K W A R T A L N I K   N A U K   O   P R Z E D S I Ę B I O R S T W I E

DOI: 10.33119/KNOP.2023.67.1.6 1/2023

Ph. D. Joanna SZCZEPAŃSKA
University of Applied Sciences in Nysa
Department of Economic Sciences
e-mail: joanna.szczepanska@pans.nysa.pl
ORCID: 0000-0002-1450-6411

Risk measurement in profitability calculation of non-financial investment

Pomiar ryzyka w kalkulacji opłacalności inwestycji rzeczowych

Key words:
NPV, CFaR, NPVaR, ES (NPV), real option

Abstract: In the paper a model of non-financial investment profitability calculation is presented. It is based on the concept of quantile risk measures and a real option valuation. Application of Monte Carlo simulation allows to receive probability distribution of Net Present Value (NPV) and implement risk measures like Cash Flow at Risk (CFaR), Net Present Value at Risk (NPVaR) or Expected Shortfall (ES) in relation to NPV (ES (NPV)). The main contribution of the article is implementation of ES (NPV) that shows the average of worst losses regarding NPV. ES (NPV) informs the investors what the worst result of the project may be.

Słowa kluczowe:
NPV, CFaR, NPVaR, ES (NPV), opcje realne

Streszczenie: W artykule przedstawiono model kalkulacji opłacalności inwestycji rzeczowych. Jest on oparty na koncepcji kwantylowych miar ryzyka i wycenie opcji realnych. Zastosowanie symulacji Monte Carlo pozwala otrzymać rozkład prawdopodobieństwa wartości zaktualizowanej netto (Net Present Value – NPV) i wdrożyć miary ryzyka, takie jak przepływy pieniężne narażone na ryzyko (Cash Flow at Risk – CFaR), wartość zaktualizowana netto narażona na ryzyko (Net Present Value at Risk – NPVaR) czy oczekiwana strata (Expected Shortfall – ES) w stosunku do NPV – ES (NPV). Głównym wkładem artykułu jest implementacja ES (NPV), która pokazuje średnią najgorszych strat względem NPV. ES (NPV) informuje inwestorów, jaki może być najgorszy wynik projektu.

JEL:
C630, G310, G320

Introduction

Investments are the driving force behind the development of enterprises. They are an interdisciplinary issue that combines many aspects, such as: market and environment analysis, defining strategic goals of the company, defining a marketing strategy, determining a method of financing investment projects, forecasting, creating financial plans, risk analysis, investment profitability calculation. The increasing volatility of operating conditions forces a more dynamic view of the investment process. In such a situation we are dealing with a kind of profitability management of an investment project. Changing significant factors directly affecting the final result of investment activities requires verification of the previously adopted assumptions and looking at the legitimacy of continuing the investment process from a different perspective.

The basic characteristic of an investment process is that investment outlays are incurred at present and investment benefits are expected in the future. Very often an investment process is a long term one. Conditions can change through the years, so that is why risk and uncertainty are significant factors in the process of investment profitability calculation.

The most universal method of investment project evaluation is Net Present Value. Despite its shortcomings, it is widely used in many different areas [Rivers et al., 2015; Balen, Mens, and Economides, 1988]. It assumes that forecasted structure of cash flows is known. The main disadvantage of this method is that the calculation is made at the time of the appraisal and the level of cash flow is taken for granted. The question is how to capture the element of risk into the calculation. Some methods take the risk into account directly. These methods are Certainty Equivalent Adjustment (CEA) [Zhang, 2010; Žižlavský, 2014] and Risk – Adjusted Discount Rate Approach (RADRA) [Tibiletti, 2022; Blaset, Kastro and Kulakov, 2020; Saługa, 2019; Saługa, Zamasz, Dacko-Pikiewicz, Szczepańska-Woszczyna and Malec, 2021]. The methods that capture risk indirectly are: scenario analysis [Ren, 2022; Brzakovic, Brzakovic and Petrovic, 2016; Gaspars-Wieloch, 2019; Andros, Akimov, Akimova, Chang and Gupta, 2021], decision tree analysis [Ranosz, 2016; Brandão, Dyer and Hahn, 2005; Wang, 2010; Yao and Jaafari, 2003; De Reyck, Degraeve and Vandenborre, 2008], sensitivity analysis [Marchioni and Magni, 2018; Nwanekezie, Iroegbu, Wogu and Okorocha, 2014; Liu, 2022; Anysz and Rogala, 2019; Mentari and Daryanto, 2018; Zenad, 2015; Anas, Amalia, Qaidahiyani, Djamaluddin and Herin, 2020] and Monte Carlo simulation [Rodriges Amorim, Ferreira Silveira, Alves dos Santos, Rosa Tostes and Camargo de Abreu, 2017; Shaffie and Jaaman, 2016; Zahid, 2019; Wicaksono, Bin Arshad and Sihombing, 2019; Maric and Grozdic, 2016]. The approach to investment profitability calculation may also be a combination of existing methods [De Reyck, Degraeve and Vandenborre, 2008; Miller and Waller, 2003; Mills, Weinstein and Favato 2006; Yao and Jaafari, 2003] or their modification. Some authors use fuzzy values to underline the uncertainty of parameters [Tsao, 2012; Liao and Ho, 2010; Appadoo, 2014; Chiu and Park, 1994; Filho, Vellasco and Tanscheit, 2012]. Uncertainty can also be presented by unknown probabilities understood mainly as frequencies [Gaspars-Wieloch, 2019].

The main goal of this article is to present a model of non-financial investment profitability calculation. The model is based on a concept of quantile risk measures and a real option valuation. Thanks to the Monte Carlo simulation it is possible to obtain risk measures like Cash Flow at Risk (CFaR), Net Present Value at Risk (NPVaR) or Expected Shortfall (ES) in relation to Net Present Value (NPV). Value at Risk (VaR) is used as a border of the worst loss. It does not inform about losses above a specified level. Expected Shortfall can give us information about the average of worst results.

