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Risk Measures and Portfolio Construction in Different Economic Scenarios

(Pengukuran Risiko dan Penjanaan Portfolio dalam Senario Ekonomi Berbeza)

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ABSTRACT

This paper compared the composition and performance of portfolios constructed by employing different risk measures utilizing the Malaysian share market data in three diverse economic scenarios. The risk measures considered were the mean-variance (MV) and their alternatives; the semi-variance (SV), mean absolute deviation (MAD) and conditional value at risk (CVAR). The data were divided into three sub-periods representing the growth period in the economy, financial crisis and the recovery period. The results of this study showed different optimal portfolios' performances and compositions for the three economic periods. Nevertheless, among the risk models tested, CVAR(0.99) model gave the highest portfolio skewness. High skewness means that the probability of getting large negative returns is decreased. As a conclusion, for the Malaysian stock market, the CVAR(0.99) model is the most appropriate portfolio optimization model for downside risk aversion investors in all three economic scenarios.

Keywords: Optimization; return; share market; skewness; variance

ABSTRAK

Kertas ini membandingkan komposisi dan prestasi portfolio yang dibina menggunakan pengukuran risiko berlainan ke atas data pasaran saham Malaysia dalam tiga senario ekonomi berbeza. Ukuran risiko yang dipertimbangkan ialah min-varians (MV) dan alternatifnya; semi-varians (SV), min sisihan mutlak (MAD) dan nilai bersyarat pada risiko (CVAR). Data dibahagi kepada tiga sub-tempoh yang mewakili tempoh pertumbuhan ekonomi, krisis kewangan dan tempoh pemulihan. Keputusan kajian menunjukkan prestasi dan komposisi portfolio yang optimum adalah berbeza bagi tiga tempoh ekonomi tersebut. Namun begitu, daripada model risiko yang diuji, model CVAR(0.99) memberikan kepencongan portfolio tertinggi. Kepencongan tinggi bermakna kebarangkalian mendapat pulangan negatif yang besar berkurangan. Kesimpulannya, untuk pasaran saham Malaysia, model CVAR(0.99) merupakan model pengoptimuman portfolio yang paling sesuai untuk pelaburan penghindaran risiko ke bawah dalam ketiga-tiga senario ekonomi.

Kata kunci: Kepencongan; pasaran saham; pengoptimuman; pulangan; varians

INTRODUCTION

Portfolio selection models were originated from the seminal work of Markowitz (1952). Markowitz model consists of allocating capital over a number of available assets with the objective to maximize the return on the investment while minimizing the risk associated with the investment. Markowitz measured the risk associated to the return of investment that deviated from the mean of the return distribution, the variance and in the case of a portfolio of assets, the level of risk was estimated using the covariance between all pairs of investments. The novelty of Markowitz mean-variance (MV) model is the measurement of the portfolio risk via the multivariate distribution of returns of all assets.

Markowitz's mean-variance model became the basis of many other models that use its fundamental assumption (Bodie et al. 2011; Elton et al. 2007). These classical models, as known today, give the portfolio's expected return as the linear combination of the participations of all assets in the portfolio and its expected returns. However, the portfolio risk measure varies, often it is based on the moments about the mean of the linear combination of the participations and the time series of returns of its assets. In spite of the classical models favorable reception, their fundamental assumption has been intimidated in many ways by actual data. Fama (1965), Kon (1984), Prakash et al. (2003) and Samuelson (1970) documented that often the series of returns' distribution depart from normality, exhibiting kurtosis and skewness. These factors cause the variance of the returns to be an inappropriate measure of risk. Arditti (1967), Kraus and Litzenberger (1976), Li et al. (2010), Prakash et al. (2003), Samuelson (1970) and Tanaka and Guo (1999) argued that unless there were evidences that the returns were symmetrically distributed or that higher moments were irrelevant to the investors' then higher moments could not be neglected. It is a stylized fact that the distributions of many financial return series are non-normal, with the existence of skewness and/or kurtosis.

