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Construction of Equity Portfolio on the Basis of Data Envelopment Analysis Approach

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Abstract. **The research focus of the scientific paper is on the problem of equity portfolio construction. The author recommends applying frontier analysis technique such as Data Envelopment Analysis to the performance measurement of emitters. Using modern computer technologies, the author has calculated efficiency score of twenty Baltic companies which are quoted at NASDAQ OMX Riga and NASDAQ OMX Tallinn stock exchanges on the basis of DEA CCR approach and elaborated proposals for effective asset allocation.**

Keywords: **portfolio construction, DEA (Data Envelopment Analysis), Decision Making Units (DMUs), performance measurement**

I. INTRODUCTION

Recent macroeconomic events played a major role in current Eurozone financial crisis. In the last decade of October 2011 European country leaders agreed to reduce bank losses up to 50% of the nominal value of their Greek debt that makes around 100 billion euro. European country leaders are also very close to settle an agreement for creating Continent's bailout fund. This fund volume could make around 1 trillion euro. Such immense sum is necessary to deter similar speculations (that pushed Greece to need a rescue) around larger European economies like Portugal, Italy and Spain.[7] Additional indicators could be news from Standard & Poor's that has downgraded Italy rating from A +/A+1 to A/A-1, estimating Italy's economy growth perspectives as "negative". [8] The continuing uncertainty in Europe's recovery and the future of euro puts additional pressure on all economical subjects of European countries, making European companies especially vulnerable and unattractive to potential investors.

Creation of profitable and effective equity portfolio is becoming of vital importance for investors nowadays. Traditionally the portfolio construction process includes four steps: risk profile creation, asset allocation, correction of portfolio structure corresponding to the decision maker's requirements and regular control over portfolio structure to avoid the excessive risk in a particular asset field. At present risk measurement and asset allocation phases of portfolio construction are set up using Modern Portfolio Theory by H.Markovitz, methods of technical and fundamental analysis and Sharpe ratio analysis etc. The assumption that market price of an asset reflects impact of all influencing factors information is the main principle of technical analysis. Technical analysis does not take into consideration either the growth strategy of the company and perspectives, or balance sheet data. Fundamental analysis in its turn is based on the estimation of financial statements and figures, and relative competitive advantages. Modern Portfolio Theory is the theory of investment decision to maximize portfolio expected return on interest for an accepted amount of portfolio risk, or equivalently minimize risk for an accepted level of expected return on interest, by thoroughly choosing quantities of various assets. So far all efforts to "translate" theoretical foundations into a viable portfolio step by step construction algorithm are in vain due to technical difficulties, trying to formulate stable original optimization framework within the available data limitations.

The results based on the above-mentioned approaches frequently provide inconsistent conclusions concerning potential investment opportunities and do not grant possibility to evaluate the enterprise activity of emitters as a single process. Problem of equity performance measurement, estimating performance of production process of each company could be faced a principally different approach by usage of methods of frontier analysis. Such method framework provides an opportunity of complex analysis of company's efficiency level for a certain period of time and its comparison among investigated objects. The objective of the author's research is to improve and supplement the methodology of risk measurement before the equity portfolio construction on the basis of the Data Envelopment Analysis approach.

In the circumstances of unstable macroeconomic environment and competition, profitability and market capitalization are among the most important indicators of stability and development of companies for the potential investor. Total operating revenue is a measure of the market value of company's production and the demand for it. Market capitalization is a parameter that reflects market value of all of a company's outstanding shares. It is a basic determinant of asset allocation and risk-return parameters. In this connection, the author analyzed the performance of a set of Baltic companies, assuming total operating revenue and market capitalization value as outputs. The objects of the research are Baltic companies which are quoted at NASDAQ OMX Riga and NASDAQ OMX Tallinn stock exchanges; their efficiency level is analyzed using data for the second quarter 2011. Evaluating the performance on the basis of the Data Envelopment Analysis approach, the author included into the set of investigated objects companies that are considered to be liquid at the Baltic stock markets (according to the amount of operations): JSC "Latvijas Balzāms", JSC "Grindeks", JSC "Latvijas gāze", JSC "Liepājas metalurgs", JSC "Latvijas Kuģniecība", JSC "Olainfarm", JSC "Rīgas kuģu būvētava", JSC "SAF Tehnika", JSC "Ventspils nafta", JSC "Valmieras stikla šķiedra", JSC "Arco Vara", JSC "Baltika", JSC "Ekspress Grupp", JSC "Harju Elekter", JSC "Olympic

Entertainment Group", JSC "Silvano Fashion Group", JSC "Tallink Grupp", JSC "Tallina Kaubamaja", JSC "Tallina Vesi", JSC "Viisnurk".