The contribution of this article is an implementation of Expected Shortfall of Net Present Value (ES (NPV)) in the process of investment profitability calculation.

Cash Flow at Risk (CFaR), Net Present Value at Risk (NPVaR)

Many factors can have an influence on the final level of cash flows. Their value cannot be estimated with 100% certainty. That is why there are so many attempts to implement the element of risk and uncertainty into the calculation.

Riskmetrics Group in [RiskMetrics Group, 1999] outlined a conceptual framework of measurement of market risk in the corporate environment. The five-step process is a simulation-based approach and consists of:

- Metric specification,
- Exposure mapping,
- Scenario generation,
- Valuation,
- Risk measure computation.

The simulation allows to use a large set of market rate scenarios and generate a distribution of a future financial result. A variety of risk measures may be obtained from the distribution.

Risk statistic like Cash Flow at Risk (CFaR) was proposed there.

Definition 1: Cash Flow at Risk (CFaR) is the maximum shortfall of net cash generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level [RiskMetrics Group, 1999, p. 34].

Similarly, I would like to propose Net Present Value at Risk (NPVaR) as a risk measure. This measure is based on uncertain, risky cash flows.

Definition 2: Net Present Value at Risk (NPVaR) is the maximum shortfall of Net Present Value generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.

$$P\left(NPV \leq NPV_0 - NPVaR\right) = \alpha), \qquad (1)$$

where:
NPV – Net Present Value (random value) in a given period,
$NPVaR$ – Net Present Value at Risk,
NPV_0 – the planned Net Present Value in a given period,
α – tolerance level,
$1-\alpha$ – confidence level.

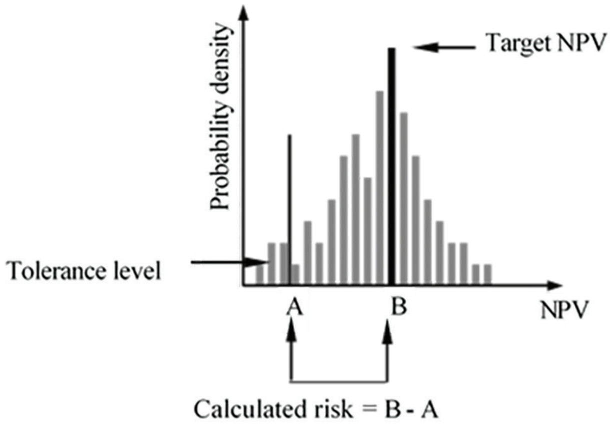
Definition 3: Net Present Value at Risk (NPVaR) – the level of NPV for a given tolerance level.

$$P(NPV \leq -NPVaR) = \alpha \qquad (2)$$

Therefore, risk can be presented in two ways.

Firstly, as the difference between the target NPV and the quantile value of the probability distribution of NPV – it will be relative to the target risk measure, Figure 1. The target NPV could be the value expected by investors, or NPV calculated in a traditional way without a simulation process, or mean of the NPV distribution (it is assumed that this value illustrates the basic variant). Then the definition of NPVaR is analogous to the definition of VaR understood as the maximum decrease in value.

Figure 1 Relative to target risk measure



Source: adopted from [RiskMetrics Group, 1999, p. 29].

Assuming a normal distribution of NPV, NPVaR can be represented as the difference:

$$NPVaR = \mu - z(\alpha) * \sigma, \tag{3}$$

where:
μ – average of NPV,
$z(\alpha)$ – number of standard deviation units in relation to the given tolerance level,
σ – standard deviation.

For example, when for a 5% tolerance level $z(\alpha)$ is 1.65, it means that 95% of possible NPVs is in the range from (μ-1.65σ) to ∞.

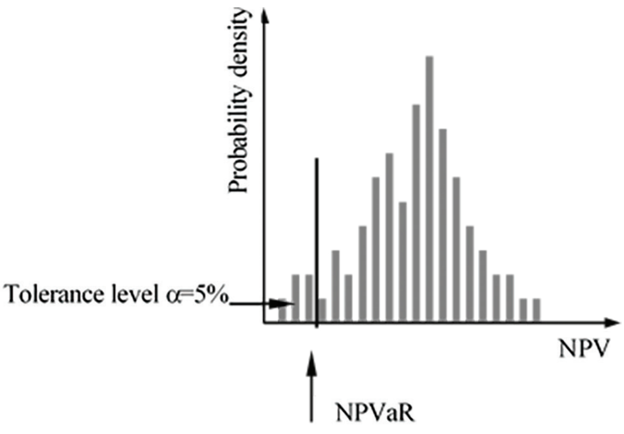
NPVaR is a semivariance approach, because we are interested in how much the NPV may turn out to be less (and not greater) than the mean (base) value.

Formula 3 also makes it possible to formulate a rule supporting decision making.

Decision rule 1: The investment project may be accepted for implementation when NPVaR, being the difference between the mean value and the standard deviation, is greater than zero.

Secondly, the risk can be presented as a quantile of the probability distribution of NPV, constituting the so-called absolute risk measure, Figure 2. In this case, NPVaR ($NPVaR^{(5\%)}$) will be a measure of the minimum level of NPV for a given tolerance level. It will show that the probability of getting lower value than $NPVaR^{(5\%)}$ in a given time period will be less than 5%.

Figure 2 Absolute risk measure



Source: adopted from [RiskMerics Group, 1999, p. 29].

In other words, NPVaR is a value at which α of possible NPV levels is lower and $(1 - \alpha)$ greater than this value.

