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——基于g-h分布和VaR方法的理论与实证研究

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摘　要

风险价值(Value-at-Risk,以下简称 VaR),是目前金融市场风险管理和金融监管的主流方法,它被用来度量某个金融资产或投资组合在一定的持有期内和给定的置信水平下的最大可能损失,是一个明确且能全面反映金融资产或投资组合所承受风险的测度,简单清晰地表示市场风险的大小,又有严谨系统的概率统计理论做依托,克服了过去风险度量方法只能针对特定的金融工具或在特定的范围内使用,不能综合反映风险的局限,因而得到了国际金融界的广泛支持和认可。国际性研究机构 30 人小组、国际掉期交易商协会、国际清算银行和巴塞尔委员会等团体一致推荐,将 VaR 作为市场风险测量和控制的最佳方法。目前 VaR 已被全球各主要银行、非银行金融机构、公司和金融监管机构广泛采用。

然而,VaR 理论还有很多方面需要进一步研究,主要表现在:1. 不同的 VaR 方法计算所得的 VaR 并不相同。至今还没有一个既简单方便又准确的 VaR 方法。2. 虽然传统的 VaR 计算方法已经对金融资产或投资组合回报中的厚尾现象进行了较为细致的研究,但是绝大多数研究都没有结合回报中同时具有的不对称现象,只是估计计算,没有彻底地解决这一问题。3. 对 VaR 方法的评价研究大多集中在准确性评价方面,很少有保守性和有效性方面的研究。至今,还没有一个 VaR 评价的明确规范和评价体系。现有的评价研究大多是对某种 VaR 方法的蒙特卡洛模拟,而不是实证研究,还无各种 VaR 方法及其评价方法间的比较研究,也无法鉴别各种评价方法的

有效性和实用性。4. 目前，国内外对投资组合 VaR 及其分解研究相对较少。虽然近期有些学者做出了一些尝试，但都具有相当强的约束条件，即假定投资组合回报分布服从正态分布或双变量椭圆分布，显然这与组合实际回报中存在的不对称现象和厚尾现象严重不符。此外，如何分解由非参数方法（历史模拟法和蒙特卡洛模拟法）和半参数方法（极值理论方法）计算出来的投资组合 VaR 还有待进一步研究。

为此，本书在总结国内外现有 g-h 分布和 VaR 研究成果的基础上，以基于 g-h 分布的 VaR 计算方法——g-h VaR 法为研究对象，以统计学、金融学为研究工具，以定量实证研究为主，结合定性分析讨论，集中深入地研究了基于 g-h VaR 法的金融风险管理理论，提出了基于 g-h 分布的蒙特卡洛模拟法的 g-h MC 法与基于 g-h 分布的 VaR 参数方法的三个 g-h VaR 模型（根据 g-h 分布可对分布、分布左侧和分布左尾部分分别建模的统计特性，提出了基于金融资产或投资组合回报损益、损失、极端损失的 g-h VaR 参数模型），给出了参数估计方法，阐述了各方法的性质、特点和应用，建立了 VaR 方法的评价体系，给出了投资组合 VaR 分解的一般过程，提出了全局最小二乘法、非对称响应模型估计法、局部线性近似估计法和理性近似估计法四种分解方法，填补了 VaR 理论在这些方面的空白。

本书的主要研究工作及成果可归纳如下：

1. 第一章在系统地阐述 VaR 理论研究现状的基础上，分析了研究中存在的不足，在此基础上提出了本书所要解决的问题。

2. 第二章介绍了金融风险的概念、特点和分类，详细地分析了金融市场风险管理的动因、功能和管理过程，深入讨论了金融市场风险度量方法及其历史演变，以及金融市场风险的度量框架。

