Journal of Accounting and Finance
Volume 26, No. 1
October 2011-March 2012

Construction and Evaluation of Optimal Portfolio Using Sharpe's Single Index Model

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Abstract

This paper attempts to construct an optimal portfolio by using Sharpe's Single Index Model of Capital Asset Pricing and further to evaluate the performance of the portfolio by Sharpe's Ratio, Treynor's Ratio and Jenson Alpha. For this purpose, BSE SENSEX and all the 30 scrips which are part of it have been used as market index for preparing portfolio. The monthly data for all the scrips and index for the period April 2006-March 2011 have been considered. The proposed method formulates a unique cut off point (Cut off rate of return) and selects stocks having excess of their expected return over risk-free rate of return surpassing this cut-off point. Percentage of investment in each of the selected stocks is then decided on the basis of respective weights assigned to each stock depending on respective beta value, stock movement variance representing unsystematic risk, return on stock and risk free return vis-a-vis the cut off rate of return. As per our findings, our optimal portfolio consists of seven scripts, selected out of 26 short listed scripts, giving the return of 46.54% with the portfolio standard deviation of 15.2%.The Sharpe ratio, Trynor's ratio and Jenson alpha for the same optimal portfolio is 2.63, 0.38 and 0.28 respectively.

Keywords: *Optimal Portfolio, Sharpe's Single Index Model, Risk, Return, Variance, Standard Deviation, Sharpe's Ratio, Treynor's Ratio, Jenson Alpha*

Introduction

The foundation of Modern Portfolio Theory was laid by Markowitz in 1951. Markowitz theory advises investors to invest in multiple securities rather than put all eggs in one basket because efficient diversification of the portfolio involves combining securities with less than positive correlation in order to reduce risk in the portfolio without sacrificing any of the portfolio return. In a nutshell, investors should select portfolios and not individual securities. In 1990, Markowitz shared a Nobel Prize with Merton Miller and William Sharpe in Economics for introducing and extending the Capital Asset Pricing Model (CAPM). This model breaks up the riskiness of each security into two components - the market related risk which cannot be diversified called systematic risk measured by the beta coefficient and another component which can be eliminated through diversification called unsystematic risk.

Sharpe's Single Index Model

The Markowitz model is extremely demanding in its data needs for generating the desired efficient portfolio. It requires N (N+3)/2 estimates (N expected returns + N variances of returns + N*(N-1)/2 unique covariances of returns). Because of this limitation, the single index model with less input data requirements has emerged. The single index model requires 3N+2 estimates (estimates of alpha for each stock, estimates of beta for each stock, estimates of variance for each stock, estimate for expected return on market index and an estimate of the variance of returns on the market index) to use the Markowitz optimization framework. The single index model assumes that co-movement between stocks is due to movement in the index.

Single Index Model

The basic equation underlying the single index model is:

$$Ri = ai + b*Rm$$

Where,

Ri = Return on the ith stock

ai = component of security i that is independent of market performance

b = coefficient that measures expected change in Ri given a change in Rm

Rm = rate of return on market index¬

The term ai in the above equation is usually broken down into two elements ai which is the expected value of ai and ei which is the random element of ai. The single index model equation, therefore, becomes:

$$Ri = ai + b*Rm + ei$$

This paper attempts to construct an optimal portfolio using Sharpe's Single Index Model of capital asset pricing and further to evaluate the performance of such portfolios by Sharpe's ratio, Treynor's ratio and Jenson alpha.

Review of Literature

Markowitz (1952, 1959) framework uses the variance (or standard deviation) of asset returns as the risk measure, thereby placing equal emphasis on return deviations below and above the mean. As such, a risk-averse investor in Markowitz's mean-variance world views downside and upside variation with equal distaste.

Linter (1965) showed in his empirical analysis that there exist limitations on diversification to reduce risks as the 70 large mutual funds had greater conditional standard errors of estimate than risk free return.

Sortino and van der Meer (1991) proposed a modification to the Sharpe ratio whereby the (lower) semi-variance replaces standard deviation in the denominator.

The advent of the Value-at-Risk measure is a further indication of the asymmetric nature of investor concern over risk.

Fama and French (1992) found that three variables market equity, the ratio to book equity to market equity and leverage variables capture much of the cross section of average stock returns. The three variables were found to have more explaining power as compared to market beta.

