



# Model averaging in risk management with an application to futures markets<sup>☆</sup>

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## ABSTRACT

This paper considers the problem of model uncertainty in the case of multi-asset volatility models and discusses the use of model averaging techniques as a way of dealing with the risk of inadvertently using false models in portfolio management. Evaluation of volatility models is then considered and a simple Value-at-Risk (VaR) diagnostic test is proposed for individual as well as ‘average’ models. The asymptotic as well as the exact finite-sample distribution of the test statistic, dealing with the possibility of parameter uncertainty, are established. The model averaging idea and the VaR diagnostic tests are illustrated by an application to portfolios of daily returns on six currencies, four equity indices, four ten year government bonds and four commodities over the period 1991–2007. The empirical evidence supports the use of ‘thick’ model averaging strategies over single models or Bayesian type model averaging procedures.

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## 1. Introduction

Multivariate models of conditional volatility are of crucial importance for optimal asset allocation, risk management, derivative pricing and dynamic hedging. However, their use in practice has been rather limited, particularly in the case of portfolios with a large number of assets. There are only a few published empirical studies that consider the performance of multivariate volatility models involving a large number of assets, and for operational reasons most of these studies focus on highly restricted versions of the multivariate generalized autoregressive conditional heteroscedastic (GARCH) model of Bollerslev (1986). The risk associated with possible model misspecification could then be sizeable. Also for riskmanagement purposes, the main focus is often on the tail behavior of the predictive density of the asset returns, and not simply to obtain the ‘best’ approximating volatility model. This in turn implies that a unified treatment of empirical portfolio analysis requires shifting the focus from a statistical to a decision-

<sup>☆</sup> This is a substantially revised version of a paper previously circulated under the title of “Model Averaging and Value-at-Risk based Evaluation of Large Multi Asset Volatility Models for Risk Management”. The present version deals with active as well as passive risk management problems under model uncertainty. We are grateful to the Editor, three anonymous referees, and the participants of the 2007 London-Oxford Financial Econometrics Study Group, in particular Enrique Sentana for constructive comments and suggestions. We would also like to thank GSA Capital for allowing us to use data from their futures data base for this paper.

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theoretic framework for model evaluation. This paper provides an integrated econometric approach to the portfolio optimization subject to the Value at Risk (VaR) constraint in the presence of model uncertainty, and the associated risk monitoring problem.<sup>1</sup> In this paper we focus on uncertainty of multivariate volatility models and abstract from return prediction uncertainty already addressed extensively in the literature.<sup>2</sup> One of the main contributions of the paper is to solve the mean-variance optimization problem subject to the VaR constraint when a probabilistic average of several models is used to take account of model uncertainty. This optimization strategy assumes the existence of conditional return volatilities, but allows the conditional distribution of returns to be non-Gaussian. The various practical issues involved in implementation of such an strategy are discussed and evaluated in the context of an empirical application.

Many variants of the multivariate GARCH have been proposed in the literature. These include the conditionally constant correlation (CCC) model of [Bollerslev \(1990\)](#), the Risk-metrics specifications popularized by [J.P.Morgan \(1996\)](#) and used predominantly by practitioners, the orthogonal GARCH model of [Alexander \(2001\)](#), and the dynamic conditional correlation (DCC) model advanced by [Engle \(2002\)](#).<sup>3</sup> Recent surveys are provided in [Bauwens et al. \(2003\)](#) and [McAleer \(2005\)](#). Multivariate stochastic volatility (SV) models have also been considered in the literature, with reviews by [Ghysels et al. \(1995\)](#) and [Shephard \(2005\)](#).<sup>4</sup> We consider models frequently used by practitioners together with many models recently proposed in academic papers, and consider their empirical performance within a decision-theoretic framework.

The highly restricted nature of the multivariate volatility models advanced in the literature could present a high degree of model uncertainty which ought to be recognized at the outset. This is particularly important since due to data limitations and operational considerations it is not possible to subject these models to rigorous statistical testing. Application of model selection procedures also involves additional risks that are difficult to assess *a priori*. This is especially true when the number of assets is moderately large, and it might well be that no single model choice would be satisfactory in practice.

