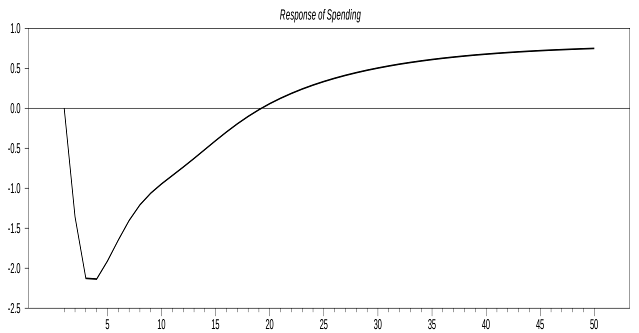
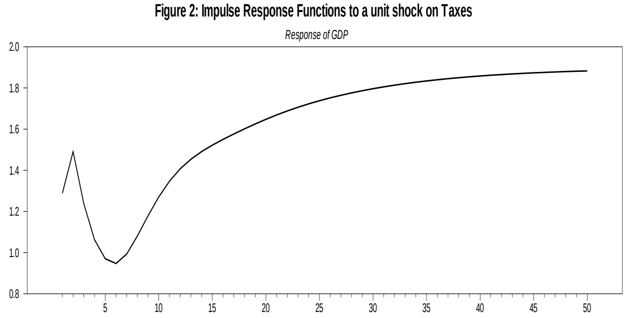


