Is DSGE-VAR a Useful Methodology for Caribbean Forecasters and Policymakers?

Abstract

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Abstract:

This study determines the extent to which, a small Caribbean economy can use a vector autoregressive (VAR) representation of a Dynamic Stochastic General Equilibrium(DSGE) model with informed priors of the economy to better forecast key economic variables. The empirical findings indicate that the DSGE-VAR produces superior forecasts to both the Bayesian VAR and unconstrained VAR methods used, especially as the analysis goes further into the forecasting horizon. The salient policy implication of this study is that a more robust forecasting performance can be achieved from a model with an informed prior distribution on the economy, even more than traditional methodologies such as unconstrained VAR with OLS-like estimates and Bayesian methods. It is therefore prudent that policymakers and central bankers consider the DSGE-VAR methodology as a robust way of accurately forecasting estimates for key economic variables which are usually critical components in understanding the economy.

Keywords: Bayesian VAR, Dynamic Stochastic General Equilibrium Models, VAR

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1.0: Introduction

The research objective is to determine the most robust forecast estimates of key economic variables for a small Caribbean economy. Using various methodological approaches, such as a vector autoregressive (VAR) representation of a Dynamic Equilibrium model with an informed prior distribution on the economy on a modified New Keynesian model with normal rigidities, Bayesian VAR (BVAR) models and an unconstrained VAR with Ordinary Least Square (OLS) like estimates, are derived. The forecast estimates of each of these methodologies are derived over a horizon of 12 quarterly periods and compared by using the root mean square errors (RMSE) to determine the most robust forecast estimation.

The study provides policy makers and central bankers with another tool to help determine the most optimal way to forecast key economic variables (in this case: output, real exchange rate, inflation and nominal interest rate) for Jamaica. However, the methodology could be applicable to any similar economy using a modified New Keynesian (NK) model with normal price and wage rigidities. This is critical as these variables are usually components of key economic components within most economies and policymakers or central bankers are continually searching for methods that will provide more robust forecasts. This paper provides evidence that the VAR representation of the DSGE model with informed priors gives robust forecast estimations of four key economic variables, ahead of the BVAR and unconstrained VAR methods. The DSGE-VAR framework is particularly advantageous as it seeks to explain aggregate economic relationships based on micro founded models and therefore is not susceptible to the Lucas critique.

The main results of the paper are that the DSGE-VAR approach provides more robust forecast performances for all variables, especially after the initial periods of the forecast horizons. In contrast, the unconstrained VAR with OLS estimates provides results that are the direct opposite of the DSGE-VAR model. The BVAR models with tight prior mean and variance – covariance in the error terms that shrink the estimates towards a random walk and white noise respectively, provide robust results for at least two of the four variables (output and price inflation). These results, however, are still inferior to the DSGE-VAR representational model.

The paper is organized as follows: Section 2 contains the stylized facts of the key economic variables used within the study, their trend and volatility, along with factors impacting growth, inflation and real exchange rate. Section 3 presents a brief comparison of the methodologies examined in the paper. Section 4 discusses the theoretical and empirical literature. Section 5 discusses the methodologies used, the modified New Keynesian model and the baseline parameters used in deriving the DSGE –VAR representational model. This is followed by the estimation results, policy implications and conclusions.

2.0: Stylized Facts on Economic Indicators: 1996Q1: 2013Q2

Table 1: Economic Indicators

Year	Real GDP Growth	Inflation	Exchange rate (J$:US$1.00)	Treasury Bill Interest rates
1996			37.26	
1997	-1.6	9.2	35.51	
1998	-1.2	7.9	36.65	22.68
1999	1	6.8	39.18	18.76
2000	0.8	3.1	43.11	16.72
2001	1.3	11.8	46.09	15.42
2002	0.7	6.9	48.54	14.41
2003	3.7	14.1	57.92	22.54
2004	1.3	15.8	61.34	14.2
2005	0.9	10.5	62.51	12.6
2006	2.9	5.5	65.89	12.02
2007	1.4	16.8	69.06	11.81
2008	-0.8	16.8	72.93	14.69
2009	-3.4	10.2	88.47	18.12
2010	-1.4	11.7	87.43	8.84
2011	1.4	6	86.08	6.38
2012	-0.5	8	89.01	6.41
Average	0.4	10.1	61.9	14.4

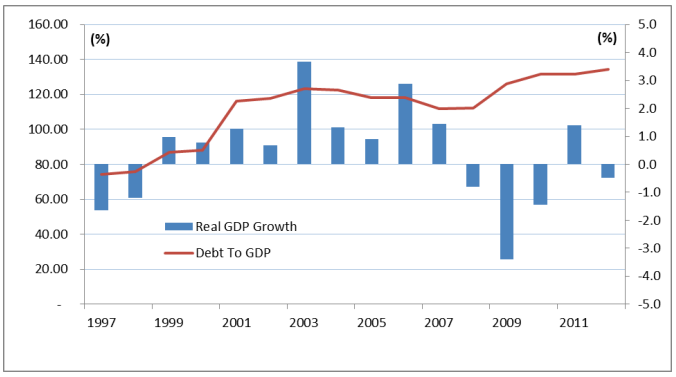
Growth

Although the Jamaican economy is considered to possess strong growth potential, due to its proximity to the United States as well as its human and natural resources, over the last decade growth has been marginal. For the period 1997 to 2012, economic growth averaged only 0.4 percent, substantially below that of emerging market economies. The growth performance demonstrates, inter alia, Jamaica's extreme vulnerability to external events such as hurricanes and other adverse external shocks, as well as volatility in investors' sentiments (Blavy, 2006). Sustained growth has also been hampered by significant increases in public debt in the 1990s that has fostered a large debt overhang, with the ratio of public debt to GDP gradually increasing from 74.2 per cent in 1997 to 134.25 percent in 2012. Other factors contributing to the low growth in output include a high crime rate and deficiencies in the quality of the labour force. Furthermore, Jamaica's economic performance is also traced to low productivity[1]. Productivity is