II. THE CCR DEA MODEL

The CCR DEA model was proposed by Charnes, Cooper and Rhodes in 1978 for the performance evaluation of Decision Making Units (DMUs). The notion of Decision Making Unit might be applied to refer to any organization that is to be evaluated in terms of its efficiency to convert inputs into outputs. These evaluations can involve different types of entities profit and non-profit organizations as well as educational and medical institutions.

The process of production might be concentrated either at minimization of inputs or maximization of output volumes. The model's orientation should be concentrated on variables which are over control. Volumes of inputs are usually controlled by management; therefore only input-oriented models will be introduced in the research.

The comparative performance estimation is based on the concept that the efficiency of each Decision Making Unit is calculated, comparing its performance to ***n*** investigated DMUs. Each Decision Making Unit uses different amounts of ***m*** variable inputs in the production process of ***s*** different outputs. $\boldsymbol{DMU_j}$ uses volume $\boldsymbol{x_{ij}}$ of input ***i*** and produces volume $\boldsymbol{y_{rj}}$ of output ***r***. The assumption $\boldsymbol{x_{ij}} \geq 0$ and $\boldsymbol{y_{rj}} \geq 0$ shall be maintained and each investigated entity has at least one input and output having positive value. Firstly the DEA CCR model was formulated in fractional form. Using this formulation of the model, the ratio of outputs/inputs is considered to measure the relative performance of the specific $DMU_j = DMU_0$ to be estimated in comparison to the ratios of all of the ***j = 1,2, ..., n*** DMU_j. The CCR model construction might be formulated as the minimization of the output/input ratio for each analyzed DMU to that of a single optimal (i.e. 'virtual') output and input. For an investigated DMU the fraction of this single optimal output to single optimal input provides a measure of performance that is a function that might be expressed in multiplier form. According to the mathematical programming methodology, this ratio is the objective function for the investigated DMU. Normalizing constraints ensure the execution of the condition that the optimal output to optimal input ratio of each analyzed Decision Making Unit, including $DMU_j = DMU_0$, must be lower than or equal to 100%. [4] The mathematical programming problem will be formulated in (1):

$$\max h_0(u,v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io}$$
$$\textit{subject to}$$
$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \leq 1 \;\; \textit{for} \;\; j = 1,...,n,$$
$$u_r, v_i \geq 0 \;\; \textit{for all } i \textit{ and } r, \qquad (1)$$

where
h_0 – the function of virtual output and virtual input ratio of DMU_0;
u_r – the output multiplier of DMU_0;
v_i – the input multiplier of DMU_0;
y_{r0} – the output of DMU_0;
x_{i0} – the input of DMU_0;
y_{rj} – outputs of 1,2…n DMUs;
x_{ij} – inputs of 1,2…n DMUs.

The above-mentioned fractional form of the model has an infinite number of solutions; if ***(u*, v*)*** is optimal, ***(αu*, αv*)*** is also optimal for $\boldsymbol{\alpha > 0}$. The transformation which was proposed by Charnes and Cooper in 1962 for linear fractional programming selects a solution ***(u, v)*** for which $\sum_{i=1}^{m} v_i x_{io} = 1$ and yields the multiplicative linear programming problem in which variables from ***(u, v)*** are changed to ***(μ, v)***. The Charnes-Cooper transformation is expressed in (2):

$$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$$
$$\textit{subject to}$$
$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$
$$\sum_{i=1}^{m} v_i x_{io} = 1$$
$$\mu_r, v_i \geq 0, \qquad (2)$$

where
z – the CCR input-oriented function of DMU_0 (multiplier form);
μ_r – the output multiplier of DMU_0;
v_i – the input multiplier of DMU_0;
y_{r0} – the output of DMU_0;
x_{i0} – the input of DMU_0;
y_{rj} – outputs of 1,2…n DMUs;
x_{ij} – inputs of 1,2…n DMUs;

