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Evidence from a Bayesian VAR**

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How important are external shocks in explaining growth in Sub-Saharan Africa? Evidence from a Bayesian VAR*

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Abstract

This paper assesses the relative importance of external shocks in explaining the GDP growth in Sub-Saharan African countries. We estimate a Bayesian VAR model with the Stochastic Search Variable Selection (SSVS) approach for five countries in the region - Botswana, Ethiopia, Kenya, Mauritius, and Nigeria - two of which are among the fastest growing countries over the last decade, while the other three are countries for which relatively complete data are found on variables of interest. The results suggest the following two points. First, the contribution of external shocks to the variation in the growth rate of GDP of the home country varies significantly across the countries considered. Second, the terms of trade shock is the most important of the external factors we included in our analysis. One lesson that can be drawn from this study is that generalizations about the impact of external shocks to the whole Sub-Saharan African region are misleading.

JEL classifications: C11; E32; F40; O11; O55

Keywords: Bayesian VAR; Economic fluctuations; External shocks; Low-income countries; Sub-Saharan Africa

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1 Introduction

The period spanning from the mid 1990s to the recent global economic crisis is considered to be a period of recovery and economic expansion for most countries in Sub-Saharan Africa (SSA). During this period many countries in the region registered high and sustained rates of economic growth with few fluctuations. For instance, SSA as a whole experienced an average growth rate of about 5 percent during the decade 2001-2010. This period coincides with a time of relative stability and growth in the rest of the world (see figure 1 below). However, this does not mean that the world economy was in absolute tranquility since there were crises such as the 1994-95 Mexican economic crisis, the 1997-98 Asian financial crisis, and the bursting of the 2001 dot-com bubble. Nevertheless, these events did not pose a similar danger to the whole world like the 2007-2009 financial crisis¹.

This unprecedented sustained economic growth in SSA led some economists to assert that African countries can achieve the Millennium Development Goal of halving poverty on time if the recent trend is maintained (see, for example, Sala-i-Martin and Pinkovskiy (2010)). Indeed, it is tempting to argue this way given the fact that almost all the countries in SSA that had high growth rates during the decade 2001-2010 are the poorest countries of the world². Therefore, if these countries maintain this rate of economic growth for the years to come, they could achieve the goals mentioned above. We argue that whether these countries can maintain the success stories depends on the sources of the economic growth they experienced. If the growth was brought about by adjustments in the domestic conditions such as structural change that led to increased productivity of all factors of production and improvements in the quality of institutions that enhanced efficiency and stability, then the success might be maintained. However, if the sources of growth were improvements in external conditions like increased inflows of resources such

¹Figure 1 shows the relative importance of all these crises. As can be seen from the figure, the growth of SSA trails the growth of the OECD with a lag except for 2009 when the growth of both groups fell contemporaneously. SSA10 represents ten of the 11 countries that experienced an average growth rate that is above the SSA average during the period 2001-2010.

²For example, eleven countries of the region that had an average growth rate above the regional (SSA) - Burkina Faso, Chad, Equatorial Guinea, Ethiopia, Ghana, Mali, Mozambique, Nigeria, Rwanda, Sierra Leone, Zambia - are all countries referred to as the poorest nations.

as official development assistance, aid, foreign direct investment and remittances, then it is reasonable to have doubts about the continuation of the high growth scenario in this part of the world, given the current shape of the global economy and the lingering uncertainties about its future. For instance, Sala-i-Martin and Pinkovskiy's (2010) argument is based on the data of the period 1970-2006. Part of this period is characterized by many favorable domestic and external conditions that might have contributed to the high rates of growth recorded in SSA countries.

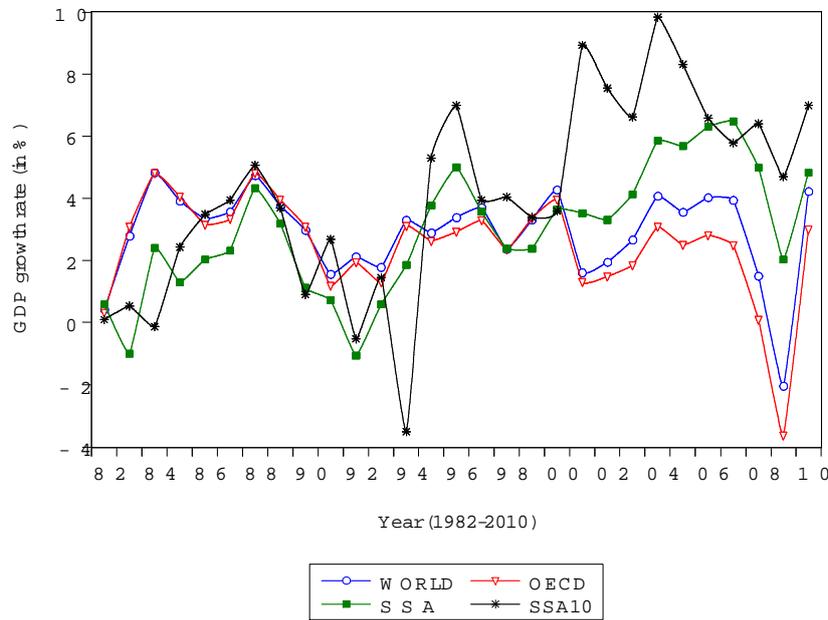


Figure 1: The GDP growth rate of the World, OECD, SSA and 10 SSA countries that experienced average growth rates above the SSA average during 2001-2010. *Data source:* The World bank, WDI_GDF database.

The literature identifies three domestic conditions the improvement of which could have triggered or reinforced the observed economic growth in SSA countries (Brambila-Macias and Massa (2010)). These are policy reforms introduced in many of the countries to attain sound macroeconomic fundamentals, the relative political stability, and the attractiveness of natural resources to emerging economies such as China. All three conditions seem to have played important roles in enhancing economic growth in the countries. Furthermore,

during the same period SSA countries experienced notable improvements in external conditions, like increasing inflows of aid, foreign direct investment (FDI), and remittances. Many countries also benefited from the debt relief programs as well as from the commodity price booms. According to Ratha (2008), over the period 2000-2006 the official development assistance and FDI increased by about 300 percent while net private bond and bank lending rose by more than 600 percent. Over the same period, remittances from migrant workers more than doubled while institutional remittances almost doubled (see also Brambila-Macias and Massa (2010)). It seems reasonable to argue that the inflow of these resources eased the foreign exchange constraints that countries face to import raw materials and intermediate inputs which facilitate the utilization of the existing capacity. Likewise, these same resource inflows helped the countries to narrow the existing gaps between national savings and investment thereby increasing their capacity. However, due to the recent global economic meltdown some of these components have been falling. For instance, SSA countries have experienced a fall in the demand for their exports to advanced countries, while remittances from migrants in developed countries also dropped (Drummond and Ramirez (2009)). The economic difficulties in the developed world that started as a financial crisis in the US do not seem to be over any time soon as the uncertainty still lingers due to the debt crisis in some European countries. It can be argued that these recent troubles in advanced countries not only have affected but also might pose lasting difficulties for the economies of low-income countries. The argument is that even if the current uncertainties will be solved once and for all, it is doubtful that the global economic conditions will recreate the pre-crisis favourable external conditions experienced by SSA countries, that we discussed above, anytime soon. The slow growth in many advanced countries together with the austerity measures being introduced (which will continue in to the future) in a number of developed countries is expected to decrease the demand for the exports of low-income countries and reduce the inflows of aid and remittances (both from migrant workers and institutions) to these countries. Hence, the fear by some that the recent global economic and financial crisis will have effects on economic growth of SSA countries and might reverse the economic successes recorded seems reasonable (see, for example, Allen and Giovannetti (2011) and Drummond and Ramirez (2009)). Therefore,

understanding the relative importance of the external factors vis-a-vis the domestic factors to the commendable macroeconomic performance of these countries is very helpful to forecast the future trends of the economies in the region.

In this study we investigate the relative importance of the domestic and external shocks to the variability in the growth rate of GDP for selected SSA countries. We employ the Bayesian Vector Autoregression (BVAR) model with Stochastic Search Variable Selection approach. To our knowledge, this is the first study to apply the Bayesian VAR method to assess the effects of external shocks on macroeconomic performance of the economies of SSA, though there are many studies that tried to address the same issue using traditional techniques. As will be discussed in section 3, the importance of the Bayesian method is not exaggerated given the fact that all the countries in the region possess short time series data compared to the rest of the world. This approach is also found to have a higher forecasting accuracy compared to the traditional/classical VAR models.

The rest of the paper is organized as follows. In section 2 we discuss the transmission mechanisms of external shocks to SSA countries and review related literature, while in section 3 we present the Bayesian VAR model with Stochastic Search Variable Selection approach to specify priors. The data and the implementation of the model are discussed in section 4. We report our results in section 5 and in section 6 we discuss the sensitivity of results and the accuracy of the model. Section 7 concludes.