Figure 2: Impulse Response Functions to a unit shock on Taxes



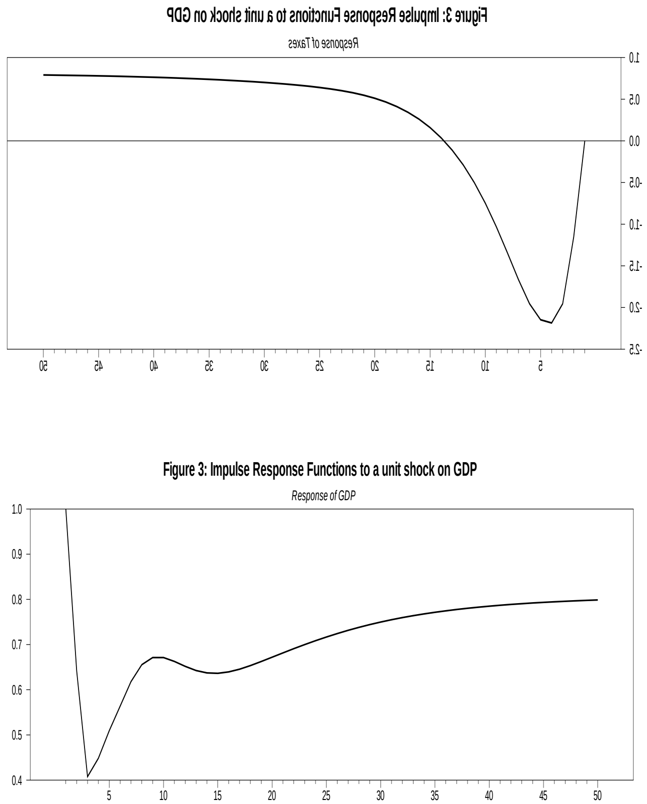


Figure 2: Regime one and its Impulse Responses

Figure 1: Impulse Response Functions to a unit shock on spendin

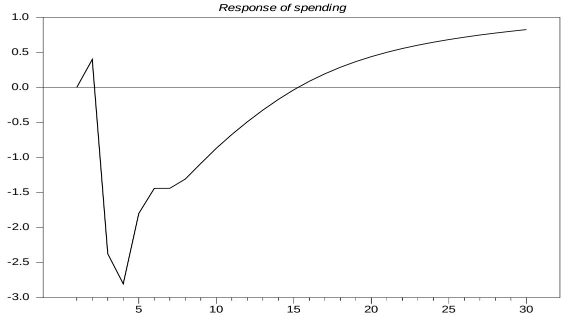


Figure 1: Impulse Response Functions to a unit shock on spending

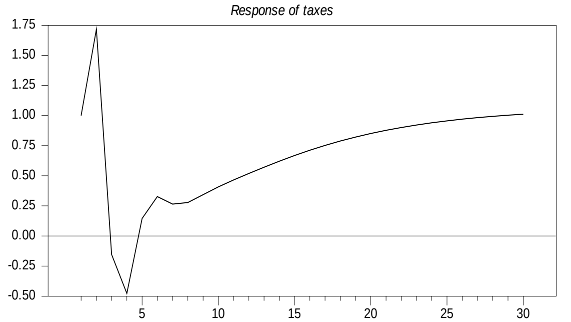


Figure 1: Impulse response functions to a unit shock on spending

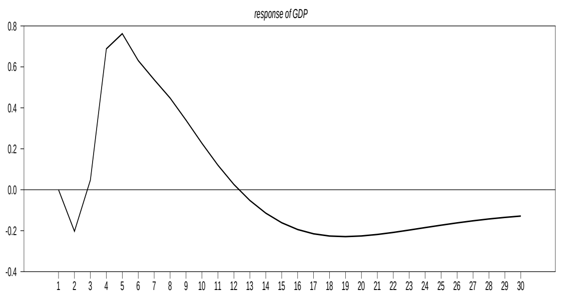


Figure 2: Impulse Response Functions to a unit shock on Taxes

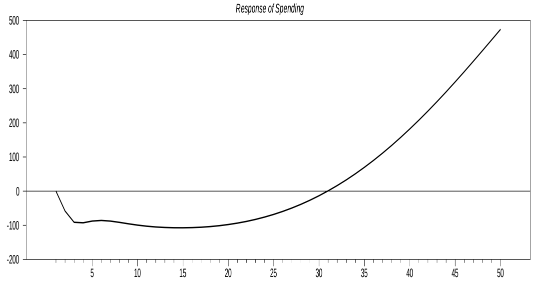


Figure 2: Impulse Response Functions to a unit shock on Taxes

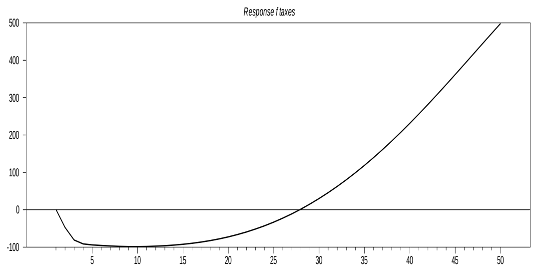


Figure 2: Impulse Response Functions to a unit shock on Taxes

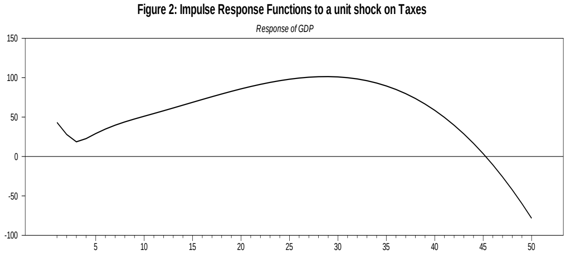
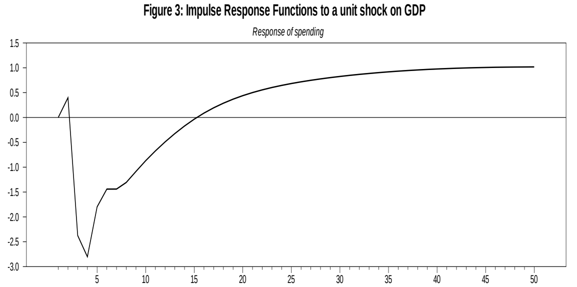


Figure 3: Impulse Response Functions to a unit shock on GDP



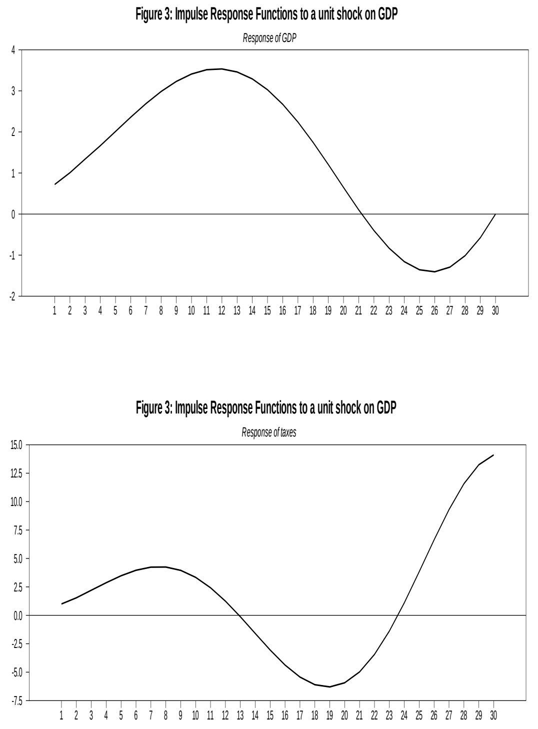


Figure 3: Regime two and its Impulse Responses

Annexure B

Chow Lin Procedure to Generate Quarterly Estimates from Annual Series

Chow and Lin (1971) procedure was originally develop for temporal disaggregation to convert quarterly series to monthly observation. However, later on Friedman (1962), Lisman and Sandee (1964), and Boot et al. (1969) proposed econometric methods to lessen the shortcomings in Chow-Lin procedure and make it possible to convert annual data into quarterly. Chow-Lin procedure combines other quarterly indicator series that relate to annual series to generate the quarterly volatility.