[1] Amidst other factors the World Bank report attributed Jamaica's disappointingly low productivity to deficiencies in human capital and entrepreneurship that are due to high migration rates as well as to deficiencies in the quality of education and training offered to the labor force (World Bank, 2011).

also hampered by a persistently high level of low skilled works in the labour force. The relatively lackluster growth since the mid-1990s would have had an impact on the unemployment rate that averaged 12.8 per cent. Of note, the fall in output following the financial crises of the mid to late 1990's would have had an impact on aggregate demand.

Figure 1: GDP Growth and Debt to GDP



Inflation

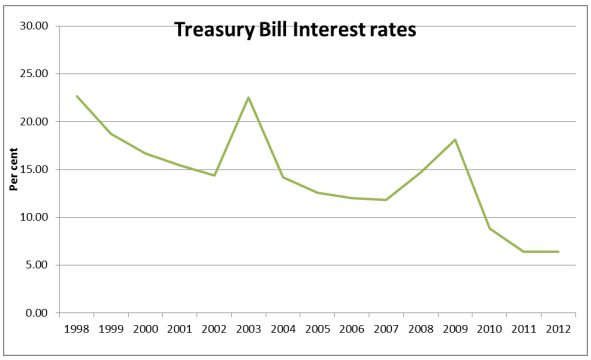
Jamaica's economic experience over the review period has also been characterized by an average inflation and average depreciation of 10.1 per cent and 5.8 per cent, respectively. Deviations in inflation from the average trend correspond to shocks from the exchange rate, and structural shocks such as import prices and domestic costs. The deviations in exchange rate from the average trend reflect periods of underlying macroeconomic uncertainty. Given the trends in inflation and exchange rates, the real exchange rate (RER), a measure of external competitiveness, on average has decline since the mid-1990s to 2012. The decline in external competitiveness is illustrated in the average appreciation in the RER by 21 per cent between 2002 and 2012. Even though there has been a nominal depreciation of the Jamaican dollar with respect to the U.S. dollar, the high inflation rate of Jamaica relative to the U.S has caused the real exchange rate to appreciate.

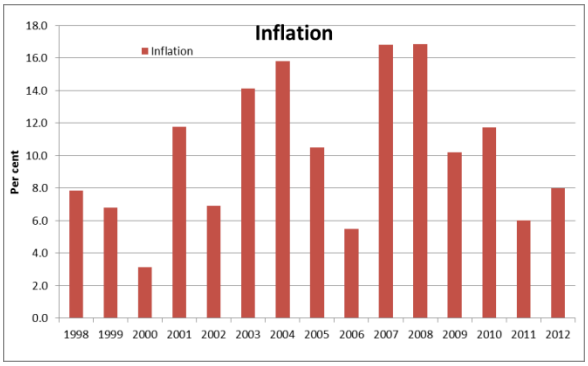
Nominal interest rates

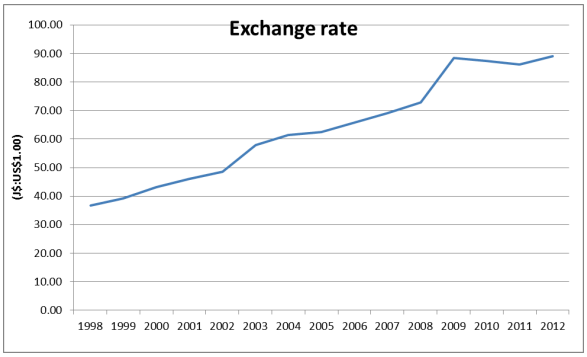
Jamaica's heavy indebtedness and the associated high interest rates have resulted in high capital costs. For many years, the high cost of borrowing of the Government effectively resulted in the crowding out of credit to the private sector by the public sector. This was further compounded by structural constraints such as the absence of credit registries, since the asymmetry of information increases lending risks for the banking sector. However, following the Jamaica Debt Exchange (JDX) in early 2010 and a subsequent stand-by agreement (SBA) between the International Monetary Fund (IMF) and the Government of Jamaica, Treasury Bill rates, which are indicative interest rates, plummeted from 22.7 per cent in 2009 to 6.4 per cent in 2012. Of note is the fact that Jamaican government undertook a second debt exchange in February of 2013, seeking to

lower interest costs (in June 2013, the interest rate on foreign currency loans was 7.33%, 19 percentage points less with respect to February) and the debt burden over time.

