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Performance Analysis Based on Adequate Risk-Adjusted Measures

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Abstract

There are many potential investment options for investors and they should be able to compare them on a risk-adjusted basis. If investors rely only on pure return they can be exposed to a high risk. Therefore, many investors rely on adequate performance measures to evaluate potential investment opportunities. In this paper, we describe widely used risk-adjusted performance measures and add correlation through the M3 measure. We apply described measures to real financial data in order to rank managers and compare rankings between measures. We also look at the following year measures to compare the results with predictions.
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JEL classification G11, G17

Introduction

According to the Investment Company Institute (2018) in 2017 total net assets of worldwide regulated open-end funds was more than $ 49 trillion and have more than doubled in the past decade. Therefore, investors need instruments to analyse and choose the best funds.

Investors rely on risk-adjusted measures. However, there are a lot of measures that can be used, and it is not clear which ones are better or worse since none of the investors uses the same measures. In addition, such variety can be explained by investors not being able to define risk in such a way that it would incorporate all necessary parameters. We present several performance measures discussing the advantages and disadvantages of each.

In addition, to giving different risk definitions we will incorporate a correlation using the M3 measure (see Muralidhar (2000)). Correlation is an important parameter when one wants to create a portfolio rather than investing in a single stock. If we define risk as a standard deviation of stock returns (as most investors do) or some sort of standard deviation, then if we have a portfolio of two or more stocks then the combined standard deviation is not a sum of single standard deviations. Instead, we have a correlation term and a portfolio standard deviation looks like this

$$\sigma^2_{Portfolio} = \sigma^2_A\omega^2_A + \sigma^2_B\omega^2_N + 2\rho_{A,B}\omega_A\omega_B\sigma_A\sigma_B,$$

where σ_A and σ_B are standard deviations of stocks A and B respectively, ω_A and ω_B are weights invested om stocks A and B respectively, $\rho_{A,B}$ is a correlation between stocks A and B.

It is clear from this equation that investors should seek negative or small correlation to decrease the portfolio risk. That is why it is important to be able to select new investments not only by their returns but also making an adjustment for correlation between new stock and an existing portfolio.

Another way to incorporate correlation is to use the approach that was proposed by Dowd (2000). His method shows how to adjust for correlation using the most popular and widely used risk-adjusted measure — Sharpe ratio. Dowd's basic idea is the following: calculate the Sharpe ratio before accepting new stock and calculate on the stock was accepted a while ago, then we can compare these two ratios and if it increased then we would proceed with the deal. In this case, we account for correlation when we calculate the new Sharpe Ratio.

In addition, in a recent research done by Ornelas, Silva Júnior, and Fernandes (2010) shows that performance ratios matter. Previously, Eling (2008) showed that some measures have a very high correlation in ranking with the Sharpe ratio and it might be enough just to look at Sharpe Ratio. However, Ornelas, Silva Júnior, and Fernandes (2010) exploited other measures in their research and agreed with Eling to some degree but not all measures produced a high correlation. Therefore, we should look at and compare measures and we cannot use only the Sharpe Ratio.

Risk-Adjusted Performance Measures

As was mentioned previously there are many risk-adjusted performance measures and their variations. In this paper, we describe some of the most commonly used measures and discuss their advantages and disadvantages. More detailed information can be found in Bacon (2013), Dowd (2000), Goodwin (1998), Grinold and Khan (1999), Harlow (1991), Lo (2002), Madgon-Ismail and Atiya (2004), Modigliani and Modigliani (1997), Muralidhar (2000, 2001, 2005), Papageorgiou (2005), Rollinger and Hoffman (2015), Prokopczuk, Rachev, and Truck (2004), Sharpe (1966, 1994), Sortino and van der Meer (1991) and Young (1991). Table 1 shows some widely used measure.

As we can see from Table 1 there are multiple definitions of risk and it is almost impossible to choose one. However, investors can choose the one that suits their vision of the market the best. We will apply all these measures to real-life financial data and later we will describe how investors can incorporate correlation using Dowd's (2000) approach.

Fund case-studies

In this section, we describe the procedure that was used to calculate all ratios and the way funds were selected.

Article by Bill Harris "'The 10 Biggest Mutual Funds: Are They Really Worth Your Money?" in Forbs brought our attention and 8 out of 10 funds presented were chosen for the illustration. Two funds from this article were eliminated because they are fixed income funds. To be able to compare apples to apples they were not selected because comparison would not be fair when we have to select a benchmark.

Monthly data was taken for the 11 years from 1/1/2006 up to 1/1/2017 for all 8 funds. First, ten years were used to analyse the risk-adjusted performance of all funds when the last year was used to compare the results for the previous 10 years and the following year. The data were obtained for all funds and for the benchmark which was chosen to be S&P500 because funds are different by their nature and we need a common benchmark. Also, one should note that the financial crisis of 2008–2010 was included in calculations. Therefore, some returns were small however we decided they are not outliers because it is a part of the risk of investing in a market.