2 External shocks and Sub-Saharan African Countries

Most countries in SSA, like many other low-income countries, are not only characterized by relatively high exposure to shocks, but also by a weak ability to absorb these shocks. The domestic financial institutions are not well developed and the countries have limited access to the international financial and asset markets. This implies, for instance, that in the event of an adverse shock the countries experience a significant fall in economic activity. This vulnerability and inability to absorb shocks make these countries experience high macroeconomic instability. The shocks that these countries are facing are both domestic and external, though the relative importance of these two types of shocks in influencing the performance of the overall economy varies from country to country. As

a stylized fact, in more open economies (where openness is measured as trade to GDP ratio), the external shocks are expected to be more important in explaining macroeconomic fluctuations than in economies with the opposite characteristics. It is also well documented that low-income countries in general, and the economies in SSA in particular, are highly open and that international economic interactions play a significant role in their overall economic performance. Kose and Riezman (2001), for example, reported that trade represents more than 70 percent of GDP for African countries which implies that these countries are highly exposed to the effects of economic and political developments beyond their borders. In addition to the openness, the structure of exports and imports of these countries also makes the external shocks of paramount importance in the macroeconomic dynamics of the countries. Most economies in SSA are exporters of primary commodities. For instance, according to Raddatz (2008), primary commodities represented more than 70 percent of the total exports of these countries over the period 1985-2000. There are two important features of these primary commodities that are worth mentioning. First, it is a well documented fact that the prices of primary commodities are determined in international markets, which implies that prices of exports are exogenous to the exporting economies. Second, studies show that the prices of these primary commodities are generally highly volatile though the negative shocks tend to be more persistent than the booms (Cashin et al. (2000)). Since in a large number of countries some of these primary commodities are produced by households that earn subsistence income, the consequences of the volatility of the prices of these commodities on the living standards of these households is straightforward. In addition, many primary commodity exporting countries depend heavily on export taxes as a source of government revenue. As a result negative shocks significantly affect the provision of public goods (and public capital) and services which, in turn, negatively affects overall economic activity.

On the other hand, the imports of these countries consist mainly of manufactured and semi-manufactured goods whose prices are determined by the economic situation in the developed world. This feature of the import of the countries in the region and the two features of their exports discussed above imply that the countries face exogenous and fluctuating terms of trade which is one of the defining features of low-income countries

(Agenor and Montiel (2008)). Hence, a terms-of-trade shock is one of the most important external shocks that SSA countries face.

Based on the low degree of integration of the region in to the international financial markets, many argue that trade is the primary conduit for the external shocks to the economies of SSA. However, recent studies show that the shocks emanating from the international financial markets also have a significant effect on the performance of the economies of the region. As we discussed above, many studies report that official development assistance, aid, FDI, remittances, and cross-border bank lending have become important contributors to growth in SSA over the last decade (Allen and Giovannetti (2011), Ratha (2008)). Therefore, a reduction in inflows of these resources due to economic downturns in developed countries will have significant negative consequences on economic activities in SSA countries. For instance, Brambila-Macias and Massa (2010: 375) using data over the period 1980-2008, for a sample of SSA countries, report that a 10 percent decrease in FDI results in to a 3 percent fall in the growth of per capita income while a 10 percent drop in cross-border bank lending leads to a 1.5 percent fall in the growth of per capita income.

As we indicated above, due to the structure of their economies, countries in SSA are highly vulnerable to external shocks and weak to undertake measures in order to absorb these shocks. Therefore, it is reasonable to expect that external shocks have a significant effect on the performance of these economies. However, the studies on this issue so far are not conclusive. On the one hand, there are studies that show that external shocks significantly contribute to the macroeconomic instability in the region. For instance, Kose and Riezman (2001) assert that external shocks explain about half the fluctuation in aggregate output in African countries. This result is similar to the findings of other studies conducted on other developing countries, such as Osterholm and Zettelmeyer (2008) who investigated the effect of external factors on economic growth for Latin America (six Latin American countries) and Abrego and Osterholm (2010) for Columbia. Osterholm and Zettelmeyer (2008) found that financial and trade shocks together with shocks to the growth of the economies of the rest of the world (the three important external shocks) explain more than half of the variance in the growth of the Latin American GDP. Furthermore, many

studies report that economies in SSA are highly exposed to external shocks and less able to cope with them, as a result of which the effects of these shocks are not only disruptive at impact but also persistent (see, among others, Allen and Giovannetti (2011), Naude (2010), and Oduro (2010)).

On the other hand, there are studies that claim that domestic shocks explain most of the macroeconomic fluctuations in low-income countries and external shocks play a marginal role, if any. For instance, Raddatz (2007) investigates the relative importance of domestic and external shocks on the output instability of a sample of 40 low-income countries of which 32 are SSA countries. The findings show that the external shocks explain only 11 percent of the variation in income of these countries while the remaining 89 percent is attributed to domestic shocks. Furthermore, Raddatz (2007) reported that aid flows into low-income countries increase when the GDP of developed countries increases and the GDP of low income countries and commodity prices decrease. As a result, Raddatz argues that aid flow is in line with the demand for and supply of it. This finding has a very important implication: low-income countries could smooth the effect of external shocks (say a fall in prices of primary commodities) using foreign aid. However, this is a highly contestable result as it is a polar opposite of the findings of other studies (see, for example, Bulir and Hamman (2003 and 2008)) which document that aid inflows into low-income countries are procyclical, i.e., aid inflows fall when they are badly needed by the recipient countries.

This study is different from previous studies conducted to assess similar issues for the economies in SSA. Three of the studies that specifically addressed the effect of external shocks to SSA are Kose and Riezman (2001) and Raddatz (2007 and 2008). The studies by Raddatz (2007 and 2008) employed a panel VAR model which helps to overcome the drawbacks of short time series of the data for low-income countries though it also requires assuming some symmetry among countries. Raddatz (2007: 156-157) argues, for example, “... we use a panel VAR model in which the dynamics of the countries are assumed identical ... to increase the degrees of freedom of our estimation”. It is well known that there is a serious problem with respect to the availability and length of time series data for low income countries in general and SSA countries in particular. However, the degree

of symmetry imposed by Raddatz (2007 and 2008) is untenable to investigate the effects of various shocks on macroeconomic performance of countries; that are heterogenous with respect to both the shocks they are exposed to and the capacity to absorb. On the other hand, Kose and Riezman (2001), studied the effects of external shocks on macroeconomic fluctuations in Africa with emphasis on trade shocks using a calibrated small open economy dynamic stochastic general equilibrium (DSGE) model of Real Business Cycle (RBC) tradition. In addition to the symmetry assumed, their approach is contestable since these models are criticised of being too abstract to represent the real world economies, which makes the results in Kose and Riezman (2001) problematic.

Under the circumstances of short time series data, the Bayesian VAR models are natural alternatives. For these models we do not need to make the assumption that countries have identical economic dynamics since parsimonious VAR models can be estimated for individual countries.

3 The Bayesian VAR Model

Since their introduction by Sims (1980) the VAR models are arguably the most popular models to analyse the macroeconomy or to accomplish what Stock and Watson (2001) refer to as the four tasks of macroeconometricians: data description, forecasting, structural inference, and policy analysis. These models allow the researcher to explicitly recognize and model the existence of interrelatedness between macroeconomic variables instead of imposing an assumption that some of the variables are dependent and others are independent. However, this same virtue of the VAR models is also the origin of the main drawback of these models - the problem of overparametrization. This problem arises since in an unrestricted VAR model the number of parameters to be estimated increases with the number of dependent variables in the model which, in turn, leads to inefficient and less precise parameter estimates. From the outset, in the work that launched the VAR models, Sims (1980: 16) identified the overparametrization problem associated with these models when he argued that “if every variable is allowed to influence every other variable with a distributed lag of reasonable length, without restriction, the number of parameters grows with the square of the number of the variables and quickly exhausts degrees of freedom”.

The problem of overparametrization is acute when dealing with models that have many variables and when the time dimension of the data is short. This is always the case when modeling low-income economies for which the available time series data are very short. There are some solutions to this problem that are suggested in Sims (1980) and other works that followed. According to Koop and Korobilis (2010: 269), all the solutions developed so far to overcome the problem of overparametrization have one thing in common; that is, they are all based on the idea of shrinkage which is restricting some of the elements of the coefficient matrix of the VAR model and the associated variance-covariance matrix to zero. One of these solutions, which is as old as the VAR models, is the Bayesian approach in which prior information is used to impose restrictions on the parameters. Such VAR models are currently very popular and are referred to as the Bayesian Vector Autoregressive (BVAR) models. However, until recently, the development and expansion of this approach has been hampered by the computational complexities that it entails. The development of the Markov Chain Monte Carlo (MCMC) methods helped circumvent the computational complexities of the multivariable Bayesian models and spurred the development of many more promising and popular prior specifications. Ciccarelli and Rebucci (2003) and Koop and Korobilis (2010) provide detailed discussions of the developments of various prior specifications and implementation procedures in a VAR framework. In what follows, we will discuss the Stochastic Search Variable Selection (SSVS) approach which is a recent addition to the econometrics toolkit and is less susceptible to researcher's bias and has been enjoying high popularity.