The limitations of the MV models help develop various alternative models. As extension of variance, semi-variance was proposed to measure risk so that only returns below expected value were measured as risk (Markowitz 1959). Semi-variance is a widely used measure of total downside risk combining into one measure information provided by two statistics, variance and skewness. The semi-variance measures the volatility of the returns that falls below the average return. Given that rational investors are more receptive to downside losses compared with upside gains, the semi-variance of returns is a more appealing measure of risk (Chow & Denning 1994; Grootvel & Hallerbach 1999; Markowitz 1993).

Konno and Yamazaki (1991) proposed the mean absolute deviation (MAD) model. Instead of variance, they employed the absolute deviation as a measure of risk. The MAD model is said to be able to measure risk appropriately. Unlike MV model which is a quadratic programming problem, MAD model is a linear programming problem (Konno & Yamazaki 1991, 2001). The MAD portfolios have fewer assets (Simaan 1997) and the model gives better efficient frontier than the MV model (Liu & Gao 2006). Rockafellar and Uryasev (2000) introduced the condition value at risk (CVAR) model. The CVAR model was applied by Krokhmal et al. (2002) to study the portfolio optimization. They found that the CVAR model was efficient for computing large (hundreds or thousands) of assets to be combined in a portfolio.

The main objective of this study was to analyze the compositions and performances of the optimal portfolios by employing four different risk measures; the variance, semi-variance, absolute deviation and conditional value at risk on three diverse economic sub-periods. The period of study is divided into three sub-periods representing the growth period in the economy, financial crisis and the recovery period. This study also aimed to determine whether the same risk measure applies in all three sub-periods or different risk measure suits different sub-period. This paper is organized as follows. The next section discusses the concepts and mathematical models of the four risk measures; variance, semi-variance, absolute deviation and conditional value at risk. Section 3 presents the empirical evidence on real data from the Malaysian Stock Market. Finally, some concluding remarks are provided.

DATA AND METHODOLOGY

RISK MEASURES

The MV model proposed by Markowitz (1952) employed variance as the risk measure and mean return as expected return. Variance measures the deviation above and below the mean. This model not only penalizes the downside deviation but also the upside deviation. However, the upside deviation is desirable for the investors because they wish to gain in their investment (Chow & Denning 1994). The objective of this model is to minimize the portfolio variance. The MV model is a quadratic programming model. The mathematical model is as follows:

$$\begin{aligned} \text{minimize} \quad & \sum_{i=1}^{n}\sum_{j=1}^{n}\sigma_{ij}x_i x_j, \\ \text{subject to} \quad & \sum_{j=1}^{n} r_j x_j \geq \rho, \\ & \sum_{j=1}^{n} x_j = 1, \\ & x_j \geq 0, \end{aligned} \tag{1}$$

where σ_{ij} is the covariance between assets i and j, x_j is the amount invested in asset j, r_j is the expected return of asset j per period and ρ is a parameter representing the minimal rate of return required by an investor.

Instead of using the variance, Markowitz (1959) proposed semi-variance (SV) as risk measure. Semi-variance is the downside risk measure which focuses on the deviation below the mean return. This model only penalizes the downside deviation and not the upside deviation. Therefore, this model matches investor's perception towards risk better as investors will have less downside risk exposure (Grootvel & Hallerbach 1999). The semi-variance model is presented as:

$$\begin{aligned} \text{minimize} \quad & \frac{1}{T}\sum_{t=1}^{T}\left(\max\left[0, E(R) - R_{pt}\right]\right)^2, \\ \text{subject to} \quad & E(R_p) = \mu, \\ & \sum_{j=1}^{n} x_j = 1, \\ & x_j \geq 0, \end{aligned} \tag{2}$$

where T is the number of periods, R_{pt} is the portfolio return at period t, $E(R_p)$ is the mean return and x_j is the amount invested in asset j.