Let Y^a is annual time series available for time T years and the quarterly observation to be estimated from the above annual time series is given by (4n× 1) vector Y^q. The multiple linear regressions in which the quarterly series is supposed to be predicted from annual series is given by

$$\mathrm{C}Y^q = Y^a = \mathrm{C}X^q\beta + \mathrm{C}\varepsilon^q \tag{A.1}$$

$$\mathrm{C}Y^q = X^a\beta^a + \varepsilon^a \tag{A.2}$$

With $\mathrm{E}(\varepsilon) = 0$, $\mathrm{E}(\varepsilon\varepsilon') = \Omega$

where X^q is the matrix of quarterly input series and is related to the annual time series Y^a. The matrix C is a temporal aggregation-extrapolation matrix which converting the 4T quarterly observations into T annual series. C defines the type of temporal aggregation and could be of temporal aggregation of a flow, could be average of an index and could be interpolation depending on whether we have

$\mathrm{C} = [1, 1, 1, \ldots\ldots..1]$, $\mathrm{C} = [1/s, 1/s, 1/s, \ldots\ldots..1/s]$ or $\mathrm{C} = [0, 0, 0, \ldots\ldots..1]$.

The aim here is to find the best linear unbiased of Y^q in terms of C and Ω by applying GLS as follows

$$y^{q^\wedge} = X^q\beta^{a^\wedge}{}_{GLS} + \Omega^q C'(C\Omega^q C')^{-1}\varepsilon^{a^\wedge} \tag{A.3}$$

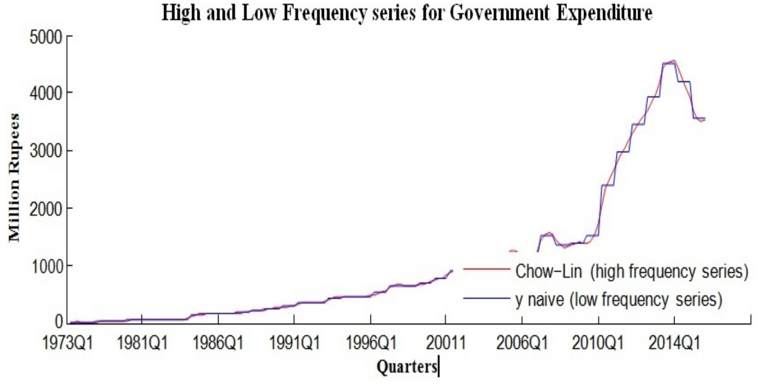
where $\beta^{a^\wedge}{}_{GLS} = \left(X^{a\prime}C\Omega^q C' X^a\right)^{-1}\left(X^{a\prime}C\Omega^q C' y^a\right)^{-1}$

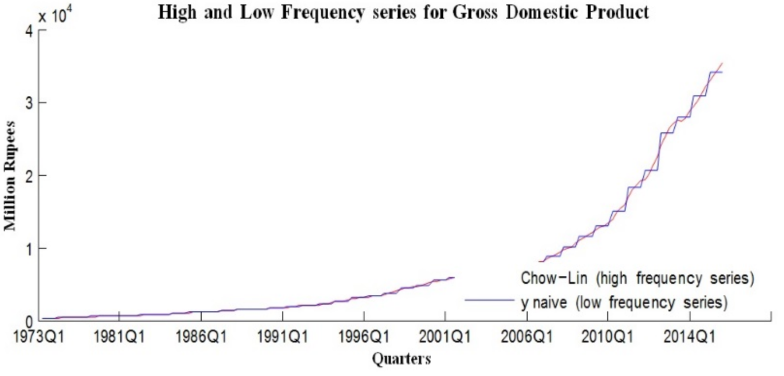
where Ω^q is covariance matrix of ε^a which is a stochastic vector with zero mean and can be obtained as follows