Figure 2: Inflation, Treasury bill Rates and Nominal Exchange Rate







3.0: A brief comparison between DSGE –VAR, BVAR, and VAR with unrestricted constraints

Based on the authors´ knowledge, most Caribbean central banks use VAR, OLS, and simple weighed averages in as their forecasting methodologies. We have no evidence of DSGE-VAR or any form of DSGE modeling being used at this time. It is therefore probably worthwhile to document some of the differences between these three methodologies. Unconstrained VAR's (with OLS like estimates) serve as an important starting point for econometric modeling and a benchmark for dynamic economic analysis (Ciccarell and Rebucci, 2003), however VAR with an unrestricted lag structure may result in over fitting and loss of degrees of freedom. To avoid the fitting problem, the Bayesian approach to specification and estimation of VARs has sometimes been adopted. The BVAR methodology takes the true population structure as uncertain and does not assign too much weight on any particular value of the model parameters. It takes this uncertainty into account in the form of a prior probability distribution of the model parameters, which can be modified by the information contained in the data. With the use of prior beliefs, BVARs are known to produce better forecasts than unrestricted VARs (Ciccarell and Rebucci, 2003)

When comparing DSGE models with VARs, the authors Gürkaynak, Kisacikoglu, and Rossi (2013) found mixed results. They realized that DSGE Models failed forecast efficiency tests, and that VARs outperformed DSGE Models at a number of horizons. The authors also found that when forecasting output, they find that simple VAR models are most accurate at short horizons and DSGE models at long horizons, while for inflation forecasts the results are reversed, due to rigidity in the cross-equation restrictions of the DSGE models. They also found that BVARs appear over-parametrizied, making them poor benchmarks when comparing to other forecasting models.

Del Negro and Schorfheide (2004) were among the first authors to develop a methodology using a DSGE model for a time series; they found that this methodology relaxes the theoretical restrictions of the original DSGE model and provided more than useful economic forecasts. Del Negro and Schorfheide (2012) and Warne et al 2013, ECB Working Paper suggested that DSGE-VAR models could be the new benchmark in forecasting, however, the methodology remains difficult to use for policy analysis, since the model still faces the same identification problems as standard VAR models.

4.0: Theoretical and Empirical Literature Review (brief)

Different types of econometric methods have been used in forecasting key economic variables, from simple time series methodology to single and multiple equation models. Schorfhiede (2000) showed, however, that the vector autoregressive (VAR) methodology provided the most robust results for output growth and inflation data in his paper. Smets and Wouters (2003a, 2003b) compared a standard VAR with a DSGE model with nominal and real rigidities to evaluate forecasting performance for capital accumulation using the Euro area and the United States (U.S.) data files. The Euro area data favored the VAR, while DSGE model perform better with the U.S. data. Christiano, Eichenbaum and Evans (2005) showed that DSGE models are better at impulse matching than standard VAR and VAR estimations with Bayesian methods.

A VAR representation of a DSGE new Keynesian model with nominal rigidities for price and wage contracts was developed by Del Negro and Schorfheide (2004, 2006 and 2008) and Del Negro et al (2004), which provide forecasts that outperform the standard VAR and the DSGE model itself. However, the model used recommended a passive fiscal policy (FP) rule without the inclusion of a government budget constraint and monetary policy being aggressive and following an interest rate feedback rule.

Warne et al (2013), in a forecast comparison of DSGE-VAR models, BVAR models and a simple multivariate random walk model, showed that DSGE-VAR models provided improved forecast performance at the certain horizons on Euro data, while the BVAR models had superior log predictive scores and the multivariate random walk model was only competitive at the one step ahead forecast horizon.

The general contribution of the literature on DSGE-VAR approaches to forecasting has been significant, with most policy makers and central bankers starting to use the tool in examining the forecasted estimates of key economic variables (Del Negro and Schorfheide, 2009). However, a general weakness has been observed in some estimation. This includes limited considerations to the inclusion of government expenditure and the financing of this expenditure. This paper attempts to do this, by developing a modified New Keynesian model with nominal rigidities in price and wage contracts that takes significant consideration of the government constraint, and comparing the forecasting estimates of the modified Rabanal and Rubio-Ramirez New Keynesian model with their standard New Keynesian model to determine which provided more robust results. Additionally it hoped that this paper will broaden the understanding of DSGE-VAR forecast application to Caribbean economic data as well as contribute, in a practical sense, to the policy discourse on improving forecast performance application in the Caribbean. To the best of our knowledge, no evidence of this method has used for any Caribbean economy.

5.0: Methodological Approach, Data and Baseline Parameters.

5.1: Methodology and Data

The paper compares the forecasting performance of Bayesian vector autoregressive (BVAR) models, an estimated unconstrained (VAR) with uninformative priors and a VAR representation of a DSGE model with informed parameters. The marginal likelihood of BVARs compare models consistently even when mis-specified and is therefore an efficient estimator (Fernandez – Villaverde and Rubio – Ramirez, 2004, Leeper and Zha 2000), while an estimated unconstrained VAR with uninformative prior provide consistent and efficient estimates similar to Ordinary Least Squares (OLS). These methodologies are compared to the dynamic general equilibrium model with informed parameters of the economy to determine which methodology provides a more robust forecast performance in evaluating key economic indicators (output, real exchange rate, inflation and nominal interest rate) by computing the root mean square error (RMSE) at 1 to 12 quarterly forecast horizons through a rolling procedure.

