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BENEFITS OF USING BAYESIAN ESTIMATION FOR MACROMODELS OF UKRAINE: THE CASE OF APPLICATION TO BIVARIATE VAR MODEL

Ukrainian econometricians often face a shortage of observations necessary for providing precise answers to complex macroeconomic questions. Recent studies have shown that the Bayesian Estimation approach can solve this problem as it is partially based on nonsample information. In this paper the theoretical analysis and practical application of using the Bayesian Estimation is presented. A bivariate VAR(2) model has been build to estimate quarterly GDP growth and CPI for Ukraine using Gibbs sampling and a Minnesota prior The empirical results show robust correlation between the estimate and actual quarterly GDP and CPI figures, indicating the ability of the Bayesian Estimation to provide a high level of accuracy in macromodels of Ukraine.

Keywords: Bayesian Estimation, Gibbs sampling, Minnesota prior, random walk, the Inverse Wishart Distribution, bivariate VAR.

Introduction

One of the goals of econometric analysis on macro level is to provide quantitative answers to major macroeconomic questions. Some questions require high-dimensional empirical models. For instance, the analysis of the effect of external sector on economic growth might involve processing information from a large cross section of macroeconomic and financial variables. But, sometimes, sample information alone is not enough to enable sharp inference about model parameters and implications. Moreover, in some countries, Ukraine in particular, the statistical database is extremely poor due to short history of the country and its statistical institutions. Other questions do not necessarily require a very densely parameterized empirical model, but they do demand identification restrictions that are not obvious and that are highly questionable in the empirical literature. Thus, documenting the uncertainty associated with empirical findings or forecasts is of first-order importance for scientific reporting [1].

In 1980 Sims first proposed that VARs should replace large-scale econometric models inherited from the 60s, because the latter put incredible restrictions that were largely inconsistent with the notion that economic agents take the effect of today`s choices on tomorrow`s utility into account. As a result, it became widely used in macroeconomic modeling. However, the problem still remains in the quality of forecasts if the number of dependent variables is large. Meanwhile, Bayesian approach has proved to be very useful in small sample sized models, as it uses prior nonsample information that allows the researcher to get more accurate forecasts not having reliable database. The Bayesian VAR model can also be seen as an alternative to the use of factor models or panel vector autoregression in the analysis of large dynamic systems. To sum up, this kind of models has become increasingly popular mainly for the following reasons. First of all, it allows estimation of highly complicated models. Secondly, it provides usable results in small samples, which is particularly important for countries with weak statistical database like Ukraine. Thirdly, there is a strong evidence of improved forecasting performance. This paper introduces Gibbs sampling and Minnesota prior within Bayesian Estimation and applies them to VAR model.

Literature review

A substantive review of theoretical and applied Bayesian methods can be found in various studies. The most prominent works were done by Kim and Nelson [2], Koop and Korobilis [3] and [4], Litterman [5], Zelner [6] and others. For example, in [3] a complex analysis of Bayesian approach to macroeconomic multivariable time series has been done as well as considerable investigation of parameterization problem. In [4] the Bayesian approach was thoroughly investigated including Gibbs sampling and the choice of VAR variables for Great Britain`s economy. Meanwhile, Bayesian methods slowly gain popularity among Ukrainian scientists too. For example, in [7] the main aspects of Bayesian estimation regarding the mathematical and statistical models of the processes of arbitrary nature are described using numerical Monte Carlo method in the analysis of stochastic volatility. In [8] the practical application of Bayesian approach for parameters estimation of vector autoregressive model with different priors have been done and comparative analysis of nineteen received models was studied. However, still, there is a lack of academic work on the use of Bayesian Estimation in vector autoregressive macromodels for Ukraine.

Purpose of the research

The main purpose of the research is to provide fundamental theoretical analysis and practical application of the Bayesian Estimation for Ukraine's macromodels by building and analyzing the bivariate VAR (2) model using Gibbs sampling and a Minnesota prior.

Results

In general, the logic behind the Bayesian Estimation can be broken down in to several steps. First, gathering prior information about the analyzed parameter. It is usually based on the history of its functioning and the professional theoretical judgment of nature of the analyzed process. All mentioned above information must be collected at this stage in order to derive prior distribution function which is basically a probability function (discrete case) or density distribution function (continuous case) of analyzed parameter. Second, obtaining the raw statistical data required for likelihood function. All the observations that are given for the analyzed parameter must be gathered. Third, likelihood function definition. This is the information from the statistical data. In other words, likelihood function is the conditional function that returns statistical data on the condition of the analyzed parameter. Finally, derivation of posterior distribution. This is the distribution that can be obtained by applying Bayesian Theorem. Basically, this theorem combines the prior distribution and the likelihood function to evaluate the posterior distribution. Stated succinctly, posterior distribution is the update prior distribution function on the basis of the information in the data.