Sharpe Ratio

First, let's show how the Sharpe Ratio can be applied to the 8 selected funds. As we know from the definition of the Sharpe ratio we need an appropriate risk-free rate. In this example, US 10 years T-Bond rate as of 12/31/2005 was chosen and equal to 4.39%. 10 years T-Bonds were chosen because we want to make sure we would make more on our investments rather than investing in a risk-free rate and leaving money there for 10 years. In Table 2 we can see the Sharpe ratio and all the information needed for all 8 funds:

As we can see from the Table 2 all funds produce positive returns and greater than the risk-free rate. Therefore, it would be more beneficial for investors in a long run to invest in any of these funds rather than risk-free rate even though the financial crisis of 2008–2010 are included in this dataset.

Table 2 allows us to make the following conclusions:

If we compared pure return without adjusting for risk, then the fund 3 would be the most attractive. Fund 3 was the best even after adjusting for the risk (standard deviation) because its return to risk had the best ratio.

Fund 6 produced a quite small annual return over the last 10 years comparing to the risk they took. They produced only 5.13% return per year, but they took 22.05% of the risk, which was the highest risk among all 8 funds.

In addition, maybe fund 5 did not produce the highest return but its risk was relatively small keeping in mind that the Financial Crisis period was included and fund 5 got the 5th rank.

Table 1
Risk-adjusted performance measures

Name	Definition	Advantages	Disadvantages
Sharpe Ratio	$SR = \frac{\mu - R_f}{\sigma}$	– Allows to compare and rank fund /managers – Most of its advantages and disadvantages are known	– σ is not always an appropriate risk measure – σ punishes companies for upward momentum – no interpretation of the number
Information Ratio	$IR = \frac{\overline{ER}}{\hat{\sigma}}$	– Useful measure when the benchmark is carefully chosen	– Not a complete statistic – Only maximizing IR can lead to wrong decisions
M3	$r(CAP) = a\mu + bR_B + (1-a-b)R_f$	– Adjust for correlation – Provide guidance on how to build a portfolio	– Correlation is not stable over time – Hard to compare funds on the after-fee basis
Sortino Ratio	$S = \frac{\mu - R_T}{TDD}$	– Accounts only for the downside deviation – Accounts for risk better if the distribution is not symmetric	– Does not account for correlation – No guidance on how to build a portfolio
Calmar Ratio	$Calmar = \frac{\mu - R_f}{MDD}$	– Shows a long-term perspective – Shows the cumulative loss investors can have – Not sensitive to momentum changes	– No easy way to change frequencies – Needs a lot of time to reflect momentum changes
RAROC	$RAROC = \frac{\mu}{VaR}$	– Allows to compare businesses with different sources of risk – A powerful tool in asset allocation and risk control	– Hard to determine Cost of Capital Rate – More accounting-based ratio –Hard to calculate VaR if a small number of returns are present

Source: the authors.

Note:

$\mu = E(R_t) = \frac{1}{T}\sum_{t=1}^{T} R_t$ – mean return

$\sigma^2 = \frac{1}{T}\sum_{t=1}^{T}(R_t - \mu)^2$ – variance of returns

$\overline{ER} = \frac{1}{T}\sum_{t=1}^{T}(R_{P_t} - R_{B_t})$ – mean excess return over the benchmark, where R_{P_t} – return of the portfolio, R_{B_t} – return of the benchmark

$\hat{\sigma} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(ER_t - \overline{ER})^2}$ – standard deviation of excess return, where $ER_t = R_{P_t} - R_{B_t}$

σ_i – standard deviation of stock i or portfolio i

σ_B – standard deviation of the benchmark

$a = \sqrt{\frac{\sigma_B^2\left(1-\rho_{T,B}^2\right)}{\sigma_1^2\left(1-\rho_{1,B}^2\right)}}$ – portion invested in a fund

$b = \rho_{T,B} - a\frac{\sigma_1}{\sigma_B}\rho_{1,B}$ – portion invested in the benchmark

R_T – target return

$TDD = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Min\left(0, R_t - R_T\right)\right)^2}$ – target downside deviation

$MDD = \frac{\text{Through value - Peak value}}{\text{Peak value}}$ – maximum drawdown

$VaR: P\left(X < -VaR\right) = \alpha \text{ or } \int_{-\infty}^{-VaR} f\left(x\right)dx = \alpha$ – where X is a random variable that the represents the profit and loss of the business.

Table 2
Sharpe ratio case-studies for 2006–2016

Fund	Return	Standard Deviation	Sharpe Ratio	Rank
F	4.39%	0		
1	6.56%	14.15%	0.15313	VI
2	6.33%	21.33%	0.09116	VII
3	10.00%	18.77%	0.29881	I
4	9.29%	19.83%	0.24690	IV
5	5.13%	4.54%	0.16248	V
6	5.51%	22.05%	0.05064	VIII
7	9.13%	18.38%	0.25801	III
8	9.60%	18.53%	0.28103	II

Source: the authors.

As we can see Sharpe ratio gives different ranking rather than a pure return. In addition, it allows easy calculations and comparison between the fund's return and risk.