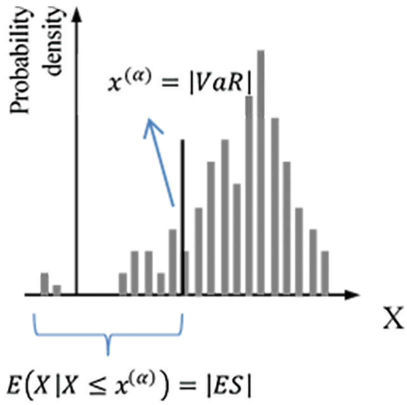
Decision rule 2: The project may be accepted for implementation when, for a given tolerance level, NPV will be greater than 0.

Expected Shortfall (ES)

Having probability distribution we get risk measures like standard deviation and quantile value. Standard deviation shows how much variation or dispersion exists from the average (mean), or expected value. Quantile value that represents Value at Risk shows that for a certain tolerance level (for example $\alpha = 0.05$) there is 5% chance that the received value of NPV will be lower than the value indicated by the quantile value. Value at Risk measure "provides no handle on the extent of losses that might be suffered beyond the threshold amount indicated by this measure. It is incapable of distinguishing between situations where losses that are worse may be deemed only a little bit worse, and those where they could well be overwhelming." [Rockafellar and Uryasev, 2002].

In the paper it is proposed to use the ES concept to determine the average worst NPV of an investment project. Figure 3 shows the approximation of the density distribution of the probability of the random variable X = NPV.

Figure 3 Illustration of VaR and ES



Source: own work based on [Birbilis and Mitra, 2003].

An alternative measure that does quantify the losses that might be encountered in the tail is Expected Shortfall, Figure 3.

In order to illustrate the concept of ES, assumptions and basic definitions will be presented.

Let:
X – real-valued random variable X on a probability space $(\Omega, \mathcal{A}, P)$,
$E[\ldots]$ – expectation with respect to P,
$\alpha = (0,1)$ – tolerance level that presents the sample of the worst calculation results (the worst scenarios).

Indicator function:

$$1_A(a) = 1_A = \begin{cases} 1, & a \in A, \\ 0, & a \notin A. \end{cases} \tag{4}$$

Definition 4 (Quantiles)

For random variable X:

$$\begin{aligned} x_{(\alpha)} &= q_{(\alpha)}(X) = \inf\{x \in \mathbb{R} : P[X \le x] \ge \alpha\} \text{ is the lower } \alpha\text{-quantile of } X, \\ x^{(\alpha)} &= q^{(\alpha)}(X) = \inf\{x \in \mathbb{R} : P[X \le x] > \alpha\} \text{ is the upper } \alpha\text{-quantile of } X. \end{aligned} \tag{5}$$

The x-notation is used if the dependence on X is evident, otherwise the q-notion is relevant.

Note that

$$x^{(\alpha)} = \sup\{x \in \mathbb{R} : P[X \le x] \le \alpha\}.$$

From $\{x \in \mathbb{R} : P[X \le x] > \alpha\} \subset \{x \in \mathbb{R} : P[X \le x] \ge \alpha\}$
it is clear that $x_{(\alpha)} \le x^{(\alpha)}$.

Moreover

$$x_{(\alpha)} = x^{(\alpha)} \text{ if and only if } P[X \le x] = \alpha \text{ for at most one } x \tag{6}$$

and in case $x_{(\alpha)} < x^{(\alpha)}$

$$\{x \in \mathbb{R} : \alpha = P[X \le x]\} = \begin{cases} \left[x_{(\alpha)}, x^{(\alpha)}\right), & P\left[X = x^{(\alpha)}\right] > 0, \\ \left[x_{(\alpha)}, x^{(\alpha)}\right], & P\left[X = x^{(\alpha)}\right] = 0. \end{cases} \tag{7}$$

$VaR^{(\alpha)}$ can be defined as the smallest value such that the probability of the absolute loss being at most this value is at least (1-a) [Acerbi and Tasche, 2002].

Definition 5 (VaR)

$$VaR^{(\alpha)} = VaR^{(\alpha)}(X) = -x^{(\alpha)} = q_{(1-\alpha)}(-X) \text{ is the VaR at level a of } X \text{, where:}$$

$$x^{(\alpha)}(X) = \sup\{x | P[X \le x] \le \alpha\}$$

$$q_{(1-\alpha)}(Y) = \sup\{x \in \mathbb{R} : F_Y(x) \le 1 - \alpha\}$$

$$F_Y(x) = P(Y \le x)$$
$$Y = -X \tag{8}$$

Definition 6 (Expected Shortfall)

Let X be a real integrable random variable on some probability space $(\Omega, \mathcal{A}, P)$ and $\alpha \in (0,1)$ be fixed. Then

$$ES^{(\alpha)}(X) = -\frac{1}{\alpha}(E\left[X1_{\{X \le x^{(\alpha)}\}}\right] - x^{(\alpha)}\left(P\left[X \le x^{(\alpha)}\right] - \alpha\right)) \tag{9}$$

Definition of Expected Shortfall at a given α level is a literal mathematical transcription of the concept „average loss in the worst a cases".