This paper considers model averaging as a risk diversification strategy in dealing with model uncertainty, and provides a detailed application of recent developments in model averaging techniques to multi-asset volatility models. Frequently used model selection criteria are the Akaike Information Criterion (AIC) and the Schwartz Bayesian Information Criterion (SBC). However, such a two-step procedure is subject to the pre-test (selection) bias problem and tends to under-estimate the uncertainty that surrounds the forecasts. Of course, the use of model averaging techniques in econometrics is not new and dates back to the work of [Granger and Newbold \(1977\)](#) on forecast combination.<sup>5</sup> However, this literature focusses on combining point forecasts and does not address the problem of combining forecast probability distribution functions which is relevant in risk management.

Concerning model evaluation, the standard forecast evaluation techniques that focus on metrics such as root mean square forecast errors (RMSFE), also run into difficulties when considering volatility models. Since volatility is not directly observable, it is often proxied by the square of daily returns or more recently by the standard error of intra-daily returns, known as realized volatility (see, for example, [Andersen et al. \(2003\)](#)). In multi-asset contexts the use of standard metrics such as RMSFE is further complicated by the need to select weights to be attached to errors in forecasts of individual asset volatilities and their cross-volatility correlations and the choice of such weights is not innocuous in a multivariate framework (see [Pesaran and Skouras \(2002\)](#)). Here we develop a simple criterion for evaluation of alternative volatility forecasts by examining the Value-at-Risk (VaR) performance of their associated portfolios. Our test, which can be applied to individual as well as to average models, belongs to a class of so-called unconditional coverage tests, the most important case of which is the [Kupiec \(1995\)](#) binomial test. In contrast to the existing literature, though, we formally establish both the asymptotic as well as the exact finite-sample distribution of our test statistics. Further, we provide formal conditions that ensure that the asymptotic distribution of the familiar VaR diagnostic test statistics do not depend on the sampling variability associated with parameter estimation. Conditional coverage tests (see [Christoffersen \(1998\)](#)) and density forecast tests ([Crnkovic and Drachman \(1997\)](#) and [Berkowitz \(2001\)](#)) could also be adapted to our model averaging framework, although the related distribution theory will need to be established. For a review of existing approaches to the evaluation of the VaR estimates see [Andersen et al. \(2006\)](#). The VaR based diagnostic tests developed in this paper can be used both for risk monitoring of a given portfolio as well as for construction of optimal (in the VaR sense) portfolios.

The remainder of the paper is organized as follows: the decision problem that underlies the VaR analysis is set out in Section 2. Section 3 provides a brief outline of the different types of multivariate volatility models considered in the paper. Several approaches to model averaging are reviewed and discussed in Section 4. Section 5 introduces the Value-at-Risk (VaR) diagnostic test and establishes its finite-sample as well as its asymptotic distribution. Section 6 provides a detailed empirical analysis using daily returns for eighteen futures contracts covering equity indices, government bonds, exchange rates and commodities over the period 2 January 1991 to 11 July 2007. Section 7 concludes with a summary of the main results and suggestions for future research. The mathematical proofs and a description of the multivariate volatility models are provided in three appendices.

<sup>1</sup> It is also possible to consider measures of down-side risk other than VaR, such as expected short-falls. The VaR has the advantage of being analytically more tractable and its use in risk management is by far the most popular. For these reasons we shall confine our risk analysis to VaR constraints and leave the use of other risk measures to future research.

<sup>2</sup> See, for example, [Pesaran and Timmermann \(1995\)](#).

<sup>3</sup> The DCC model is also related to the VCC model of [Tse and Tsui \(2002\)](#).

<sup>4</sup> So far the focus of the SV literature has been on univariate and multivariate models with a small number of assets, with the notable exceptions of [Diebold and Nerlove \(1989\)](#), [Engle et al. \(1990\)](#), [King et al. \(1994\)](#) and [Harvey et al. \(1994\)](#), that are similar in structure to the class of factor GARCH models that we do consider below.

<sup>5</sup> For reviews of the forecast combination literature see [Clemen \(1989\)](#), [Granger \(1989\)](#), [Diebold and Lopez \(1996\)](#) and [Hendry and Clements \(2002\)](#).

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