Now let's compare the results for the following year. Risk-free rate was chosen as 1-year US rates of 0.89%.

As we can see from the Table 3 that all Sharpe ratios increased because in the previous examples Financial Crisis was included. Table 3 allows us to make the following conclusions:

If we compare just pure annual returns, then fund 2 would have the first place but fund 2 has one of the highest risks among all 8 funds which brings fund 2 to the 4th place.

Previous Sharpe Ratio ranked fund 6 as the least attractive fund. However, as we can see from its performance in the following year fund 6 got one of the highest returns and one of the lowest risks. That is why Sharpe ratio ranked fund 6 as the first one.

Another big change was for fund 5. Even with Financial Crisis fund 5 had the average annual return of 5.13%. However, in 2017 it returns dropped to 2.4% which brought it to the last place even though it has the lowest risk among all 8 funds.

Table 3
Sharpe ratio case-studies for 2017

Fund	Return	Standard Deviation	Sharpe	Previous Sharpe	Ranking	Previous Ranking	Increase/ Decrease
F	0.89%	0.00%					
1	8.99%	3.83%	2.12	0.1531	VI	VI	Increase
2	24.63%	7.17%	3.31	0.0912	IV	VII	Increase
3	24.39%	9.15%	2.57	0.2988	V	I	Increase
4	17.84%	8.94%	1.90	0.2469	VII	IV	Increase
5	2.39%	1.79%	0.84	0.1625	VIII	V	Increase
6	23.83%	4.42%	5.20	0.0506	I	VIII	Increase
7	19.48%	4.33%	4.30	0.2580	III	III	Increase
8	18.98%	4.18%	4.33	0.2810	II	II	Increase

Source: the authors.

Table 4
Information ratio case-studies for 2006–2016

Fund	Return/Excess Return	Standard Deviation	Information Ratio	Rank
B	7.25%	18.74%		
1	–0.69%	8.85%	–0.0781	VI
2	–0.91%	12.17%	–0.0750	V
3	2.75%	10.18%	0.2702	III
4	2.04%	8.50%	0.2399	IV
5	–2.12%	18.30%	–0.1158	VI
6	–1.74%	11.95%	–0.1456	VIII
7	1.88%	5.73%	0.3290	II
8	2.35%	5.53%	0.4251	I

Source: the authors.

Information Ratio

First, let's discuss how the benchmark was selected and the details of these calculations.

Since funds that were selected have different nature then it would be beneficial for all of them to select a benchmark which is a whole market or S&P500 since some of these funds are stock market indexes, some are growth funds, etc. Therefore, to be consistent, S&P500 was selected as a benchmark.

As we know from the definition of the Information ratio we need to have an average annual excess return and standard deviation of the excess return. Therefore, to obtain these values annual returns for each fund were used then S&P500 annual returns were subtracted from the fund's returns. Further, the average was taken and the standard deviation for each fund. Hence, we can see the result of the calculations in Table 4.

As we can see from Table 4 not many funds managed to produce a positive excess return over the 10 years if the market (S&P500) was selected as a benchmark.

Table 4 allows us to make the following conclusions:

As in the Sharpe ratio fund, 3 managed to produce the highest excess return. However, in the relationship to a benchmark, this fund was exposed to one of the highest risks among all 8 funds.

Fund 8 produced almost the same excess return as fund 3. However, fund 8 did not take as much "extra" risk as fund 3. Therefore, now fund 8 has the highest Information ratio and the lowest tracking error among all funds. It means that

Table 5
Information ratio case-studies for 2017

Fund	Return/Excess Return	Standard Deviation	Information Ratio	Previous IR	Ranking	Previous Ranking	Increase/ Decrease
B	17.32%	5.68%					
1	–12.64%	8.82%	–1.4333	–0.0781	VII	VI	Decrease
2	0.15%	10.65%	0.0137	–0.0750	I	V	Increase
3	–0.21%	13.23%	–0.0160	0.2702	II	III	Decrease
4	–5.54%	12.90%	–0.4294	0.2399	IV	IV	Decrease
5	–17.90%	6.04%	–2.9618	–0.1158	VIII	VI	Decrease
6	–0.39%	7.65%	–0.0515	–0.1456	III	VIII	Increase
7	–3.98%	8.09%	–0.4923	0.3290	V	II	Decrease
8	–4.39%	7.88%	–0.5569	0.4251	VI	I	Decrease

Source: the authors.

Table 6
M2 ratio case-studies for 2006–2016

Fund	Return	Standard Deviation	d	RAP	Rank
F	4.39%	0.00%			
B	7.25%	18.74%			
1	6.56%	14.15%	0.3247	7.26%	VI
2	6.33%	21.33%	–0.1214	6.10%	VII
3	10.00%	18.77%	–0.0015	9.99%	I
4	9.29%	19.83%	–0.0551	9.02%	IV
5	5.13%	4.54%	3.1264	7.43%	V
6	5.51%	22.05%	–0.1501	5.34%	VIII
7	9.13%	18.38%	0.0196	9.22%	III
8	9.60%	18.53%	0.0111	9.66%	II

Source: the authors.

funds 8 is more attractive for the investor rather than funds 3 if we compare it to the Sharpe ratio.

