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Statistical Analysis of the Risk Assessment of Investors' Investments in Securities Portfolio

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Abstract

The subject of the research study is the measurement of the total investment risk through the statistical measures of dispersion (variance and the standard deviation), which give the investor information on the deviation of the realized annual return from average returns when making decisions on investing in company shares on the market. However, we should bear in mind the fact that the investor also wants to know how returns on investments in the shares of different companies move together. This cannot be determined by observing risk dispersion measures. Therefore, when making a decision on investing in securities, investors also use the measures of the degree of the linear relationship between the shares, such as covariance and a correlation coefficient.

The aim of the research study is to point out the fact that diversified investors strive to provide the least risky instruments in their possession on the basis of risk assessment through statistical risk assessment measures. However, the problem of assessing the risk of investing in securities is a complex concept, because it includes the interdependence of assessing the rate of return on securities and investment risk, based on which the investor considers a possible return offered individually by each observed security.

Keywords: statistical analysis, investment risk management, variance, standard deviation, diversification

Introduction

On the financial market, investors can choose between a large number of the shares and bonds of various issuers. Before making an investment decision, potential investors consider the possible return offered by each individually observed security. However, in addition to the assessment of return, the investor should also make an assessment of investment risk when making a decision on investing in securities. Measuring portfolio risk and measuring portfolio return are interrelated, which makes it difficult for the investor to assess them. Therefore, investors often use the statistical measures of dispersion (variance and the standard deviation) that give them information about the deviations of the realized return from the mean value (the arithmetic mean) of the companies "A" and "B". Dispersion measures aim to determine the dispersion of shares in one sample around the mean value, i.e. the higher the sample dispersion, the higher investment risk for a diversified investor. Variance is the deviation of the value of the return of one share from the average value of the return. The standard deviation is an even more precise measure of dispersion, because it is calculated as the root of variance. This measure is most often used by investors when making a decision on investing in securities.

In addition to the statistical dispersion measures, investors also use the measures that show the degree of the linear correlation of shares. There are a large number of linear dispersion coefficients in the literature, and two dispersion

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measures will be analyzed in this paper, these namely being covariance and a correlation coefficient. Covariance is a measure of the connection between shares between two companies. If it is positive, it means that stock prices are moving in the same directions, and if it is negative, a diversified investor can conclude that stock prices are moving in the opposite directions. A correlation coefficient is obtained when covariance is divided by the product of the standard deviations of such two companies, and it shows how much the two shares are interconnected, i.e. how they react to each other. It ranges from -1 to 1, and in case the value is equal to 0, it means that there is no connection between the actions, where the numerical value shows the strength of the connection and the sign shows the direction of the connection.

The concrete examples of two companies will be used in the paper to show the calculation of these statistical coefficients and, based on that, the potential investors' decision to invest in the securities portfolio. Statistical analysis is an unavoidable and comprehensive analysis, because it includes the assessment of risks and returns, as well as their interdependence, based on which potential investors choose the financial instrument which to invest their funds in.

Management of the Risk of Investment in Financial Instruments

Measuring risk is one of the most important phases of the entire financial instrument investment risk management process. The most commonly used risk assessment methods are dispersion measures (variance and the standard deviation) and the measures of common variation or covariance (covariance and correlation). The market return variance is the expected square deviation from the expected return. (Brealey, et al. 2020)

Suppose an investor has a choice between investing in the shares of the Company A and the Company B, with the following individual characteristics (Table 1):

Table 1: The expected returns and risks of investing in the shares of the companies A and B

	Investments in the shares of the company A	Investments in the shares of the company B
Expected return	0.630	0.120
Standard deviation	0.432	0.093
Correlation coefficient	1.980	1.230

There is a low investment risk with the shares of the company for which a smaller standard deviation of the return and a smaller variance are determined. The investments in the shares of company A have a greater standard deviation than the investments in the shares of the company B by more than 5 times (0.630 : 0.120 = 5.25). This means that the return on the shares of this company can vary over 5 times more than the investments in the shares of the company B.