When X is a continuous and increasing cumulative distribution, then $P\left(X \le x^{(\alpha)}\right) = \alpha$ and $ES^{(\alpha)}(X)$ is reduced to:

$$ES^{(\alpha)}(X) = -\frac{1}{\alpha}(E\left[X1_{\{X \le x^{(\alpha)}\}}\right] = -E\left(X \middle| X \le x^{(\alpha)}\right) = TCE^{(\alpha)} = TCE^{(\alpha)}(X), \tag{10}$$

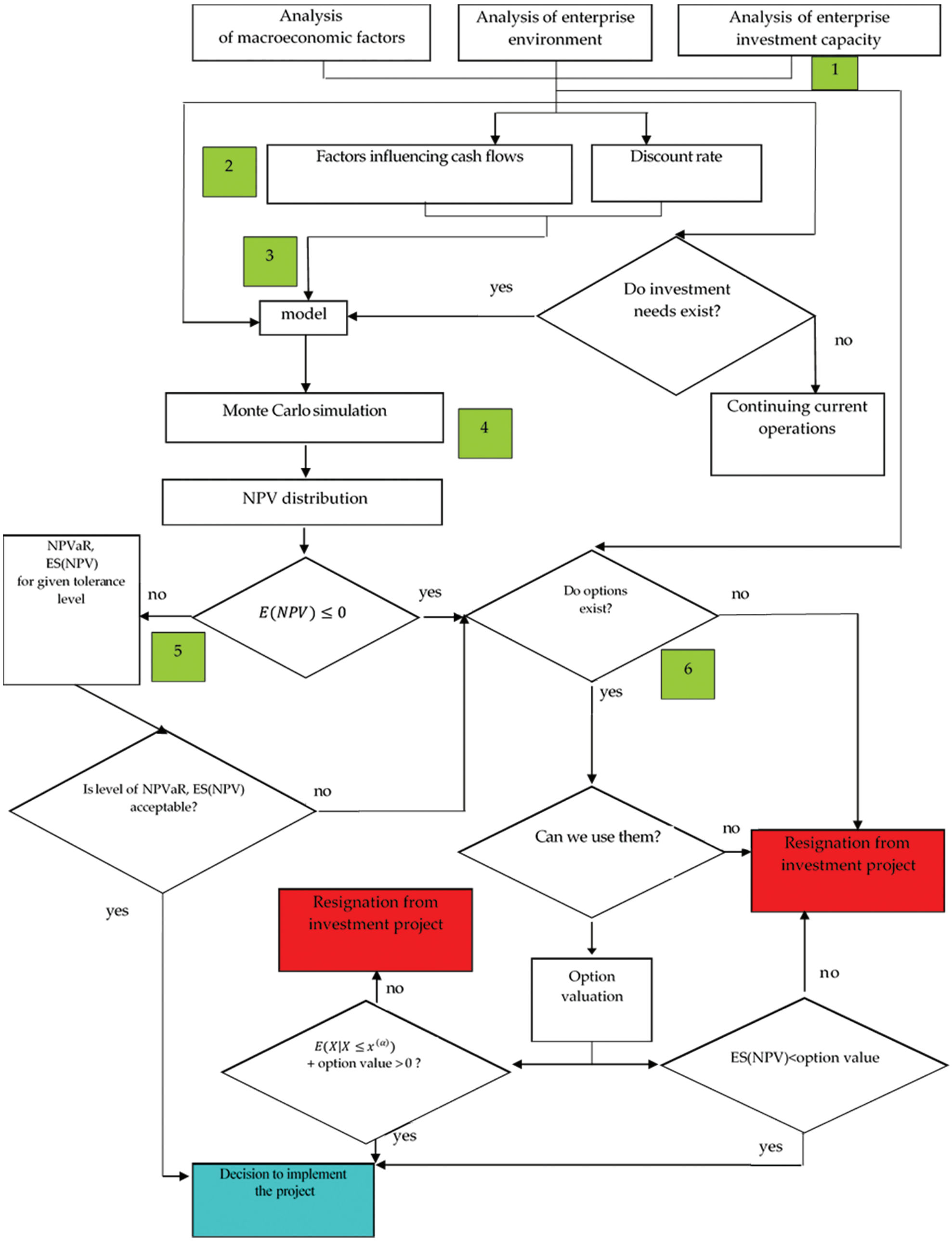
where TCE (Tail Conditional Expectation) is a notion introduced earlier by [Artzner, Delbaen, Eber and Heath, 1999].

Value at Risk seems to be an inefficient risk measure in investment profitability calculation. It only gives information that for a certain tolerance level there is α chance that the received value of NPV will be lower than the value indicated by the quantile value. It says nothing about the possible lower value, which may be a little or a lot worse than the quantile value. "VaR, in other words, is a sort of best of worst cases scenario and it therefore systematically underestimates the potential losses associated with the specified level of probability" [Acerbi, Nordio and Sirtori, 2001]. Expected Shortfall, unlike VaR, is in general subadditive and therefore it is a coherent risk measure in the sense of [Artzner et al., 1999].

The proposed model of calculation of investment profitability

In the manuscript a model of investment profitability calculation based on NPVaR, ES (NPV) and real options is proposed. The method used is the Monte Carlo simulation, the investment profitability measure – NPV. This measure is a random variable, it is the sum of discounted cash flows, which are also random variables. The discount rate was assumed to be constant over the lifetime of the project. The risk is captured in NPV distribution.

Figure 4 **The proposed model of calculation of investment profitability**



Source: own study.

NPV calculations ignore an investor's ability to modify his behavior in response to incoming information. In the situation when investment conditions are constantly changing it is possible that the calculation based on NPV formula can turn out to be insufficient and inadequate to new circumstances [Bieliński, 2004]. If it is possible, it is worthy to supplement investment analysis with a real option valuation.

Options capture the ability of an enterprise to take specific actions when investment conditions change. The change in operating conditions, as opposed to the NPVaR or ES (NPV) calculation, may be caused by factors unknown at present. However, this does not mean a failure of the project, because the real option (if it exists at all) has a value that may exceed a possible negative NPV, thus providing an argument in favor of the investment. Real options can therefore be treated as a response to the uncertainty of investment implementation conditions.

The proposed investment profitability calculation model can be divided into several stages:

Stage 1: This is the stage preceding the decision to make a potential investment. It consists of the analysis of the company's strengths and weaknesses, its opportunities and threats from the closer and further environment.