As we compare Information Ratio ranking with the Sharpe ratio overall there is a difference but most of the funds are changed places by one ranking. However, Information ratio allows us to compare returns not only with a risk-free rate but it can be interpreted as how much "additional" risk each fund brings to the market risk.

Finally, if we use Grinold and Khan (1999) approach and compare Information ratio with 0.5, 0.75, and 1.0 we can see that none of the funds produced even "good" Information ratio over the 10 years period.

Now let's compare the results for the following year.

There are few things could be noted from the Table 5.

Almost all funds except for fund 2 had a negative excess return which means that all of them did not manage to beat the benchmark for the following year.

Fund 8 that was previously ranked the worst fund now got the third rank and it is one of two funds which information ratio increased even though it is still negative.

Since almost all funds have negative information ratio then based on the information ratio investor shouldn't invest in any of the funds. Even fund 2 which have a positive information ratio have a ratio of 0.01.

Table 7
M2 ratio case-studies for 2017

Fund	Return	Standard Deviation	d	RAP	Previous RAP	Ranking	Previous Ranking	Increase/ Decrease
F	0.89%	0.00%						
B	17.32%	5.68%						
1	8.99%	3.83%	0.4831	12.90%	7.26%	VI	VI	Increase
2	24.63%	7.17%	−0.2086	19.68%	6.10%	IV	VII	Increase
3	24.39%	9.15%	−0.3798	15.46%	9.99%	V	I	Increase
4	17.84%	8.94%	−0.3651	11.65%	9.02%	VII	IV	Increase
5	2.39%	1.79%	2.1761	5.66%	7.43%	VIII	V	Decrease
6	23.83%	4.42%	0.2854	30.38%	5.34%	I	VIII	Increase
7	19.48%	4.33%	0.3113	25.27%	9.22%	III	III	Increase
8	18.98%	4.18%	0.3591	25.48%	9.66%	II	II	Increase

Source: the authors.

M2 Ratio

As we know from the definition of M2 we need a benchmark and a risk-free rate. Risk-free rate and the benchmark were chosen the same way and the same values as in Sharpe and Information ratios. Results of the calculations can be found in Table 6.

As we know from the nature of M2 measure it produces the same ranking as a Sharpe Ratio but instead of having a number which can be hard or impossible to interpret (Sharpe ratio), RAP gives investors a risk-adjusted return that was calculated based on the leverage/deleverage of the portfolio.

Table 6 allows us to make the following conclusions:

Funds 1, 5, 7, and 8 produced higher risk-adjusted return rather than a pure return. However, funds 2, 3, 4, 6 produce a lower risk-adjusted return.

On a pure return fund, 5 did not look very attractive to the investors. However, it was not exposed to a lot of risks (just 4.54%) and after adjusting for risk fund 5 produced a 7.43% return.

Fund 6 was exposed to the highest risk among all funds which brought this fund to the 8th place.

Now let's compare the results with the following year:

There are few things could be noted from the Table 7:

Fund 6 had the highest risk-adjusted return of 30%.

Fund 5 had the only RAP measure that decreased for the following year in comparison to the previous year. However, its risk-adjusted return was 5.6% when the pure return was only 2.4%.

Fund 3 moved from the first place to the fifth having a risk-adjusted return of 15.46% when the pure return was 24.4%.

M3 Ratio

As we established, in the beginning, it is important to adjust for the correlation between a benchmark and a fund's return. One of the measures that adjust for the correlation is M3. It requires benchmark returns (S&P500), risk-free rate (US T-Bond) and a target tracking error. For the target tracking error was 7% selected. Which corresponds to 0.9302 of the target correlation $1-\frac{0.07^2}{2\times(0.1874)^2}$. The choice of the tracking error was made based on the risk-free return and the return of a benchmark. Investors always should seek a target return higher than a risk-free therefore it is higher than 4.4% but it is lower than the market because we want to be conservative and prepare for a lower return of the market than in previous years. Investors can choose any target tracking error, but calculations will be exactly the same.

Table 8 allows us to make the following conclusions:

Correlation influences ranking funds/managers. For example, the Sharpe ratio suggested that

Table 8
M3 ratio case-studies for 2006–2016

Fund	Return	Standard Deviation	$\rho_{1,B}$	d	TE	a	b	1-a-b	M3	Rank
F	4.39%	0.00%	0							
B	7.25%	18.74%	1	100%						
1	6.56%	14.15%	0.8921	132.47%	7.26%	1.0758	0.2057	−0.2815	7.31%	VI
2	6.33%	21.33%	0.8231	87.86%	6.10%	0.5678	0.3983	0.0339	6.63%	VII
3	10.00%	18.77%	0.8526	99.85%	9.99%	0.7014	0.3313	−0.0327	9.27%	III
4	9.29%	19.83%	0.9043	94.49%	9.02%	0.8125	0.1526	0.0349	8.80%	IV
5	5.13%	4.54%	0.2155	412.64%	7.43%	1.5509	0.8492	−1.4001	7.96%	V
6	5.51%	22.05%	0.8404	84.99%	5.34%	0.5755	0.3611	0.0634	6.06%	VIII
7	9.13%	18.38%	0.9525	101.96%	9.22%	1.2292	−0.2182	−0.0110	9.60%	II
8	9.60%	18.53%	0.9560	101.11%	9.66%	1.2653	−0.2661	0.0008	10.22%	I

Source: the authors.

