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RISK ASSESSMENT OF INVESTMENT PORTFOLIO OF A DIVERSIFIED GROUP BASED ON SOFT COMPUTING

Contemporary methods of quantitative risk assessment of investment based on the theory of fuzzy sets and fuzzy logic are analyzed in this study. A new method of risk assessment, which includes the risk of post-contractual opportunistic behavior of investment process participants, due to the appropriation of additional income (quasi-rent) is developed. The results of risk calculations by the basic and the proposed approaches are presented.

Keywords: *corporate investment; fuzzy analysis; risk; incomplete contracts.*
JEL classification: G3, C6, D810, D820, D860.

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ОЦІНЮВАННЯ СТУПЕНЮ РИЗИКУ ІНВЕСТИЦІЙНОГО ПОРТФЕЛЮ ДИВЕРСИФІКОВАНОЇ ГРУПИ НА ОСНОВІ М'ЯКИХ ОБЧИСЛЕНЬ

У статті розглянуто сучасні методи кількісного оцінювання ризику інвестицій на основі теорії нечітких множин і нечіткої логіки. Розроблено власний метод оцінювання ризику, що включає ризик пост-контрактної опортуністичної поведінки учасників інвестиційного процесу, в зв'язку з присвоєнням додаткового доходу (квазіренти). Представлено результати розрахунків ризику за базовим і за запропонованим підходами.

Ключові слова: *корпоративні інвестиції; нечітко-множинний аналіз; ризик; неповні контракти.*
Форм. 14. Рис. 1. Табл. 3. Літ. 19.

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ОЦЕНКА СТЕПЕНИ РИСКА ИНВЕСТИЦИОННОГО ПОРТФЕЛЯ ДИВЕРСИФИЦИРОВАННОЙ ГРУППЫ НА ОСНОВЕ МЯГКИХ ВЫЧИСЛЕНИЙ

В статье рассмотрены современные методы количественной оценки риска инвестиций на основе теории нечетких множеств и нечеткой логики. Разработан собственный метод оценки риска, включающий риск пост-контрактного оппортунистического поведения участников инвестиционного процесса в связи с присвоением дополнительного дохода (квазиренты). Представлены результаты расчетов риска по базовому и по предлагаемому подходам.

Ключевые слова: *корпоративные инвестиции; нечетко-множественный анализ; риск; неполные контракты.*

Problem setting. The issue of optimal allocation of available investment capital between different assets is sufficiently relevant for progressive development of large diversified groups of companies. Activities of these business units are accompanied by uncertainty growth, external business environment variability and unpredictability of final results, which means the inevitable risk of losses. Thus, effectiveness of investment decision making requires the ability and skill of quantitative risk measurement. However, the probabilistic methods of risk assessment dominating in the contemporary risk management theory based on the assumption of normal distribution of the

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random variable of the rate of return had not proved themselves in practice. Hence, there is a need to find alternative methods, which would take into account the uncertainty of today's business environment.

Recent research and publications analysis. There is a considerable number of both domestic and foreign works dedicated to investigation of problems with quantitative risk assessment based on the tools of fuzzy sets and fuzzy logic. Substantial research results are demonstrated by A. Altunyn and M. Semuhyn (2005), P. Derevyanko (2004), O. Kotsyuba (2006), F. Luban (2007), O. Nyedosyekin (2002), O. Nyedosyekin and K. Voronov (1999), P. Syevastyanov and L. Dymova (2007), T. Tischuk (1997) and others. The presence of a significant amount of fundamental research in contemporary risk management indicates the development of a new scientific field and practical significance of the results.

The research objective is to develop a new way of diversified group investment portfolio risk assessment based on soft computing.

Key research findings. The issues of efficient allocation of available investment funds hold a special place in management theory. Uncertainty, incompleteness, inaccuracy of information, based on which a decision is taken, appropriately cause uncertainty, which, according to O. Nyedosyekin (2003: 52) "generates the incertitude of a person who makes decisions, creates the risk of misinterpretation of the initial information for decision making. And this uncertainty has long had to be measured quantitatively".