The model in Formula 2 can be solved using its dual problem (3):

$$\theta^* = \min \theta$$
$$\textit{subject to}$$
$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{io} \qquad i = 1,2,...,m;$$
$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{ro} \qquad r = 1,2,...,s;$$
$$\lambda_j \geq 0 \qquad j = 1,2,...,n, \qquad (3)$$

where
θ^* – the optimal value of dual variable θ of DMU_0;
θ, λ_j – dual variables of DMU_0;
y_{r0} – the output of DMU_0;
x_{i0} – the input of DMU_0;
y_{rj} – outputs of 1,2…n DMUs;
x_{ij} – inputs of 1,2…n DMUs.

According to the dual linear programming theorem $z^* = \theta$. The efficiency score can be obtained, solving the dual linear problem. Setting $\theta = 1$ and $\lambda_k^* = 1$ with $\lambda_k = \lambda_o^*$ and all other $\lambda_k^* = 0$, a solution of dual linear problem always exists, the solution implies $\theta^* \leq 1$. However, the optimal solution, θ^*, reflects the performance score for an analyzed DMU. [3]

The optimization process is repeated for each DMU, solving the model, expressed by [3]. DMUs for which $\theta^* < 1$ are considered inefficient, while Decision Making Units for which $\theta^* = 1$ are boundary points. Some of these points may be considered "weakly efficient", having non-zero slacks. It may appear due to the fact that alternate optima may have non-zero slacks only in some solutions. However, this effect might be avoided by solving the linear program in which the slack volumes are maximized (4).

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

$$subject\ to$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta^* x_{io} \qquad i = 1,2,...,m;$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro} \qquad r = 1,2,...,s;$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \ \forall\ i, j, r, \qquad (4)$$

where
s_i^- – input slacks;
s_r^+ – output slacks;
θ^* – the optimal value of dual variable θ of DMU_0;
λ_j – the dual variable of DMU_0;
y_{r0} – the output of DMU_0;
x_{i0} – the input of DMU_0;
y_{rj} – outputs of 1,2…n DMUs;
x_{ij} – inputs of 1,2…n DMUs.

To sum up, the choices of slacks s_i^- and s_r^+ do not have impact on the optimal θ^* which is calculated from model expressed by (3). According to these conclusions, the following definitions of DEA efficiency can be formulated:

Definition of DEA Efficiency: "The performance of DMU_0 is fully (100%) efficient if and only if both (i) $\theta^* = 1$ and (ii) all slacks $s_i^{-*} = s_r^{+*} = 0$." [1]

Definition of weakly DEA Efficiency: "The performance of DMU_0 is weakly efficient if and only if both (i) $\theta^* = 1$ and (ii) $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$ for some i and r in some alternate optima." [1]

The CCR efficiency score is indicative of the overall efficiency level of investigated DMUs. [5]

III. THE APPLICATION OF DATA ENVELOPMENT ANALYSIS APPROACH TO THE EQUITY PORTFOLIO CONSTRUCTION

Methodology of the research

According to the methodology, the Data Envelopment Analysis approach of comparative performance measurement does not require the specific functional form of the model. Therefore choice of outputs and inputs that are corresponding to the objectives of the research is among significant conditions for the achievement of plausible results. The problem of keeping profitability is especially important in the circumstances of unstable macroeconomic environment. The market capitalization value reflects the risk-return parameters that are indicative of company's stability and development opportunities. In this connection, there is developed a concept of efficiency measurement of companies which are quoted at the NASDAQ OMX Riga and NASDAQ OMX Tallinn in the research, assuming total operational revenue to be outputs, while equity, operating expenses and finance (interest) expenses are defined as inputs. The performance evaluation will be completed on the basis of DEA CCR approach that allows calculating overall efficiency score of investigated companies.

Efficiency measurement results of Baltic companies on the basis of CCR DEA approach

The application of the DEA approach requires the determination of assumptions, concerning orientation measures of the model and the concept of returns to scale (RTS). The production process may be concentrated either at minimization of inputs or maximization of outputs. It is emphasized in researches in the field of productivity analysis that the orientation of the model should be concentrated on controllable variables. Usually volumes of resources are considered to be over control of management, therefore there is applied the input orientation in the research. Since the constant returns to scale CRS approach represents the total (overall) efficiency level, CCR DEA model is considered to be the basic concept of the research. [2]

The results of companies' performance evaluation on the basis of CCR input-oriented model, assuming total operating revenue and market capitalization values as outputs, are represented in Figure 1.