The main manner to reduce the investors' general (market) investment risk is to diversify the portfolio. Diversification is a very old term. The saying "never put all your eggs in one basket" originated before economic theory. The diversification model was developed by the creator of said saying, Harry Markowitz, in 1952, for which he won the Nobel Prize in Economics. During the 1990s, for example, many investors were only investing in stock portfolios. They did not want to invest in stock, bond, and other financial instrument portfolios so as not to make a smaller profit, because technology companies were on the rise at that time. After the collapse of the technology sector, however, investors felt how dangerous it was to keep a portfolio only consisting of the shares of one single company or similar shares. (Bodie, et al. 2009)

When investors are concerned, even a small diversification can provide a significant reduction in variability. (Brealey, et al 2020)

The investor will reduce general market risk based on the analysis of the effects that the shares of each company may have on the risk of the entire share portfolio. Diversification seeks to reduce (if it cannot already eliminate such risk) the risk characteristic of a company's share. These are the risks of fluctuations in the return of the market price of a company's share under the significant influence of the market (macroeconomic) trends.

Diversification can eliminate specific risks, but diversification cannot eliminate certain risks – namely market risk. (Brealey, et al. 2020)

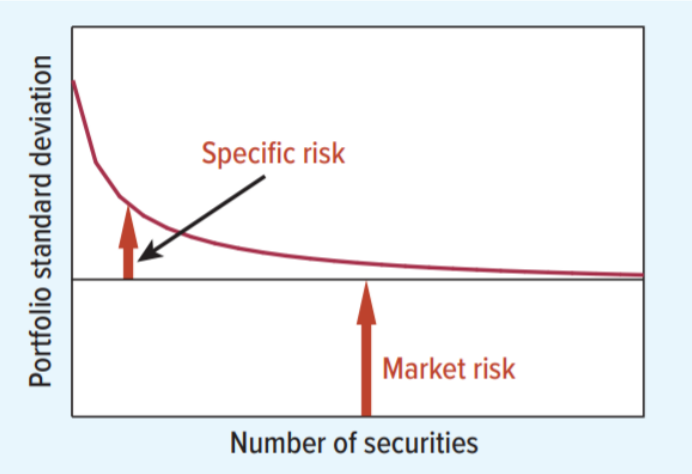

Figure 1. Diversification and risk (Brealey, et al. 2020)

In Figure one, risk is divided into two parts – a specific risk and a market risk. If an investor only had one stock, the specific risk would be very significant: on the other hand, if the investor opted for a portfolio of 20 or more shares, diversification would reduce the exposure to risk. For a well-diversified portfolio, only market risk is important. Therefore, the predominant source of uncertainty for a diversified investor is that the market will grow or that it will collapse, carrying with itself the investor's portfolio. (Brealey, et al. 2020)

Therefore, if an investor decides to form his portfolio from only one share, he will be exposed to company risk and general (market) risk. By diversifying a portfolio, i.e. by forming a portfolio from several instruments, the exposure of the securities (owned by the investor) to the influences within the issuing company is reduced because:

1. by investing funds in a diversified portfolio, the share of individual securities in the total portfolio is reduced. A reduction in the market price of only one of these securities will not have a significant impact (or any impact at all) on the market value of the entire portfolio. Conversely, if an investor owns a portfolio of only one security, with a change in the market price of that (one) security, the total market value of the portfolio will also change.
2. the market prices of individually observed securities change (either upwards or downwards), depending on the financial performance of the issuer. If an investor has a diversified portfolio, a shift in the market prices of some securities may affect the overall market value of the portfolio. The impact will be smaller or larger in the value of the entire portfolio, depending on the percentage share of the securities whose prices have changed. Practically, if the number of the securities in a portfolio was to increase indefinitely, no change in the market price of a financial instrument would have any impact on the market value of the portfolio (although this cannot be the rule).