The research on the existing methods of risk assessment has shown that the views on the very essence of the concept of risk have significantly evolved since the days of G. Markovitz (1950s) when risk was understood as the degree of volatility of asset returns relatively to their mean value (Markovitz, 1987). According to the contemporary theory of risk management risk is commonly understood as expectations of losses or the lack of effectiveness of certain activities or assets.

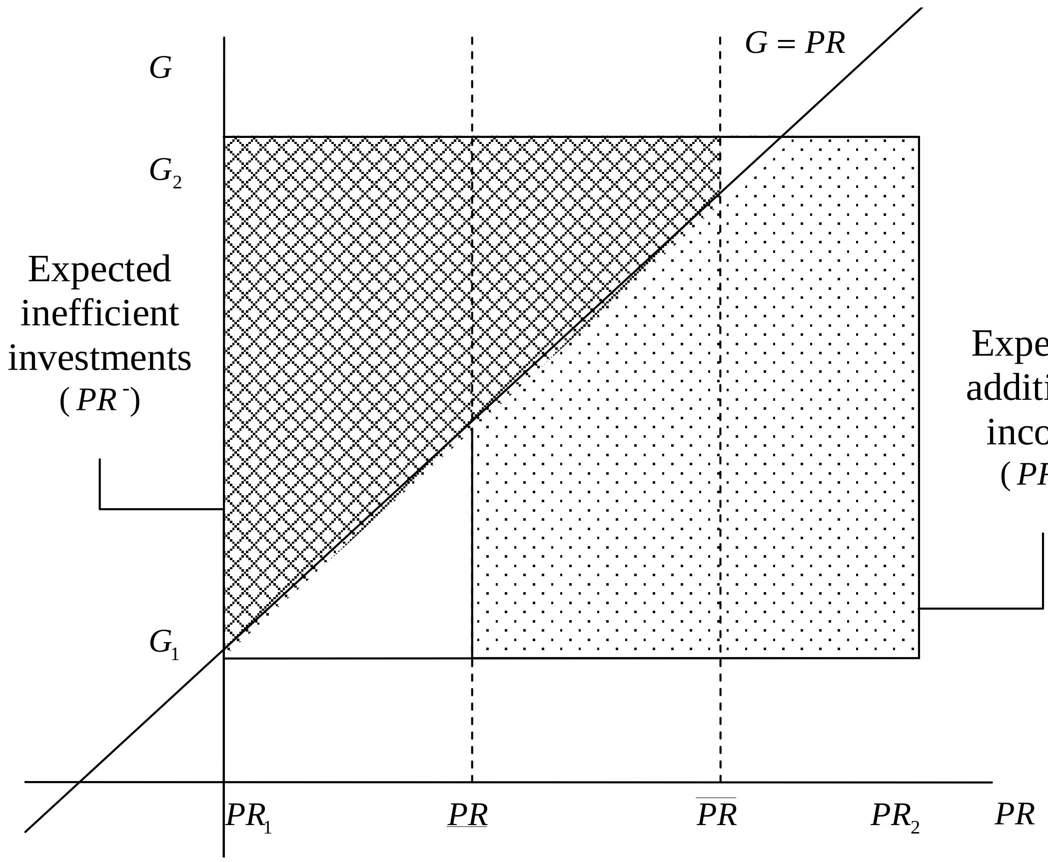
However, focusing on the possibility of a shortfall in income levels, the researchers bypassed another aspect of investment risk, which relates to the post-contract opportunistic behavior, due to the possibility of appropriation of some additional income (quasi-rent).

In order to better explore this aspect we should turn to the two of the leading institutional theories including the transaction cost economics (TSE) and the property right theory (PRT). The first theory predicts that under conditions of high specificity of assets combined with the vertical market failure and high frequency of transactions there is a high risk of post-contract opportunistic behavior of indivi-duals. The second theory is based on the possession of property rights by one party that triggers this party to break the existing arrangements with the other party, increasing its bargaining power. That is, under the conditions of contracts' incompleteness, high specificity of assets and limited rationality there appears a risk of opportunistic behavior of individuals regarding the appropriation of some additional income (quasi-rent), which can occur in case of possession of certain advantages by one contract party, and as a result, this will provoke this side to violate the terms of previous agreements.