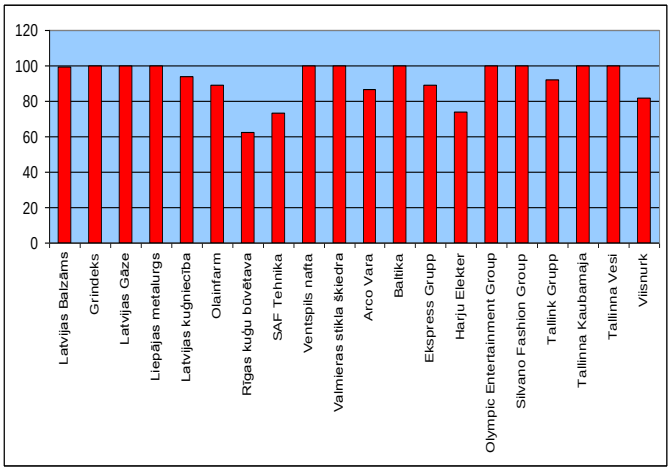

Fig. 1. DEA CCR efficiency score of Baltic stock exchange quoted companies, (%)

According to the obtained results, investigated companies might be separated into three groups. The first group includes

100% DEA CCR efficient companies: JSC "Latvijas Balzāms", JSC "Grindeks", JSC "Latvijas gāze", JSC "Liepājas metalurgs", JSC "Ventspils nafta", JSC "Valmieras stikla šķiedra", JSC "Baltika", JSC "Olympic Entertainment Group", JSC "Silvano Fashion Group", JSC "Tallina Kaubamaja", JSC "Tallina Vesi". The above-mentioned companies have demonstrated the best result, operating on the efficiency frontier at the observation period. High efficiency level of these emitters is indicative of their ability to maximize the volume of outputs using minimal volumes of inputs and to ensure optimal proportions of output and inputs in the process of production, thus of both 100% technical and scale efficiency in comparison to the set of investigated objects. For example, the state-owned company JSC "Latvijas gāze" ensuring 375.9 million euro market capitalization value and 278.9 million euro total revenue, is operating using only equity capital and having no interest expenses. Despite of high volatility of the share price, JSC "Liepājas metalurgs" has the total revenue value 183 million euro at the second quarter 2011. According to the latest company's announcement, JSC "Liepājas metalurgs" is investing into the equipment modernization project; the commercial pledge of 72.19 million lats is guaranteed by the Ministry of Finance of the Republic of Latvia. Due to this fact, potential investors might expect the reduction of company's operational costs. JSC "Olympic Entertainment Group" and JSC "Tallina Kaubamaja" are among the leading companies on the Tallinn stock exchange according to their output values. The enterprise activity of JSC "Olympic Entertainment Group" is oriented at casino and hotel business segments, ensuring the total revenue of 60.8 million euro by the end of the second quarter 2011. JSC "Tallina Kaubamaja" is the largest department store in Estonia that is listed since 1996 on the Tallinn stock exchange. This fact makes securities of the emitter attractive for potential investors.

The second group consists of companies that are having the performance above the 80% level: JSC "Latvijas Kuģniecība", JSC "Olainfarm", JSC "Arco Vara", JSC "Ekspress Grupp", JSC "Tallink Grupp", JSC "Viisnurk". JSC "Olainfarm" is one of the most rapidly growing Baltic companies. According to the latest company's announcement, preliminary sales results of JSC "Olainfarm" for September 2011 show that sales have increased by 102% compared to the same period last year and have reached 3.71 million lats (5.28 million euro). The most rapid sales increase has been experienced in Canada, where sales have increased 442 times, in Ukraine they increased nearly 4 times, in Belarus, a country heavily hit by its currency crisis, the sales have grown by 71%, in Russia by 63%. Main sale markets of AS "Olainfarm" during September 2011 were Ukraine, Russia, Belarus and Latvia. Nevertheless, the company has lower production volumes, higher finance expenses (228 thousand euro) than its nearest competitor JSC "Grindeks", having the 88.89% performance level. Having the highest market capitalization value 467.6 million euro and total revenue of 400.8 million euro, JSC "Tallink Grupp" is only 92.31% DEA CCR efficient. Among possible reasons are high finance (26.7 million euro) and operational expenses (391.5 million euro). This fact is indicative of inefficient organization of company's operational activity.

