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## Review

## Frontiers in VaR forecasting and backtesting

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## ABSTRACT

The interest in forecasting the Value at Risk (VaR) has been growing over the last two decades, due to the practical relevance of this risk measure for financial and insurance institutions. Furthermore, VaR forecasts are often used as a testing ground when fitting alternative models for representing the dynamic evolution of time series of financial returns. There are vast numbers of alternative methods for constructing and evaluating VaR forecasts. In this paper, we survey the new benchmarks proposed in the recent literature. © 2015 International Institute of Forecasters. Published by Elsevier B.V. All rights reserved.

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## 1. Introduction

“The advantage of knowing about risks is that we can change our behaviour to avoid them” (Engle, 2003).

The value at risk (VaR) measures the potential loss in value of a risky portfolio over a defined period of time for a given probability. Forecasting VaR has attracted a great deal of attention in the financial econometrics literature, due to its relevance for financial and insurance institutions. Some adverse results in the past have forced the agencies that regulate financial activity to look for a quantitative way of defining the risk associated with a given position in the market; see Granger (2002) for alternative definitions and measures of risk. The Basel accords explicitly recognize the role of VaR as a measure that financial institutions must implement and report in order to monitor their financial risk and determine the amount of capital that is subject to regulatory control. Consequently, VaR is now established as the most popular risk measure for controlling and managing market risk. Although VaR has been analyzed mainly as a measure of risk associated with financial institutions, the recent Solvency 2 regulation also establishes it as the risk measure to be considered by insurance companies that are operating in the European Union; see Dowd and Blake (2006) and Sandström (2011) for descriptions of applications of VaR in the insurance sector. The recent deregulation has also heightened the importance of risk management in electricity markets; see for example Chan and Gray (2006). All in all, forecasting VaR is crucial for many different sectors.

From a methodological point of view, VaR is a quantile of the density of returns, and forecasting quantiles raises several issues of interest. Furthermore, the forecasting of VaR is also important because it is implemented routinely as an empirical check for alternative models for forecasting conditional means and variances; see for example Asai and McAleer (2008), Brownlees and Gallo (2010), Grigoletto and Lisi (2009), Martens, van Dijk, and Pooter (2009), and Wilhelmsson (2009), among many others.

In this paper, we survey recent methodological and empirical developments in VaR forecasting and testing, updating previous surveys in the literature; see Chen and Lu (2012), Christoffersen (2009), Gouriéroux and Jasiak (2010a), and Kuester, Mittik, and Paoletta (2006) for previous surveys, and Christoffersen (2012), Dowd (2007), Danielsson (2011), Embrechts, Klüppelberg, and Mikosch (2000), Jorion (2006), and McNeil, Frey, and Embrechts (2005) for comprehensive textbooks. Given that the number of recent contributions related to VaR forecasting and testing is extremely large, we attempt to focus this survey by describing only univariate models, putting aside the interesting discussion on multivariate VaR forecasts. Furthermore, we consider only the VaR on the left tail of the distribution of returns, as it has attracted most of the interest in the literature. Finally, note that

although the Basel accords require daily forecasts of the VaR for returns over a holding period of 10 days, they do allow these forecasts to be obtained from returns over shorter holding periods by using the square-root-of-time-rule. Consequently, we focus on daily one-step-ahead VaR forecasts that correspond to returns over a holding period of one day.<sup>1</sup> Moving to daily one-step-ahead forecasts of the VaR corresponding to returns over a holding period of 10 days, as required by the Basel accords, raises interesting forecasting issues.

The rest of the paper is organized as follows. Section 2 describes the VaR and establishes the notation. Section 3 is devoted to the description of alternative procedures for point VaR forecasting, while Section 4 deals with the construction of VaR forecast intervals. Section 5 describes backtesting procedures. Section 6 describes empirical implementations of VaR forecasting. Finally, Section 7 concludes the paper.

## 2. VaR as a risk measure

“VaR is defined as a *worst-case scenario on a typical day*”. (McAleer, 2009).

The VaR is defined as the  $100\alpha\%$  quantile of the distribution of returns, such that, at time  $t$ , there is an  $100\alpha\%$  probability that the return of a portfolio over a one-day holding period,  $R_t$ , will fall below it. By regulatory convention, the VaR is positive; consequently, it is given by

$$\text{VaR}_t^\alpha = -\sup [r \mid P [R_t \leq r] \leq \alpha]. \quad (1)$$

The probability in Eq. (1) is usually defined with respect to the distribution of returns, conditional on the information available at time  $t - 1$ .<sup>2</sup>

The Basel accords describe a standard approach to obtaining VaR forecasts which is known to produce VaR estimates that are larger than necessary, leading to excessively high capital requirements (CR); see for example McAleer (2009), Pérignon, Deng, and Wang (2008) and Pérignon and Smith (2010b). Alternatively, the accords allow financial institutions to use internal models to forecast their VaR. From the perspective of financial institutions, it is undesirable to use the standard approach, given that regulatory capital involves an opportunity cost. Hence, they have an incentive to use their own VaR forecasts; see Pérignon and Smith (2008), who present empirical evidence that the use of internal models is widespread among large financial institutions. Although internal VaR models are subject to supervisory approval based on qualitative

<sup>1</sup> We focus on the horizon allowed by the Basel accords. However, the VaR horizon required in other sectors could be different.

<sup>2</sup> Some authors instead define the VaR with respect to the marginal distribution of returns; see for example Lien, Yan, and Ye (2014).

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