There is agents' opportunism at the heart of opportunistic behavior. Explicit opportunism includes lies, theft, fraud, cheating, threatening, blackmail, robbery, assault, raiding etc. Implicit opportunism includes intent, concealment, evasion of contract enforcement, information asymmetry, uncertainty and other misconduct that has the purpose of prosecuting one's own goals and benefits.

A way of overcoming/reducing the risk of opportunistic behavior is the formation of a vertically integrated (diversified) organization or signing long-term contracts, which, according to some researchers, are also considered as a form of vertical integration (diversification) (Klein et al., 1978: 297–326). However, even vertical integration (diversification) does not guarantee protection of the rights of interested parties from the predatory inclinations of the opposite side, and thus the risk of opportunism will always accompany investment activities when a quasi-rent occurs. Thus, there is a need to measure it quantitatively.

Let us consider Figure 1. The shaded area PR^- represents the zone of inefficient investment, and demonstrates the case of occurrence of investment portfolio's losses or the lack of effectiveness. It can happen when the portfolio yield decreases below a threshold level of a certain criterial meaning of investor ("negative" risk). At the same time, the shaded area PR^+ represents the zone of occurrence of investment portfolio additional income (quasi-rent), which can occur if portfolio yield exceeds the maximum threshold level of investor's criterial meaning ("positive" risk).



Source: O. Nyedosyekin (2004) and the author's own research.

Figure 1. **The area of extreme investment expectations**

Figure 1 demonstrates the case in which the area of the shaded figure of the expected inefficient investments is equal to the area of a trapezoid with the bases $(G_2 - G_1)$ and $(G_2 - \overline{PR})$ and height $(\overline{PR} - PR)$, while the area of the shaded figure of expected additional income equals the area of a pentagon, which is limited by straight lines $\underline{PR}, PR_2$ and G_1, G_2 and by the bisector of coordinate angle $G = PR$.

The mutual arrangement of the parameters G and PR allows making the following generalizations on the assessment methods for "negative" (Table 1) and "positive" risk (Table 2).

Table 1. **Evaluation of a "negative" risk,** *the author's own research*

#	within the case PR^{-}	Arrangement
	within the case $G_2 \le PR_1$	
1	0	
	within the case $G1 < PR_1 < G2 \le PR_2$	
2	$\frac{(G_2 - PR_1) + (G_2 - \overline{PR})}{2}(\overline{PR} - PR_1)$	$\overline{PR} \le G_2 \le PR_2$
3	$\frac{(G_2 - PR_1)^2}{2}$	$(PR_1 < G_2 < \underline{PR}) \mid\mid (\underline{PR} \le G_2 < \overline{PR})$
	within the case $PR_1 \le G_1 < G_2 \le PR_2$	
4	$(G_2 - G_1)(\overline{PR} - PR_1) - \frac{(\overline{PR} - G_1)^2}{2}$	$((PR_1 \le G_1 \le \underline{PR}) \mid\mid (\underline{PR} < G_1 \le \overline{PR}))$ $\&\&(\overline{PR} < G_2 \le PR_2)$
5	$\frac{(G_2 - PR_1) + (G_1 - PR_1)}{2}(G_2 - G_1)$	$((PR_1 \le G_1 \le \underline{PR}) \mid\mid (\underline{PR} < G_1 < \overline{PR}))\&\&$ $((PR_1 < G_2 \le \underline{PR}) \mid\mid (\underline{PR} < G_2 \le \overline{PR}))$
6	1	$(\overline{PR} < G_1 < PR_2)\&\&(\overline{PR} < G_2 \le PR_2)$
	within the case $G_1 \le PR_1 < PR_2 \le G_2$	
7	$\frac{(G_2 - PR_1) + (G_2 - \overline{PR})}{2}(\overline{PR} - PR_1)$	
	within the case $PR_1 \le G_1 \le PR_2 \le G_2$	
8	$(G_2 - G_1)(\overline{PR} - PR_1) - \frac{(\overline{PR} - G_1)^2}{2}$	$((PR_1 \le G_1 \le \underline{PR}) \mid\mid (\underline{PR} < G_1 \le \overline{PR}))$
9	1	$\overline{PR} < G_1 \le PR_2$
	within the case $PR_2 \le G_1$	
10	1	