The analysis of hitherto sales markets and expansion opportunities is conducted. It is closely related to the demand for a given product, as well as to the existence of competition in a given industry. Activities performed within this stage, which appear in the proposed model as an introduction to further stages, can be classified as continuous monitoring of the company's market situation. In a situation of increased demand for the company's products, the bankruptcy of a competitor, or other factors favoring the development of a given enterprise, a natural consequence is to increase the volume of production. Being competitive on the market means offering better-quality products or reducing production costs, which is often associated with the purchase of modern machines, devices, and a technological line.

On the other hand, the company's ability to make investments is also important. The current degree of indebtedness of an enterprise may make it difficult to obtain a loan to finance investments or to service the debt at a later date.

The company's infrastructure is also a significant factor. Real estate, fixed assets and the state of their wear and tear are determinants that affect the effectiveness of the goals pursued by the enterprise.

Many factors influence the determination of the investment capacity of enterprises. Apart from the "countable" ones, the human factor cannot be underestimated – a qualified managerial staff and its ability to take on new challenges.

Stage 2: Investment profitability calculation is based on cash flows. Therefore, it is important to identify key factors that influence their level. Risk factors are those that significantly affect the final level of cash flows and, at the same time, those whose future values cannot be forecasted, with a certain amount of accuracy, based on forecasts and models. They are also factors whose values can change over time. Factors that affect the final profitability of an investment project can be divided according to their source of origin, namely:

- Macroeconomic factors (e.g. interest rate, exchange rate, inflation rate)
- And factors specific for a given industry and enterprise (e.g. prices of raw materials, sales markets, competition, product price, sales level).

At this stage, the discounting rate needed for the calculation of present value of future cash flows is also determined.

Stage 3: Construction of a mathematical model illustrating the relationships between the variables that have a significant impact on the final value of cash flows. Proforma statements like balance sheet, income statement, cash flow statement, financing plan, depreciation plan, working capital demand etc. are used here. There is a close relationship between the components of individual statements. A change in the value of one item entails changes in the others, which may have a significant impact on the final level of cash flows and, consequently, on the NPV. Pro forma reports will present the relationship between the measured value and the risk factors included in the individual market scenarios of the simulation.

Cash flow is a kind of portfolio of factors, whose values should not be taken with 100% certainty. The exact future level of sales or the currency exchange rate affecting the profitability of export sales is unknown. However, the model can be used to determine the level of export sales and also the level of exchange rate to make the activity profitable.

The use of one predicted value, which forms the basis for the calculation of subsequent values, is by definition erroneous. From the point of view of conscious acceptance of risk as a factor influencing the company's operations, the following approach seems to be more appropriate:

- Identifying the key risk-generating factors affecting the final level of cash flows (Stage 2),
- Determining the probability distribution of these factors (Stage 3),
- Performing the simulation process (Stage 4),
- Analysis of obtained results (Stage 5).

Adopting an appropriate probability distribution of factors influencing the level of cash flows is not an easy task, but the basis of this approach is the assumption that value distribution will always be better than a single value.

When historical data is available, the distribution and parameters of the values of past variables can be used, or an analogy can be used and a distribution of past observed variables analogous to the analyzed values can be applied. In the absence of historical data, distributions of variables can be based on subjective estimates made by managers, e.g. [Wiśniewski, 2006]:

- Having three values of the variable (the most probable, minimum and maximum) it is possible to adjust the triangular distribution,
- Having two parameters of a variable without a predefined dominant value, a uniform distribution can be assumed,
- Having two or more levels of the input variable and the corresponding probabilities, a discrete or interval distribution can be used.

Another difficulty at this stage is determining the relationships between the randomized input parameters. Simple correlation coefficients are assumed. However, in the case of the implementation of one variable in time – autocorrelation coefficients. Autocorrelation of variables means that their increase (decrease) above (below) the average level in the earlier period increases (decreases) the chances that in the next period the values of these variables will also be higher (lower) than the average. The assumption of autocorrelation will increase the risk of the project by more frequent occurrence of values lying on the same side of the probability distribution.

Stage 4: Simulation of the final result, which, for the purposes of the investment profitability study, is NPV. From the probability distributions of *risky factors* (defined in Stage 3), values are randomly selected and are the basis for NPV calculation. As a result, NPV probability distribution is obtained.

Stage 5: Analysis of the obtained results. As a result of the simulation, not only one possible value is received, but the entire range of possible values with the associated probabilities of occurrence. In case the risk measures: NPVaR and ES (NPV) are acceptable, a decision can be made to implement the project. If not, go to Stage 6, where the potential options inherent in the investment project are analyzed.

Stage 6: Analysis of potential real options inherent in the investment project. It may happen that, despite receiving a negative NPV, it is beneficial to decide to implement a given project for strategic reasons. The currently implemented investment project may only be an introduction to a greater expansion of the company on the market.

Of course, it should be emphasized that obtaining a positive NPV does not mean resigning from using a possible option inherent in the project. The proposed model (Figure 4) presents a diagram of how to proceed in a situation where the option would only cover the loss on the base project. The main goal was to present the application of the new risk measure based on the value at risk (Expected Shortfall) in the process of investment profitability calculation. A more advanced variant of the model could indicate the NPVaR extended by the value of real options, the so-called VaR of the Expanded Net Present Value (ENPV), as well as the Expected Shortfall of ENPV.

The proposed model should be treated as a supplement to the calculation of NPV in a traditional way. Thanks to the simulation process information about the potential risk of not gaining NPV calculated without the use of simulation is received. The model is based on the analysis of the risk associated with the implementation of a given investment project. It somehow requires an in-depth analysis of the factors affecting the level of cash flows. As a result of the simulation many possible NPVs, due to the shaping of scenarios of individual variables affecting the profitability of the project, are obtained.