In determining the VAR representation of a DSGE model, we used both a modified New Keynesian (NK) model developed from Rabanal and Rubio-Ramirez (hereafter the RRR, 2005) which incorporates government budget expenditure and a standard RRR, 2005 model without the constraint. Estimates of both dynamic general equilibrium models with some rigidity are developed using Jamaican data. The forecasting performances of the standard model and the modified approached are compared for the key economic variables to determine which provides most robust estimates, against the BVAR models and unconstrained VAR.

The DSGE –VAR models equations were expressed in log linear format to represent output growth with real interest rate, production function with real marginal cost of production, the marginal rate of substitution between consumption and hours worked, real wage rate, nominal wage growth rate, domestic inflation and the real exchange rate.

Using quarterly data from the Bank of Jamaica for the period 1996Q1 – 2013Q2 for the series output, real exchange rate, inflation and nominal interest rate. A VAR representation to the law of motion of the DSGE model is obtained, using informed parameter values.

5.1.1: The Rabanal and Rubio-Ramierz (RRR, 2005) Baseline Model

The base model equations derived from Rabanal and Rubio- Ramirez (RRR, 2005) with sticky prices and wages, in log-linear form are:

$c_t = E_t[c_{t+1}] - \sigma_c(r_t - E_t[\pi_{t'+1}] + \sigma_c(1-\rho_g)g_t$ equation (1) Euler Rule for domestic demand

Where c_t is the domestic demand, σ_c is the elasticity of intertemporal substitution, r_t is the nominal interest rate, g_t is the preference shifter shock, p_g is a smoothing parameter for preference shock and π_{t+1} is the expected price level.

$y_t = a_t + (1-\delta_y)n_t$ equation (2) Aggregate Production

Where y_t is output, a_t is the technology shock and n_t is the amount of hours worked.

The marginal rate of substitution between domestic output and hours worked derived below:

$mrs_t = \frac{1}{\sigma_c}c_t + \gamma_n n_t - g_t$ equation (3) Marginal Rate of Substitution

γ_n is the inverse elasticity of labour supply with respect to real wages, σ_c is the elasticity of substitution

$r_t = p_r r_{t-1} + (1-p_r)(\gamma_\pi \pi_t + \gamma_y y_t + \gamma_{rer} rer_t) + z_t$ equation (4) Taylor Rule

Here the specification for the Taylor rule shows, the long-run responses of the monetary authority to deviations of inflation and output (γ_π and γ_y), z_t is the monetary policy shock and p_r is the interest rate smoothing parameter.

$wr_t = wr_{t-1} + (\Delta w_t - \pi_t)$ equation (5) Real Wage Rate

Real wage rate is a function of previous real wage rate, nominal wage growth less inflation.

Here wr_t is real wage rate, Δw_t is nominal wage growth and π_t is current inflation.

$\pi_{h,t} = \gamma_b \pi_{h,t-1} + \gamma_f E_t[\pi_{h,t+1}] + \frac{\kappa_p}{1+\beta\chi_p}(wr_t + n_t - y_t)$ equation (6) Domestic Inflation

Where γ_b and γ_f are the backward and forwarding looking coefficients for domestic inflation, κ_p is the slope of the Phillips curve for inflation, wr_t is real wage rate, n_t is number of hours worked and y_t is aggregate production.

$\Delta w_t - \chi_w \pi_{t-1} = \beta E_t[\Delta w_{t+1}] - \chi_w \pi_t + \kappa_w(mrs_t - wr_t)$ equation (7) Wage inflation

Wage inflation is equal to Δw_t nominal wage growth less wage inflation share of previous inflation χ_w. β is the elasticity of expected nominal wage growth and κ_w is the slope of the Phillips curve for wage inflation.

$$y_t = (1-\alpha_c)c_t + \alpha_c y^*_t + (\eta_c + \eta_f \frac{\alpha_c}{1-\alpha_c})rer_t$$ equation (8) Demand for domestic goods

The demand for domestic goods is dependent on share of foreign demand (1-α_c) on domestic demand goods (c_t), share of domestic demand (α_c) impacted by y^*_t (foreign demand shock) and the elasticity of domestic demand (η_c) plus foreign demand elasticity impacted by the changing real rate of exchange (rer_t)

$$\pi_t = \pi_{h,t} + \frac{\alpha_c}{1-\alpha_c}(rer_t - rer_{t-1})$$ equation (9) Relationship between domestic inflation and CPI inflation.

Where CPI inflation (π_t) is dependent on domestic inflation $\pi_{h,t}$ and the ratio of the share of domestic demand to foreign demand for goods times the change in the real exchange rate (Δrer_t)

The evolution of the technology shock (a_t), preference shifter shock (g_t), monetary policy shock (z_t) and foreign demand shock (y^*_t) according to RRR, 2005 are as follows:

$$a_t = p_a a_{t-1} + \varepsilon^a_t$$
$$g_t = p_g g_{t-1} + \varepsilon^g_t$$
$$z_t = \varepsilon^z_t$$
$$y^*_t = p_{y^*} y^*_{t-1} + \varepsilon^{y^*}_t$$

The baseline RRR, 2005 model solves the equations where (c_t, y_t, $mrs_t, r_t, wr_t, \pi_{h,t}, \pi_{w,t}$ and π_t) are domestic demand, aggregate production, marginal rate of substitution, nominal interest rate, real wage rate, domestic inflation, wage inflation and CPI inflation.