The third group includes companies that are having the efficiency below the 80% level: JSC "Rīgas kuģu būvētava", JSC "SAF Tehnika", JSC "Harju Elekter".

According to the JSC "SAF Tehnika" interim report data in August 2011, the company's non-audited net sales for 12 months of the financial year 2010/11 were 10.9 million LVL (15.5 million EUR) representing a year-on-year increase of 7%. Sales in the Asia Pacific, Middle East and Africa region formed the largest sales proportion (37%) comprising 4.05 million LVL (5.76 million EUR) although it was by 32% less than in previous financial year 2009/10. The net profit of JSC "SAF Tehnika" for the 12 months of financial year 2010/11 was 780 thousand LVL (1.1 million EUR) representing 52% of the net profit of previous financial year 2009/10. JSC "SAF Tehnika's" non-audited net sales for the fourth quarter of financial year 2010/11 were 1.99 million LVL (2.84 million EUR), representing 53% of the fourth quarter of the previous financial year. [8] Reporting quarter was the weakest in this financial year unlike from last financial year 2009/10 when the fourth quarter was the best. This information had negative impact on the share price of JSC "SAF Tehnika" that decreased by 27.27% since January 2011.

Operating with loss in both 2010 and 2011 financial years (572.6 thousand euro in the second quarter 2011), JSC "Rīgas kuģu būvētava" has the lowest performance level among all investigated companies. Nevertheless, on October 19th 2011 JSC „Rīgas kuģu būvētava" has received an official announcement from SJSC «Черноморнефтегаз» tenders trade commission about the approval of the proposed price by JSC „Rīgas kuģu būvētava". The proposal of JSC „Rīgas kuģu būvētava„ to delivery gas platform for the sum 399,8 million USD was considered the most beneficial and was accepted by SJSC «Черноморнефтегаз». [7] This corporative event caused the increase of equity price by 77.6%, demonstrating that shares of JSC „Rīgas kuģu būvētava" are a good investment opportunity for a risk-tolerant investor.

IV. CONCLUSIONS

The scientific paper is devoted to the equity portfolio construction problem. The most important stages of this process are choice of potential assets, risk evaluation and asset allocation. Traditionally potential investors are using methods of technical and fundamental analysis, Modern Portfolio Theory for this purpose. However, the results which are obtained on the basis of the mentioned approaches often provide inconsistent conclusions concerning investment opportunities and do not provide the possibility to evaluate the enterprise activity of emitters as a process.

The methodology of Data Envelopment Analysis is considered to be a sophisticated tool for performance measurement that allows the investigation of complex production processes among a set of Decision Making Units (DMUs). The author has implemented the DEA CCR approach, analyzing efficiency scores of a set of companies which are quoted at NASDAQ OMX Riga and Tallinn. According to the results, emitters might be divided into three

groups: 100% DEA CCR efficient, having the performance above 80% level and having the performance below 80% level. Equities of fully CCR DEA efficient companies could be included into the portfolio with conservative investment strategy. Companies, which are included into the second and the third group, have lower level of performance. However, securities of these emitters might be attractive for investors with a higher level of risk tolerance.

To sum up, the author recommends using the Data Envelopment Analysis approach methodology as an additional tool for analysis of investment opportunities and equity portfolio creation.

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Tatjana Aršinova. Vērtspapīru portfeļa veidošana, pielietojot datu čaulas analīzes metodi