3. 第三章阐述了 VaR 的历史演变，详细地介绍了 VaR 的概念、优缺点、替代方法和应用，分析了 VaR 的参数选择及其影响因素，深

入讨论了 VaR 的计算方法。通过对现有 VaR 计算方法的比较，指出了各种计算方法(参数法、非参数法和半参数法)的不足，及如何根据实际需要选择不同的计算方法。

4. 第四章首先围绕证券回报的厚尾现象和不对称现象，分别从文献、概念和测量等方面对其进行了详细地介绍，从组合回报分布和波动性两个角度讨论了两者对 VaR 计算的影响，综述了描述厚尾现象和不对称现象的各种统计分布，指出了它们的特性及优缺点，讨论了具有厚尾性和不对称性的 GARCH 模型，为接下来的研究做了理论上的铺垫；然后，构建了基于 g－h 分布的 VaR 计算方法体系，提出了基于 g－h 分布的蒙特卡洛模拟法、g－h MC 法，根据 g－h 分布可以对整个分布、分布左侧以及分布的左尾部分分别建模的统计特性，提出了基于金融资产或投资组合损益、损失以及极端损失的三个 g－h VaR 参数模型，并应用 g－h VaR 法度量了金融资产的市场风险；最后，通过实证研究表明，在低置信水平(95%)下，g－h VaRⅢ明显低估了风险，而遭到拒绝，其他方法都比较准确，在中高置信水平(97.5%、99%、99.5%、99.9%)下，g－h VaRⅢ表现得最为出色，这说明 g－h VaRⅢ对极端市场条件下的风险度量更为准确，而其他三种方法明显有些保守，高估了风险，总体上看，g－h VaRⅠ、g－h VaRⅡ和 g－h MC 在各个置信水平上表现得都比较准确，而 g－h VaRⅢ更适合在中高置信水平下度量风险。

5. 第五章构建了 VaR 方法评价的基本框架，应用多种统计方法对 VaR 方法进行了保守性、准确性和有效性评价。该章详细介绍了 VaR 的评价方法：用于保守性评价的均值相对误差和均值平方根相对误差、用于准确性评价的失败检验法和损失函数检验法、用于有效性评价的标准覆盖乘子法和分布预测检验法；比较了各种评价方法的优缺点；指出了其各自的适用范围，试图为中国金融市场风险管理的规范化发展提供理论和经验参考。在此基础上，评价了 g－h VaR 法的表现，并将之与两种非参数计算方法(历史模拟法、基于正态分

布假设的蒙特卡洛模拟法)、四种参数方法或模型(GARCH 模型、LGARCH 模型、RiskMetric 方法、Delta-Normal 方法)以及半参数方法的极值理论方法进行了比较研究。结果表明:(1) 随着置信水平的增加,基于 g-h 分布的四种 VaR 计算方法、历史模拟法和极值理论方法的保守性不断增强;而 MC-Normal、Delta-Normal、GARCH、LGARCH 与 RiskMetric 方法的均值相对误差则逐渐地减少,保守性不断减弱。这表明前六种方法在较高置信水平下得到了较高的风险度量,减少了投资者在极端市场条件下的损失,但增加了风险成本,而后五种 VaR 计算方法则恰恰相反。(2) 失败检验法和损失函数法的准确性的评价结果基本一致。在中低置信水平下,历史模拟法、g-h VaRⅠ和 g-h VaRⅡ准确地度量了风险;g-h VaRⅢ方法低估了风险;其他七种方法高估了风险。在较高的置信水平下,g-h VaRⅢ方法准确地度量了风险;极值理论方法、g-h VaRⅠ、g-h VaRⅡ与 g-h MC 法显得过于保守,高估了风险;历史模拟法低估了风险;MC-Normal、Delta-Normal、RiskMetric 和 GARCH 类方法明显地低估了风险。(3) 在中低置信水平下,各 VaR 方法的有效性差异不大。在 95% 的置信水平下,g-h VaRⅠ、g-h VaRⅡ、g-h MC、历史模拟法和 GARCH 类方法较为有效,其他方法有效性较差。在 97.5% 的置信水平下,GARCH 类方法和历史模拟法最为有效。在较高的置信水平下,各 VaR 方法的有效性有较大的差异。在 99% 和 99.5% 的置信水平下,基于 g-h 分布的四种方法、极值理论方法和历史模拟法较为有效,而 GARCH 类方法最为保守。在 99.9% 的置信水平下,g-h VaRⅢ表现得最为有效,四种 g-h VaR 方法都比较保守,高估了风险。其中极值理论方法最为保守。