Now there is a need to express PR and G for a given level α, which is not difficult to do from the general equation of the line $\alpha(PR_1) = a \times PR_1 + b$, having found the coefficients a and b:

$$\alpha(PR_1) = \frac{PR_1 - PR_{min}}{\underline{PR} - PR_{min}} \tag{1}$$

or

$$PR_1 = \alpha(\mathrm{Pr}_{min} - PR_{min}) + PR_{min}. \tag{2}$$

Similarly we can define PR_2, G_1, G_2:

$$PR_2 = PR_{max} - \alpha(PR_{max} - \mathrm{Pr}_{min}); \tag{3}$$

$$G_1 = \alpha(G_{av} - G_{min}) + G_{min}; \tag{4}$$

$$G_2 = G_{max} - \alpha(G_{max} - G_{av}). \tag{5}$$

Table 2. **Evaluation of a "positive" risk,** *the author's own research*

#	PR^+	Arrangement
	within the case $G_2 \le PR_1$	
1	1	
	within the case $G_1 < PR_1 < G_2 \le PR_2$	
2	1	$PR_1 < G_2 \le \underline{PR}$
3	$(PR_2 - \underline{PR})(G_2 - G_1) - \frac{(G_2 - \underline{PR})^2}{2}$	$(\underline{PR} < G_2 \le \overline{PR}) \vert\vert (\overline{PR} < G_2 \le PR_2)$
	within the case $PR_1 \le G_1 < G_2 \le PR_2$	
4	1	$(PR_1 \le G_1 < \underline{PR}) \& \& (PR_1 < G_2 \le \underline{PR})$
5	$(G_2 - G_1)(PR_2 - \underline{PR}) - \frac{(G_2 - \underline{PR})^2}{2}$	$(PR_1 \le G_1 \le \underline{PR}) \& \& ((\underline{PR} < G_2 \le \overline{PR}) \vert\vert (\overline{PR} < G_2 \le PR_2))$
6	$\frac{(PR_2 - G_1) + (PR_2 - G_2)}{2}(G_2 - G_1)$	$(\underline{PR} < G_1 \le \overline{PR}) \vert\vert (\overline{PR} < G_1 < PR_2)$
	within the case $G_1 \le PR_1 < PR_2 \le G_2$	
7	$\frac{(\underline{PR} - G_1) + (PR_2 - G_1)}{2}(PR_2 - \underline{PR})$	
	within the case $PR_1 \le G_1 \le PR_2 \le G_2$	
8	$\frac{(\underline{PR} - G_1) + (PR_2 - G_1)}{2}(PR_2 - \underline{PR})$	$PR_1 \le G_1 \le \underline{PR}$
9	$\frac{(PR_2 - G_1)^2}{2}$	$(\underline{PR} < G_1 \le \overline{PR}) \vert\vert (\overline{PR} < G_1 \le PR_2)$
	within the case $PR_2 \le G1$	
10	does not exist	

