



Forecasting macroeconomic data for an emerging market with a nonlinear DSGE model



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ABSTRACT

This paper considers the forecasting performance of a nonlinear dynamic stochastic general equilibrium (DSGE) model. The results are compared with those of a wide selection of competing models, which include a linear DSGE model and a variety of vector autoregressive (VAR) models. The parameters in the VAR models are estimated with classical and Bayesian techniques, where some of the Bayesian models are augmented with stochastic variable selection, time-varying parameters, endogenous structural breaks and various forms of prior shrinkage (where the Minnesota prior is included as a special case). The structure of the DSGE models follows that of New Keynesian varieties, which allow for nominal and real rigidities. The nonlinear DSGE model makes use of the second-order solution method of Schmitt-Grohé and Uribe (2004), and a particle filter is used to generate values for the unobserved variables. Most of the parameters in these models are estimated using maximum likelihood techniques. The models are applied to the macroeconomic data of South Africa, which is classified as an emerging market economy. The initial in-sample period of 1960Q1 to 1999Q4 is used to generate an eight-step ahead forecast. The models are then estimated recursively, by extending the in-sample period by a quarter, to generate successive forecasts over the out-of-sample period 2000Q1 to 2011Q4. We find that the forecasting performance of the nonlinear DSGE model is almost always superior to that of its linear counterpart, particularly over longer forecasting horizons. The nonlinear DSGE model also outperforms the selection of VAR models in most cases.

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1. Introduction

Dynamic stochastic general equilibrium (DSGE) models are used by central banks and other policy-making institutions for policy investigations and forecasting purposes.¹ Modern variants of these models incorporate a prodigious amount of nominal and real rigidities, and a relatively large number of shocks. These features have improved their forecasting potential to the extent that they have outperformed most other multivariate models, when applied to developed-world macroeconomic data.² Most of these models make use of a linearised state-space system to characterise the equilibrium dynamics of business cycle fluctuations; however, as noted in Del Negro and Schorfheide (2011), such a linear approximation may be unreliable when applied

to an economy that is affected by large shocks, as is the case for most emerging market economies.³

Against this backdrop, the objective of this paper is to analyse whether the nonlinearities would improve upon the out-of-sample fit of a New Keynesian DSGE model that may be applied to macroeconomic data from an emerging market economy. In addition, we also compare the forecasting performance of the nonlinear DSGE model to a large variety of BVAR models. In this study, the data for the emerging market economy pertains to South Africa, which was recently included in the BRICS nations of fast-growing newly industrialised or emerging economies. When compared with Brazil, Russia, India and China, it is worth noting that South Africa is significantly smaller, accounting for approximately 2% of combined BRICS economic output, which may imply that

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¹ See Tovar (2009) for an overview of the use of these models in central banks. Edge et al. (2010) provide details of the DSGE model that has been used at the Federal Reserve Bank, while Ratto et al. (2008) describe the model that has been used at the European Central Bank. An early exposition of the multi-country DSGE model that has been used at the International Monetary Fund (IMF) is provided in Carabenciov et al. (2008).

² See Smets and Wouters (2007) for an early indication of the forecasting performance of these models.

³ In addition, Fernández-Villaverde and Rubio-Ramírez (2005) and Fernández-Villaverde (2010) note that linearisation would result in an approximation error that influences the likelihood function and the eventual parameter estimates. When combined with the assumption of Gaussian errors, it would also eliminate the possibility of investigating asymmetric or threshold effects; as well as the influence of time-varying volatility (as in Fernández-Villaverde et al., 2011; Binsbergen et al., 2012).

it would be susceptible to large shocks, where nonlinearities could be of greater importance.⁴

The forecasting performance of linear DSGE models that have been applied to South African data has been somewhat mixed. Initial studies by Liu and Gupta (2007), Liu et al. (2009, 2010), and Gupta and Kabundi (2011) suggest that the forecasting potential of Bayesian vector autoregressive (BVAR) models may be superior to that of small closed-economy DSGE models, for key macroeconomic variables. However, studies by Steinbach et al. (2009), Gupta and Kabundi (2010), Alpanda et al. (2011) and Gupta and Steinbach (2013) indicate that when one allows for open-economy features and a relatively large number of rigidities, DSGE models would appear to compete favourably with BVAR models.

The structure of the DSGE model in this chapter follows the specification of Pichler (2008), who found that there was little difference in the forecasting performance of linear and nonlinear models, when applied to data for the United States economy. Therefore, the use of this specification would allow for us to compare the results from an emerging market with those from a developed-world economy. In addition, the results of previous studies that were applied to South African data suggest that the forecasting performance of small closed-economy DSGE models is usually inferior to that of other forecasting models (such as those that employ a VAR structure). Hence, if we find that the forecasting performance of this nonlinear model is superior to that of other models, it would suggest that there could be important nonlinear features in the underlying South African data-generating process for this emerging market economy.

As noted above, the majority of DSGE models that are used for forecasting purposes would usually make use of a first-order linear approximation of the theoretical model that incorporate several nonlinear features and a number of forward-looking expressions.⁵ After applying such a log-linear approximation, one is able to derive the model solution, before making use of the Kalman filter to approximate the likelihood function of the model (which may include several unobserved variables).⁶ While this procedure has been successfully applied to many problems, as noted above, a first-order linear approximation may exclude important nonlinearities and the possibility of large deviations from the steady-state of the respective variables.