We will support the claim that portfolio diversification reduces the risk of changes in the market price of one security to the total market value of the portfolio, with a concrete example. At the same time, the effects of increasing the number of instruments (in a portfolio) on the variance of individual securities will be considered. This variance, even more so the covariance of the entire portfolio, provides an answer to the questions: Why can diversification reduce a risk? and How much risk does it reduce? (Brealey et al., 2009)

For example, an investor intends to form his share portfolio by buying shares from the companies A and B. Before making a decision on investing funds, the investor will perform a risk analysis of investing in these companies. He will carry out said analysis based on the business results of the companies A and B in the previous period, taking into account the view that the present is a sum of the past and that the future is the projected present. In other words, in the real life of the company, riskiness in achieving returns in the past is most often confirmed in its future life, which our investor believes in. Suppose these companies achieved certain rates of return thanks to the investments of funds made by one (same) investor in the past period from 2015 to 2020.

The return growth rates were calculated according to the following equation:

Return in the current year i.e. in the year in which the calculation is made) $= \frac{\text{The market price for a share in the current year} - \text{The market price for a share in the previous year} + \text{The dividend in the current year}}{\text{Market share price in the previous year}}$

Using this formula, let us determine the achieved individual annual returns, based on which the average returns of the companies A and B are calculated:

Table 2: The annual rates of the realized growth (decline) of the returns of the companies A and B in the period from 2015 to 2020 (in %)

Year	The return achieved in the company A	The return achieved in the company B
2015	11%	48%
2016	56%	-30%
2017	-12%	5%
2018	-10%	120%
2019	26%	124%
2020	32%	150%
Total	103%	417%

The realized average return (AR) and the average value for the companies A and B are as follows:

$$AR_A = \frac{103}{6} = 17.17\% = 0.172$$

$$AR_B = \frac{417}{6} = 69.5\% = 0.695$$

Based on the arithmetic mean, no information on the differences between the individual values in Column 1 (Table 3) is obtained. An estimate of the deviation from the mean is needed. (Bodie et al., 2009). Thus, the deviation of the first value of the company A is as follows:

$$0.11 - 0.172 = -0.062$$

The other deviations are calculated in the identical way, as shown in Tables 3 and 4:

Table 3 : The squares of the deviation of the realized annual returns from the average returns of the company A

Year	The realized company return by years (1)	The arithmetic mean (2)	The deviation of the realized return from the arithmetic mean of the company A (3 = 1 - 2)	The squared deviation of the realized return from the arithmetic mean (4 = 3^2)
2015	11% = 0.11	0.172	-0.062	0.0038
2016	56% = 0.56	0.172	0.388	0.1505
2017	-12% = - 0.12	0.172	- 0.292	0.0853
2018	-10% = - 0.10	0.172	-0.272	0.0739
2019	26% = 0.26	0.172	0.088	0.0077
2020	32% = 0.32	0.172	0.148	0.0219
Total	103% = 1.03	0.172	0.00	**0.3431**

The arithmetic mean of the return achieved by the company A is 1.03 : 6 years = 0.172, i.e. 17.2%.

The total sum of all the deviations from the mean value is equal to zero, due to the mutual cancellation of the positive and negative deviations. One way to avoid undoing the positive and negative deviations is to square each deviation and then calculate their sum. These deviations are now squared in order to calculate variance and the standard deviation. The variance was obtained by subtracting the mean value from each value and squaring the results. The sum of the square deviations from the arithmetic mean of the company A is 0.3431. Finally, the mean square deviation from the value of the arithmetic mean (the variance) is determined by dividing the sum of the square deviations by n-1, where n denotes the number of the years of the analyzed period. The return variant of the company A is as follows:

$$s^2 = \frac{0.3431}{n-1} = \frac{0.3431}{5} = 0.0687$$

Variance shows the deviation of the realized return in each of the years of the analyzed period in relation to the average return.

The square root of variance is called the standard deviation, which in this case is as follows:

$$s = \sqrt{0.0687} = 0.26 \text{ or } 26\%$$

The previous procedure is repeated for the company B.