Since all realizations (PR, G) regardless of the level α are equally possible, then the expectation of the "negative" ($R^{\min}_{expectation}$) and the "positive" ($R^{\max}_{expectation}$) risk is defined as the ratio of a risk function $\aleph^-(G, PR) = PR^-$ (Table 1) and $\aleph^+(G, PR) = PR^+$ (Table 2) to the overall function of uncertainty – $\aleph(G, PR) = (G_2 - G_1)(PR_2 - PR_1)$ of the investment portfolio:

$$R^{\min}_{expectation} = \frac{PR^-}{(G_2 - G_1)(PR_2 - PR_1)}; \tag{6}$$

$$R^{\max}_{expectation} = \frac{PR^+}{(G_2 - G_1)(PR_2 - PR_1)}. \tag{7}$$

Then the total risk can be defined as follows:

$$Risk = \sum_{i=0}^{n}\left(R^{\min}_{i\_expectation} \times \int_0^1 \varphi_i(\alpha)\partial\alpha\right) + \sum_{i=0}^{n}\left(R^{\max}_{i\_expectation} \times \int_0^1 \gamma_i(\alpha)\partial\alpha\right), \tag{8}$$

where n is the number of intervals for risk calculation.

Thus, the risk size ($\varphi(\alpha)$) at a given level of α can be defined as the geometric probability of getting the point (PR, G) in the zone of inefficient investments:

$$\varphi(\alpha) = \frac{PR^-_\alpha}{(G_{\alpha 2} - G_{\alpha 1})(\overline{PR}_\alpha - PR_{\alpha 1})}, \tag{9}$$

where

$$\int_0^1 \varphi(\alpha)\partial\alpha =$$

$$= \int_{\alpha_0}^{\alpha=\alpha_1} \varphi_1(\alpha)\partial\alpha + \int_{\alpha_1}^{\alpha=\alpha_2} \varphi_2(\alpha)\partial\alpha + \int_{\alpha_2}^{\alpha=\alpha_3} \varphi_3(\alpha)\partial\alpha + \int_{\alpha_3}^{\alpha=\alpha_4} \varphi_4(\alpha)\partial\alpha + \int_{\alpha_4}^{\alpha=\alpha_5} \varphi_5(\alpha)\partial\alpha +$$
$$+ \int_{\alpha_5}^{\alpha=\alpha_6} \varphi_6(\alpha)\partial\alpha \int_{\alpha_6}^{\alpha=\alpha_7} \varphi_7(\alpha)\partial\alpha + \int_{\alpha_7}^{\alpha=\alpha_8} \varphi_8(\alpha)\partial\alpha + \int_{\alpha_8}^{\alpha=\alpha_9} \varphi_9(\alpha)\partial\alpha + \int_{\alpha_9}^{\alpha=\alpha_{10}} \varphi_{10}(\alpha)\partial\alpha . \quad (10)$$

The size of positive risk ($\gamma(\alpha)$) at a given level of α can be calculated similarly:

$$\gamma(\alpha) = \frac{PR_\alpha^+}{(G_{\alpha 2} - G_{\alpha 1})(PR_{\alpha 2} - \underline{PR_\alpha})}, \quad (11)$$

where

$$\int_0^1 \gamma(\alpha)\partial\alpha = \int_{\alpha_0}^{\alpha=\alpha_1} \gamma_1(\alpha)\partial\alpha + \int_{\alpha_1}^{\alpha=\alpha_2} \gamma_2(\alpha)\partial\alpha + \int_{\alpha_2}^{\alpha=\alpha_3} \gamma_3(\alpha)\partial\alpha + \int_{\alpha_3}^{\alpha=\alpha_4} \gamma_4(\alpha)\partial\alpha + \int_{\alpha_4}^{\alpha=\alpha_5} \gamma_5(\alpha)\partial\alpha +$$
$$+ \int_{\alpha_5}^{\alpha=\alpha_6} \gamma_6(\alpha)\partial\alpha \int_{\alpha_6}^{\alpha=\alpha_7} \gamma_7(\alpha)\partial\alpha + \int_{\alpha_7}^{\alpha=\alpha_8} \gamma_8(\alpha)\partial\alpha + \int_{\alpha_8}^{\alpha=\alpha_9} \gamma_9(\alpha)\partial\alpha + \int_{\alpha_9}^{\alpha=\alpha_{10}} \gamma_{10}(\alpha)\partial\alpha \quad (12)$$

where

$$PR_\alpha^- = \aleph^-(G, PR, \alpha); \quad (13)$$

$$PR_\alpha^+ = \aleph(G, PR, \alpha) \quad (14)$$

are determined in accordance with Tables 1 and 2.