Therefore, it can be assumed that each investment project is unique, and the proposed model is only intended to indicate the approach to the risk analysis of the project.

In the proposed model, attention is paid to estimating cash flows, analyzing factors that affect the level of cash flows, and the relationships (correlations) between them. The focus is mainly on factors influencing cash flows, and not on premature determination of the level of risk associated with the receipt of individual cash flows. Rather, it is better to analyze the individual variables in depth and separate each single variable that is potentially a risk carrier into prime factors, than to plan the cash flows by giving oneself a kind of *consent* to the margin of error, blaming it for the existence of risk. The use of simulation is, one could say, a natural way of presenting risk, because it is not possible for a human being to think about all variable configurations simultaneously and draw a final conclusion from it. An analysis without simulation will always be a *coarse* analysis, which by definition does not take into account many possible combinations of variables. Obtaining the final result in the form of a distribution is therefore a certain form of presenting all scenarios of events that can occur on the basis of the assumptions of the model.

Usually, depending on the design of the model, the Monte Carlo simulation, like the scenario analysis, does not take into account the effects of diversification of projects within the company and investors' investment portfolios. It focuses only on the individual risk of the project. When a project is assessed separately and its highly uncertain earnings are not correlated with earnings from other enterprise assets, then the project may not be as risky in terms of enterprise risk or market risk. In a situation where the revenues from the project are negatively correlated with the revenues from other assets of the enterprise, then such a project may reduce the risk of the enterprise. Also, when project revenues are not positively correlated with the stock market, even then shareholders with a well-diversified portfolio do not have to worry that a project with highly volatile revenues is risky [Brigham and Gapenski, 2000].

Conclusions

The presented model of calculation of investment project profitability, based on projected cash flows, quantile risk measures and a real option valuation is a good estimate of the value of an investment project due to the fact that:

- Monte Carlo simulation, is based on many possible values of factors (and not only on single values) that affect the level of cash flows. In [Yousefi, Yakhchali, Saparauskas and Kiani, 2018] it is underlined that Monte Carlo simulation can be used for solving complex problems like path dependency, non-linearity, multiple risk factors, interdependencies, fat tails etc.

- The level of risk related to the implementation of a given project is also received after taking into account many possible scenarios.
- Quantile risk measures illustrate, on the one hand, the so-called value at risk (NPVaR), and on the other hand, specify what the average worst result of the investment profitability calculation, i.e. ES (NPV), may be, calculated on the basis of the model assumptions. ES (NPV) seems to be a more accurate risk measure. NPVaR only estimates the probability of occurrence of losses above a specific level. It does not give information about the left-hand tail of the distribution. It does not measure the loss beyond NPVaR. At the same time it must be stated that in the proposed model normal distribution was assumed. In other case, the risk will be underestimated. That is why ES is the appropriate measure to get a better estimate of tail risk [Yousefi et al., 2018].
- It takes into account the value of flexibility (real option) inherent in a given investment project. The simulation models generally incorporate a "normal business" strategy. Should unforeseen events occur, the simulation results will no longer be reliable. And at this point, a need arises for the valuation of additional possibilities (options) of the company's activity, which would complement the process of evaluation of the investments profitability [Brealey and Myers, 1999].
- The model is consistent with the superior goal of the company (maximization market value).

Due to the interdisciplinary nature of issues related to investments, the main goal of the paper was to present a model of an investment project profitability calculation. The aim of the study was not to propose a specific method of forecasting economic values, indicate the best method of real options valuation or a new risk measure creation. The attention was paid to ES (NPV) as a measure of fulfillment of the most unfavorable scenarios.

"Risk measurement has changed and we now have many good risk measures to choose from: coherent measures, quantile risk measures or transforming risk measures. In a sense, we currently have too many risk measures available, and it is not (usually) possible to judge which of these measures would be the best: even the best measure of risk depends on the assumptions made in the model and, in addition, possibly also on the context. Any search for the only "best" measure – the only one that is good for all external circumstances must be viewed as ineffective and practitioners will also be pragmatic. De gustibus non disputandum est" [Trzpiot, 2008, p. 139].

References

Acerbi, C., Nordio C. and Sirtori, C. (2001), *Expected Shortfall as a Tool for Financial Risk Management*, https://arxiv.org/abs/cond-mat/0102304 (15.02.210).

Acerbi, C. and Tasche D. (2002), *On the Coherence of Expected Shortfall*, "Journal of Banking & Finance", 26(7), pp. 1487–1503, https://doi.org/10.1016/S0378–4266(02) 00283–2.

Anas, A.V., Amalia R., Qaidahiyani N.F., Djamaluddin N. and Herin S. (2020), *Sensitivity Analysis of Net Present Value Due to Optimal Pit Limit in PT Ceria Nugraha Indotama*,

Kolaka Regency, Southeast Sulawesi Province, "IOP Conference Series: Materials Science and Engineering", 875(1), https://doi.org/10.1088/1757-899X/875/1/012050.

Andros, S., Akimov, O., Akimova, L., Chang, S. and Gupta, S.K. (2021), *Scenario Analysis of the Expected Integral Economic Effect from an Innovative Project*, "Marketing and Management of Innovations", pp. 237–51. https://doi.org/http://doi.org/10.21272/mmi.2021.3–20.

Anysz, H. and Rogala W. (2019), *Sensitivity Analysis of the Contractor's Financial Effects Achieved on a Single Building Site*, "Scientific Review Engineering and Environmental Sciences", 28(2), 183–91, https://doi.org/10.22630/PNIKS.2019.28.2.17.

Appadoo, S.S. (2014), *Possibilistic Fuzzy Net Present Value Model and Application*, "Mathematical Problems in Engineering", 2, pp. 1–11, https://doi.org/10.1155/2014/865968.