The VAR model in its standard³ form can be given as

$$Y_t = \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} + \dots + \Gamma_p Y_{t-p} + \Phi Z_t + \varepsilon_t \quad (3.1)$$

where $Y_t = (y_{1t}, y_{2t}, \dots, y_{nt})$ denotes an $(n \times 1)$ vector of dependent variables, Z_t is an $(m \times 1)$ vector of deterministic components or exogenous variables of the model and p is the lag length. Φ is an $(m \times m)$ matrix of the coefficients of the exogenous variables, and Γ_i ($i = 1, \dots, p$) are $(n \times n)$ matrices of the coefficients of the dependent variables, while ε_t is an $(n \times 1)$ vector of independently and identically distributed error terms that satisfy the condition $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Sigma$. Estimation of the model provides

³See Chapter 5 of Enders (2010).

the estimates for the elements of Γ_i 's, Φ , and Σ that are basic inputs in the process of achieving the four tasks of a macroeconometrician highlighted above.

As indicated above, empirical implementation of the VAR model in its standard form leads to the overparametrization problem⁴. The Bayesian approach addresses this problem by introducing the prior distributions of the parameters of the dynamics of the model, the deterministic components and exogenous variables, and the variance-covariance matrix to achieve shrinkage. That is, the Bayesian implementation of (3.1) requires specification of the prior distribution of the Γ_i s, Φ , and Σ . There are various approaches developed over the years on the prior specifications. These various approaches, according to Koop and Korobilis (2010), differ on three counts: the way the priors help attain the restriction (shrinkage) of the parameters, whether they can lead to an analytical solution or not, and the degree of flexibility the priors can provide the researcher to deal with VARs different from the unrestricted VAR.

One of the first of these approaches is the most commonly cited prior specification referred to as the Litterman/Minnesota prior (Minnesota prior) developed by Litterman and colleagues (see Doan et al. (1984) and Litterman (1986)). The Minnesota prior is based on some basic observations of the behaviour of economic aggregates. First, the own lags of a variable explain the behaviour of the variable more than the lags of other variables. Second, the recent past values of a variable are more important in explaining the dynamics of the variable than the values in a distant past. These are the ideas that underlie Litterman's (1986) argument in the frequently cited work when he states "... the estimator suggested here imposes the information that a reasonable approximation of the behaviour of an economic variable is a random walk around an unknown, deterministic component" (p. 29).

However, unlike other VAR methods where restrictions are imposed with certainty (i.e., the coefficients of the variables deemed less important by a researcher are assigned a value of zero and hence the variables are excluded from the model with certainty), the Minnesota prior expresses the degrees of uncertainty via the specification of prior variance

⁴In this case where we have a VAR model with n variables and p lag lengths we have $n + pn^2$ parameters to estimate (see Enders (2010) for discussion).

for each coefficient of the variables in the model (see Litterman (1986) and Ciccarelli and Rebucci (2003)⁵). Accordingly, the coefficients of the first own lags of the model variables are set to unity with large variance and the coefficients of other lags are set to zero with smaller variance. Furthermore, the coefficients of the own higher order lags are assigned higher variance than those of other variables to express that the dynamics of a variable is more explained by its own lags than by the lags of other variables. That is, given (3.1) the discussion above can be formalized as follows. Let

$$\beta = \text{vec}(\Gamma_1, \Gamma_2, \dots, \Gamma_p) \quad (3.2)$$

be the vector of all the dynamic coefficients of the model⁶. The Minnesota prior can be specified as

$$\beta \sim N(\underline{\beta}, \underline{V}) \quad (3.3)$$

where $\underline{\beta}$ and \underline{V} ⁷ are the prior mean and variance of the coefficients, respectively. The Minnesota prior replaces Σ with the estimated covariance matrix, $\widehat{\Sigma}$, and Φ is assigned noninformative (flat) priors⁸.

This approach is popular partly due to its simplicity in computation and interpretation. However, as mentioned above the recent developments in Markov Chain Monte

⁵Ciccarelli and Rebucci (2003) provide a survey of various alternatives of priors used in Bayesian VAR.

⁶Given any matrix Γ of dimension $(n \times p)$, the $\text{vec}(\Gamma)$ is a vector of $(np \times 1)$ where the columns of Γ are stacked below one another, that is the first n elements are the first column of Γ and the next n elements are the second column of Γ and so on.

⁷The literature uses various representations to distinguish priors of parameters from their posteriors. We here adopt the convention that parameters with an underscore are priors and those with a bar are posteriors. As in most of the literature parameters with a hat are estimates.

⁸Litterman (1986: 29) justifies the employment of noninformative priors for Φ arguing “without observing the data very little is known about the distribution of the parameters of the deterministic component. To represent this ignorance, a noninformative prior is used”. However, he also highlights the drawbacks of using these priors. There are some who disagree with this approach asserting that economists have more prior information on the deterministic coefficients than on the dynamic ones. For example, Villani (2009) developed an alternative approach where informative priors can be used for the deterministic component after transforming the standard VAR model into a *steady-state VAR* where all variables in the VAR are represented by their deviation from their unconditional mean; i.e., after the standard VAR is transformed into mean adjusted VAR.

Carlo (MCMC) methods resolved the computational complexities and many alternative approaches of prior specifications have been developed. One of these prior specifications is the one associated with the Stochastic Search Variable Selection (SSVS) approach.

The SSVS was first introduced by George and McCulloch (1993) as an alternative approach to select explanatory variables or predictors in a multiple regression model based on data⁹. The approach was extended to VAR models by George et al. (2008) to obtain a restricted VAR model based on the data and no or few inputs in the form of prior information from the researcher, and is currently becoming a popular approach in VAR estimation and forecasting (see Jochmann et al. (2011), Jochmann et al. (2010), Koop and Korobilis (2010), Korobilis (2011 and 2008) among others). The SSVS does shrinkage since the variable selection process means setting the value of the coefficients of those variables that are not selected to zero.

The basic idea behind the Bayesian variable selection in general is to allow the data to determine the exclusion and inclusion of explanatory variables into a model based on their posterior probability instead of imposing some form of restriction based on researcher's judgement when there is no clear theory to do so. This is performed by developing a multilevel - hierachical - prior specification where the priors of the coefficients of the model are specified in terms of other parameters which in turn have prior specifications. That is, given (3.1), this approach works as follows.

$$\beta_j | \gamma_j \sim (1 - \gamma_j) N(0, \kappa_{0j}^2) + \gamma_j N(0, \kappa_{1j}^2) \quad (3.4)$$

where γ_j is a dummy variable that determines the inclusion/exclusion or participation of the variable. κ_{0j}^2 and κ_{1j}^2 are known as prior hyperparameters with $\kappa_{1j}^2 > \kappa_{0j}^2$ and express the degree of uncertainty over the corresponding prior value of the parameter. In this modeling, if γ_j equals zero β_j is drawn from the first normal distribution in which case the mean of β_j is zero with small variance. Hence, the variable that corresponds to β_j can be excluded from the model. On the other hand, if γ_j equals one β_j is drawn from the second normal distribution with mean zero and large variance. In this case, there is

⁹See O'Hara and Sillanpaa (2009) for the discussion of the comparative advantages of various methods of Bayesian Variable selection.

higher uncertainty that the coefficient is zero and therefore the variable that corresponds to it will be included in the model. George and McCulloch (1993) suggested a Bernoulli distribution for γ_j where

$$\Pr(\gamma_j = 1) = \underline{p}_j \text{ and } \Pr(\gamma_j = 0) = 1 - \underline{p}_j \quad (3.5)$$

They also suggested a prior value of 0.5 for all \underline{p}_j which implies that all variables have equal probability to be included and hence the process of selection is not biased towards or against some variables. However, others argue that this prior specification is not non-informative as it is biased in favour of models with about half of the variables included resulting in more complex models in some cases (see O’Hara and Sillanpaa (2009)). Likewise, George et al. (2008: 558) indicate what they refer to as “a default semiautomatic” approach to assign prior values to the hyperparameters κ_{0j}^2 and κ_{1j}^2 as

$$\kappa_{0j} = c_0 \sqrt{\widehat{var}(\beta_j)} \text{ and } \kappa_{1j} = c_1 \sqrt{\widehat{var}(\beta_j)} \quad (3.6)$$

where $\widehat{var}(\beta_j)$ is the estimate of the variance of β_j of the unrestricted VAR model and c_0 and c_1 are set in such a way that $c_0 < c_1$ (see George and McCulloch (1993) for an in-depth discussion on the choice of c_i). Hence, the input from the researcher is on the values of c_0 and c_1 .

There are alternatives to specify the prior distribution for Σ and one of these is to use the Wishart prior (Koop and Korobilis (2010)),

$$\Sigma^{-1} \sim W(\underline{v}, \underline{S}^{-1}) \quad (3.7)$$

where \underline{S}^{-1} is a prior of the matrix of the standard errors of the model and \underline{v} degrees of freedom. George et al. (2008) developed an MCMC algorithm that implements this variable selection procedure where promising explanatory variables (the different own lags and lags of other variables in the VAR) with higher posterior probability are included into the model.

In this paper we use this approach to investigate the relative importance of external shocks in explaining the macroeconomic fluctuations in SSA¹⁰.

¹⁰The Matlab programs used to generate the results discussed in this paper are the modified version of the codes written by Dimitris Korobilis (2010) to replicate the results in Koop and Korobilis (2010). I would like to thank Dimitris Korobilis for responding to queries about some bugs in the code.