6. 第六章详细地阐述了边际 VaR、成分 VaR 和增量 VaR 的概念、含义和相互关系,提出使用 g-h VaR 方法计算投资组合 VaR,提出了全局最小二乘法、非对称响应模型估计法、局部线性近似估计法和理性近似估计法四种投资组合 VaR 分解方法,对边际 VaR、成

分 VaR 和增量 VaR 进行了估计计算，分解了基于 g－h VaR 方法计算出的投资组合 VaR。结果表明：全局最小二乘法、非对称响应模型估计法分别使用了组合回报的损益数据、损失数据，对组合中各资产回报和组合回报间的关系取一阶线性近似，计算简单、便捷。相比之下，非对称响应模型估计法只需对回报的损失数据进行建模，对数据的要求更少，应用范围更广，当组合回报不对称现象明显时，该方法表现得更为出色。局部线性近似估计法是一种在组合 VaR 附近取线性近似的分解方法，只需要 VaR 附近少量的回报数据，适合包括极值理论方法在内的所有 VaR 计算方法估计出的投资组合 VaR 的分解，可同时处理组合回报具有的不对称现象和厚尾现象，但也较为复杂。通过对投资组合 VaR 分解为投资者和金融监管方提供了更多有关组合市场风险的信息，使资产组合管理者能更全面地了解投资组合风险的内在结构，调整组合资产和优化资本配置。

7. 第七章对全书进行了总结，并对今后的研究做出了展望。

本书主要特色和创新有：

1. 建立了基于 g－h 分布的 VaR 计算方法——g－h VaR 法的理论分析框架。提出了基于 g－h 分布的蒙特卡洛模拟方法：g－h MC法；提出了基于 g－h 分布的 VaR 参数计算方法，即根据 g－h 分布可对分布、分布左侧和分布左尾部分分别建模的统计特性，提出了基于金融资产或投资组合回报损益、损失、极端损失的三个 g－h VaR参数模型。

2. 提出了使用 g－h VaR 法度量市场风险。分别应用基于回报损益、损失、极端损失的 g－h VaR 参数模型以及基于 g－h 分布的蒙特卡洛模拟方法 g－h MC 法对金融资产和投资组合的市场风险进行了度量。

3. 提出了全局最小二乘法、非对称响应模型、局部线性估计法和理性近似估计法四种方法分解投资组合 VaR。使用全局最小二乘法、非对称响应模型和局部线性估计法对投资组合 g－h VaR 进行了

分解研究。

4. 构建了 VaR 计算方法的评价体系，即保守性评价、准确性评价和有效性评价。使用多种统计方法对 g－h VaR 法及其他 VaR 方法进行了评价研究，并将 g－h VaR 方法与各种 VaR 方法进行了比较。结果表明：g－h VaR 法是一种准确、有效且较为保守的 VaR 方法。

ABSTRACT

VaR, Value-at-Risk, is the mainstream method for risk management and regulatory in the financial market. It has been used to measure the possible loss of a portfolio or a financial asset with a given duration and confidence level. VaR, based on the probability and statistics theory, can precisely measure the financial assets or portfolio risk and overcome the disadvantages of the current risk measurement methods used only as the special financial tools or in the certain areas. So VaR has been recognized and supposed by the international financial circles. Some institutions, such as G-30 and BIS, have recommended VaR as the most powerful market risk measurement method. Now, VaR has been widely used by the famous banks and corporations, financial institutions and regulatories.