Stutzer (2000) has proposed a new approach to portfolio construction and performance measurement that has both academic rigour and practical appeal. In the light of the widespread practice of benchmarking, both investors and fund managers are acutely concerned with fund performance relative to the designated benchmark. In some respects, common usage of the term 'risk' has evolved to represent the probability that an investment will underperform a given target.

Brandt and Clara (2006) in their article on dynamic portfolio selection by augmenting the assets space have used Markowitz approach in a novel manner. They expanded the set of assets to include mechanically managed portfolios and optimize statistically the extended assets space. They have created conditional portfolios. Their study suffers from finite size of sample returns. It relied on the intuition that the static choice in mechanically managed portfolios is equivalent to a dynamic strategy in the basis assets. This paper paves an easy way to undertake dynamic portfolio selection.

Anthony Renshaw (2008) described a systematic calibration procedure for incorporating more than one risk model in a portfolio construction strategy. The result explains that calibration of the portfolio construction parameters is essential since the region over which both risk models affect the solution is difficult to predict a priori and can be relatively narrow.

Robert A. Stubbs Dieter Vandenbussche (2009) demonstrated the pros and cons of two approaches that each has foundations in economic theory, the Cournot-Nash equilibrium and the collusive solution. The multi-portfolio optimization approach outlined in the study allows institutional managers to rebalance multiple accounts simultaneously while ensuring that each account is optimized according to either the collusive solution or the Cournot-Nash equilibrium solution, and adheres to all account-specific constraints as well as any additional constraints that span across multiple accounts.

Vinicio Almeida (2009) attempted to test different techniques of correlation structure prediction applied to stock price time series. Comparison is made among the historical model, the single index model, Blume and Vasicek adjustments to the single index model, the mean model and a naive model. The results indicate that the shrinkage procedure produces better estimates of covariance matrices.

Chin W. Yang and Ken Hung (2010) proposed a generalized Markowitz portfolio investment model via adding measures of skewness and peakedness into the original Markowitz investment model. The finding of the study shows that the magnitude of risk and the shape of the efficient frontier are different from that of the original model and the original Markowitz model can be seen as a special case of the generalized model.

Asmita Chitnis (2010) constructed two optimal portfolios from two different samples using Sharpe's Single Index Model of Capital Asset Pricing and further compared the performance of these two portfolios by Sharpe's Ratio. Using Sharpe's Single Index Model a unique cut off point was defined and the optimal portfolio of stocks having excess of their expected return over risk-free rate of return greater than this cut-off point was generated for both the samples separately. The findings of the study show that both of the optimum portfolios constructed are largely diversified as securities in the individual portfolio represent different sectors of the economy.

Objectives of the Study

The present study has the objective of constructing a portfolio that is optimal giving the highest return at minimum risk and also finding out the necessary facts regarding performance of that portfolio which can benefit the investors heavily.

The specific objectives of the study are:

1. To construct an optimal portfolio by using Sharpe's single index model.
2. To evaluate the performance of that optimal portfolio using Sharpe's ratio, Treynor's ratio and Jenson alpha.

Data And Sources of Study

The study aims at constructing and evaluating the optimal portfolio. For this purpose, monthly data have been collected for all the scripts and index value for the period of 1st April 2006 to 31st March 2011 (5 years). This study takes all the 30 scripts which are part of BSE SENSEX and BSE SENSEX as market index. The stocks whose data were available were selected out of those 30 BSE SENSEX stocks. Finally, 26 scripts were short listed for the study. The study has used secondary data because it pertains to historical analysis of reported financial data. Monthly closing prices of the shares and monthly closing index value of the benchmark market index (BSE SENSEX) have been used for the study. The main sources of data have been the official website of Bombay Stock Exchange (www.bseindia.com) and other online sources.

Methodology

Firstly, for each security selected in the portfolio, expected return is calculated using equation (1) along with its intercept and beta. Next step towards construction of an optimum portfolio using Sharpe's Single Index Model is to select securities on the basis of following criteria:

- The average excepted return is greater than the risk free return and
- The beta value for that security is positive.

$$Rj = Ln\ (Pt) - Ln\ (Pt-1) \qquad (1)$$

Where,

Rj = Return of stock j

Pt = Price of the stock at the time t

Pt-1 = Price of the stock at the time t-1.