4 The Data

The model is estimated for five SSA countries. We initially planned to estimate the model for five of the ten countries that registered average growth rates above the regional average during 2001-2010; the countries that we referred to as SSA10 in Fig. 1. However, most of the countries do not have complete data on the variables of interest. As a result, in our analysis, we included two countries from the fastest growing countries and three countries that are not in that list but have complete data and interesting economic history and structure. These countries are Botswana, Ethiopia, Kenya, Mauritius, and Nigeria. Though these countries cannot be considered a representative sample of a region with more than 40 countries and diverse economic structures, they capture some salient features of the countries in the region. Oil exporting (Nigeria), non-oil mineral exporting (Botswana), agricultural product exporting (Ethiopia and Kenya), and a relatively diversified economy (Mauritius). Furthermore, three of these countries - Ethiopia, Kenya, and Nigeria - are among the five largest economies in the region; the other two being Angola and South Africa (IMF (2010))¹¹. Botswana and Mauritius are also two of the few economies in the SSA that registered good economic performance with sound macroeconomic management over the last couple of decades.

The absence of high frequency data (quarterly/monthly data) is the key constraint to conduct a VAR study for the countries in the region. We used the annual data for the years 1980-2010, the longest series available for the key variables of our study, for four of the countries, and for the years 1992-2010 for Ethiopia. The length of the time series in our study is entirely determined by the availability of the series. We converted these low frequency data to high frequency data (quarterly) using various interpolation methods¹².

In the basic model, we included four key macroeconomic variables that are believed

¹¹According to IMF (2010), the five largest economies in the region account for about 2/3 of the regional output and about half of the population.

¹²The econometric software Eviews supports various interpolation methods to convert low frequency data to high frequency data and vice versa. However, this is just a proxy and not a substitute to the actual quarterly data since the reliability of the series obtained via this conversion methods is debatable. It is also important to note that results of the model are slightly sensitive to the approaches used to convert the series from annual to quarterly.

to capture the performance of the economy and four external variables that are assumed to have a significant effect on the domestic economy. The decision on the selection of the variables for the basic model is based on two main considerations. The first is the need for a parsimonious model so that the model consists of only the important variables of the study which makes the discussion and interpretation of the results simple and tractable. That is, consistent with the objective of the study, such a model is sufficient to assess the impact of the shocks from key external factors on basic domestic macroeconomic variables. The paper does not intend to make an evaluation of specific policy shocks for a specific economy or policy prescriptions in response to specific shocks - tasks that require a more complete model. The second reason is our desire to compare our results with those of studies conducted using traditional VAR and general equilibrium models for countries in the region (Raddatz (2007 and 2008) and Kose and Riezman (2001)) and of studies conducted for countries in other continents using Bayesian VAR (Abrego and Osterholm (2010), Beechey and Osterholm (2008), Osterholm and Zettelmeyer (2008)).

Accordingly, the variables on the domestic side are GDP growth rate (y), government final consumption expenditure as a percent of GDP (g), domestic bank lending rates (r) and net inflows of foreign direct investment as a percent of GDP (fdi) to capture the attractiveness of domestic macroeconomic environment. On the other hand, the variables that are considered as exogenous to the domestic economy and assumed to have a significant effect on the behavior of the key domestic variables are the growth rate of the GDP of the rest of the world (y^w), the interest rate of the rest of the world (r^w) - where the six-month London interbank offered rate (LIBOR) is used as a proxy-, net official development assistance and official aid received as a percent of GDP (aid) and the rate of change of the terms of trade (tot) - captured by the annual percentage change in net barter terms of trade ^{13, 14}. Unlike Abrego and Osterholm (2010), Beechey and Osterholm

¹³All the variables except the six-month London interbank offered rate are taken from the World Bank World Development Indicator and Global Development Finance (WDI-GDF) database released September 2011. The six-month London interbank offered rate are taken from the IMF World Economic Outlook database. Description of the series used in this study is given in the appendix.

¹⁴Note that there is no data source on government expenditure for Nigeria for the time considered in this study. Therefore, we estimated the Nigerian VAR without government expenditure (i.e., for the other seven variables).

(2008), and Osterholm and Zettelmeyer (2008), who defined the GDP of the rest of the world as the GDP of the world less the GDP of the home country, we use the GDP of the OECD countries. The justification is that most of the countries we are considering have strong economic links to OECD countries and the shocks emanating from OECD countries seem important to the economic performances of these countries, at least for the most part of the study period¹⁵. This will also enable us to shed some light on what type of countries will be affected by the current slowdown in the performance of the economies of the OECD countries, and to what extent they will be affected. Hence, the variables in the basic VAR can be given as

$$Y_t = (y^w, r^w, aid, tot, fdi, g, y, r) \quad (4.1)$$

5 Results

5.1 The impact of external shocks - the Impulse Response Functions

The impulse response functions and the forecast error variance decomposition are the two outputs of the VAR analysis that are most commonly reported and used. The impulse response functions trace the dynamic responses of each of the variables of the VAR to a change in one of the VAR errors/shocks. Since this analysis is based on the response of variables to a change in the shock of one of the variables, the underlying assumption is that the shocks to other variables are zero which implies that the error terms or the shocks included in the model are independent; which is not often the case. The standard practice in studies that employ reduced form or standard VAR models is to use the Cholesky decomposition of the variance-covariance matrix to identify independent shocks (see Enders (2010) and Lutkepohl (2006) for the theory and Abrego and Osterholm (2010), Beechey and Osterholm (2008), Osterholm and Zettelmeyer (2008) for empirical works). The Cholesky decomposition brings this solution at a cost: it introduces asymmetry in such a way that some of the variables have contemporaneous effects on others while they are not affected contemporaneously by some other variables. The ultimate result of the

¹⁵The qualification is needed since recent trends show that the influence of emerging economies such as China and India is becoming important in the region.

decomposition is imposing a restriction on the correlation among the error terms or shocks of the model that are the basis of both the impulse response and variance decomposition. Hence, the ordering of the variables influences the results - both the impulse responses and the variance decomposition since it determines the impact multipliers. This is so since the Cholesky decomposition of the variance-covariance matrix leads to a lower triangular matrix that forces some of the covariances among the error terms/shocks to zero. If this is not the true nature of the system, then the results from impulse responses and variance decomposition are misleading/erroneous; the degree of the imprecision due to this practice depends on the size of correlation among the shocks. Therefore, the variable ordering decision here requires guide from economic theory (see Enders (2010) and Lutkepohl (2006))¹⁶. In this paper we adopted the ordering employed by studies that investigated the same issue we are dealing with, i.e., Abrego and Osterholm (2010), Beechey and Osterholm (2008), Osterholm and Zettelmeyer (2008); the ordering in (4.1)). This ordering implies that variables have contemporaneous effects on variables to their right but not on variables to their left. Therefore, the first variable is assumed to have immediate effects on all other variables but none of the variables have immediate effect on it.

In what follows we discuss the posterior of impulse responses of the growth rate of GDP to a one unit shock to both the domestic and external variables in the model. Since all the variables in the model are measured in percents, a unit shock in a variable is an increase in the value of that variable by one percentage point. The solid line represents the posterior median while the dotted lines represent the 10th and the 90th percentiles.

5.1.1 Botswana

Fig. 2 below illustrates the dynamic responses of the growth rate of GDP of Botswana to the shocks in all the variables of the model. The impulse responses of the GDP growth rate of Botswana show that most of them are of the expected sign except for the domestic lending rate. As the lending rate increases, say due to contractionary monetary policy, economic activity is expected to decline and hence the growth rate of GDP is expected to

¹⁶Enders (2010: 309-311) and Lutkepohl (2006: 51-67) provide a comprehensive discussion of the Cholesky decomposition and the importance of the ordering of the variables in the VAR that comes with the Cholesky decomposition.

fall. But the impulse responses show that the growth rate of GDP of Botswana responds positively to a shock in lending rate though the response does not seem significant. For instance, a one percentage point increase in the lending interest rate leads to 0.03 percentage points rise in growth rate of GDP after 4 quarters. On the other hand, a one percentage point increase in the growth rate of the GDP of the rest of the world leads to a 0.12 percentage point rise in the growth rate of GDP of the domestic economy in the first quarter and falls thereafter, while a one percentage point shock in LIBOR leads to a fall in the growth rate of GDP by 0.08 percentage points in the first quarter.

The responses of the growth rate of GDP to the shocks in aid, the terms of trade and FDI are of the expected signs. For example, one percentage point shock in the net official aid and assistance received as a percent of GDP leads to a 0.09 percentage point rise (in the first quarter) in the growth rate of GDP while the response to a shock of the same magnitude to the growth rate of terms of trade is 0.64 percentage point (after 5 quarters). Likewise, a one percentage point shock in government expenditure leads to a 0.15 percentage point rise in the growth rate of GDP (in the first quarter) while a one percentage point shock in net FDI inflows as a percent of GDP leads to a 0.123 percentage points fall in GDP (in the first quarter). The negative response of the growth rate of GDP at impact to the shocks in FDI seems counterintuitive, but it is consistent with the theoretical and empirical works that established that FDI has a negative effect on growth in the short run (see Liu (2008)).