Konno and Yamazaki (1991) proposed the mean absolute deviation (MAD) model using absolute deviation as risk measure to replace variance. This model is a linear programming model which can easily be solved as there is no need to calculate the covariance matrix as compared to the MV model. The MAD model can solve large scale portfolio optimization problem because the optimal portfolio consists of at most $2T+2$ assets regardless of the sample size (Feinstein & Thapa 1993). The mathematical model is as follows:

$$\begin{aligned} \text{minimize} \quad & \sum_{t=1}^{T} y_t / T, \\ \text{subject to} \quad & y_t + \sum_{j=1}^{n}\left(r_{jt} - r_j\right)x_j \geq 0, \quad t = 1, \ldots, T, \\ & y_t - \sum_{j=1}^{n}\left(r_{jt} - r_j\right)x_j \geq 0, \quad t = 1, \ldots, T, \\ & \sum_{j=1}^{n} r_j x_j \geq \rho, \end{aligned}$$

$$\sum_{j=1}^{n} x_j = 1,$$

$$x_j \geq 0, \quad (3)$$

where y_t is the continuous variable representing the deviation between the portfolio mean return and portfolio return at time t, T is the number of period, r_{jt} is the realization of random variable R_j during period t, r_j is the expected return of asset j per period, ρ is a parameter representing the minimal rate of return required by an investor and x_j is the amount invested in asset j.

The conditional value at risk (CVAR) model has been proposed by Rockafellar and Uryasev (2000). The CVaR is also known as mean excess loss, mean shortfall or tail VaR. The CVAR can be defined as the conditional expectation of loss above that amount α at a specified probability level β (Lima et al. 2011). CVAR satisfies the four properties of coherent risk which are: the wealth at risk declines when an amount of riskless wealth is added; more wealth is preferred as compared to less wealth; the aggregated risk of two investments is less than the sum of the two associated single risk and risk must also grow with the same proportionality when the wealth at risk is multiplied by a positive factor (Szegö 2002). This model is a linear programming model. The mathematical model is given as follows:

$$\text{minimize} \quad \alpha + \frac{1}{T(1-\beta)} \sum_{t=1}^{T} z_t,$$

$$\text{subject to} \quad z_t \geq 0,\ t = 1,2,\ldots,T,$$

$$\sum_{j=1}^{n} r_j x_j \geq \rho,$$

$$\sum_{j=1}^{n} x_j = 1,$$

$$x_j \geq 0, \quad (4)$$

where α is the lowest amount of loss, β is the probability that the loss will not exceed α, T is the number of period, z_t is the variable, r_{jt} is the realization of random variable R_j during period t, x_j is the amount invested in asset j and r_j is the expected return of asset j.

In this study, we follow the framework of (4) with the risk confidence levels chosen are $\beta = 0.99$ and $\beta = 0.95$. Investors seldom experience a loss exceeding VaR(X) when β is 0.99 as compared with 0.95. CVAR(0.99) means investors have greater downside risk aversion than CVAR(0.95). Konno et al. (2002) and Rockafellar and Uryasev (2000) give the definition of CVAR as:

$$\text{CVAR}(\beta) = \frac{1}{1-\beta} E[L(X) \mid L(X) \geq VaR(X)],$$

where $L(X)$ is the loss function and β is the probability level.

DATA

The data for this study consists of the weekly returns of twenty-four shares included in the Kuala Lumpur Composite Index (KLCI) drawn from Malaysian Stock Market. KLCI is the main index for Malaysian Stock Market acting as a barometer that measures the performance of the major capital and industry segments of the Malaysian and regional markets. Furthermore, the up and down movements of KLCI reflect how investors feel about the economy.

Based on the Malaysian quarterly gross domestic product (GDP) growth, this study divides the economic periods into three sub-period; period from January 1994-June 1997 represents the economic growth, period from July 1997-December 2001 represents the economic crisis and period from January 2002-June 2008 is the recovery period.

Employing models (1) – (4) presented above, the optimal portfolios are constructed for each sub-period. The average risk free rate from January 1994 to June 2008 is calculated to be 0.00074. Thus this value is set to be the investor's minimum required rate of return in this study. Portfolio mean return is calculated as follows:

$$\text{Portfolio mean return} = \sum_{j=1}^{n} r_j x_j. \quad (5)$$

EMPIRICAL RESULTS

PORTFOLIO PERFORMANCES

The summary statistics of the optimal portfolios for the three economic periods are shown in Table 1.

The minimum required return of 0.00074 set in this study is achieved for all the models. This means that the portfolios constructed were able to generate returns of at least equivalent to the risk free return. The mean returns were highest during the recovery period for all portfolios generated by all four risk measures. On the other hand, as shown by the portfolios' variances during the economic crisis investors incur more risks. Portfolios constructed by CVAR(0.99) model gave the highest mean return for period during the economic growth - mean return is 0.00082 and during the recovery period, mean return is 0.002691. During the economic crisis, CVAR(0.95) portfolio gave the highest portfolio with a mean return of 0.0011.