The construction of an optimal portfolio is simplified, if a single number measures the desirability of including a security in the optimal portfolio. For Sharpe's Single Model, such a number exists. In this case, the desirability of any security is directly related to its excess return-to-beta ratio given by:

$$\frac{(Ri - Rf)}{\beta i} \qquad (2)$$

Where,

Ri = average expected return of stock j

R f= average risk-free rate of return

β i = beta of stock j

For determining which of these stocks will be included in the optimal portfolio it is necessary to rank the stocks from highest to lowest based on excess return to beta ratio. So, securities are ranked in descending order of magnitude according to their excess return-to-beta ratio. Further, the next step is to determine the stocks for which the excess return to beta ratio is higher than a particular unique cutoff point C* such that all stocks with excess return-to-beta ratios greater than this unique cutoff C* are included and all stocks with lower ratios are excluded. The value of C* is computed from the characteristics of all securities that belong to the optimum portfolio. To determine C* it is necessary to calculate its value as if different numbers of securities were in the optimum portfolio. For a portfolio of stocks, Ci is given by:

$$Ci = \frac{\sigma 2m \, \Sigma \, \frac{(R_i - R_f)\, \beta i}{\sigma^2 i}}{1 + s2m \, \Sigma \, \frac{\beta^2 i}{\sigma^2 i}} \qquad (3)$$

Where,

σ2m = Variance of market

σ2i = Variance of stock j

Definition of all remaining symbols being the same as explained before.

Over establishing the cutoff rate C*, the investor knows which securities are qualified for the optimum portfolio and hence the optimum portfolio is constructed using qualified securities. Once the composition of the optimal portfolio is known, the next step is to calculate the percentage to be invested in each security which is given by:

$$X_i = \frac{Zi}{\Sigma Zi}$$

$$`Zi = \frac{\beta i \ (Ri\text{-}Rf - C^*)}{\sigma 2i \quad \beta i} \qquad (4)$$

Where,

C * = cutoff rate

Ri = average expected return of stock j

Rf = average risk-free rate of return

β i = beta of stock j

σ2 =Variance of stock j

Thus, the above expression determines the relative investment in each security.

Finally, expected return of the optimum portfolio Rp is calculated using the following equations;

$$R_p \quad = \Sigma \text{ X iRi} \qquad (5)$$

Where,

X_i = the proportion of the portfolio devoted to security j

R_i = average expected return of stock j

R_p = Expected portfolio return

Portfolio variance is calculated using the Co-Variance Matrix. For calculating the portfolio variance it is necessary to find the covariance between individual stocks.

Format of 7 securities Covariance Matrix

Format of 7 securities Covariance Matrix

W12 s12	*w1w2 cov(1,2)*	*w1w3 cov(1,3)*	*w1w4 cov(1,4)*	*w1w5 cov(1,5)*	*w1w6 cov(1,6)*	*w1w7 cov(1,7)*
w1w2 cov (1,2)	W22 s22	w2w3 cov(2,3)	w2w4 cov(2,4)	w2w5 cov(2,5)	w2w6 cov(2,6)	w2w7 cov(2,7)
w1w3 cov(1,3)	w3w2 cov(3,2)	W32 s32	w3w4 cov(3,4)	w3w5 cov(3,5)	w3w6 cov(3,6)	w3w7 cov(3,7)
w1w4 cov(1,4)	w4w2 cov(4,2)	w4w3 cov(4,3)	W42 s42	w4w5 cov(4,5)	w4w6 cov(4,6)	w4w7 cov(4,7)
w1w5 cov (1,5)	w5w2 cov(5,2)	w5w3 cov(5,3)	w5w4 cov(5,4)	W52 s52	W5w6 Cov (5, 6)	W5w7 Cov (5, 7)
w1w6 cov (1,6)	w6w2 cov(6,2)	w6w3 cov(6,3)	w6w4 cov(6,4)	w6w5 cov(6,5)	W62 s62	W6w7 Cov (6, 7)
w1w7 cov (1,7)	w7w2 cov(7,2)	w7w3 cov(7,3)	W7w4 cov(7,4)	w7w5 cov(7,5)	W7w6 Cov (7, 6)	W72 s72

