[Bayesian Vector Autoregressions]

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Vector Autoregressions (VARs) are linear multivariate time-series models able to capture the joint dynamics of multiple time series. The pioneering work of Sims (1980) proposed to replace the large-scale macroeconomic models popular in the 1960s with VARs, and suggested that Bayesian methods could have improved upon frequentist ones in estimating the model coefficients. Bayesian VARs (BVARs) with macroeconomic variables were first employed in forecasting by Litterman (1979) and Doan et al. (1984). Since then, VARs and BVARs have been a standard macroeconometric tool routinely used by scholars and policy makers for structural analysis, forecasting and scenario analysis in an ever growing number of applications.

The aim of this article is to review key ideas and contributions in the BVAR literature, and to provide a brief introduction to estimation methods for BVARs in Economics, and selected applications such as forecasting, structural identification and scenario analysis.

We start by reviewing inference in BVARs, 'non-informative' and 'informative' priors, and methods to set the informativeness of the priors. Bayesian inference treats the VAR parameters as random variables, and provides a framework to update probability distributions about the unobserved parameters conditional on the observed data. Hence, the Bayesian approach allows to incorporate prior information – summarised by prior probability distributions about the location of the model parameters –, into post-sample probability statements. In the absence of pre-sample information, Bayesian VAR inference can be thought of as adopting 'non-informative' priors.

While non-informative priors can provide a useful benchmark, in empirical work with macroeconomic and financial variables informative priors are often adopted. The most commonly adopted macroeconomic priors for VARs are the the so-called 'Minnesota' priors (Litterman, 1980). Minnesota priors can be cast in the form of a Normal-Inverse-Wishart (NIW) prior, which is the conjugate prior for the likelihood of a VAR with normally distributed disturbances (see Kadiyala and Karlsson, 1997).

It is often useful to think of the parameters of a prior distribution – known as 'hyperparameters' – as corresponding to having observed a certain number of 'dummy' or 'pseudo-' observations with properties specified by the prior beliefs on the VAR parameters. Minnesota priors can be formulated in terms of artificial data featuring pseudo observations for each of the regression coefficients, and

that directly assert the prior on them. Dummy observations can also implement prior beliefs about relations among the VAR coefficients, such as e.g. co-integration among variables. In this case, commonly used priors are formulated directly as linear joint stochastic restrictions among the coefficients.

The hyperparameters of the prior distribution can be either fixed using prior information, or associated to hyperprior distributions that express beliefs about their values. A Bayesian model with more than one level of priors is called a hierarchical Bayes model. In empirical macroeconomic modelling, the hyperparameters associated with the informativeness of the prior beliefs (i.e. the tightness of the prior distribution) are usually left to the investigator's judgement. We discuss hierarchical modelling and common approaches to choose hyperparameters not specified by prior information.

We then move on to review common applications of Bayesian VARs. BVARs have been applied to an increasingly large number of empirical problems. Forecasting, however, has featured predominantly in the development of BVARs. BVARs with informative priors have often proved to be superior tools compared to standard frequentist/flat-prior VARs. The application of Bayesian techniques to 'big data' problems is one of the most active frontiers in the BVAR literature. Indeed, because they can efficiently deal with parameters proliferation, large BVARs are valuable tools to handle empirical analysis in data-rich environments (Bańbura et al., 2010). In this sense, BVARs are connected to factor models, another popular way to handle large datatsets (De Mol et al., 2008). Important applications in this case also concern forecasting and structural analysis, where large-information BVARs can efficiently address issues related to misspecification and non-fundamentalness.

Finally, we discuss Bayesian inference in VAR models that relax the assumption of fixed coefficients in order to capture changes in the time series dynamics of macroeconomic and financial variables, such as VARs with autoregressive coefficients, threshold and Markov switching VARs.