This study supports the earlier studies done by Jaaman et al. (2011) and Saiful Hafizah et al. (2011) that variance is not an appropriate risk measure for Malaysian market. The CVAR is the downside risk that focuses on the downside deviation below the mean return which is a better match for investor's perception against risk. As shown by the skewness statistics, CVAR(0.99) model provides the highest skewness in all three period; during period of economic growth skewness is 0.944132, skewness is 0.457970 during the economic crisis and 0.013152 during the recovery period. Positive skewness (right skewed) is desirable for it decreases the probability of getting large negative returns,

TABLE 1. Summary statistics of optimal portfolios

Economic growth	January 1994-June 1997				
	MV	SV	MAD	CVAR(0.99)	CVAR(0.95)
Mean return	0.00074	0.00074	0.00074	0.00082	0.00074
Variance	0.000437	0.000456	0.000457	0.000543	0.00055
Skewness	0.241677	0.713460	0.593782	0.944132	0.808798
Economic crisis	July 1997-December 2001				
	MV	SV	MAD	CVAR(0.99)	CVAR(0.95)
Mean return	0.001055	0.000842	0.00091	0.000926	0.0011
Variance	0.000918	0.000941	0.000946	0.001437	0.001062
Skewness	-0.421947	-0.258700	-0.404051	0.457970	0.031774
Recovery period	January 2002-June 2008				
	MV	SV	MAD	CVAR(0.99)	CVAR(0.95)
Mean return	0.002282	0.002181	0.002313	0.002691	0.002358
Variance	0.0002	0.000203	0.000206	0.000249	0.000217
Skewness	-0.449264	-0.300047	-0.548387	0.013152	-0.227901

hence the CVAR(0.99) is the most appropriate risk measure to control downside risk. As concluded by Chunhachinda et al. (1997), Lai (1991) and Prakash et al. (2003) investors are willing to trade expected returns (mean returns) and variance for the skewness. According to Arditti (1967), risk averse investor was willing to accept lower expected portfolio return in order to gain the benefit of increasing portfolio's skewness.

PORTFOLIO COMPOSITIONS

An investor can reduce risk of his investment by spreading it over a number of securities. The question arises if investor is not constrained to a single security but instead is able to form a diversified portfolio, how then will he allocate his fund among the various alternatives. In this study four models are employed to construct optimal portfolios from twenty-four available firms. Tables 2, 3 and 4 show the optimal portfolio compositions constructed for the three diverse economic periods.

As shown in Tables 2, 3 and 4 the four risk models construct different optimal portfolio compositions for all three economic periods. Studies done in different time period possibly give different optimal portfolio compositions (Prakash et al. 2003). According to Byrne and Lee (2004) different portfolio compositions are due to the non-normality of the data and investor's attitude towards risk. From the tables above it is deduced that during the period of economic growth (January 1994-June 1997), MISC makes up the highest proportion in the optimal portfolios for all four risk measures with MV portfolio invests 25.24% of fund, SV portfolio invests 32.18%,

TABLE 2. Optimal portfolio compositions for economic growth period

	MV	MAD	SV	CVAR(0.99)	CVAR(0.95)
AMMB	0.0000	0.0000	0.0000	0.0143	0.0619
BAT	0.1477	0.1171	0.1314	0.0830	0.0668
KLK	0.0775	0.0574	0.0472	0.0000	0.0000
LMCEMNT	0.0000	0.0000	0.0050	0.0755	0.0578
MAS	0.0812	0.0704	0.0788	0.0000	0.0017
MAYBANK	0.0595	0.0368	0.0000	0.0000	0.0000
MISC	0.2524	0.4018	0.3218	0.3400	0.3266
MMCCORP	0.0000	0.0000	0.0162	0.0000	0.0000
PBBANK	0.0522	0.0000	0.0611	0.0000	0.0000
PPB	0.0509	0.0309	0.0000	0.0074	0.0000
PROTON	0.0220	0.0000	0.0000	0.0000	0.0045
SHELL	0.1140	0.1209	0.1350	0.2083	0.2735
SIME	0.1181	0.1387	0.1386	0.1038	0.0839
TCHONG	0.0000	0.0000	0.0000	0.1124	0.1058
TENAGA	0.0065	0.0000	0.0000	0.0000	0.0000
TM	0.0159	0.0000	0.0097	0.0000	0.0000
UMW	0.0022	0.0260	0.0551	0.0554	0.0176