Then the Sharpe ratio, Treynor's ratio and Jenson alpha were calculated for evaluation

Sharpe Ratio

William F. Sharpe (1966) devised an index of portfolio performance measure, referred to as reward to variability ratio. The Sharpe measure provides the reward to volatility trade-off. It measures the change in the portfolio's return with respect to a one unit change in the portfolio's risk. The higher the "Reward-to-Variability-Ratio" the more attractive is the evaluated portfolio because the investor receives more compensation for the same increase in risk. It is the ratio of the fund portfolio's average excess return divided by the standard deviation of returns and is given by Equation-6.

$$\text{Sharpe Ratio} = (R_p - Rf_m)/\sigma p \qquad (6)$$

Where, Rp= Portfolio return, Rf = average risk free return over the sample period, and σp = standard deviation of portfolio

Treynor Ratio

Jack Treynor (1965) conceived an index of portfolio performance measure called reward to volatility ratio, based on systematic risk. The Treynor measure is similar to the Sharpe ratio, except that it defines reward (average excess return) as a ratio of the CAPM beta risk. Treynor's performance measure is defined as the risk premium earned per unit of risk taken. Thus, it is computed as the average return of the portfolio in excess of the risk-free return divided by the portfolio's beta. Treynor's ratio is given by Equation-7 as shown below:

$$\text{Treynor's Ratio} = (Rp - Rf)/\beta p \quad (7)$$

Where, Rp= Portfolio return, Rf = average risk free return over the sample period, and βp= Average beta of the portfolio

Jensen Alpha

Michael C. Jensen (1968) defines his measure of portfolio performance as the difference between the actual returns on a portfolio in any particular holding period and the expected returns on that portfolio conditional to the risk-free rate, its level of "systematic risk", and the actual returns on the market portfolio. Jensen's Alpha measure is given by the Equation-8 as shown below.

$$\text{Jensen Alpha} = Rp - (Rf + \beta P\ (Rm - Rf)) \quad (8)$$

Where, Rp is the Portfolio return, Rf is the average risk free return over the time period; Rm is the return on the market portfolio.

Analysis

For constructing an optimum portfolio, a sample of size 26 is selected from the securities listed on Bombay Stock Exchange and included in BSE SENSEX. BSE SENSEX is taken as the market index. Monthly closing prices and returns are considered for the selected securities in each sample from 1st April 2006 to 31st March 2011. The data are collected from www.bseindia.com. The average risk free return is considered to be 6.5% p.a.

Table 1 shows data on 26 securities selected.

Table 1: Intercept, Beta, Expected return, Risk and Excess return to Beta Ratio of the sample stocks

Company	*Std Dev.*	*Variance*	*α*	*β*	*Rj*	*Excess Return to Beta*
Bharat Heavy Electricals Ltd.	0.124	0.015	0.020	1.295	0.376	0.240
Bharti Airtel Ltd.	0.132	0.017	0.006	1.077	0.193	0.119
Cipla Ltd.	0.145	0.021	-0.162	4.342	-1.470	-0.354
HDFC	0.230	0.053	0.012	0.779	0.226	0.207
HDFC Bank Ltd.	0.101	0.010	0.008	0.765	0.184	0.156
Hero Honda Motors Ltd.	0.086	0.007	0.006	0.670	0.150	0.126
Hindalco Industries Ltd.	0.159	0.025	-0.124	1.493	-1.320	-0.927
Hindustan Unilever Ltd.	0.079	0.006	0.008	0.672	0.174	0.161