Table 9
M3 ratio case-studies for 2017

Fund	Return	Standard Deviation	$\rho_{1,B}$	d	M3	Previous M3	Rank	Previous Rank	Increase/ Decrease
F	0.89%	0.00%	0						
B	17.32%	5.68%	1	100%					
1	8.99%	3.83%	−71.22%	148.31%	37.62%	7.31%	I	VI	Increase
2	24.63%	7.17%	−36.59%	79.14%	30.69%	6.63%	VI	VII	Increase
3	24.39%	9.15%	−56.96%	62.02%	33.09%	9.27%	V	III	Increase
4	17.84%	8.94%	−53.50%	63.49%	27.30%	8.80%	VII	IV	Increase
5	2.39%	1.79%	−5.61%	317.61%	10.36%	7.96%	VIII	V	Increase
6	23.83%	4.42%	−13.54%	128.54%	35.90%	6.06%	II	VIII	Increase
7	19.48%	4.33%	−29.64%	131.13%	34.56%	9.60%	III	II	Increase
8	18.98%	4.18%	−26.33%	135.91%	33.92%	10.22%	IV	I	Increase

Fund	a	b	1-a-b	Previous a	Previous b	Previous 1-a-b	TE	Previous TE
1	2.051	1.224	−2.276	1.076	0.206	−0.282	12.90%	7.26%
2	0.826	0.621	−0.447	0.568	0.398	0.034	19.68%	6.10%
3	0.733	0.912	−0.645	0.701	0.331	−0.033	15.46%	9.99%
4	0.730	0.854	−0.584	0.813	0.153	0.035	11.65%	9.02%
5	3.089	0.294	−2.382	1.551	0.849	−1.400	5.66%	7.43%
6	1.260	0.372	−0.632	0.576	0.361	0.063	30.38%	5.34%
7	1.333	0.541	−0.874	1.229	−0.218	−0.011	25.27%	9.22%
8	1.368	0.504	−0.872	1.265	−0.266	0.001	25.48%	9.66%

Source: the authors.

Table 10
Sortino ratio case-studies for 2006–2016

Fund	Return	TDD	Sortino	Rank
B	4.39%	0.00%		
1	6.56%	14.39%	0.1505	VI
2	6.33%	20.13%	0.0966	VII
3	10.00%	17.07%	0.3285	I
4	9.29%	18.14%	0.2699	III
5	5.13%	3.35%	0.2203	V
6	5.51%	21.84%	0.0511	VIII
7	9.13%	17.59%	0.2695	IV
8	9.60%	17.05%	0.3054	II

Source: the authors.

the most attractive fund for investments is fund 3. However, if we adjust for the correlation the most attractive fund will be 8 the same as Information ratio suggested.

The M3 measure gives investors guidance on how to build a portfolio out of risk-free rate, benchmark and a fund. For example, if we used the strategy that M3 suggests we would get 10.2% of risk-adjusted return on fund 8. When its pure return was only 9.6%.

Some funds outperform on an unadjusted basis but underperform on an adjusted basis and *vice versa*. For example, fund 3 had 10% unadjusted return but only 9.3% adjusted return.

Fund 5 has one of the least attractive pure returns for the investors. However, after adjusting for risk and correlation it has the highest change to M3 of 64.4%.

For the following year, target correlations are calculated based on 7% which gives us $\rho_{T,B} = 23.9\%$. Now let's compare the results:

As we can see from the Table 9 the following conclusions can be drawn:

Fund 1 now has the first ranking most likely due to the fact that it has a very strong negative correlation with the benchmark for the following year.

Fund 1 has one of the lowest pure returns, however, after the adjustment for correlation gives it 37.62% of return after the correct allocation of investments between fund, benchmark, and a risk-free rate.

It makes sense that all ratio increased for the following year because for the previous crisis years of 2008–2010 was included. Therefore, return adjusted for correlation is greater for the following year.

Sortino Ratio

Next ratio is a Sortino ratio that uses the Target Downside Deviation (TDD) as a risk measure. In the formula of the TDD, we need to use the target required rate of return. As a target rate risk-free rate was chosen because it is a minimum return that investors should require from funds.

In Table 10 calculations are presented for all 8 funds:

Table 10 allows us to make the following conclusions:

Fund 6 as in most of the previous measures is exposed to the highest risk among all 8 funds in addition to having very low return it brings it to the last place.

