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Spatial energy market risk analysis using the semivariance risk measure

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Abstract

The paper concentrates on the analysis of semivariance (SV) as a market risk measure for market risk analysis of mean–semivariance (MSV) portfolios. The advantage of MSV over variance as a risk measure is that MSV provides a more logical measure of risk than the MV method. In addition, the relationship of the SV with the lower partial movements is discussed. A spatial risk model is proposed as a basis of risk assessment for short-term energy markets. Transaction costs and other practical constraints are also included. A case study is provided to show the successful application of the model.

Keywords: Electricity markets; Lower partial movements; Portfolio; Risk; MV; MSV

1. Introduction

There have been many studies on risk in portfolio selection and practical applications based on the Markowitz mean–variance (MV) method [1,2]. The most important aspect of the MV method is that it introduces an important concept of portfolio efficient frontier on which each point is an efficient portfolio point with the variance minimized at a given level of return expectation. After the introduction of a risk-free asset, Sharpe proposed the capital asset pricing model (CAPM) [3] that has also attracted extensive attention in academics but with limited applications in practice [26]. The logical connection of CAPM and MV is explained in detail in [3]. The problem with the MV method is that variance may not be a proper risk measure because it contains the effect of return deviations above the mean. By common sense, portfolio returns above the mean should be regarded as beneficial not as risk. Hence, using variance as a risk measure does not make a good logical sense, as argued by many. A simple improvement over the MV method for measuring risk is to use deviations below the mean, and lower semivariance (SV) is hence a simple and good choice for the purpose. The SV method, however, has attracted less attention in practice due to more computation requirement. The other problem with the traditional MV method is that it cannot take into consideration fixed transaction cost, which usually over estimates the mean return of a portfolio. Since the fixed transaction cost is a lumpy sum no matter how big the transaction deal is, a binary integer variable is needed for properly modeling it. If a portfolio does not contain asset, the binary variable is zero, the fixed transaction cost is not counted for after optimization. Since the model contains both integer and continuous variables, it is called the mixed integer programming (MIP). The SV is also called the second lower partial movement (LPM) and is one of the several downside risk measures [10]. Other downside risk measures may include the absolute downside deviation (also called semideviation (SDV) or the first LPM), etc. The SDV as a risk measure has a computation advantage but cannot take into consideration correlations of returns on assets.

LPM plays an important role in our discussion of downside risk measures. Therefore, it is appropriate that the definition of the k-degree LPM be provided:

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List of primary symbols

Indices

g	generation unit index
h	time in hour or other appropriate unit
i	power pool index (e.g., PJM, NYPOOL)
j	an alias of i
k	degree of freedom in lower partial movement calculation
m	an alias of n
n	energy product index ($n = 1$ for electricity in MWh, 2 for spinning reserve, 3 for regulation, etc.)
Mk	total number of pools of interest
N	total number of commodity products in a market
Ngi	number of generation unit in pool i
Sm	set of commodity products with minimum contracting requirement
TH	short-term planning horizon.

Parameters

fc_{in}	one time fixed charge (\$) for transacting product n in pool i (=0 if it is not required)
$Mmax$	total budget limit (\$ plus other resources, e.g., fuel reserve, etc.)
pc_{inh}	proportional charge (\$ per unit per time) for transacting product n in pool i in time h (can be zero)
$Pmax_{ig}$	capacity upper limit of generation unit (i,g)
$Pmin_{ig}$	minimum production level in MW
SDV_{inh}	semideviation of prices below the expected price μ_{inh}
w^c_{inh}	contracted sales of product n in h committed before $h = 1$
wh_{ijnh}	wheeling charge in \$ per unit product in time h (can be zero for some product)
$Wmax$	a sufficiently large positive real number (e.g., $e + 10$)
μ_d	desired net profit in \$. The Markowitz efficient frontier is obtained by solving the model with various values of μ_d, an adjustable parameter
ρ_{ijnmh}	correlation coefficient between the prices of market products w_{inh} and w_{jmh} in time h
stc_{igh}	generation unit start-up cost in \$.

Variables

CT	total cost or expenditure in \$
CP_{igh}	production cost of unit (i,g), excluding start-up or shut-down cost
I_{ijh}	a binary variable for wheeling negotiation, 1 = wheeling allowed, 0= no wheeling allowed. $I_{ijh} = 0$ can be used to disallow cross-pool sales of certain energy products (e.g., regulation)
U_{igh}	a binary variable for generation unit on/off status
$w1_{ingh}$	product n from unit g in pool i and time h
$w2_{ijnh}$	product n originated in i, wheeled to j in time h
w_{inh}	product n bid in pool i and in time h
Y_{inh}	a binary variable for selling product n in pool i in time h
μ_{inh}	the expected price (\$ per unit product) for product w_{inh}.

$$\mathrm{LPM} = \int_{-\infty}^{\tau} (\tau - R)^k \, \mathrm{d}F(R),$$

where R is a stochastic process such as the return of a portfolio, τ is a target value that an investor would use for measuring his/her preference of risk. $F(R)$ is the cumulative probability distribution of R. τ is the expected return of a portfolio for both the $SDV(k = 1)$ and the $SV(k = 2)$. LPM is closely related to the value at risk (VaR) measure where τ is defined as a percentile on the lower tail, say, 1% of the probability distribution. When $k \geqslant 1$, LPM is used for measuring the risk preference of those risk averters. However, the k-degree LPM must be correctly related to the standard statistical movements of the distribution where investors have a preference for higher values of odd movements (skewness) and a dislike of higher values of even movements (variance, kurtosis and the like). In short, LPM is used for measuring an investor's risk attitude towards the below-target returns.

The motivation for the research is based on the reasoning that the variance of a portfolio return may not be an appropriate measure of risk. It is logical to think that variance is a measure of uncertainty rather than risk and only the part of the variance with returns less than the mean return is relevant to risk. A variance also includes the effect of the returns greater than the mean return, and a rational investor should love but not to avert higher returns. Therefore, the part of the variance reflecting greater returns than the mean should not be regarded as risk. It is generally agreed that this argument offers a logical thinking and it is consistent with the framework of VaR measure being widely used in the financial industry [4]. Note that VaR is also a downside risk measure. The paper is centered on the minimization of SV subject to practical constraints currently overlooked by many portfolio software packages. However, models based on the minimization of VaR and SDV are not excluded as alternatives. In the proposal, we do not assume symmetry in distribution and normality of returns. We also incorporate integers, fixed and proportional transaction costs, and other practical constraints. We do not propose CAPM as a risk management tool for electricity markets because CAPM is for efficient markets where the characteristics do not apply for electricity markets with imperfections such as games.