The use of DSGE models that are estimated with higher-order approximations and nonlinear filters is not as widespread when used for forecasting purposes.⁷ An (2008) and Del Negro and Schorfheide (2011) suggest that one reason for this may be the computational complexities that are involved in the estimation of these models, when both the state and measurement equations are nonlinear.⁸ In addition, Andreasen et al. (2014), Den Haan and De Wind (2012) and Kim et al. (2008) have noted that the use of higher-order approximations may

result in an unstable model solution, since it would consider additional points around which the approximate solution may be unstable.⁹ These reasons also motivate for the use of a relatively simple closed-economy modelling framework when evaluating the relative forecasting potential of these models.

To the best of our knowledge, the current literature does not include an example of a nonlinear DSGE model that is applied to the macroeconomic data of an emerging market economy.¹⁰ Such an investigation would be of interest, as one would expect that this data would incorporate larger deviations from the steady-state (as well as potentially more complex nonlinear relationships). Hence, it may be the case that when applied to an emerging market economy, the nonlinear DSGE model may provide a superior out-of-sample fit, when compared with its linear counterpart. In addition, it also may have the potential to outperform other reduced-form forecasting models.

In this paper we estimate a linear and a nonlinear DSGE model (as well as a large selection of competing forecasting models) for the South African economy. The competing forecasting models include classical vector autoregressive (VAR) models and a number of BVAR varieties. These BVAR models have been estimated with various forms of the Minnesota prior and stochastic variable selection (SVS) techniques.¹¹ Some of the BVAR models that employ SVS have been extended to allow for time-varying parameters, endogenous structural breaks, and least absolute shrinkage and selection operators.

The results of this investigation suggest that the nonlinear DSGE model appears to outperform its linear counterpart for all variables in most instances. In addition, the findings suggest that these improvements are statistically significant when forecasting consumer inflation and interest rates over the medium to long horizon, as well as output over short to medium horizons.¹² The nonlinear DSGE model also appears to outperform the VAR and BVAR models when forecasting consumer inflation.¹³ In addition, when forecasting output over longer horizons, the predictive ability of the nonlinear DSGE model would appear to be superior, while over a shorter horizon, there are a few cases where a BVAR model generates better forecasts. The forecasts for interest rates are all fairly similar; however, one of the BVAR models with the Minnesota prior is able to outperform the nonlinear DSGE over the medium to long horizon.

The remainder of this paper takes the following form. Section 2 describes the theoretical structure and empirical techniques that are employed to estimate the DSGE models. Section 3 considers the specification of the wide selection of VAR and BVAR models. In Section 4, we describe the data that is used in this study and the parameter estimates from the DSGE model, before we discuss the results in Section 5. The final section comprises of the conclusion.

⁴ South Africa is classified as an emerging market economy by the International Monetary Fund (2013), as well as by the FTSE, S&P, Dow Jones, and MSCI. The data for nominal GDP in USD terms for each of the BRICS nations was obtained from the International Monetary Fund (2013).

⁵ The proliferation of forecasting models that make use of first-order approximations has been facilitated by the development of the excellent software platform, *Dynare*. Further details of which can be found in Adjemian et al. (2011).

⁶ Solution methods for linear rational expectations problems are provided by, Blanchard and Kahn (1980), Klein (2000), Sims (2001), and Uhlig (1999), among others.

⁷ Early advocates of this procedure for parameter estimation include, Fernández-Villaverde and Rubio-Ramírez (2005), An and Schorfheide (2007), An (2008), Primiceri and Justiniano (2008), and DeJong and Dave (2007). These studies would usually employ the second-order solution method proposed by Schmitt-Grohé and Uribe (2004), before utilising a particle filter to evaluate the likelihood function.

⁸ Nonlinear filters have been applied in many settings to model various features of time-series data. The form that some of these filters take is discussed in Kitagawa and Gersch (1996), Doucet et al. (2000), DeJong and Dave (2011), and others. While most of the research that makes use of nonlinear DSGE models utilise a particle filter to derive the likelihood function, DeJong and Dave (2011) suggest that using the Efficient-Information-Sampling filter may lead to improved results when applied to structural macroeconomic models.

⁹ The latest version of *Dynare*, version 4.2.2, can be used to estimate parameters in a nonlinear model with the aid of the methods that were applied in Fernández-Villaverde and Rubio-Ramírez (2005). However, at the time of writing, these routines do not allow for the generation of forecasts with the particle filter. It is hoped that the results in this chapter will motivate those who are involved with this impressive project to include second-order forecasting options in future versions of *Dynare*, while encouraging further efforts that consider more efficient algorithms for solving nonlinear models, such as those that are considered in Andreasen et al. (2014) and Maliar et al. (2013).

¹⁰ In addition, Pichler (2008) is the only example of a forecasting study that makes use of a nonlinear DSGE model that has been applied to a developed-world economy.

¹¹ The specification of BVAR models with a Minnesota prior is discussed in Litterman (1986a,b), Doan et al. (1984) and Sims and Zha (1998). The application of SVS techniques in a BVAR model is described in Koop and Korobilis (2010) and Korobilis (2013).

¹² These forecasts are evaluated after calculating the relative root-mean squared errors and the Diebold and Mariano (1995) statistics, which consider the significance of any observed improvement.

¹³ The BVAR with Minnesota prior appears to provide the second-best results in this instance.

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