Fund 5 as in most of the previous measures has the lowest risk of only 3.35%. When the majority of funds have more than 15% of the risk. However, having a very low return gives fund 5 only the 5th place.

Fund 3 having the highest return among all 8 funds get the first place because it has a relatively low risk comparing to the other funds.

Now let's compare the results for the following year:

As we can see from the Table 11 that there is a big difference between previous Sortino ratio and a current one. This difference is because different annualization method was used. Since it was calculated only for a year monthly TDD was calculated and then multiplied by $\sqrt{12}$. Therefore, the comparison between ratios is not possible.

Table 11
Sortino ratio case-studies for 2017

Fund	Return	TDD	Sortino	Previous Sortino	Ranking	Previous Ranking	Increase/ Decrease
F	0.89%	0.00%					
1	8.99%	1.60%	5.0665	0.1505	V	VI	Increase
2	24.63%	2.14%	11.1075	0.0912	IV	VII	Increase
3	24.39%	5.12%	4.5877	0.2988	VI	I	Increase
4	17.84%	5.56%	3.0471	0.2469	VII	III	Increase
5	2.39%	1.00%	1.5004	0.1625	VIII	V	Increase
6	23.83%	0.61%	37.5334	0.0506	III	VIII	Increase
7	19.48%	0.42%	44.5980	0.2580	I	IV	Increase
8	18.98%	0.43%	42.2068	0.2810	II	II	Increase

Source: the authors.

Table 12
Calmar ratio case-studies for 2006–2016

Fund	Return	MDD	Calmar	Rank
F	4.39%	0.00%		
1	6.56%	10.99%	0.1971	V
2	6.33%	19.49%	0.0998	VI
3	10.00%	13.23%	0.4238	III
4	9.29%	20.29%	0.2413	IV
5	5.13%	9.43%	0.0782	VII
6	5.51%	23.21%	0.0481	VIII
7	9.13%	9.14%	0.5185	II
8	9.60%	10.02%	0.5199	I

Source: the authors.

However, we can compare rankings and make the following conclusions:

Most of the funds have TDD around or less than 1%. However, two funds 3 and 4 have a risk higher than 5% and as we can see that the previous Sortino ratio ranked them as top 3 funds.

Funds 7 and 8 have large Sortino ratios because they have a high return comparing to a low risk which brings them to the top two places.

Fund 6 which was the least attractive fund based on past performance has the third rank in the following year.

Calmar Ratio

In the Calmar ratio Maximum Drawdown (MDD) is used as a risk measure. The basic idea of the MDD is a maximum cumulative loss over the entire period. Calculations are presented in Table 12.

The following conclusions can be made from Table 12:

Fund 5 again has the lowest risk among all 8 funds. However, as we can see from the ranking the difference in risk is not significant enough because the Calmar ratio gave it the 7th place.

Fund 3 losses it's first place again because it has 13.23% of risk which is not too high, however, fund 8 has approximately the same return but lower risk which brings fund 8 to the first place and fund 3 to the 3rd.

Fund 6 has the highest risk and one of the lowest returns among all 8 funds which bring it to the 8th place again.

Now let's compare the results for the following year:

Like the Sortino ratio, we cannot compare the previous and current Calmar ratio because pre-

Table 13
Calmar ratio case-studies for 2017

Fund	Return	MDD	Calmar	Previous Calmar	Ranking	Previous Ranking	Increase/ Decrease
F	0.89%	0.00%					
1	8.99%	1.29%	6.2839	0.1971	V	V	Increase
2	24.63%	1.63%	14.5878	0.0998	IV	VI	Increase
3	24.39%	5.03%	4.6755	0.4238	VI	III	Increase
4	17.84%	5.48%	3.0953	0.2413	VII	IV	Increase
5	2.39%	1.35%	1.1132	0.0782	VIII	VII	Increase
6	23.83%	0.54%	42.7174	0.0481	III	VIII	Increase
7	19.48%	0.34%	54.2476	0.5185	I	II	Increase
8	18.98%	0.35%	51.0389	0.5199	II	I	Increase

Source: the authors.

Table 14
RAROC ratio case-studies for 2006–2016

Fund	Return	VaR	RAROC	Rank
1	0.50%	–5.29%	0.0948	IV
2	0.46%	–9.04%	0.0505	VII
3	0.74%	–6.72%	0.1104	II
4	0.68%	–7.12%	0.0959	III
5	0.42%	–1.43%	0.2909	I
6	0.40%	–10.00%	0.0396	VIII
7	0.69%	–7.47%	0.0918	VI
8	0.73%	–7.94%	0.0918	V

Source: the authors.

vious Calmar was calculated over the last three years but the current one only over the last year. However, we can compare rankings which will give us an idea of how funds did in comparison to each other and make the following conclusions:

Almost all funds have a risk of around 1% when funds 3 and 4 have a risk higher than 5% but in the previous Calmar ratio, they were in the top 4 funds.

Funds 6–8 have large Calmar ratio because they have a high return comparing to a very small risk which allows them to get the first three positions in the ranking. Also, if we compare their previous ranks we will see that finds 7 and 8 were in the top two, however, fund 6 was the last one.