TABLE 3. Optimal portfolio compositions for economic crisis period

	MV	SV	MAD	CVAR(0.99)	CVAR(0.95)
BAT	0.3788	0.3722	0.3863	0.2644	0.4479
GENTING	0.0000	0.0217	0.0000	0.1179	0.0868
KLK	0.1032	0.0560	0.0357	0.1527	0.0103
KULIM	0.0000	0.0138	0.0000	0.1111	0.0680
LMCEMNT	0.0000	0.0000	0.0077	0.0172	0.0000
MISC	0.2075	0.1603	0.2167	0.0000	0.0912
PPB	0.2222	0.2448	0.1890	0.0810	0.1806
SHELL	0.0761	0.1012	0.1647	0.0000	0.0000
SIME	0.0000	0.0000	0.0000	0.0155	0.0355
SPB	0.0121	0.0298	0.0000	0.0878	0.0798
TCHONG	0.0000	0.0000	0.0000	0.0380	0.0000
TM	0.0000	0.0000	0.0000	0.1143	0.0000

TABLE 4. Optimal portfolio compositions for economic recovery period

	MV	SV	MAD	CVAR(0.99)	CVAR(0.95)
BAT	0.3544	0.3864	0.3294	0.2482	0.4676
IJM	0.0000	0.0000	0.0095	0.0000	0.0000
KLK	0.0101	0.0000	0.0000	0.0000	0.0000
MAYBANK	0.0999	0.1266	0.0457	0.1335	0.0240
MISC	0.1069	0.1154	0.1230	0.1085	0.0655
PBBANK	0.0989	0.1157	0.0483	0.1537	0.1783
PPB	0.0174	0.0000	0.0370	0.0000	0.0000
PROTON	0.0000	0.0051	0.0133	0.0000	0.0000
SHELL	0.1469	0.1600	0.1550	0.3561	0.1313
SPB	0.0276	0.0077	0.0310	0.0000	0.0000
TANJONG	0.0000	0.0000	0.0070	0.0000	0.0000
TCHONG	0.0074	0.0000	0.0184	0.0000	0.0037
TENAGA	0.0613	0.0265	0.0819	0.0000	0.0000
TM	0.0000	0.0000	0.0000	0.0000	0.0337
UMW	0.0691	0.0567	0.1004	0.0000	0.0959

MAD 40.18%, CVAR(0.99) invests 34.00% and CVAR(0.95) invests 32.66% .

During the economic crisis period, BAT invested the most where it was suggested that investor puts 37.88% of fund in BAT if he chooses to employ MV model, 37.22% if SV model is used, 38.63% if using MAD model, if CVAR(0.99) model is utilized then 26.44% of fund will be invested in BAT and 44.79% if CVAR(0.95) model is chosen.

During the recovery period, portfolio constructed employing CVAR(0.99) as the risk measure composed mostly of Shell (35.61%) while the portfolios generated using the other risk measures; CVAR(0.95), MV, SV and MAD, invested highly in BAT.

CONCLUSION

This paper discussed the portfolio optimization models by employing variance, semi-variance, absolute deviation and conditional value at risk as risk measures. The optimal portfolios' performances and compositions were compared for three different economic scenarios; economic growth, crisis and recovery. This study recorded different optimal portfolios' performances and compositions results for the three economic periods. Among the risk models tested, the CVAR(0.99) model gives the highest portfolio skewness. High skewness means that the probability of getting large negative returns is decreased. Investors prefer positive/high skewness because positive skewness decreases the probability of getting large negative returns. From the findings of this study, it can be concluded that the CVAR(0.99) model is the most appropriate portfolio optimization model for downside risk aversion investors for all three economic scenarios.

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