5.1.2 Ethiopia

The growth rate of GDP of Ethiopia reacts to the external shocks in a way that seems consistent with economic theory (see Fig. 3). The growth rate responds positively to the shocks in the growth rates of GDP of the rest of the world (though it shows a tendency to fall in the first quarter) and the growth rate of terms of trade, while it responds negatively to shocks in LIBOR, aid, foreign direct investment, and lending interest rate. For instance, a one percentage point shock to the growth rate of the GDP of the rest of the world leads to an increase in the growth rate of the domestic GDP by 0.3 percentage points after 6 quarters while a one percentage point shock in LIBOR leads to a 0.44 percentage points

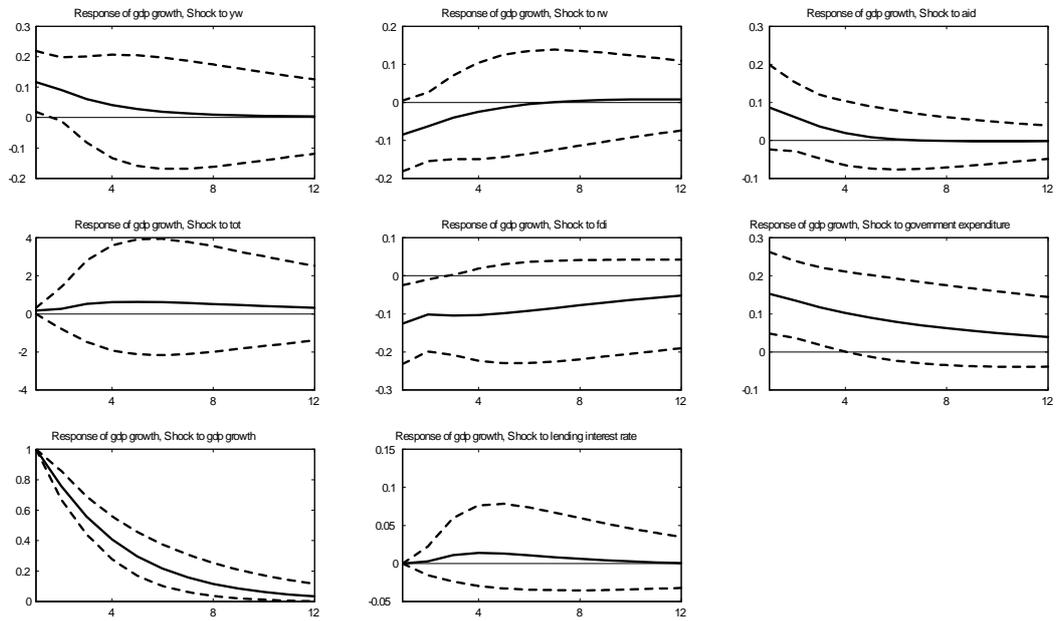


Figure 2: Responses of GDP growth of Botswana to a one unit shock in key domestic and external variables

fall in the growth rate of GDP (at the first quarter). The sign of the response of the growth rate of GDP to the net official development assistance and aid received as percent of GDP is counterintuitive but significant. A one percentage point shock in this variable leads to a 0.73 percentage point fall in the growth rate of GDP. The response of the growth rate of GDP of Ethiopia to a shock in the growth rate of the terms of trade is very strong, like that of Botswana discussed above. A one percentage point shock in the growth rate of terms of trade leads to a 1.031 percentage point rise in the growth rate of GDP after 5 quarters. The negative response of growth rate of GDP to the shock in LIBOR could be explained as follows. As the shock to this variable affects the exchange rate of the domestic economy it will affect the import of raw materials and intermediate inputs that, in turn, affect the GDP growth in the short-run.

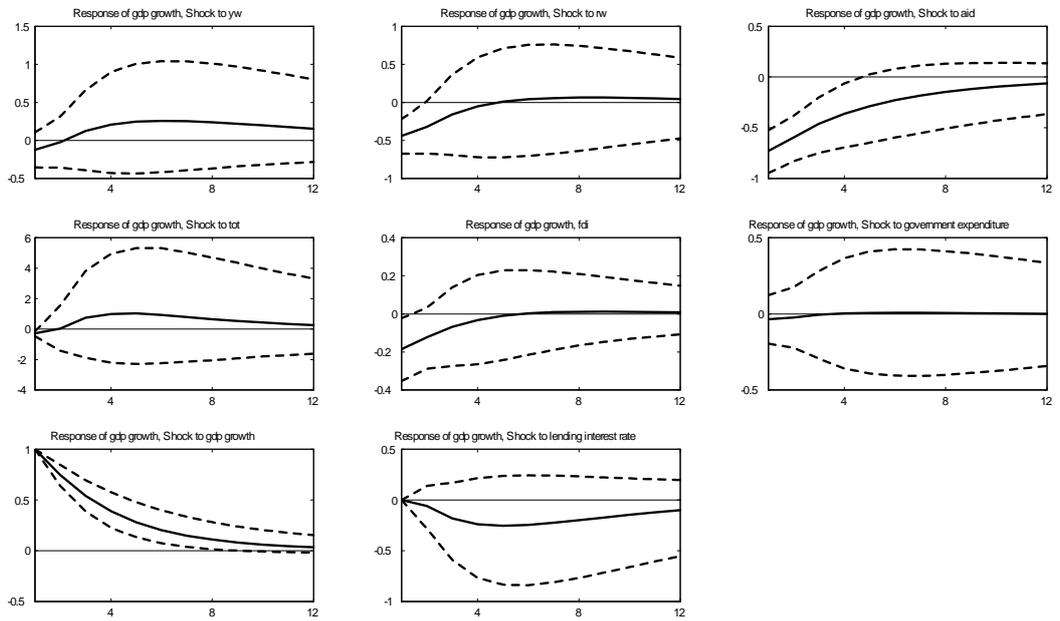


Figure 3: Responses of GDP growth of Ethiopia to a one unit shock in key domestic and external variables

5.1.3 Kenya

The impulse responses of the growth rate of GDP of the Kenyan economy to the shocks in most of the domestic and external variables is consistent with what economic theory predicts (see Fig. 4). The growth rate of the domestic GDP responds positively to the shocks in the growth rate of the GDP of the rest of the world, aid, the terms of trade, FDI, and government expenditure while it responds negatively to a shock in LIBOR. For example, a one percentage point shock in the growth rates of the GDP of the rest of the world and of the terms of trade lead, respectively, to a 0.051 percentage points (in the first quarter) and a 0.27 percentage points (after 5 quarters) rise in the growth rate of the domestic GDP. The response of the growth rate of GDP of Kenya to a shock in government expenditure is stronger than for other variables. A one percentage point shock in the government final consumption expenditure as a percent of GDP leads to 0.6 percentage point rise in the growth rate of GDP in the first quarter. On the other hand, a

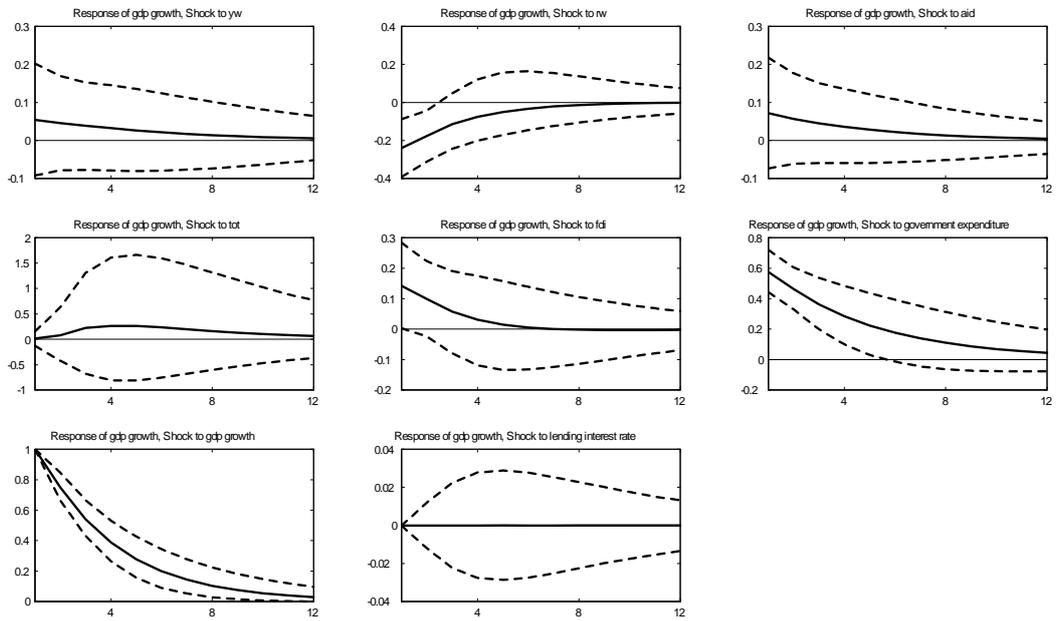


Figure 4: Responses of GDP growth of Kenya to a one unit shock in key domestic and external variables

one percentage point shock to LIBOR will lead to a 0.24 percentage point fall (in the first quarter) in the growth rate of the domestic GDP. In terms of producing strong response from the growth rate of GDP, the terms of trade shocks are important next to those of government expenditure for the the Kenyan economy.