Table 4 : The squares of the deviations of the realized annual returns from the average returns of the company B

Year	The realized company return by years (1)	The arithmetic mean (2)	The deviation of the realized return from the arithmetic mean of the company B (3 = 1 - 2)	The squared deviation of the realized return from the arithmetic mean ($4 = 3^2$)
2015	48% = 0.48	0.695	-0.215	0.04622
2016	-30% = -0.30	0.695	- 0.995	0.99002
2017	5% = 0.05	0.695	- 0.645	0.41602
2018	120% = 1.20	0.695	0.505	0.25502
2019	124% = 1.24	0.695	0.545	0.29702
2020	150% = 1.50	0.695	0.805	0.64802
Total	417% = 4.17		0.00	**2.65232**

The arithmetic mean of the return of the company B in the period from 2015 to 2020 is as follows:

4.17 : 6 = 0.69, i.e. 69%.

The return variant of the company B is as follows:

$$s^2 = \frac{2.65232}{5} = 0.53046.$$

The standard deviation is (Baker, Powell 2005) is as follows:

$$s = \sqrt{0.53046} = 0.72 = 72\%$$

Based on the data from Tables 3 and 4, Table 5 is created as a comparative overview of the average returns and the standard deviations for the shares of both companies:

Table 5: The average return and the standard deviations for the shares of the companies A and B:

	Company A	Company B
Average realized return	17.2%	69%
Standard deviation	26.0%	72%

It can be concluded that Company B has the shares almost 3 times (72% : 26% = 2.8 times) riskier than the shares of Company A are. The investor also wants to know how these two financial instruments would behave together. He cannot find it out from the variance or the standard deviation, although these are the most well-known and the most frequently used dispersion measures. These measures were used to estimate the average deviation from the arithmetic mean. The investor also wants to know the difference between the realized return and the average return in both companies. It is necessary to calculate covariance and the correlation coefficient, which are the measures of the degree of the linear relationship between the shares.

The covariance between the shares of the companies A and B is calculated by not squaring the deviations, i.e. the differences of the individual returns from the arithmetic mean of the returns of these companies, but multiplying them by each other instead, as follows:

Table 6 : The calculation of covariance

Year	The realized return of the company A (1)	The realized return of the company B (2)	The deviation of the return from the arithmetic mean of the company A (3)	The deviation of the return from the arithmetic mean of the company B (4)	The product of the deviations of the companies A and B (5 = 3 x 4)
2015	11%	48%	-0.062	-0.215	0.01333
2016	56%	-30%	0.388	-0.995	-0.38606
2017	-12%	5%	-0292	-0.645	0.18834
2018	-10%	120%	-0.272	0.505	-0.13736
2019	26%	124%	0.088	0.545	0.04796
2020	32%	150%	0.148	0.805	0.11914
Total					**-0.15465**

$$\text{Covariance}_{A,B} = \frac{-0.15465}{5} = -0.03093$$

The negative value of the covariance indicates the fact that the shares of the companies A and B tended to move in the opposite directions in the period from 2015 to 2020. The negative covariance indicates the fact that there is no direct linear relationship between the shares of these companies. As the degree of the correlation between the stocks increases, the (positive) value of the covariance also does.

The correlation coefficient is calculated by dividing the covariance by the product of the standard deviations: (Copeland et al., 1988)

$$\text{Correlation coefficient} = \frac{\text{Covariance}}{(\text{Standard deviation for company shares A}) \text{x} (\text{Standard deviation for company shares B})}$$

$$= \frac{-0.03093}{0.26 \; x \; 0.72} = \frac{-0.03093}{0.1872} = -\,0.1652$$

According to the correlation coefficient equation, it can be noticed that both the covariance and the correlation have the same (either positive or negative) value. The correlation value ranges from -1 (when there is a complete negative, i.e. inverse correlation) to +1 (when there is a completely positive, or direct correlation). In our case, the correlation coefficient is -0.1652. which indicates the fact that there is no relatively high degree of the negative correlation

between the shares of these companies, i.e. this correlation has 16% of the "strength" of a completely negative correlation.