Company	*Std Dev.*	*Variance*	α	β	R_i	*Excess Return to Beta*
ICICI Bank Ltd.	0.139	0.019	-0.017	1.463	-0.041	-0.073
Infosys Technologies Ltd.	0.119	0.014	-0.019	-0.143	-0.249	2.202
ITC Ltd.	0.116	0.013	-0.049	-0.827	-0.683	0.905
Jaiprakash Associates Ltd.	0.275	0.075	0.045	0.682	0.612	0.801
Jindal Steel & Power Ltd.	0.376	0.141	0.018	1.233	0.353	0.233
Larsen & Toubro Limited	0.210	0.044	0.030	1.115	0.479	0.371
Mahindra & Mahindra Ltd.	0.141	0.020	-0.004	0.551	0.013	-0.095
Maruti Suzuki India Ltd.	0.109	0.012	-0.019	1.317	-0.084	-0.113
ONGC Ltd.	0.224	0.050	-0.018	1.244	-0.081	-0.118
Reliance Industries Ltd.	0.136	0.019	-0.008	0.863	-0.001	-0.077
Reliance Infrastructure Ltd.	0.188	0.035	-0.042	1.151	-0.378	-0.385
State Bank of India	0.127	0.016	-0.028	1.520	-0.168	-0.154
Sterlite Industries (India) Ltd.	0.344	0.119	0.022	1.145	0.391	0.284
TCS Ltd.	0.145	0.021	-0.006	0.998	0.037	-0.028
Tata Motors Ltd.	0.162	0.026	-0.012	1.399	0.003	-0.045
Tata Steel Ltd.	0.182	0.033	-0.028	1.512	-0.169	-0.155
Wipro Ltd.	0.129	0.017	-0.070	0.846	-0.743	-0.956
Tata Power Company Ltd.	0.115	0.013	-0.032	1.690	-0.205	-0.160

(Source: Self Constructed)

From the above table it can be seen that a few stocks gave negative returns. This could be due to a host of reasons including bear hammering and recession in a sluggish secondary market. As the criteria for selection mentioned above ignores stocks with negative returns such, stocks have been ignored. The Sharpe model will automatically exclude such stocks as its ranking is based on excess returns (returns greater than risk free rate of return). Further, we use equation (3) to establish unique cutoff C*.

Table 2 shows ranking of securities in portfolio based on excess return-to-beta ratio and calculation of unique cutoff point C*.

Table 2: Ranking of securities and establishing a cutoff rate C* for portfolio with s2m= 0.007653

Company	*Excess Return to Beta*	*(Ri-Rf)* β/s2i*	*β2/σ2i*	*Σ (Ri-Rf)* β/σ2i*	*Σβ2/σ2i*	*Cut-Off rate*
Jaiprakash Associates Ltd.	0.801	4.943	6.169	4.943	6.169	0.03612
Larsen & Toubro Ltd.	0.371	10.476	28.226	15.418	34.395	0.09341
Sterlite Industries (India) Ltd.	0.284	3.145	11.064	18.563	45.460	0.10540
Bharat Heavy Electricals Ltd.	0.240	26.113	108.954	44.676	154.414	0.15672
Jindal Steel & Power Ltd.	0.233	2.506	10.751	47.183	165.165	0.15949
HDFC	0.207	2.373	11.462	49.555	176.627	0.16127
Hindustan Unilever Ltd.	0.161	11.622	71.967	61.177	248.594	0.16131
HDFC Bank Ltd.	0.156	8.950	57.465	70.127	306.059	0.16058
Hero Honda Motors Ltd.	0.126	7.673	60.852	77.801	366.911	0.15636
Bharti Airtel Ltd.	0.119	7.901	66.602	85.702	433.513	0.15191

(Source: Self Constructed)

It can be observed from Table2 that the unique cutoff i.e. C* has been derived as 0.161308. Thus, only 7 securities having excess return to beta ratio above 0.161308 are qualified for the optimum portfolio. After construction of optimal portfolio, we find the percentage invested in each of these 7 securities using the equation (4) given above.

Table 3, exhibits the optimum portfolio of seven securities and the percentage invested in each security.

Table 3: Optimal Portfollo with percentage invested in each security

Company	βi/σi	βi/s i βi	Ri-Rf -C* Zi	Xi	Xi (%)
Jaiprakash Associates Ltd.	9.04530	0.63987	5.78783	0.28656	28.65585
Larsen & Toubro Limited	25.30546	0.20983	5.30978	0.26289	26.28901
Sterlite Industries (India) Ltd.	9.66266	0.12291	1.18768	0.05880	5.88027
Bharat Heavy Electricals Ltd.	84.15408	0.07836	6.59458	0.32650	32.65012
Jindal Steel & Power Ltd.	8.72009	0.07182	0.62628	0.03101	3.10073
HDFC	14.71570	0.04570	0.67254	0.03330	3.32976
Hindustan Unilever Ltd.	107.08652	0.00018	0.01904	0.00094	0.09426

(Source: Self Constructed)

After finding the percentage invested in each of these 7 securities using the equation (4), expected return and variance of the optimum portfolio is calculated using equation (5) and covariance matrix.