5.1.4 Mauritius

The impulse response functions of the Mauritius economy show similar dynamics as those of the other countries discussed above, with one important exception. The growth rate of GDP of the domestic economy responds positively to a shock in LIBOR. This is counterintuitive since an increase of the of foreign interest rate affects the real exchange rate of the domestic economy and thereby the performance of its imports and exports. But given the structure of the Mauritius economy where the external sector is dominated by tourism, textile and sugar exports, the increased interest rate in the rest of the world (say due to

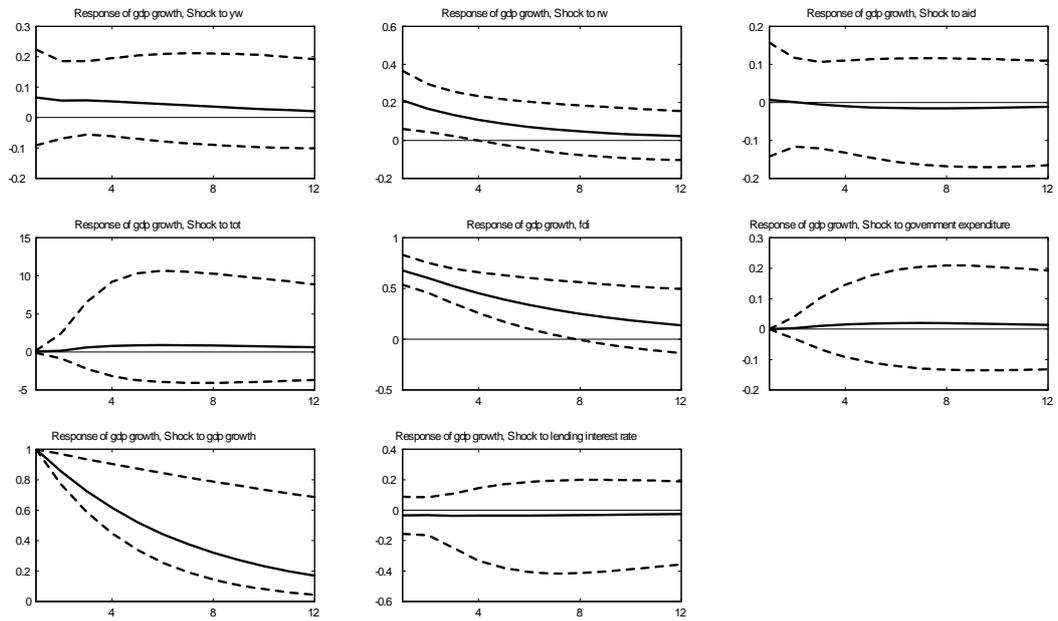


Figure 5: Responses of GDP growth of Mauritius to a one unit shock in key domestic and external variables

tight monetary policy) will increase the competitiveness of the Mauritius economy in its commodity exports and also increases its attractiveness as a tourist destination thereby increasing the growth rate of the domestic GDP. The response of the growth rate of GDP to the other variables is similar to that of the other countries. For instance, a one percentage point increase in the growth rates of the GDP of the rest of the world and the growth rate of terms of trade leads the growth rate of domestic GDP to increase, respectively, by 0.07 percentage points (in the first quarter) and 0.92 percentage points (after 6 quarters). The response of the growth rate of GDP of Mauritius to the shocks in aid, government expenditure and lending interest rate are very weak.

5.1.5 Nigeria

Close examination of the impulse responses of the Nigerian economy, presented in Fig. 6, shows that the response of the growth rate of GDP to both domestic and external shocks

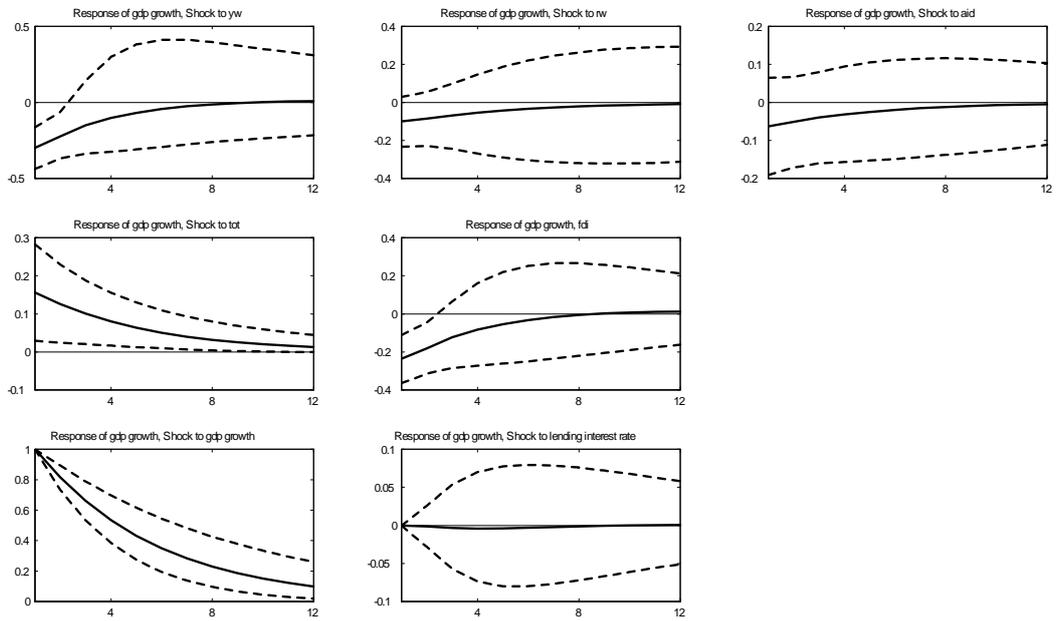


Figure 6: Responses of GDP growth of Nigeria to a one unit shock in key domestic and external variables

is of mixed signs. That is, for some of the shocks the responses of the growth rate of GDP are consistent with economic theory while for some the responses are countrintuitive. For example, the responses of the growth rate of GDP to the shocks in the growth rate of terms of trade, FDI inflows, LIBOR, and lending interest rate are of the expected sign; whereas the responses to shocks in the growth rate of GDP of the rest of the world and aid are contrary to the expected signs. The growth rate of Nigerian GDP responds positively to a shock in the growth rates of the terms of trade. For example, a one percentage point shock in the growth rate of the terms of trade leads to a 0.16 percentage point rise in the growth rate of the domestic GDP in the first quarter. On the other hand, the response to a shock in LIBOR is a 0.1 percentage point fall in the first quarter. The responses of the growth rate of GDP to shocks in aid, FDI and lending interest rate are weak.

In general, the impulse response analysis of all the countries shows that in most of the cases GDP reacts to the external shocks as predicted by economic theory and other

empirical works. The impulse responses of the growth rate of the GDP of most of the countries show that terms of trade shocks generate stronger responses from the growth rate compared to the other shocks. This is consistent with the arguments by many that for countries in Sub-Saharan Africa trade is the most important conduit of shock transmission from the rest of the world to the region. As discussed in the previous sections, this is the outcome of the structure of the economies in the region: that they are relatively open and face exogenous and highly fluctuating terms of trade.

5.2 The impact of external shocks-Variance Decomposition

To assess the contribution of different shocks to the variation in the growth rate of GDP, we generated the forecast error variance decomposition for GDP growth for 12 quarters ahead forecasts. This exercise helps to identify the fraction of the error variance of a given series accounted for by various shocks to the system. The results are reported below in graphs (Fig. 7-11)¹⁷.

The contribution of the shock in terms of trade to the variation of the GDP growth rate for a 12 quarter ahead forecast is 18 percent for Botswana, 35 percent for Ethiopia, 41 percent for Kenya, 37 percent for Mauritius and 42 percent for Nigeria. These results seem realistic when the structural features of the economies are taken into account. Oil exports represent a significant part of the GDP of Nigeria and the price of this commodity in the world market is one of the most erratic of all commodities. Ethiopia and Kenya are exporters of agricultural commodities the prices of which are also very volatile. Mauritius is also export dependent economy though the commodities (tourism, textile, and sugar exports) are different from those of Ethiopia and Kenya. The contribution of variation in terms of trade to the variation in growth rate is lower for Botswana which is also heavily dependent on the export revenues from mineral resources, particularly Diamonds. Furthermore, the contribution of growth of the economies of the rest of the world is insignificant. The largest contribution is for Mauritius (12 percent) followed by Botswana (7 percent).

¹⁷See Lutkepohl (2005: 63-66) for the details on how to compute forecast error variance from an estimated VAR and how to decompose it into fractions accounted for by the shocks to the variables in the model.