Viens no investora pamatmērķiem ir efektīva un pelnītspējīga vērtspapīru portfeļa veidošana. Aktuālie makroekonomiskie notikumi liecina par Eirozonas krīzes draudiem, kas rada papildus riskus investīciju jomā. Tradicionāli ar vērtspapīru portfeļa veidošanas process ietver sevī četrus posmus: riska profila veidošanu, aktīvu izvietošanu attiecīgajās proporcijās, vērtspapīru portfeļa struktūras korekciju atbilstoši investora stratēģijai un regulāru portfeļa struktūras uzraudzību. Pašlaik investīciju riska novērtēšana un aktīvu struktūras veidošana notiek, pielietojot tehnisko un fundamentālo analīzi, H.Markovitca mūsdienu portfeļa teoriju (MPT) un citas pieejas. Tomēr uz augstākminēto metožu pamata iegūtie investīciju risku novērtēšanas rezultāti bieži nodrošina pretrunīgas rekomendācijas attiecībā uz potenciālām investīciju iespējām, kā arī neļauj novērtēt emitentu uzņēmējdarbības procesu efektivitāti. Datu čaulas analīzes metodoloģija nodrošina principiāli atšķirīgu pieeju investīciju efektivitātes un potenciālo risku novērtēšanas problēmai. Ar šīs metodoloģijas palīdzību var novērtēt komplekso uzņēmumu procesu efektivitāti, kā arī veikt salīdzinošo analīzi izpētes objektu starpā.
Zinātniskā raksta autore pielietoja DEA CCR pieeju, lai izanalizētu 20 uzņēmumu efektivitāti 2011. gada otrajā ceturksnī, kuru akcijas tiek kotētas NASDAQ OMX Rīgas un Tallinas fondu biržās. Lai iekļautu fundamentālās un tehniskās analīzes elementus, aprēķinos tika izmantoti gan bilances dati, gan informācija par akciju tirgus kapitalizācijas vērtību. Balstoties uz pētījuma rezultātiem, emitenti tika sadalīti trijās grupās: 100% CCR DEA efektīvie, ar efektivitāti virs 80% robežas, ar efektivitāti zem 80% robežas. 100% DEA CCR efektīvo uzņēmumu akcijas var tikt iekļauti vērtspapīru portfelī ar konservatīvo investīciju stratēģiju. Savukārt, emitenti ar zemāku efektivitātes līmeni var ieinteresēt investorus ar augstāko riska tolerances līmeni.
Raksta autore rekomendē pielietot datu čaulas analīzes metodoloģiju kā papildus instrumentu investīciju risku novērtēšanai vērtspapīru portfeļa veidošanas procesā.

Татьяна Аршинова. Создание портфеля ценных бумаг с использованием метода оболочечного анализа

Одной из основных целей инвестора является создание эффективного и доходного портфеля ценных бумаг. Актуальные макроэкономические события свидетельствуют об угрозе кризиса в Еврозоне, что создаёт дополнительные риски в инвестиционной сфере. Традиционно процесс создания портфеля ценных бумаг включает в себя четыре этапа: создание рискового профиля, размещение активов в соответствующих пропорциях, коррекцию структуры портфеля в соответствии со стратегией инвестора и регулярный контроль структуры портфеля. На данный момент оценка инвестиционного риска и создание структуры активов происходит при использовании методов технического и фундаментального анализа, теории современного портфеля (MPT) Х. Марковитца и других подходов. Тем не менее, результаты оценки инвестиционных рисков, полученные на основе вышеупомянутых методов, часто приводят к противоречивым рекомендациям относительно потенциальных инвестиционных возможностей, а также не предоставляют возможности оценить эффективность процессов предпринимательской деятельности эмитентов. Методология оболочечного анализа данных обеспечивает принципиально отличный подход к проблеме оценки инвестиционной эффективности и потенциальных рисков. При помощи этой методологии можно оценить эффективность сложных процессов на предприятиях, а также провести сравнительный анализ среди исследуемых объектов.
Автор научной статьи применила метод DEA CCR с целью проанализировать эффективность 20 предприятий во втором квартале 2011 года, акции которых котировались на фондовых биржах NASDAQ OMX в Риге и Таллинне. С целью включить элементы технического и фундаментального анализа, в расчётах использовались как балансовые данные, так и информация об объёме рыночной капитализации акций. Основываясь на результатах исследования, эмитенты были поделены на три группы: 100% CCR DEA эффективные, эффективностью свыше 80% и с эффективностью ниже 80% уровня. Акции 100% CCR DEA эффективных предприятий могут быть включены в портфель ценных бумаг с консервативной инвестиционной стратегией. В свою очередь, эмитенты с более низким уровнем эффективности могут заинтересовать инвесторов с высокой рисковой толерантностью.
Автор статьи рекомендует применять методологию оболочечного анализа данных как дополнительный инструмент для оценки инвестиционных рисков в процессе создания портфеля ценных бумаг.