5.1.2: Modified RRR model, with Government Budget (GB)

To modify the RRR, 2005 model to incorporate government budget, equation (8) which represents demand for domestic goods or the aggregate resource constraint is adjusted to:

$$y_t = (1-\alpha_c)c_t + \alpha_c y_t^* + (\eta_c + \eta_f \frac{\alpha_c}{1-\alpha_c} rer_t) + \text{gb}_t$$ equation (10) Demand for domestic goods

$\text{gb}_t = p_{gb} gb_{t-1} + \varepsilon_t^{gb}$, where p_{gb} is the government budget smoothing parameter, and ε_t^{gb} is the stochastic shock. equation (11) Government budget

The model is adjusted to determine if more robust estimates can be derived for the key economic indicators, with the additional informed prior of government budget derived from fiscal balance data on the Jamaican economy for the period studied.

5.1.3: Modified RRR model, with Bonds Financing Government Budget.

Assuming that the government is allowed to finance its fiscal deficit with state sponsored bonds, then the government budget equation can be adjusted as follows:

$$gb_t = \rho_{gb} gb_{t-1} + b_{t+1} + \varepsilon_t^{gb},$$ equation (12) Government budget financed with bonds

Where b_{t+1} is the state sponsored bonds, used in financing any government budget deficit and is defined as $b_{t+1} = (1+r)b_t + \gamma_{gb} gb_{t-1}$ equation (13) State sponsored bonds.

The model is again adjusted to determine, if this new prior informed will improve the forecasting performance of the DSGE-VAR estimates.

5.2: Bayesian VARs and Unconstrained VAR:

The paper compares the forecasting performance of the VAR representation of the DSGE model to BVARs models and an unconstrained VAR with uninformed priors. The BVARs models used the Normal –Inverse Wishart prior, in specifying a prior distribution for the coefficients of VAR and the variance –covariance matrix of the errors. Several variation of prior distribution was selected for both coefficients and variance – co-variance matrix to have the estimates shrink towards a white noise. The RMSE of all these BVARs models were then compared to that of the dynamic equilibrium and unconstrained VAR model to determine which methodology provided the most robust performance.

In estimating the BVAR models we specify a prior mean distribution of 0 or 1 for the coefficients of the VAR and tight priors for the variance – covariance of the error terms (0, 0.01 and 0.001 respectively). The selection of a prior coefficient term of 0 and tight variance-covariance error term shrinks the model estimates towards a random walk, while a prior of 1 and tight error term moves the estimates towards white noise. In our analysis the former priors provided a more robust estimate.

The prior mean distribution is:

$$\beta \Big| \sum \sim N(\beta_0, \Sigma \otimes V_0)$$
$$\Sigma^{-1} \sim W(v_0, S_0^{-1})$$

5.3: Priors and Posterior Parameters for Baseline and Modified Models

The solving of the steady state system requires the using of baseline distribution of the parameters. The following parameters were chosen; see Tables 2 for prior parameters below:

Table 2: Prior Parameters

β	σ_y	ϕ_y	$\bar{\varepsilon}$	α_c	σ_c	θ_p	θ_w
0.99	0.36	6	6	0.35	0.50	0.75	0.875
γ_n	χ_p	χ_w	γ_π	σ_y	γ_{rer}	ρ_r	ρ_a, ρ_{gb},
3.0	0.75	0.75	1.50	1.00	0.00	0.85	0.90
η_c	η_f	ρ_g	ρ_{y*}	σ_g	σ_{y*}	σ_z	σ_a
0.5	0.5	0.6	0.85	2.00	2.50	0.30	1.20

The paper uses the conventional values for (beta, sigma_y, phi, and eps_bar) that are frequently expressed in the literature for the discount factor, capital share in production, elasticity of substitution among labor varieties and substitution among intermediate goods (Fabiani et al 2006).

The intertemporal elasticity of substitution (sigma_c) follows the usual inverse distribution with the selection of prior mean of 0.75 and standard deviation of 1.45, along with the selection of prior and standard deviation of distribution of average duration of prices (Rabanal and Rubio-Ramiez, 2007 and Fabiani et al 2006).

Using Taylor (1993) estimates we derived the Taylor rule coefficients results, assuming that the distribution is normal (gamma_pi, sigma_y, gamma_rer). We assumed uniformity of distribution between (0,1) for (rho_r, rho_a, rho_g and rho_y*) representing the inertia in Taylor rule, persistence of productivity shocks, demand shocks and foreign demand shocks.

In our modified model we assumed that wages are sticky for longer periods than price contracts so values of 0.875 was chosen for theta_w and 0.75 for theta_p assuming a uniform distribution of (0,1) (Maria-Dolores and Vasquez, 2006), while the weight of price and wage indexation to past inflation was assumed to be the same.

For the share of import in aggregate domestic demand, based on the period studied and from Bank of Jamaica data files it was assumed this share was approximately 0.35 for alpha_c, while the elasticity of substitution between domestic and foreign goods in local demand and foreign demand where assumed to be 0.5 respectively. The responsiveness of labour to hours worked and

the real wage rate was captured by frish labour elasticity value of 3.0, a similar result found by Maria – Dolores and Vasquez, 2006) in their study of developing countries within the Euro-area. The standard deviation of innovations in productivity, demand, monetary policy rule and foreign demand shocks were (1.2, 2.0, 0.30 and 2.5) as the impact of monetary policy rule was considered, while foreign demand shocks on a small economy was perceived the greatest impact.