Portfolio Diversification as a Way to Reduce Market Investment Risk

Faced with different risks of investing in securities, investors take appropriate countermeasures, depending on the type of investment risk. An investor cannot neutralize general (market) risks, but the effects of risk can significantly be reduced if financial instruments are diversified. (McMenamin, 1999) In practice, the largest number of investors opt for forming a portfolio from only a few securities. This determination arises as a result of the knowledge of the following:

a) most benefits of diversification can be realized based upon the ownership of only a few securities,
b) the expansion of the portfolio structure leads to a decrease in the marginal benefits of diversification and an increase in the marginal costs of such a movement (the transaction costs of monitoring), and
c) many investors are reluctant to buy the securities that they consider to be at unrealistic (overvalued) market prices, convinced that they can find undervalued financial instruments.

Company risks are much more easily and much faster coped with by the investor. If the investor has encountered risky securities for the first time (on the financial market), he can avoid being exposed to specific risk by choosing the instrument of the company that he considers to be risk-free. If the investor has a risky instrument, he will try to get rid of such an instrument by a further sale.

In the previous question, the past of the companies A and B, i.e. their respective returns, was realized on the basis of the investments in shares in the period from 2015 to 2020. Based on this analysis, the investor should make a decision for the future – a decision to invest money in stocks, convinced that the central tendencies (the average returns, i.e. the arithmetic means) will be maintained in the future.

There are two options for the investor to choose: the one implying forming a portfolio only from the shares of one company, and the other implying a combination of shares with their different shares in a single portfolio. The selection of the optimal combination is made based upon the analysis of the expected returns and standard deviations with the different combinations of the shares of both companies. The analysis is performed with the assumption that the performance indicators of these companies in the previous period (2015-2020) will be maintained in the future: the returns, the standard deviations and the covariances, which means that the expected return in the future will be at the level of the realized return from the period from 2005 to 2020, as follows: 17.22% for the company A and 69.5% for the company B. Starting from these assumptions, the investor will make the following calculation for one of the possible portfolio options (a total of 11 options are analyzed and presented in Table 7) that will be formed on the basis of an equal participation (50% of the shares of the company A and 50% of the shares of the company B):

The expected
average portfolio return = 0.5 (17.17%) + 0.5 (69.5%) = 43.44%
(50% : 50%)

The portfolio
variance = $(0.5)^2 (0.26)^2 + (0.5)^2 (0.72)^2 + 2 (0.5) (0.5) (-0.1652) (0.26) (0.72) = 0.1311$
(50% : 50%)

The portfolio standard
deviation = $\sqrt{0.1311} = 0.3621$, i.e. 36.21%
(50% : 50%)

The obtained data for the expected return and the standard deviation are entered into Table 7, under the sequence number 6, which is one of the possible portfolio options (if the investor opts for it): 50% of the shares of both companies. In the identical way, the expected return is calculated for ten different portfolio options more. Thus, for a portfolio formed on the 90 : 10% basis (the shares of the company A against the shares of the company B), the following would be appropriate:

The expected return = 0.9 (17.17) + 0.1 (69.5) = 22.40%
(90% : 10%)

The variance (Compendium, 2008) = w_1^2 σ_1^2+ w_2^2 σ_2^2+2w_1 w_2 ρ_12 σ_1 σ_2. $(0.9)^2$ $(0.26)^2$ + $(0.1)^2$ $(0.72)^2$ + 2 (0.9) (0.1) (-0.1652) (0.26) (0.72) = 0.0543
(90% : 10%)
The standard deviation = $\sqrt{0.0543}$ = 0.2330 = 23.30%
(90% : 10%)

Table 7: The expected returns and the standard deviations with the different combinations of equity participation in the portfolio