Artzner, P., Delbaen F., Eber J.M. and Heath D. (1999), *Coherent Measures of Risk*, "Mathematical Finance", 9(3), 203–28, https://doi.org/10.1111/1467–9965.00068.

Balen, R.M., Mens H-Z. and Economides M. (1988), *Applications of the Net Present Value (NPV) in the Optimization of Hydrauic Fractures*, "Proceedings of SPE Eastern Regional Meeting", Society of Petroleum Engineers SPE Eastern Regional Meeting, https://doi.org/10.2523/18541-ms.

Bieliński, J., (ed.). (2004), *Zarządzanie wartością przedsiębiorstwa a alokacja kapitału*, Warszawa: Wyd. CeDeWu Sp. z o.o.

Birbilis, G. and Mitra, G. (2003), *Using @Risk to Calculate Portfolio Performance – ISSSP for Lean Six Sigma*, Centre for the Analysis of Risk and Optimisation Modelling Application, https://www.sarisma.brunel.ac.uk/papers/GBpalisade_risk.pdf (15.03.2004)

Blaset K., Anastasia N., and Yu Kulakov N. (2020), *A Risk-Adjustment Technique for Negative Cash Flows*, "Proceedings of the 2020 IISE Annual Conference", pp. 37–42, https://www.proquest.com/docview/2511386663/fulltextPDF/87928A2BD24F4C2BPQ/1? accountid=13075 (24.05.2022)

Brandão, L.E., Dyer J.S. and Hahn W.J. (2005), *Using Binomial Decision Trees to Solve Real-Option Valuation Problems*, "Decision Analysis", 2(2), pp. 69–88, https://doi.org/10.1287/deca.1050.0040.

Brealey, R.A. and Myers S.C. (1999), *Podstawy finansów przedsiębiorstw*, Warszawa: Wyd. Naukowe PWN.

Brigham, E.F. and Gapenski L.C. (2000), *Zarządzanie finansami*, Warszawa: PWE.

Brzakovic, T., Brzakovic A. and Petrovic J. (2016), *Application of Scenario Analysis in the Investment Projects Evaluation,* "Ekonomika Poljoprivrede", 63(2), pp. 501–13, https://doi.org/10.5937/ekopolj1602501b.

Chiu, C.Y. and Park C.S. (1994), *Fuzzy Cash Flow Analysis Using Present Worth Criterion*, "Engineering Economist", 39(2), pp. 113–38, https://doi.org/10.1080/00137919408903117.

Filho, A.C.S., Vellasco M. and Tanscheit R. (2012), *Modified Net Present Value under Uncertainties: An Approach Based on Fuzzy Numbers and Interval Arithmetic*, in: *Communications in Computer and Information Science*, Greco R.R., Bouchon-Meunier S., Coletti B., Fedrizzi G., Matarazzo M., Yager B. (eds), 300 CCIS, pp.10–19. Berlin, Heidelberg: Springer, https://doi.org/10.1007/978-3-642-31724-8_2.

Gaspars-Wieloch, H. (2019), *Project Net Present Value Estimation under Uncertainty*, "Central European Journal of Operations Research", 27(1), pp. 179–97, https://doi.org/10.1007/s10100-017-0500-0.

Liao, S-H. and Ho S-H. (2010), *Investment Project Valuation Based on a Fuzzy Binomial Approach*, "Information Sciences", 180(11), pp. 2124–33, https://doi.org/10.1016/j.ins.2010.02.012.

Liu, Q. (2022), *Sensitivity Analysis and Investment Decision Making Under Uncertainty Based on NPV Method*, "Advances in Economics, Business and Management Research", 648, pp. 1861–65, Proceedings of the 2022 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022), https://www.atlantis-press.com/article/125971983.pdf (26.06.2022).

Marchioni, A. and Magni C.A. (2018), *Investment Decisions and Sensitivity Analysis: NPV–Consistency of Rates of Return*, "European Journal of Operational Research", 268(1), pp. 361–72, https://doi.org/10.1016/J.EJOR.2018.01.007.

Maric, B. and Grozdic V. (2016), *Monte Carlo Simulation in Valuation of Investment Projects* in: "Annals of DAAAM and Proceedings of the International DAAAM Symposium", 27, pp. 686–92, https://doi.org/10.2507/27th.daaam.proceedings.099.

Mentari, D., and Daryanto W.M. (2018), *Capital Budgeting Model and Sensitivity Analysis of the Project Feasibility in Vietnam for the Period of 2019–2037*, "International Journal of Business, Economics and Law", 17(2), pp. 21–28, https://www.ijbel.com/wp-content/uploads/2019/01/BUS-55.pdf (10.02.2024).

Miller, K.D. and Waller H.G. (2003), *Scenarios, Real Options and Integrated Risk Management*, "Long Range Planning", 36(1), pp. 93–107, https://doi.org/10.1016/S0024-6301(02)00205-4.

Mills, R.W., Weinstein B. and Favato G. (2006), *Using Scenario Thinking to Make Real Options Relevant to Managers: A Case Illustration*, "Journal of General Management", 31(3), pp. 49–74, https://doi.org/10.1177/030630700603100304.

Nwanekezie, O.F., Iroegbu A.N., Wogu C.L. and Okorocha K.A. (2014), *Sensitivity Analysis: A Technique for Investigating the Impact of Changes in Project Variables*, pp. 1–13, http://www.globalacademicgroup.com/journals/approaches/Sensitivity Analysis.pdf (30.06.2022).

Pluta, W. (2000), *Budżetowanie Kapitałów*, Warszawa: PWE.

Ranosz, R. (2016), *The Decision Tree in the Valuation of Mining Investments*, "Inżynieria Mineralna", 17(1), 75–78.