So, the whole process looks pretty simple, a prior distribution is updated by sample information contained in the likelihood function to form a posterior distribution. Thus, as the prior is based on non sample information, it provides the ideal framework for combining different sources of information and, by this means, sharpening inference in econometric analysis. Meanwhile, the process of applying Bayesian approach poses a number of crucial questions for the researcher. First, how to determine the "right prior distribution" of the analyzed parameter. Here, different a number of strong theories and methods can be applied. Second, how to overcome mathematical difficulties of obtaining posterior distributions in case of complex processes. The thing is that obtaining posterior distribution requires integration. But evaluating the integral is difficult or even impossible in some cases. This used to be the main obstacle in Bayesian analysis, but now numerical methods can be used to calculate the joint and marginal posterior distributions. One of the solutions to the latter problem is Gibbs sampling – a numerical method that uses conditional distributions to approximate the marginal distribution. In case of VAR modeling the Gibbs sampling algorithm can be described in the following steps. First, the priors for the VAR coefficients and the covariance matrix must be set. The prior for the VAR coefficients is normal and the prior for the covariance matrix of the residuals is inverse Wishart distribution (which is multivariate version of the inverse Gamma). Second, VAR coefficients must be sampled from their conditional posterior distribution. Finally, covariance matrix of the residuals is derived from its conditional distribution. But, theoretically more appealing is, in addition to Gibbs sampling, use soft restrictions that can be easily incorporated through probability distributions for those coefficients that are "centered" at the desired restrictions but that have a small, yet nonzero, variance. An important and empirically successful example of such a prior is the Minnesota prior [1]. The Minnesota prior assumes that the mean of the prior distribution is a random walk. In case of Minnesota prior the prior is not imposed exactly but a covariance matrix for each equation is specified in terms of certain hyper parameters.

So, the methodological framework of this paper covers Gibbs sampling and Minnesota prior applied to bivariate VAR(2) model of GDP growth rate and inflation. The model relies on a data set of quarterly observations from 1996Q1 to 2013Q2 for GDP growth and CPI of Ukraine.

As was mentioned above, Minnesota prior incorporates the belief that both variables follow a random walk. While annual CPI inflation may be nonstationary, annual GDP growth is likely to be less persistent. Hence, one may want to consider introducing the belief that this variable follows an AR (1) process in actual applications [9]. The inverse Wishart prior was used for the covariance matrix. The constructed model produces the predictive density and make the forecast of the GDP growth and inflation for the ten following periods.

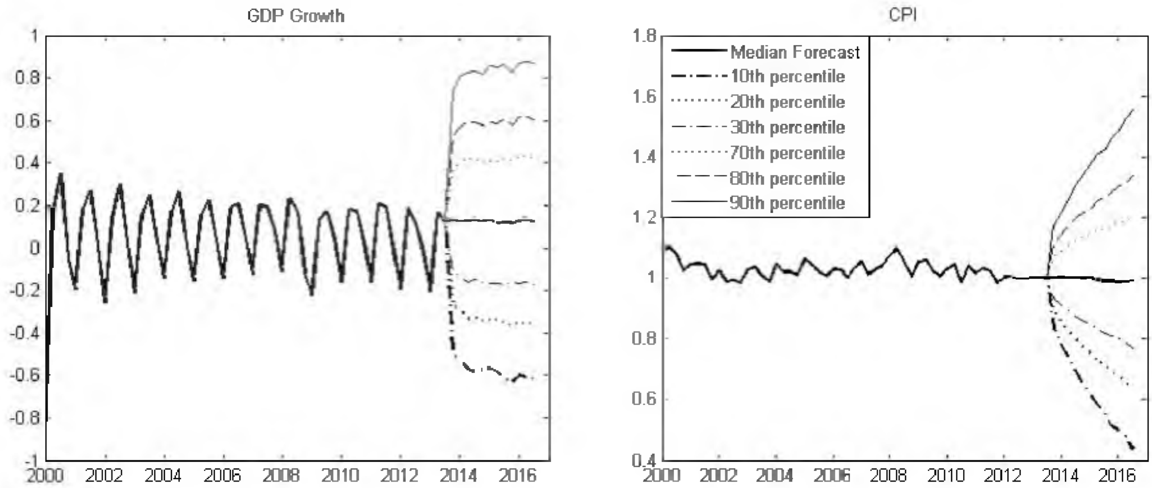

Fig. 1. Forecast for annual GDP growth and inflation using bivariate VAR(2) with Minnesota prior

Table 1. **Forecast for quarterly GDP growth using bivariate VAR(2) with Minnesota prior**

Year\ Percentile	50	10	20	30	70	80	90
2013-Q2	0.12	-0.53	-0.29	-0.14	0.40	0.57	0.81
2013-Q3	0.12	-0.57	-0.33	-0.16	0.42	0.60	0.82
2013-Q4	0.13	-0.58	-0.33	-0.15	0.42	0.59	0.83
2014-Q1	0.12	-0.58	-0.34	-0.16	0.40	0.58	0.82
2014-Q2	0.13	-0.57	-0.34	-0.17	0.41	0.59	0.85
2014-Q3	0.11	-0.58	-0.34	-0.17	0.41	0.58	0.85
2014-Q4	0.12	-0.61	-0.36	-0.17	0.42	0.61	0.86
2015-Q1	0.12	-0.63	-0.36	-0.16	0.41	0.58	0.83
2015-Q2	0.13	-0.60	-0.36	-0.17	0.43	0.61	0.87
2015-Q3	0.13	-0.61	-0.36	-0.16	0.44	0.62	0.88
2015-Q4	0.12	-0.61	-0.36	-0.17	0.42	0.60	0.87