But VaR theory is not perfect. It has some disadvantages as followed: Firstly, Different VaR method can get different VaR value. There still haven't been a simple and precise VaR method untill now. Secondly, although the traditional VaR methods have studied the fat-tailness in the portfolio return, most of them have some restrictions, and fail to combine the asymmetry of the portfolio return in the VaR calculation. Thirdly, there is a little bit attention on evaluating VaR methods. Although some people have

done some works on this problem, they mainly focus on the accuracy evaluation and ignore the conservatism evaluation and efficiency evaluation. Most of the existed literatures are Monte Carlo simulation rather than empirical study. Furthermore, there is no comparison among the different evaluation methods, or study on the efficiency and robustness of the evaluation methods. Finally, the current literatures about decomposing portfolio VaR all have some constraints because of the assumption that the portfolio return follows the normal distribution or a bivariate elliptical distribution. These assumptions do not match the asymmetry and fat-tailness seriously.

By concluding the current literature, this dissertation establishes the risk management theory based on g-h VaR method. Using the g-h VaR method as research method, this paper presents three parametric g-h VaR models based on profit & loss, loss and extreme loss of financial assets or portfolio return, and g-h Monte Carlo method based on the g-h distribution, investigates the parameter estimation method, sets forth the properties, characters and applications, sets up the evaluation system of VaR methods, presents the commonly procedure of decomposing portfolio VaR, and finally puts forwards four kinds of decomposing methods, fills up the blankness of VaR theory.

The main contents and conclusions are summarized as follows:

1. This dissertation analyzes the shortage in the current literature after setting forth the status of VaR theory, and finds the solution.

2. The second chapter introduces the concepts, characters and types of financial risk firstly, and then analys the reasons,

functions and management progress of financial risk, discusses the measurement methods and framework of fiancial risk measurement finanly.

3. The third chapter shows the historical evolvement of VaR, introduces the concept, advantages and disadvantages, substitute method and application, analyses the parameter preference of VaR, and discusses the calculation methods of VaR in detail. By comparing the existed methods, it puts forward the shortages of the different calculation methods (parametric method, nonparametric method and semiparametric method) and how to choose these methods based on the realistic requirements.

4. The fourth chapter detailedly introduces the fat-tailness and asymmetry in the financial assets or portfolio return according to the literature, concept and measurement, discusses how these two phenomena influence the VaR calculation, summarizes the different distributions that describes these two phenomena, puts forward their properties, advantages and disadvantages, and discusses the GARCH models that have fat-tailness and asymmetry. All things have done here can pave the road for the following research. Then we constructs VaR calculation system based on the g-h distribution, presents the Mente Carlo simulation method based on g-h distribution, puts forward three parametric g-h VaR models based on profit & loss, loss and extreme loss of financial assets or portfolio return according to the statistical properties of g-h distribution that can model the whole, left and tail of the distribution separately. The study shows that, under the low confidence level, g-h VaR Ⅲ method is refused because of underestimating the risk, the other three methods is accuracy and

accepted; under the middle and high confidence level, g-h VaR Ⅲ performs best which indicates this method measures most precisely in the extreme market condition, the other three methods is conservative obviously. As a whole, g-h VaR Ⅰ, g-h VaR Ⅱ and g-h MC measure accurately, and g-h VaR Ⅲ is more adaptable to measure risk under middle and high confidence level.

5. The fifth chapter sets up the evaluation system of VaR methods, and uses some statistical methods to evaluate the conservatism, accuracy and efficiency. This chapter introduces mean relative scaled bias (MRSB) and root mean squared relative bias (RMSRB) to evaluate the VaR method conservatism, uses failure test method and loss function method to evaluate VaR method accuracy, uses multiple to obtain coverage and distribution forecast method to evaluate VaR method efficiency, compares the the merits and shortages of different evaluating methods, puts forward their applied area, evaluates g-h VaR methods and compares g-h VaR with other VaR calculating methods, tries to afford the theories and empirical reference to the standardization development of our country's market risk management. Some conclusions can be obtained from the empirical results: Firstly, with the confidence levels rising, the conservatism of the g-h VaR methods, historical simulation method and extreme value theory improve gradually; MC-Normal, Delta-Normal, GARCH, LGARCH and RiskMetric method weaken gradually. This indicates that the former methods get the higher measures under the high confidence level, and so reduce the investor's loss under the extreme market condition and enhance the risk cost. And the following five methods are opposite. Secondly, the results got from