Ren, J. (2022), *The Scenario Analysis for NPV and IRR in Mutually Exclusive Projects*, "Advances in Economics, Business and Management Research", 648, pp. 2964–68. Proceedings of the 2022 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022), https://www.atlantis-press.com/article/125971628.pdf (26.06.2022).

Reyck, B.D., Degraeve Z. and Vandenborre R. (2008), *Project Options Valuation with Net Present Value and Decision Tree Analysis*, "European Journal of Operational Research", 184(1), pp. 341–55, https://doi.org/10.1016/j.ejor.2006.07.047.

RiskMerics Group (1999), *Corporate Metrics: The Benchmark for Corporate Risk Management*, https://www.msci.com/documents/10199/8af520af-3e63-44b2-8aab-fd55a989e312 (10.09.2009).

Rivers, G., Foo J., Ilic D., Nicklen P., Reeves S., Walsh K. and Maloney S. (2015), *The Economic Value of an Investment in Physiotherapy Education: A Net Present Value Analysis*, "Journal of Physiotherapy", 61(3), pp. 148–54, https://doi.org/10.1016/j.jphys.2015.05.015.

Rockafellar, R.T. and Uryasev S. (2002), *Conditional Value-at-Risk for General Loss Distributions*, "Journal of Banking & Finance", 26(7), pp. 1443–71, https://doi.org/10.1016/S0378-4266(02)00271-6.

Rodriges Amorim, F., Ferreira Silveira B.C., Alves Dos Santos E., Camargo de Abreu P.H., and Tostes J.R. (2017), *Analysis of the Economic Viability of a Rural Tourism Enterprise in Brazil: An Application of the Monte Carlo Method*, "Independent Journal of Management & Production", 8(4), pp. 1365, https://doi.org/10.14807/ijmp.v8i4.662.

Saługa, P.W. (2019), *Risk-Adjusted Discount Rate and Its Components in Evaluating Hard Coal Projects at the Feasibility Stage*, "Gospodarka Surowcami Mineralnymi / Mineral Resources Management", 35(3), pp. 63–74, https://doi.org/10.24425/gsm.2019.128530.

Saługa, P.W., Zamasz K., Dacko-Pikiewicz Z., Szczepańska-Woszczyna K. and Malec M. (2021), *Risk-Adjusted Discount Rate and Its Components for Onshore Wind Farms at the Feasibility Stage*, "*Energies",* 14(20), pp. 1–12, https://doi.org/10.3390/en14206840.

Shaffie, S.S. and Jaaman S.H. (2016), *Monte Carlo on Net Present Value for Capital Investment in Malaysia*, "Procedia – Social and Behavioral Sciences", 219, pp. 688–93, https://doi.org/10.1016/j.sbspro.2016.05.052.

Tibiletti, L. (2022), *One-Size Risk-Adjusted Discount Rate Does Not Fit All Risky Projects*, "Journal Of Risk Finance", 23(3), pp. 289–302, https://doi.org/https://doi.org/10.1108/JRF-03-2021-0035.

Trzpiot, G. (2008), *Wybrane modele oceny ryzyka. Podejście nieklasyczne*, Katowice: Prace Naukowe AE im. Karola Adamieckiego w Katowicach.

Tsao, C.T. (2012), *Fuzzy Net Present Values for Capital Investments in an Uncertain Environment,* "Computers & Operations Research", 39(8), pp. 1885–92, https://doi.org/10.1016/J. COR.2011.07.015.

Wang, A. (2010), *Comparison of Real Asset Valuation Models: A Literature Review*, "International Journal of Business and Management", 5(5), pp. 14–24, https://doi.org/10.5539/ijbm.v5n5p14.

Wicaksono, F.D., Arshad, Y.B. and Sihombing H. (2019), *Monte Carlo Net Present Value for Techno-Economic Analysis of Oil and Gas Production Sharing Contract*, "International Journal of Technology", 10(4), pp. 829–40, https://doi.org/10.14716/ijtech.v10i4.2051.

Wiśniewski, T. (2006), *Zastosowanie metody Monte Carlo do oceny ryzyka specyficznego projektu inwestycyjnego*, in: "Zeszyty Naukowe Uniwersytetu Szczecińskiego", 416, Szczecin, Prace Instytutu Ekonomiki i Organizacji Przedsiębiorstw, No. 47.

Yao, J. and Jaafari A. (2003), *Combining Real Options and Decision Tree*, "The Journal of Structured Finance", 9(3), pp. 53–70, https://doi.org/10.3905/jsf.2003.320320.

Yousefi, V., Yakhchali S.H., Saparauskas J. and Kiani S. (2018), *The Impact Made on Project Portfolio Optimisation by the Selection of Various Risk Measure*, "Inzinerine Ekonomika-Engineering Economics", 29(2), pp. 168–75.

Zahid, H. (2019), *Implementing Monte Carlo Simulation Model for Revenue Forecasting under the Impact of Risk and Uncertainty*, "Management and Production Engineering Review", 10(4), pp. 81–89, https://doi.org/10.24425/mper.2019.131448.

Zenad, Y.S. (2015), *Sensitivity Anaysis to Know the Project's Ability to Continue*, "European Journal of Accounting, Auditing and Finance Research", 3(11), pp. 60–66.

Zhang, Z. (2010), *Certainty Equivalent, Risk Premium and Asset Pricing*, "Frontiers of Business Research in China", 4(2), pp. 325–39, https://doi.org/10.1007/s11782-010-0015–1.

Žižlavský, O. (2014), *Net Present Value Approach: Method for Economic Assessment of Innovation Projects*, "Procedia – Social and Behavioral Sciences", 156(4), pp. 506–12, https://doi.org/10.1016/j.sbspro.2014.11.230.