Table 3 below, shows the mean and standard deviation of the posterior parameters, while the standard deviations in the model distribution against the data are presented in table 4, to describe the model fit.

Table 3: Posterior Parameters

β	σ_y	ϕ_y	$\bar{\varepsilon}$	α_c	σ_c	θ_p	θ_w
0.9975 (0.14)	0.375 (0.02)	6.79 (0.04)	7.52 (0.21)	0.32 (0.11)	0.53 (0.05)	0.79 (0.01)	0.899 (0.08)
γ_n	χ_p	χ_w	γ_π	σ_y	γ_{rer}	ρ_r	ρ_a, ρ_{gb}
3.21 (0.54)	0.85 (0.01)	0.94 (0.63)	2.13 (0.07)	1.034 (0.12)	0.03 (0.36)	0.93 (0.02)	0.92, 0.97 (0.17) (0.06)
η_c	η_f	ρ_g	ρ_{y^*}	σ_g	σ_{y^*}	σ_z	σ_a
0.38 (0.05)	0.61 (0.04)	0.71 (0.46)	0.88 (0.32)	2.32 (0.19)	2.74 (0.07)	0.39 (0.21)	1.37 (0.08)

Table 4: Standard Deviations in the Data and Models (express in %)

	Output	Price Inflation	Real Exchange Rate	Nominal Interest Rate	Government Budget(Fiscal balance)
Data	1.38	3.91	2.48	0.67	1.26
Modified RRR (1)	1.31 (0.16)	3.84 (0.05)	1.92 (0.56)	0.64 (0.23)	1.14 (0.17)
Modified RRR (2)	1.34 (0.12)	3.89 (0.01)	2.17 (0.18)	0.66 (0.21)	1.22 (0.09)

6.0 Estimation Results

6.1: Estimation Results with Standard Model

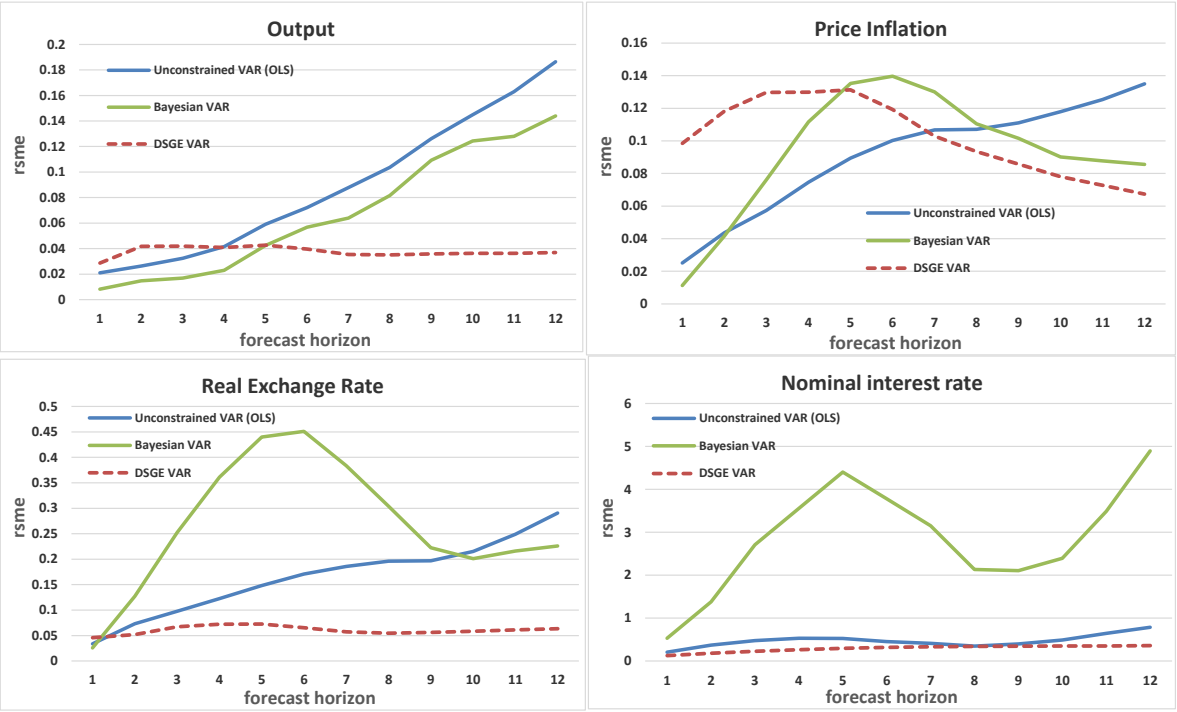
The forecasting comparison of the VAR representation of the DSGE model, with informed prior distribution of parameters from the economy provides the best forecast performance than the unconstrained VAR with OLS like estimates and the BVARs, among the four key economic variables. The results show that in the initial period of the 12 quarterly horizon forecast the performance is more robust for the unconstrained VAR but the VAR representation of the DSGE model performs best later in the forecast horizon for all four variables (output, real exchange rate, price inflation and nominal interest rate). The rationale for this is likely due to the informed prior distribution of the parameters of the economy, providing a more suitable distribution of the estimates further in time.