Fund 1 did not change its ranking in comparison to other and fund 5 moved from the 7th position to the last one.

RAROC

As was discussed previously RAROC uses VaR as a measure of risk. In order, to determine VaR historical approach and monthly data was used in order to obtain VaR because 10 years are not enough to calculate the percentile carefully. Also, the 5th percentile was used to obtain Va R. Table 14 shows the calculations:

As we can see from Table 14 it gives very different results compared to other measures most likely because monthly data was used and not yearly. However, we still can make the following conclusions from Table 14.

All funds have negative VaR which means that none of the funds produced positive returns in the 5% of worst scenarios. Fund 6 has the highest risk among all funds. However, previously fund 6 had a lot higher risk than other

Table 15
RAROC ratio case-studies for 2017

Fund	Return	VaR	RAROC	Previous RAROC	Rank	Previous Rank	Increase/Decrease
1	0.75%	−1.00%	0.7502	0.0948	VI	IV	Increase
2	2.05%	−1.40%	1.4643	0.0505	IV	VII	Increase
3	2.03%	−2.48%	0.8188	0.1104	V	II	Increase
4	1.49%	−2.63%	0.5660	0.0959	VII	III	Increase
5	0.20%	−0.48%	0.4119	0.2909	VIII	I	Increase
6	1.99%	0.11%	18.1709	0.0396	III	VIII	Increase
7	1.62%	−0.05%	30.4743	0.0918	I	VI	Increase
8	1.58%	−0.08%	19.9601	0.0918	II	V	Increase

Table 16
Putting all measures together for the previous 10 years

Fund	Sharpe	Information	M2	M3	Sortino	Calmar	RAROC
1	VI	VI	VI	VI	VI	V	IV
2	VII	V	VII	VII	VII	VI	VII
3	I	III	I	III	I	III	II
4	IV	IV	IV	IV	III	IV	III
5	V	VI	V	V	V	VII	I
6	VIII	VIII	VIII	VIII	VIII	VIII	VIII
7	III	II	III	II	IV	II	VI
8	II	I	II	I	II	I	V

Source: the authors.

but using RAROC fund 2 has a risk almost as high as the fund's 6.

Fund 5 produced the lowest risk again and a relatively high monthly return which brings fund 5 to the first place.

Now let's compare the results for the following year:

RAROC was calculated based on a monthly basis because otherwise there is not enough data to calculated 5th percentile. From Table 15 we can draw the following conclusions:

Even though fund 6 has the third-ranking but it is the only fund which VaR is positive meaning that even the lowest 5% of returns is positive. That is why it is supposed to be the most attractive fund based on RAROC.

Fund 5 which had the first ranking before now has the lowest and it is the least attractive fund for investors.

If we compare the previous ranking and for the following year we can notice that it has a very big difference. Previous ratios changed places for fund just a little bit but RAROC brought some funds from the top ranking to the lowest and *vice versa*.

Putting All Ratios Together

Now, we would like to look at all the measures together. It will provide an easier comparison between measures and their rankings.

As we can see from the Table 16 all measures have quite different results. However, RAROC has the most distinct ranking most likely because it used monthly data.

If we look at specific funds the following can be noted:

All ratios ranked fund 6 as the least attractive fund for the investments including RAROC.

All measures except RAROC put fund 5 on places 5–7 (most of them gave it 6th place). However, based on RAROC this fund got the first place.

Table 17
Putting all measures together for the following year

Fund	Sharpe	Information	M2	M3	Sortino	Calmar	RAROC
1	VI	VII	VI	I	V	V	VI
2	IV	I	IV	VI	IV	IV	IV
3	V	II	V	V	VI	VI	V
4	VII	IV	VII	VII	VII	VII	VII
5	VIII	VIII	VIII	VIII	VIII	VIII	VIII
6	I	III	I	II	III	III	III
7	III	V	III	III	I	I	I
8	II	VI	II	IV	II	II	II

All measures agree that fund 3 must be at the top of the list. However, only Sharpe, M2 and Sortino ratios put it on the first places. Others gave it either second or third places. Especially, if we look at M3 it gave it the third place and we know that fund 3 underperforms on a risk-adjusted basis if we add correlation and benchmark into account and into the portfolio. Therefore, fund 3 shouldn't take the first place.

An interesting observation is that all ratios except for RAROC agreed on which funds take places from 1–4, and 5–8. All ratios ranked funds 3, 4, 7, and 8 as the top 4 funds out of 8. Even though they had different rankings they all shared the first half of the ranking.

Now let's look at the following year measures ranking:

From Table 16 and Table 17 we can make the following conclusions:

As we can see from the Table 17 almost all ratios agree that fund 7 and 8 should be on the first 3–4 positions. It agrees with the ratios of the previous 10 years. Almost all ratios gave funds 7 and 8 the top rankings.

The same as for the past 10 years all measures agree on the worst fund which this year it happens to be fund 5. Previously, all measures ranked fund 5 from 5–7th places except for RAROC which gave it the 1 place.