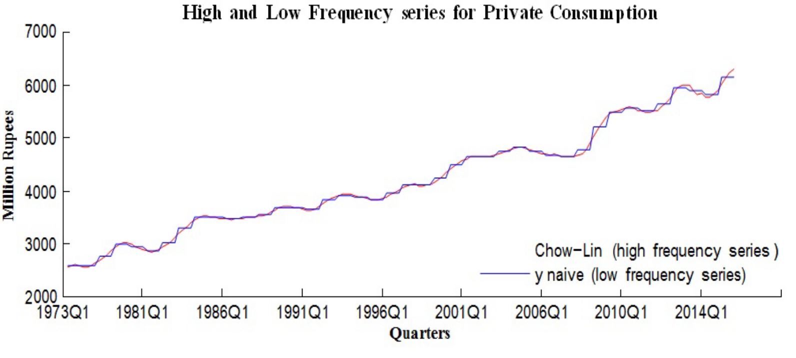
$$\varepsilon^{a^\wedge} = Y^a - X^a \beta^{a^\wedge}{}_{GLS} \quad \text{(A.4)}$$

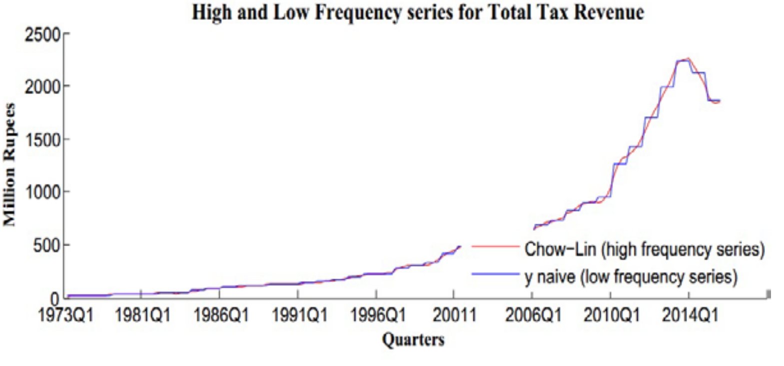
The predicted quarterly Y^q is given by the first term on right hand side in equation (3) while the residuals of the annual series $\varepsilon^{a^\wedge}$ is allocated among the quarters of the years in such a way that the observed value Y^a and the annual sum of the interpolated values become equal. The final quarterly series given in equation (3) is the sum of the two components. The first component on the right hand side of equation (3) is the estimated regression coefficients applied to the quarterly indicators. The second component is the residual in the annual regression distributed over the quarters which ensures that the final quarterly series sums to the known annual series.

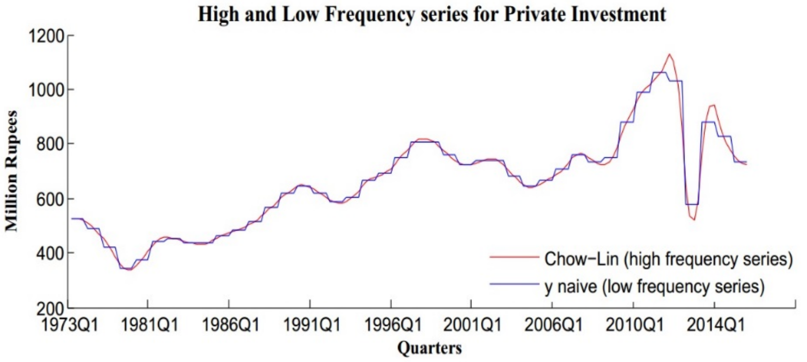
The quarterly estimates of Gross Domestic Product (GDP), private consumption, private investment, total government expenditure and total tax revenue are constructed using the above mentioned Chow-Lin procedure from 1973Q1 to 2014Q4. The annual data of GDP, private consumption, private investment, total government expenditure and total tax revenue is obtained from Economic survey of Pakistan's various issues. Whereas Consumer Price Index (CPI) and Industrial Production Index (IPI) are used as indicator variable to generate quarterly data, which are taken from IFS.




High and Low Frequency series for Gross Domestic Product
x 10^4
Million Rupees
Chow−Lin (high frequency series)
y naive (low frequency series)
1973Q1 1981Q1 1986Q1 1991Q1 1996Q1 2001Q1 2006Q1 2010Q1 2014Q1
Quarters


High and Low Frequency series for Private Consumption
Million Rupees
Chow−Lin (high frequency series)
y naive (low frequency series)
1973Q1 1981Q1 1986Q1 1991Q1 1996Q1 2001Q1 2006Q1 2010Q1 2014Q1
Quarters


High and Low Frequency series for Total Tax Revenue
Million Rupees
Chow−Lin (high frequency series)
y naive (low frequency series)
1973Q1 1981Q1 1986Q1 1991Q1 1996Q1 20011 2006Q1 2010Q1 2014Q1
Quarters



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