The BVAR model with a prior mean of zero and tight priors of the variance co-variance matrix produced results superior to the unconstrained VAR for output throughout the forecast horizon and improved forecasts for inflation, real exchange rate and nominal interest rates as estimates go further into the horizon, as estimates shrink towards a white noise. The DSGE –VAR representation however outperforms the BVAR model for all variables except price inflation during the earlier periods of its forecast horizon.

The results show that the DSGE-VAR representation provides the most robust results as the prior distribution of the parameters are informed from the economy. For the standard RRR, 2005 model, the DSGE-VAR provides a better forecast than both BVAR and unconstrained VAR from the initial period for the variable nominal interest rate, the 2nd period for real exchange rate and approximately from the fourth and fifth periods for output and inflation (see figure 3 below)

Below please see a graphical representation of the forecasting performances of the four (4) variables in the 12 period forecast horizon.

Figure 3: Showing forecast performance of DSGE –VAR, Unconstrained VAR and BVAR



The unconstrained VAR with OLS like estimates generally performs better than the Bayesian and DSGE VAR at the initial stage of the forecast horizon; however the estimates deteriorate towards the end of the horizon. It however seems to provide creditable estimates for nominal interest rate in line with the forecasting performance of the DSGE-VAR representation.

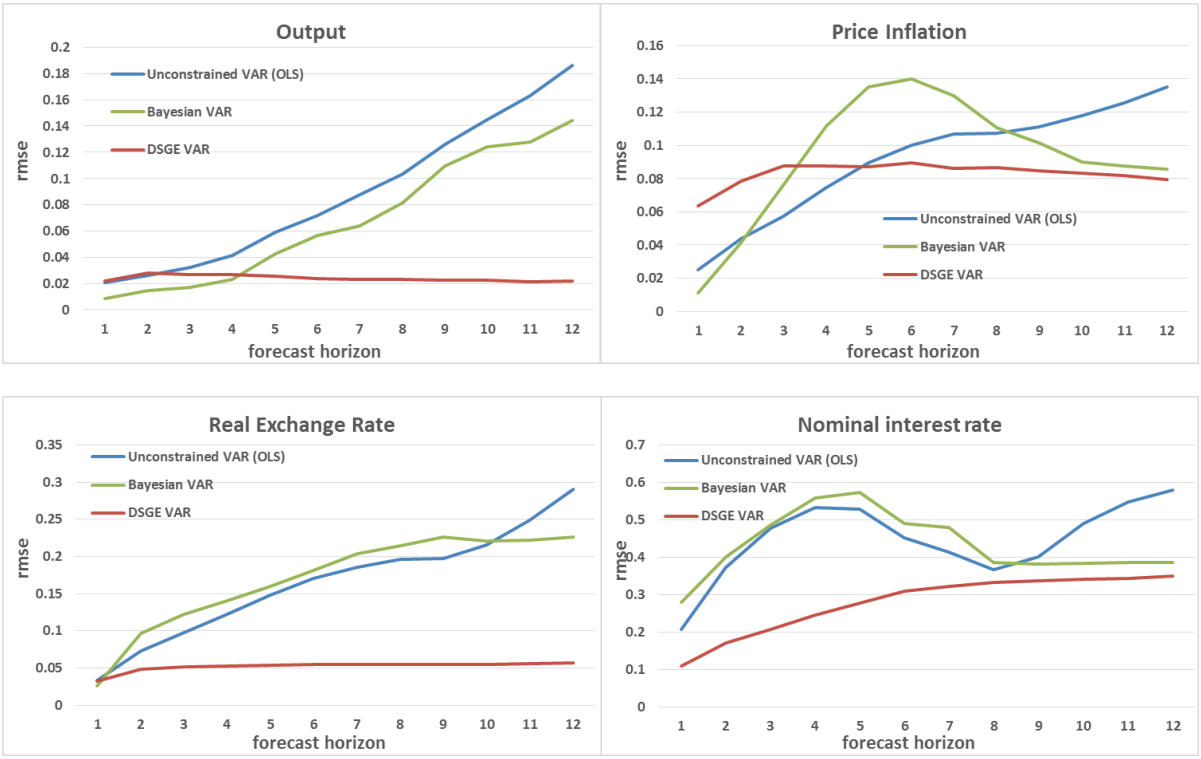
6.2: Estimation Results with Modified model with government budget.

Using the modified RRR model with the inclusion of government budget, forecasting performance of the DSGE-VAR with informed priors improve for all four key economic indicators (output, price inflation, real exchange rate and nominal interest rate) against the BVAR and unconstrained VAR with OLS like estimates. The inclusion of the government constraint in the modified model, forecasting performance improves earlier in the forecast horizon than in the standard model for the variables output, price inflation and improving its dominance in performance for real exchange rate and nominal interest rate against the BVAR and unconstrained VAR. This result continues to suggest that the informed prior better explain aggregate relationships over time.

The specific results (see Figure 4 below) show that the DSGE-VAR provides a better forecast than both BVAR and unconstrained VAR from the initial period for the variable nominal interest rate, the 1st period for real exchange rate and approximately from the second and fourth periods for output and inflation, improved results over the standard RRR, 2005 model.