Table 4 gives calculations for expected return

Table 4: Expected Return

Company	*XiRi*	*Xiβi*	*Xi2*	*Xi2*σi*
Jaiprakash Associates Ltd.	0.17527	0.19544	0.08212	0.00619
Larsen & Toubro Limited	0.12597	0.29323	0.06911	0.00305
Sterlite Industries (India) Ltd.	0.02297	0.06733	0.00346	0.00041
Bharat Heavy Electricals Ltd.	0.12261	0.42272	0.10660	0.00164
Jindal Steel & Power Ltd.	0.01093	0.03823	0.00096	0.00014
HDFC	0.00754	0.02594	0.00111	0.00006
Hindustan Unilever Ltd.	0.00016	0.00063	0.00000	0.00000
Total	0.46546	1.04353		0.01148

(Source: Self Constructed)

Covariance matrix is shown below.

Table 5: Covariance Matrix

0.006191722	0.001768654	0.000513633	0.001001744	0.000219807	0.000160432	1.10902E-06
0.001768654	0.003046278	0.000352268	0.000913723	0.000194768	0.000100155	1.00074E-06
0.000513633	0.000352268	0.000409762	0.000282736	5.08449E-05	3.49929E-05	3.40548E-07
0.001001744	0.000913723	0.000282736	0.001640076	0.000167995	5.75777E-05	8.16552E-07
0.000219807	0.000194768	5.08449E-05	0.000167995	0.000135934	7.00181E-06	1.14978E-07
0.000160432	0.000100155	3.49929E-05	5.75777E-05	7.00181E-06	5.86858E-05	8.34781E-08
1.10902E-06	1.00074E-06	3.40548E-07	8.16552E-07	1.14978E-07	8.34781E-08	5.57616E-09

(Source: Self Constructed)

The values in the table 5 are added to get the portfolio variance which is 0.23.

Table 6 shows the portfolio standard deviation, portfolio variance and portfolio return.

Table 6: Portfolio variance, Standard Deviation and Portfolio Return

σ2p	σp	Rp
0.023142059	0.152125144	0.465457996

(Source: Self Constructed)

And lastly, Sharpe's ratio, Treynor ratio and Jenson Alpha are used to demonstrate the performance of an optimal portfolio given by expression (7, 8, 9 respectively).

Table 7: Sharpe ratio, Treynor ratio and Jenson Alpha

Sharpe Ratio	Rp-Rf /σp	2.631051953
Trynors Ratio	Rp-Rf/ Weighted Beta	0.383754331
Jenson Alpha	Rp-CAPM Return	0.282548538

(Source: Self Constructed)

Findings

- The optimum portfolios thus constructed are largely diversified as securities in the individual portfolio represent different sectors of the economy-, Financial Institutions, FMCG, Capital Goods, Metal, Metal Products and Mining, Housing, etc.
- From Table 2, it is observed that the cutoff rate C* for the Portfolio is 0.161308.
- Expected return on portfolio is 46.54 %.
- Portfolio risk is 15.21%.
- Sharpe's ratio, Treynor ratio and Jenson Alpha as a measure of performance evaluation for the Portfolio work out to be 2.631051953, 0.383754331 and 0.282548538 respectively.

Conclusion

Individual securities, as we have seen, have risk-return characteristics of their own. Portfolios, which are combinations of securities, tend to spread risk over many securities and thus help to reduce the overall risk involved. If we try to conclude about the risk involved, then Portfolio outperforms the individual securities as its variability in return is less in comparison. Investor with less risk appetite will definitely prefer diversified portfolio with less risk and decent return. A comprehensive measure of performance evaluation of the Portfolio is given by Sharpe's ratio, Treynor ratio and Jenson Alpha together. The greater these measures, the better is its performance. This method of construction of optimal portfolio and further evaluation of its performance is very effective and convenient as revision of the optimal portfolio can be an on-going exercise. The existence of a cutoff rate is also extremely useful because most new securities that have an excess return-to beta ratio above the cutoff rate can be included in the optimal portfolio.

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ISSN 2231-1769

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