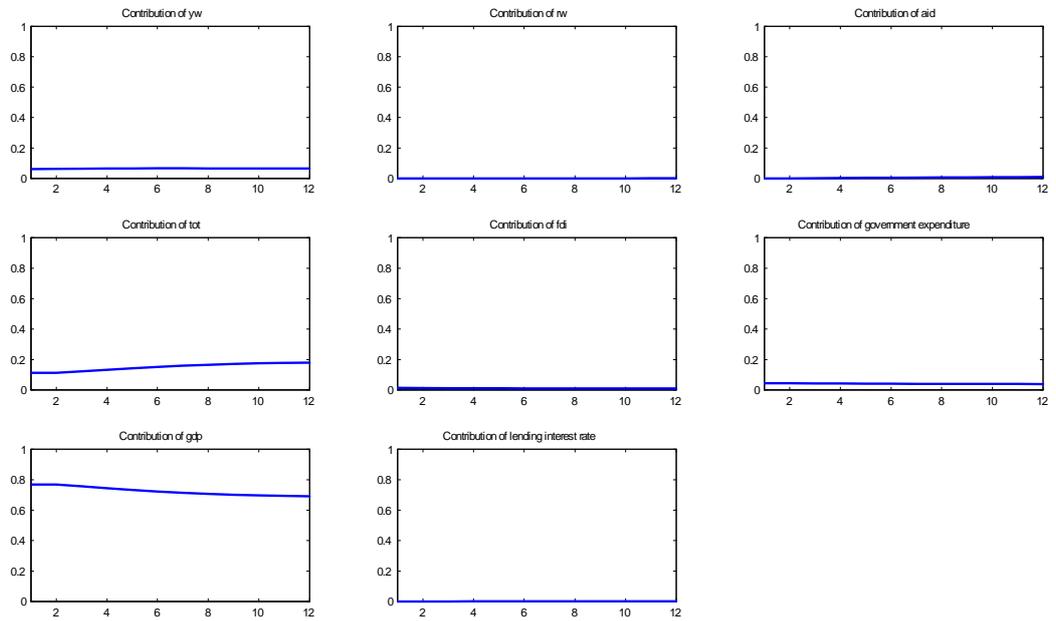


Figure 7: Botswana, Forecast Error Variance Decomposition for GDP growth

Furthermore, the growth rate of GDP is less sensitive to aid and the interest rate of the rest of the world (captured by LIBOR). The variation in the growth rate of GDP accounted by aid is larger for Ethiopia and Mauritius which is about 25 percents and 7 percents, respectively. On the other hand, the shock in LIBOR contributes about 7 percents and 2 percent for the economies of Ethiopia and Mauritius, respectively.

The variance decomposition for GDP growth rates of the five countries we analyzed seems to be consistent with the commonly held belief that SSA economies are less integrated into the global financial markets and therefore less affected by the shocks emanating from these markets compared to the developed economies. One of the indicators that is popularly used to capture the financial shock is the variation in the global interest rate. We included the shock in LIBOR, the most commonly used rate of interest of the rest of the world, to assess its contribution to the growth rates of the countries. As discussed above the contribution of this variable is small except for Ethiopia and Mauritius.

This forecast error variance decomposition exercise for the growth rate of GDP shows

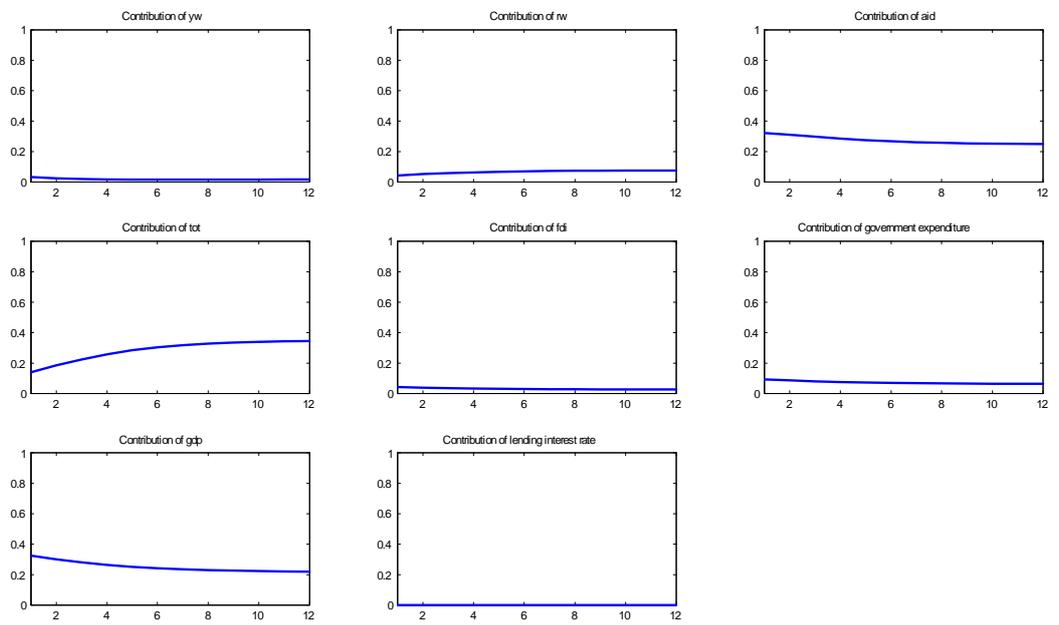


Figure 8: Ethiopia, Forecast Error Variance Decomposition for GDP growth

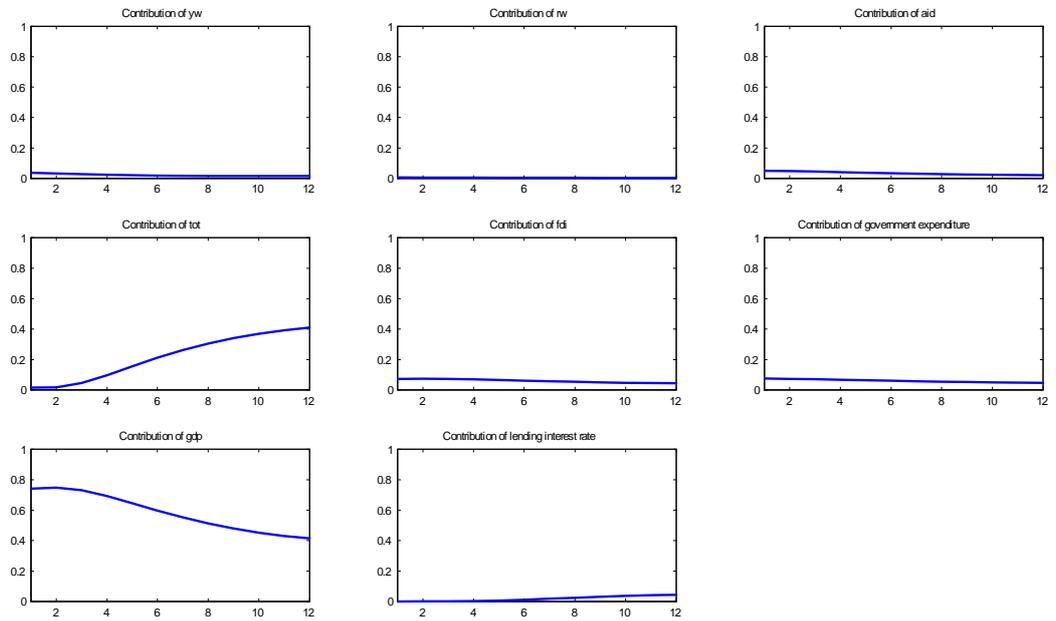


Figure 9: Kenya, Forecast Error Variance Decomposition for GDP growth

two important points. First, the contributions of different external shocks vary from country to country and the variation is of significant magnitude. Hence, it is misleading to make generalizations about the contribution of external shocks to the countries of SSA as a whole (see the assertions of Raddatz (2007 and 2008) and Kose and Reizman (2001)). For example, in our simple model the total contributions of the four external variables (growth of the rest of the world, interest rate of the rest of the world, aid and terms of trade) are about 26 percent for Botswana, 69 percent for Ethiopia, 46 percent for Kenya, 58 percent for Mauritius and 51 percent for Nigeria. Second, consistent with both theoretical and empirical works, of all the external shocks the terms of trade shocks make an important contribution to the variations in the growth rates of all the countries we investigated.

The variance decomposition reported above again warns against generalizations of the contributions of domestic and external shocks to fluctuations in key macroeconomic variables in SSA. The countries in the region have different export and import compositions

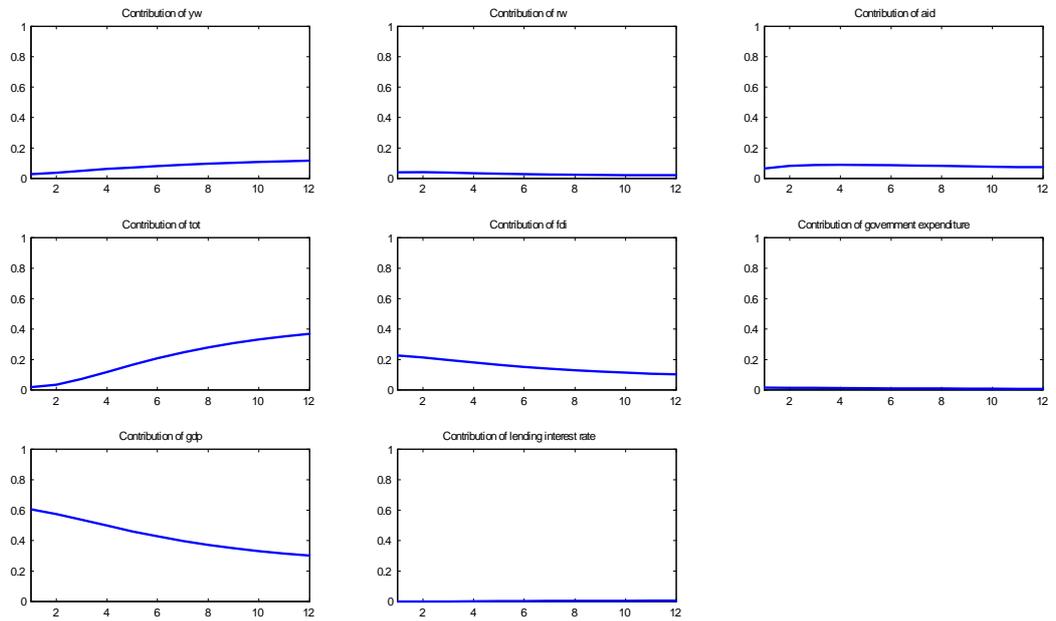


Figure 10: Mauritius, Forecast Error Variance Decomposition for GDP growth

and different levels of development of domestic financial markets. Furthermore, the degree of integration to the global financial markets is not the same. This poses questions to the results reported in some previous studies such as Raddatz (2007 and 2008) that make symmetry assumptions and generalize the effects of various external shocks on the macroeconomic performance of countries in the region.¹⁸