Table 2. **Forecast for quarterly CPI using bivariate VAR(2) with Minnesota prior**

Year\ Percentile	50	10	20	30	70	80	90
2013-Q2	1.00	0.78	0.86	0.91	1.09	1.14	1.22
2013-Q3	1.00	0.74	0.82	0.90	1.11	1.17	1.26
2013-Q4	1.00	0.70	0.80	0.88	1.12	1.19	1.30
2014-Q1	1.00	0.65	0.78	0.86	1.13	1.22	1.34
2014-Q2	1.00	0.62	0.75	0.85	1.14	1.23	1.37
2014-Q3	1.00	0.58	0.73	0.83	1.16	1.25	1.41
2014-Q4	0.99	0.56	0.71	0.82	1.16	1.27	1.42
2015-Q1	0.99	0.51	0.69	0.81	1.18	1.29	1.46
2015-Q2	0.99	0.50	0.68	0.80	1.18	1.30	1.48
2015-Q3	0.99	0.48	0.66	0.79	1.19	1.32	1.53
2015-Q4	0.99	0.44	0.64	0.77	1.20	1.34	1.55

The quintiles of the predictive density are shown in fig. 1.

Table 1 shows the forecasts for the GDP growth from 2013Q3 to 2015Q4.

Table 2 shows the forecasts for the CPI from 2013Q3 to 2015Q4.

On this stage of the research the model was built mainly for the illustrative purposes to understand and show the main aspects and practical peculiarities of applying Bayesian Estimation to VAR macromodels and, therefore, includes only two variables. Nevertheless, the median forecast for both variables is very close to the consensus forecast for the years 2015–2016 of the Ministry of Economic Development and Trade of Ukraine. Moreover, forecasts for the estimated parameters are almost the same as the actual figures of CPI and GDP for the third and fourth quarter of 2013 reported by State Statistics Service of Ukraine.

Conclusion

Projecting distributions of future observations on macro level is of extreme importance for macro econometricians and policy makers. These distributions need to include different risks regarding structural shocks as well as uncertainty associated with estimated variables. Since shocks and variables are treated symmetrically in Bayesian framework, namely as random variables, accounting for these two sources of uncertainty simultaneously is conceptually straightforward. To the extent that fundamental analysis requires the researcher to consider multiple theoretical and empirical frameworks, Bayesian Estimation allows the investigator to assign probabilities to different model specifications and update these probabilities from data view [1]. Moreover, Bayesian approach allows estimation of parameters with small sample size. This is highly important for such countries as Ukraine that has only 23 years of market independent economy. So, with the proposed above characteristics this method becomes one of the key empirical tools in modern macroeconometrics.

Constructed in this paper VAR model is only a first attempt to apply Bayesian Estimation to econometric models of Ukraine`s economy. Nevertheless, the empirical results show strong correlation between the estimate and actual quarterly GDP and CPI figures. To sum up, it can be concluded that the study and application of Bayesian approach in relation to Ukraine`s econometric macromodels has a strong potential as it provides a high level of accuracy in forecasts for the Ukrainian economy.

Recommendations for future research

In general, obtained results lay the basis for further research of the effects of usage of Bayesian Estimation method to complex econometric macromodels of Ukraine. Further studies may relate either to expanding the described model by adding other parameters like interest rates of different types to investigate the GDP growth rate more precisely or experiments with model itself by adding new prior information and methods related to Bayesian Estimation in addition to Minnesota prior to improve the accuracy of the forecast.

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ПЕРЕВАГИ ЗАСТОСУВАННЯ БАЙЄСІВСЬКОГО ОЦІНЮВАННЯ ДО МАКРОМОДЕЛЕЙ УКРАЇНИ: ВИПАДОК ДВОМІРНОЇ ВЕКТОРНОЇ АВТОРЕГРЕСІЙНОЇ МОДЕЛІ

Українські економетристи часто стикаються з проблемою нестачі даних для проведення комплексного макроеконометричного аналізу. Останні дослідження показали, що байєсівське оцінювання може вирішити цю проблему, бо воно частково не залежить від вибірки спостережень. У цій роботі зроблено теоретичний аналіз байєсівського оцінювання та застосовано його на практиці. Побудовано двомірну векторну авторегресійну модель на щоквартальних даних приросту ВВП і ІСЦ для України з використанням вибірки Гіббса і Міннесота prior. Емпіричні результати показали стійку залежність між фактичними та оціненими показниками щоквартальних ВВП і ІСЦ, що вказує на здатність байєсівського оцінювання забезпечувати високий рівень точності в макроекономічних моделях України.

Ключові слова: байєсівське оцінювання, вибірка Гіббса, Міннесота prior, випадкове блукання, зворотний розподіл Уішарта, двомірна векторна авторегресійна модель.

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