It should be noted that for the given fuzzy numbers the functions $\varphi(\alpha)$ and $\gamma(\alpha)$ cannot exist simultaneously on all intervals and some components of the integral will equal zero. Which ones – this will depend on the specific type of fuzzy numbers.

Calculation example. The company "N", in the part of the strategy of diversification, intends to invest in the development of its strategic activities (A, B, C). According to the investment program it was planned to invest in the following proportions: 0.604 (A), 0.0127 (B), 0.3833 (C). Key performance indicators of the project (*NPV*) are represented as the fuzzy trapezoidal numbers:

- NPV_A [100.2; 133.82; 135.27; 141.67] mln UAH;
- NPV_B [52.05; 69.52; 70.27; 73.60] mln UAH;
- NPV_C [192.2; 256.66; 259.46; 271.76] mln UAH;

The marginal criterion of the investment project efficiency – *G* [126.8; 143.0; 202.2] mln UAH.

The solution of the problem. The effectiveness of the investment project (*PR*) of the diversified company is the fuzzy number of trapezoid type with the parameters $PR = [PR_{min}, \underline{PR}, \overline{PR}, PR_{max}]$ = [134.852; 180.088; 182.047; 190,669] mln UAH, calculated as follows:

$$PR_{min} = 100.2 \times 0.604 + 52.05 \times 0.0127 + 192.2 \times 0.3833 = 134.85;$$
$$\underline{PR} = 133.82 \times 0.604 + 69.52 \times 0.0127 + 256.66 \times 0.3833 = 180.09;$$
$$\overline{PR} = 135.27 \times 0.604 + 70.27 \times 0.0127 + 259.46 \times 0.3833 = 182.05;$$
$$PR_{max} = 141.67 \times 0.604 + 73.60 \times 0.0127 + 271.76 \times 0.3833 = 190.67.$$

Calculations of the risk by the basic risk calculation method (Nyedosyekin, 2004: 63) and by the proposed method are presented in Table 3.

Table 3. **Calculations of risk by the basic and by the proposed method of risk calculation,** *authors'*

Indicators	Basic method	Proposed method
PR, mln UAH	[134.852; 180.088; 182.047; 190.669]	[134.852; 180.088; 182.047; 190.669]
$Risk_{min}$, %	7.07002	10.0734
$Risk_{max}$, %	–	2.83736
$Risk_{total}$, %	7.07002	12.9108

Table 3 demonstrates that the risk of investment portfolio «N» will be ineffective based on the proposed risk calculation method at 10.07% against 7.07% by the basic method. The size of potential additional income (quasi-rent) is 2.83%. In general we can conclude that the risk level of 12.91% is the boundary one and it requires additional measures for its reduction, including strengthening the legal defense of investments of the diversified group, while the risk level calculated by the basic method (7.07%) is considered to be acceptable for an investor.

Thus, for the same level of return on the investment portfolio there has been received higher risk level by the proposed method of risk assessment (12.91%) than by the basic one (7.07%). This indicates the adequacy of the results, since the new method firstly takes into account the investor's marginal expectations about possible losses and excess profits, and secondly, the proposed method of risk measurement takes into consideration the risk of opportunistic behavior of the investment project participants, due to the appropriation of additional income (quasi-rent), that, in its turn, affects the increase of the resulting risk for portfolio as a whole.

Conclusions. As a result of this study a new method of risk assessment is proposed, the fundamental difference of which is taking into consideration the risk associated with opportunistic behavior of the investment process participants, due to the desire to appropriate additional income (quasi-rent) that may occur if portfolio's excess return exceeds the maximum threshold level of a criterial meaning of an investor. The use of this method will allow managers of diversified groups increase the effectiveness of investment decisions given the uncertainty of today’s business environment.

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Стаття надійшла до редакції 23.10.2014.