failure test method and loss function method are almost the same. Under the low and middle confidence level, historical simulation method, g-h VaR Ⅰ and g-h VaR Ⅱ measure risk precisely, g-h VaR Ⅲ underestimates risk, other methods overestimate risk; under the higher confidence level, g-h VaR Ⅲ measure risk precisely, historical simulation method, g-h VaR Ⅰ, g-h VaR Ⅱ and g-h MC overestimate risk, other methods underestimate risk obviously. Thirdly, under the low and middle confidence level, the efficiency of the different VaR methods is almost in the same case. At the 95% confidence level, historical simulation method, g-h VaR Ⅰ, g-h VaR Ⅱ and g-h MC are the most efficient, the efficiency of g-h VaR Ⅲ is the lowest. At the 97.5% confidence level, GARCH, LGARCH and historical simulation method are most efficient and most conservative. Under the higher confidence level, the efficiency is different obviously. At the 99% and 99.5% confidence level, all the VaR methods are conservative, the four g-h VaR methods, extreme theory method and historical simulation method are most efficient and GARCH, LGARCH methods are most conservative. At the 99% confidence level, g-h VaR Ⅲ is most efficient. MC-Normal, Delta-Normal, RiskMetric and GARCH method are most conservative, they all overestimate risk.

6. The sixth chapter briefly introduces the concept and calculation method of the portfolio VaR, detailedly sets forth the concepts and mutual relationships of marginal VaR, component VaR and incremental VaR, presents using g-h VaR methods to calculate portfolio VaR, puts forward global OLS method, asymmetry response method, local linear approximation method and rational approximation method to decompose portfolio VaR,

estimates marginal VaR, component VaR and incremental VaR, decomposes the portfolio VaR which are calculated by the four g-h VaR methods. The result shows that global OLS method and asymmetry response method respectively used the profit & loss and loss data of the portfolio return. These two methods are simple and valuable. Furthermore, asymmetry response method performs better because it requires the loss data of the portfolio return and applies wider. Linear local approximation method is a decomposition method, which is linear approximation near portfolio VaR, precisely but complicate. Linear local approximation method can be used to decomposing almost all the portfolio VaR and also can deal with asymmetry and fat-tailness in the portfolio return. Decomposing portfolio VaR provides more market risk information about portfolio, makes people know the internal structure of portfolio risk, regulates portfolio assets and optimizes capital assignment.

7. The seventh chapter concludes the dessertation and does some prospects for the future study.

The primary innovations include:

1. Presenting the Mente Carlo simulation method based on g-h distribution, putting forward the two parametric g-h VaR methods based on profit & loss, loss and extreme loss of financial assets or portfolio return according to the statistical properties of g-h distribution that can model the whole, left and tail of the distribution separately.

2. Using the g-h VaR non-parametric method g-h MC method and the g-h VaR parametric methods based on the profit & loss, loss and extreme loss to measure the financial assets and portfolio.

3. Putting forward global OLS method, asymmetry response method and local linear approximation method to decompose portfolio VaR, using these methods to decompose the portfolio VaR that are calculated by the four g-h VaR methods.

4. Constructing the evaluation system of VaR methods: conservatism evaluation, accuracy evaluation and efficiency evaluation, evaluating g-h VaR methods with some statistical methods and comparing g-h VaR methods with other VaR calculating methods. The result shows that g-h VaR method is precise, efficient and conservative.

KEY WORDS: VaR, g - h distribution, g - h VaR, portfolio VaR decomposition, VaR method evaluation