Seq. no.	Weight (the participation of the company shares in the investor's portfolio)		The expected return	Standard Deviation
	Company A	Company B		
1	100%	0%	17.2%	26.00%
2	90%	10%	22.40%	23.30%
3	80%	20%	27.64%	18.82%
4	70%	30%	32.87%	25.83%
5	60%	40%	38.10%	30.68%
6	50%	50%	43.44%	36.21%
7	40%	60%	48.57%	42.73%
8	30%	70%	53.80%	49.71%
9	20%	80%	59.03%	56.97%
10	10%	90%	64.27%	64.42%
11	0%	100%	69.50%	72.00%

With the different weights of the companies A and B, the investor may expect different returns: the lowest expected return (17.2%) can be achieved if the ratio of the shares in the total portfolio is 100% to 0%, in favor of the shares of the company A; the highest return (69.50%) is achievable with a portfolio of 100% of the shares of the company B. However, the lowest standard deviation (18.82%) is achieved with the third combination, when the shares of the company B have a 100% share in the total investor's portfolio.

If the investor does not want to take risk, he will opt for a portfolio formed from 80% of the shares of the company A and 20% of the shares of the company B, when the standard deviation is the smallest. He will do so because he wants to avoid investment risk, regardless of the fact that he could then expect a return of 27.64%, which is 2.65 times lower than the highest return (69.50 : 27.64 = 2.5). Of course, he can also opt for a portfolio providing him with the highest return, regardless of the risks. That would be the 11^{th} combination, when the portfolio only consists of the shares of the company B, with the expected return of 69.50%. With such a choice, however, the greatest possibility of varying the return was estimated (as much as 72%), which not every investor will accept, because he does not agree to such a risk. If the investor only owned the shares of the company B, his return would vary almost three times more than they would if he only owned the shares of the company A (72% : 26% = 2.77). Therefore, the investor will not opt for a portfolio exclusively composed of the shares of Company B, nor of the shares of Company A. He will form a diversified portfolio. He will opt for one of the combinations (from 2 to 10 in Table 7), according to his personal affinity for the estimated risk and the expected rate of return.

Conclusion

It can be concluded that the risks of investing funds in one financial instrument are higher than those of investing in two or a larger number of financial instruments. Unlike a diversified investor, a non-diversified investor bears the risk specific to the company. If a portfolio is formed from two instruments (from the shares of the companies A and B), the standard deviation of such a portfolio is the function of correlating the return between these securities. As a correlation coefficient decreases, the standard deviation of the portfolio decreases as well. Then, the benefit of diversification increases. With an increase in the correlation coefficient of the return between these two instruments, the benefit of the portfolio diversification becomes smaller. Benefits will (to a greater or lesser extent) exist as long as a correlation coefficient is less than 1. (Copeland et al.)

Based on the previous analysis of the portfolio of the two financial instruments that confirmed the greater usefulness of investing in two securities rather than in a single security, it is logical to conclude that the investor will consider the usefulness of forming a portfolio from three or a larger number of instruments. However, there must be a measure

in that. The marginal benefits of diversification diminish with each introduction of a new instrument to the portfolio. This is because diversification can be expensive due to the fact that the costs of collecting necessary data, making an analysis and so forth are high. The diversified investors who already have a portfolio of the shares of a number of companies and who now want to include the shares of another company also ask themselves the question of market risk. That is the reason why they are referred to as marginal investors.

A diversified investor seeks to provide less risky financial instruments in his possession based upon a market risk assessment, which serves him as the basis for making an appropriate investment decision, which he makes being aware of the fact that a higher risk is a real challenge and an opportunity to earn more. As is shown in the paper, diversified investors successfully overcome the problem of return and risk assessment by applying the methods that are an indispensable tool in investment decision-making. Hence the investors' motivation to measure the risk and return of the securities portfolio by using the presented methods. The previous analysis shows how investors choose the optimal combination with the different shares of company shares in their portfolios, faced with the different risks of investing in securities. For that reason, they are also called diversified investors, who try to provide less risky financial instruments in their possession based upon this assessment. Only on the basis of this assessment will the investor make an investment decision appropriate for him, being aware of the fact that the expected return on investment and risk are interrelated, which means that a potential investor will invest in the securities that bring him a satisfactory return, with a risk acceptable for him.

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