The estimation results with government budget financed by state sponsored bonds, however was similar to the results obtained in the modified model with government budget.

Figure 4: Showing forecast performance of DSGE –VAR, Unconstrained VAR and BVAR



7.0 Policy Implications

The economic variables of output, real exchange rate, inflation and nominal interest rate are vital components of the attempt by policy makers and central bankers in forecasting economic performance. The use of both the DSGE –VAR representation and BVAR models with informed priors from the economy to better derive the forecast of these variables provide policy makers and central bankers with more robust methodologies. The unconstrained VAR which provide estimates similar in nature to OLS performs better in the initial stage of the forecast horizon, however generally this methodology appears weaker than both the DSGE-VAR representation and BVAR methods. Policy makers and central bankers looking at longer-term forecast would be better advised to look at these methods.

7.0 Conclusions

The forecasting performance of the DSGE-VAR representation (for both the standard and modified models) was found to be most robust for all four economic variables (output, real exchange rate, and inflation and nominal interest rate) over the general period of the 12 quarterly forecast horizons. For some variables the unconstrained VAR or OLS like estimates perform better but only in the initial stages of the horizon, however its performance deteriorated towards the latter stages of the horizon. BVAR model with tight prior mean and tight variance co-variance matrix provided a more robust forecasting performance than the unconstrained VAR for most variables. Policy makers and central bankers might find the methodologies useful in forecasting key economic variables with informed priors based on the economy.

References

Ciccrelli, Frank and Alessandro Rebucci. “Bayesian VARs: A Survey of the Recent Literature with an Application to the European Monetary System.” IMF Working Paper WP/03/102.

Blavy, Rodolphe. "Public Debt and Productivity: The Difficult Quest for Growth in Jamaica." IMF Working Papers 06/235 (2006), International Monetary Fund.

Del Negro, Marco., and Frank Schorfheide. “Priors from General Equilibrium Models for VARS.” *International Economic Review* 45 (2004): 643-673.

Del Negro, Marco.,Schorfheide, Frank, Smets, Frank and Raf Wouters. “On the Fit and Forecasting Performance of New Keynesian Models.” Working Paper No. 3 (2004), Federal Reserve Bank of Atlanta.

Del Negro, Marco and Frank Schorfheide. "Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)." Working Paper 2006-16 (2006), Federal Reserve Bank of Atlanta.

Del Negro, Marco and Frank Schorfheide. "Inflation dynamics in a small open-economy model under inflation targeting: some evidence from Chile." Staff Reports 329 (2008), Federal Reserve Bank of New York.

Fabiani, Silvia., Druant, Martine., Hernando, Ignacio., Kwapil, Claudia., Landau, Bettina., Loupias, Claire., Martins, Fernando., Mathä, Thomas., Sabbatini, Roberto., Stahl, Harald., and Ad Stokman. "What Firms' Surveys Tell Us about Price-Setting Behavior in the Euro Area." *International Journal of Central Banking, International Journal of Central Banking* 2 (2006).

Fernández-Villaverde, Jesús., Rubio-Ramírez, Juan Francisco., and Manuel Santos. "Convergence properties of the likelihood of computed dynamic models." Working Paper 2004-27 (2004), Federal Reserve Bank of Atlanta.

Gurkaynak, Refet., Kisacikoglu, Burçin., and Barbara Rossi. “Do DSGE Models Forecast More Accurately Out-of-Sample than VAR Models?” Discussion Paper Series, Centre for Economic Policy Research.

Christiano., Eichenbaum, Martin., and Charles Evans. “Nominas rigidities and the dynamic effects of a shock to monetary policy.” *Journal of Political Economy* 113 (2005).

Leeper, Eric M. and Tao Zha. "Assessing simple policy rules: a view from a complete macro model." Working Paper 2000-19 (2000). Federal Reserve Bank of Atlanta.

María-Dolores Ramón and Jesús Vázquez. "How Does the New Keynesian Monetary Model Fit in the U.S. and the Eurozone? An Indirect Inference Approach." *The B.E. Journal of Macroeconomics* 6 (2006): 1-51.

Rabanal, Pau and Juan Francisco Rubio-Ramirez. "Comparing New Keynesian Models of the business cycle: a Bayesian approach." *Journal of Monetary Economics* 52 (2005): 1151 -1166.

Rabanal, Pau and Juan Francisco Rubio-Ramirez. "Comparing New Keynesian Models in the Euro Area: A Bayesian approach." (2007).

Schorfheide, Frank. "Loss Function-Based Evaluation of DSGE Models." *Journal of Applied Econometrics* 15 (2000): 645-670.

Smets, Frank and Raf Wouters. "An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1 (2003a): 1123-1175.

Smets, Frank and Raf Wouters. "Forecasting with a Bayesian DSGE Model. An Application to the Euro Area." Working Paper No. 389 (2003b), European Central Bank.

Taylor, John B. "Discretion versus policy rules in practice." Carnegie-Rochester Conference Series on Public Policy, Elsevier (1993), vol. 39: 195-214.

Warne, Anders., Coenen, Günter and Kai Christoffel. "Predictive likelihood comparisons with DSGE and DSGE-VAR models." Working Paper Series 1536 (2013), European Central Bank.

World Bank. "Jamaica Country Economic Memorandum: Unlocking Growth." World Bank (2011), Washington, DC.