It is also interesting that all ratios except for M3 ranked fund 1 from 5–7th places. However, M3 gave it the first place which shows how much correlation affects the ranking. If we go back and look at Table 9 (3.8) we will see that fund 1 had the lowest negative correlation with the benchmark. Which proves our previous assumptions about correlation: investors seek investments with the negative correlation and the lower correlation the better because it helps to diversify the risk.

Conclusions

Risk-adjusted performance measures can play an important role when choosing new investments. Ranking managers can help to determine the best or the worst manager not only based on pure return but also adjusting for risk.

These measures can be applied not only while choosing new investments but also when hiring a new manager. If a fund wants to hire a new manager, they can calculate presented measures and select manager that attract them the most based on ratios between return and risk.

References

Bacon, C.R. (2013). Practical risk-adjusted performance measurement. Chichester, U.K.: Wiley.

Dowd, K. (2000). Adjusting for risk: An improved Sharpe ratio. International Review of Economics and Finance, 9(3), 209–222.

Eling, M. (2009). Does Hedge Fund Performance Persist? Overview and New Empirical Evidence. European Financial Management, 15, 362–401.

Goodwin, T. (1998). The Information Ratio. Financial Analysts Journal, 54(4), 34–43.

Grinold, R. C., & Kahn, R. N. (1999). Active portfolio management: A quantitative approach for providing superior returns and controlling risk. New York: McGraw-Hill.

Harlow, W. (1991). Asset Allocation in a Downside-Risk Framework. Financial Analysts Journal, 47(5), 28–40.

Harris, B. (2012, August 8). The 10 Biggest Mutual Funds: Are They Really Worth Your Money? Forbes. Retrieved May 8, 2018, from https://www.forbes.com/sites/billharris/2012/08/08/the-10-biggest-mutual-funds-are-they-really-worth-your-money/\#373c7f8f3cfe.

Investment Company Institute. (2018). Investment Company Fact Book. Retrieved from https://www.ici.org/pdf/2018_factbook.pdf.

Lo, A. (2002). The Statistics of Sharpe Ratios. Financial Analysts Journal, 58(4), 36–52.

Magdon-Ismail, M., & Atiya, A. F. (2004). Maximum Drawdown. Risk Magazine, 17(10), 99–102.

Modigliani, F. and Modigliani, L (1992). Risk-Adjusted Performance. Journal of Portfolio Management, 23(2), 45–54.

Muralidhar, A. (2000). Risk-Adjusted Performance: The Correlation Correction. Financial Analysts Journal, 56(5), 63–71.

Muralidhar, A. (2001). Optimal Risk-Adjusted Portfolios with Multiple Managers. Journal of Portfolio Management, 27(3), 97–104.

Muralidhar, A (2005). Why Maximizing Information Ratio is incorrect. Derivatives Use, Trading & Regulation, 11(3), 233–244.

Ornelas, J. R., Silva Júnior, A. F. and Fernandes, J. L. (2012), Yes, the choice of performance measure does matter for ranking of us mutual funds. International Journal of Finance and Economics, 17, 61–72.

Papageorgiou, N. (2005). Performance Measures. Retrieved from http://neumann.hec.ca/pages/nicolas.papageorgiou/qfm/slides/PerformanceMeasures.pdf.

Rollinger, T. and Hoffman, S. (2015). Sortino: A Sharper Ratio. Retrieved from https://www.cmegroup.com/education/_les/rr-sortino-a-sharper-ratio.pdf

Prokopczuk, M., Rachev, S., Truck, S. (2004). Quantifying risk in the electricity business: a RAROC based approach. *Journal of Energy Economics,* 29, 1033–1049.

Sharpe, W. (1966). Mutual Fund Performance. *The Journal of Business*, *39*(1), 119–138.

Sharpe, W. (1994). The Sharpe Ratio. *The Journal of Portfolio Management*, *21*(1), 49–58.

Sortino, F and van der Meer, R. (1991). Downside Risk. *The Journal of Portfolio Management*, *17*(4), 27–31.

Young, T. (1991). Calmar ratio: A Smoother Tool. *Futures Magazine*, *20*(1), 40.

Анализ инвестиционной деятельности на основе количественных мер, настроенных на риск

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Аннотация. Для инвесторов существует множество инвестиционных решений, и у них должна быть возможность сравнивать их эффективность с помощью количественных показателей, учитывающих риски. Если инвестор основывает свой выбор инвестиционного решения только на величине доходности, то он подвергается риску невозврата его инвестиций. Ввиду этого обстоятельства инвесторы основываются на таких количественных показателях качества своей инвестиционной деятельности, которые отражают возникающие при этом риски. В статье даются развернутые характеристики не только широко распространенных показателей такого типа, но и показателю M3, который учитывает корреляцию активов. Арсенал этих и других показателей применяется к реальным финансовым данным для более адекватного ранжирования инвестиционных менеджеров, позволяя при этом сравнивать полученные результаты с одногодичным прогнозом.

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