6 Sensitivity of results and model accuracy

Given the restrictive assumptions we employed for the selection of the variables of the model, the identification of the shocks, and the prior specifications, it is necessary to closely

¹⁸It is also important to note that the contributions of different variables to the variation in the growth rate of GDP generated via the variance decomposition process have their own shortcomings. This is so since some of the external and domestic variables in the model interact strongly, leading to the case where the contributions of variable x to the variation in variable z might be due to the influence of variable y on variable x where x is a domestic variable and y is an external variable. (see Abrego and Osterholm (2010)).

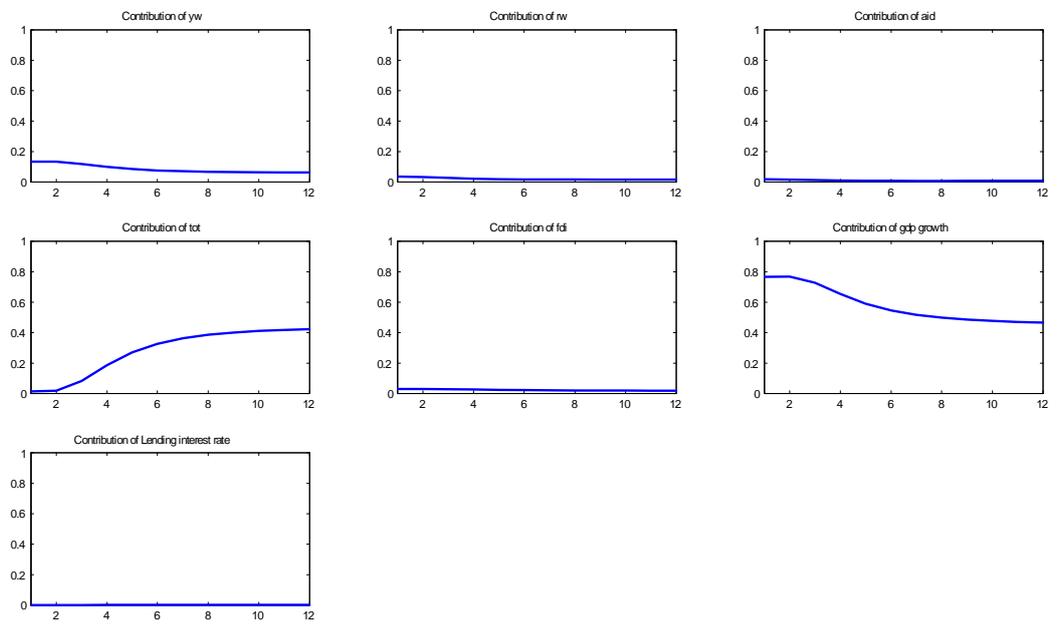


Figure 11: Nigeria, Forecast Error Variance Decomposition for GDP growth

examine the accuracy of the model. The literature on Bayesian data analysis suggests different methods of checking the accuracy of the models estimated or the robustness of the results obtained. Some of these are assessing the sensitivity of results to changes in prior and likelihood specifications, the plausibility of results within the existing theories, and posterior predictive checks to compare the features of the data replicated by the model with that of the actual data (see Gelman et al. (2004, ch 6) for more methods and details).

We tried to check the accuracy of the results based on sensitivity analysis and the posterior predictive checking. The results are sensitive to the changes in the values of hyperparameters. However, the prior values of the hyperparameters used are less informative and employed in many studies - as discussed in the model section - we do not see convincing reason to judge the model on the basis of this approach of robustness.

The second method, the posterior predictive checking, seems more persuasive to establish confidence in the accuracy of the models. According to Gelman et al. (2004: 159), the basic idea behind this approach is that “If the model fits, then replicated data generated under the model should look similar to observed data”. We compared the summary statistics for three domestic variables (government expenditure, growth rate of GDP, and the lending interest rate) calculated from the actual data and the simulated data from the posterior densities of the VAR model for all countries. But the values differ significantly and systematically for some of the variables and countries. For illustration purpose, we included the posterior predictive densities of the domestic variables for Nigeria in the appendix.

However, it is important to note that the results from VAR models (particularly the reduced form VARs) are known to be imprecise as they are influenced by the decomposition methods used and the ordering of the variables in addition to the large number of parameters in the model. As Sims stated by (1980), the pioneer of the VAR models, the main goal of the VAR models is to assess the interrelationships among the variables and not the precision of the estimated parameters. In the Bayesian VAR case the imprecision in the parameters also affects the data simulated under the model and hence the summary statistics of such data.

Under such circumstances, assessing the model on the basis of the plausibility of the

results seems the proper approach. As discussed in the previous section, most of the results of interest are consistent with the existing body of economic theories and the stylized facts of the countries considered in this study. Hence, evaluated from the point of view of the plausibility of results and the main goal set to the VAR models the results seem to be robust.

Furthermore, two points are worth mentioning. First, as it is discussed in the text and as it is well documented in the literature, both the impulse responses and the forecast error decomposition are sensitive to the ordering of the variables in the model. Second, the results are also sensitive to the method of frequency conversion used. This is so since different methods yield different quarter to quarter variability of variables of the model.

7 Conclusion

In this paper we attempted to assess one of the issues repeatedly raised in academia and policy making institutions: How much of the fluctuations in the key macroeconomic variables of low income countries is due to the variation in external variables? We posed this question and tried to answer using data from five SSA countries. It is a very interesting question at a time when the global economy, particularly the economies of the developed world, is experiencing an unprecedented situation in decades. Given the uncertainties about the direction of some of the economies assumed to have large spillover effects to the developing world, the answer to the above question will help understand a lot about the current and future trends of the economies in the region.

We employed the Bayesian VAR model with Stochastic Search Variable Selection (SSVS) priors. This approach is considered to be less influenced by the subjective judgments of the researcher. The different strands of SSVS are currently becoming very popular as they require almost no or minimum input from the researcher and hence are free of subjective biases.

Our results from both the impulse response analysis and the forecast error variance decomposition indicate the following points. First, the responses of the growth rate of GDP to the various external shocks vary significantly across countries. For instance, the terms of trade shock accounts for the largest proportion of the variations in GDP growth

rates of Kenyan and the Nigerian economies while the external factors contribute relatively little to the variation in GDP growth rates of the economy of Botswana. There are also differences in the magnitudes of the fractions of the variation in the growth rate of GDP of the countries that can be attributed to the shocks in domestic variables across the countries.

Second, the analysis in this paper suggests that the economies we considered have one thing in common. That is, terms of trade shocks are the most important of all the four external shocks for all countries, though the contribution of this type of shocks to the variation of the growth rate of GDP varies significantly across the countries.

We believe that there is at least one important lesson to be drawn from this study. Most of the generalizations about the relative importance of various external factors in explaining key domestic macroeconomic variables for countries in SSA are misleading. Though the countries in the region seem similar in many aspects, they also have features in which they differ considerably. More reliable results can be obtained by developing a Bayesian VAR for each country in which the choices of both domestic and external variables are dictated by the underlying structure of the economy.

There are many issues that can be addressed in this same line of research. First, undertaking a historical decomposition to assess which factors contributed towards the unprecedented high and sustained growth rate in most of the countries in the region would be more enlightening. Second, building a larger BVAR model for a specific country using the data available to the country (where the issue of comparison will not be a constraint) and undertaking conditional and unconditional forecasting would shed light on the trends of the economies in the region.

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8 Appendix

Table A1: Description of the series. All variables except the world interest rate are taken from the World Bank WDI-GDF database.	
y^w	Annual percentage growth rate of GDP of OECD countries
r^w	Six-month London interbank offered rate (LIBOR) - (IMF World Economic Outlook)
aid	Net official development assistance and official aid received as percent of GDP.
tot	Net barter terms of trade index is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000.
fdi	Net inflows of Foreign direct investment as percentage of GDP.
g	General government final consumption expenditure as percentage of GDP.
y	Annual percentage growth rate of GDP of the domestic economy.
r	Lending interest rate is the rate charged by banks on loans to prime customers .

Fig A1: Posterior Predictive Densities

The following figures are the posterior predictive densities of the domestic variables of Nigeria. The summary statistics (mean and the standard deviations) from the data used for estimation, standard deviations in parenthesis, are as follows: 3.8 (4.35), 3.24 (1.87), and 0.32 (3.44), respectively, for the growth rate of GDP, the FDI inflows as a percent of GDP, and lending interest rate.

