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2020 / Vol. 14
ISSN 2073-0438
cfjournal.hse.ru

JOURNAL OF CORPORATE FINANCE RESEARCH

Электронный журнал
«**Корпоративные финансы**»

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Корпоративные финансы

2020. № 1, т. 14
Электронный журнал
www.cfjournal.hse.ru
ISSN 2073-0438

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Journal of Corporate Finance Research

2020. Vol. 14. # 1
e-journal
www.cfjournal.hse.ru
ISSN 2073-0438

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 7-19 (2020)
DOI: https:// 10.17323/j.jcfr.2073-0438.14.1.2020.7-19
Received 4 February 2020 | **Peer-reviewed** 10 March 2020 | **Accepted** 13 March 2020

Capital Structure in Emerging Markets: Evidence from China

Abstract

Although corporate capital structure has been intriguing to scientists for a number of years, very little research has been conducted on the topic for companies in emerging markets. The purpose of this paper is to investigate the determinants of capital structure using a sample of 195 non-financial firms from emerging markets in 2012-2016.

The inclusion of a specific dataset from Chinese companies lends vital focus to this investigation and provides crucial ballast for the investigative function. The final sample contains data on 57 China companies and 90 other companies of emerging markets. Our article focusses on identifying the determinants of capital structure of Chinese companies in comparison with companies of other BRIC countries (Brazil, Russia, India), and sets out a series of hypotheses concerning capital structure with domestic and international variables. We compare and contrast our data using a series of custom evaluation models based on linear regressions.

The results confirm positive impact of tangibility on total debt ratio due to a high share of capital-intensive industries in the sample. It is revealed that growth rates and firm size have positive impacts on financial leverage in Chinese companies as compared to other BRIC countries, and these effects are stronger in capital-intensive industries. We illustrate how a strong negative impact of ROA has increased in recent years, and connect this phenomenon to a considerable decrease in lending rates following a large-scale stimulus program which encouraged Chinese companies to borrow money instead of relying on retained earnings. The presence of the Chinese state in the ownership structure of companies is revealed to be significant for the majority of Chinese companies, especially for the oil and gas and metallurgical sectors.

Our conclusions highlight the importance of government policies and special market conditions in explaining the financing behaviour of companies in emerging countries like China. While capital structure choice varies significantly across industries, nevertheless the differences between Chinese and other BRIC companies reflect the differences in the institutional structure of financing mechanisms in countries. This research and evaluation is especially timely considering the increased focus on Chinese commercial exposure on the world stage, a tendency which is bound to increase research interest in the near future across a range of disciplines. As such, our study and our broad range of conclusions will prove invaluable for students, researchers, policymakers, and decision makers in business, commerce, politics and academia at all levels.

Key words: Chinese companies, capital structure, emerging markets, debt ratio, BRIC companies, financial leverage, financing policies, emerging capital markets

JEL classification: F21; F38; E22; G31; G32

Introduction

Capital structure decisions are an essential part of any business. Firms are regularly faced with controversial issues connected to financing their activities. in general, financing resources may be divided into two categories – debt and equity. Both groups resources are vital for business, and the capital structure is represented as a dynamic combination of both. The equity to debt ratio influences the company value and the willingness of creditors to lend money for the business. It is believed that there is a particular proportion of the debt and equity combination that allows for maximising the firm value and for minimising the weighted average cost of capital. Many studies have been devoted to discovering this proportion. All the existing theories have their supporters and opponents, and as the results vary from one research to the next, empirical studies still cannot provide a reliable prescription for optimal capital structure. Discrepancies may be attributable to the usage of different methodologies. This situation is equally uncertain for both developed and developing countries, but in the case of emerging economies this is especially important as their markets are very young and sensitive, which makes them quite unstable. A clear solution to the capital structure problem could give companies in these markets a solid base for sustainable development, and will substantially contribute to stabilising their markets as a whole.

The research problem for this paper is that nowadays there is no clear answer to the question of what the optimal capital structure for firms in a developing economy should be. Responding to the needs of this problem, the goal of this research will be to study how different firm characteristics associated with capital structure influence firm growth in emerging markets. This will help to identify methods to bring the capital structure closer to the optimal level and to form some recommendations about maximisation of the firm's chances for successful development through rearrangement of the capital structure. This knowledge can also be a guide for such firms to prevent against possible dangerous mistakes in hindering sustainable growth when making capital structure decisions. As previously mentioned, this could be immensely important in the conditions of developing markets, which usually lack stability. As such, solving the research problem will have significant managerial importance and clear future implications for firms.

According to a number of studies, emerging capital markets have grown substantially over the past decades, most notably so during the 1990s. Among the numerous governmental initiatives aimed at facilitating this process, the liberalisation of the financial sector is perhaps the most important. It normally includes such stages as stock market liberalisation, weakening the grip on interest rates, lowering the number of programs of directed credit, etc., in order to make the financial sector more efficient, provide the market with more freedom, facilitate the use of securities, and introduce more options for cross-border risk diversification. In turn, technological advances contribute to this process through lower transaction costs and an overall simplification of operations, leading to increased efficiency. Foreign investors start buying securities to diversify their portfolios. Moreover, such financial tools as illiquid asset securitisation are also a major factor in emerging market development.

However, there are a number of aspects that hinder market development and stand in the way of incoming capital resources. Companies that operate in developing economies are influenced by the following conditions:

- Limited access to capital resources
- Considerable information asymmetry and agency costs
- Great macroeconomic risks resulting from the instability of the system and constant changes
- Poor corporate management

Any of these distinctions may have a considerable impact in a given situation; however, the most important issue here is the extent of their influence on the big picture.

Limited access to capital resources may prevent a company from benefitting from certain types of financing that could potentially improve its capital structure and lead to long-term growth.

Asymmetric information also may lead to significant consequences for investors (both local and from other countries), companies, and governments. According to Sara Xiaoya Ding [1], it may have critical effects on the result of certain investment decisions. While emerging markets offer a wide variety of investment options, information asymmetry makes them extremely difficult to assess, which means that a lot of potential investors choose not to deal with developing economies.

The general instability of both emerging economies and macroeconomic risks also has a detrimental influence on the capital market: potential creditors and investors are put off by high inflation rates, which means that they cannot be certain about making financial decisions when it comes to developing markets [2]. A number of studies claim that a volatile economy may result in fewer financing options for companies, which takes us back to the aforementioned issue of access to capital resources.

Heavily concentrated ownership and ineffective corporate governance are also typical of emerging markets. The biggest companies are often family- or state-owned. According to Rajagopal [3], compared to developed European countries or the USA, Thailand is marked by extremely concentrated ownership. This, in turn, leads to ineffective corporate management, as managerial positions are often given to one's friends or relatives, who may lack the necessary qualifications [4]. These problems may stand in the way of attracting foreign investment, which in turn may hinder market development.

To summarise, when it comes to developing economies, economic development and capital structure are influenced by the markets' unique characteristics in both positive and negative ways.

Nevertheless, while emerging markets may have their problems, they have undoubtedly become a vital part of the global economy. According to the data of European Central Bank (n.d.), 80% of people live in developing economies. Their output is now more than 30% of the global total, and World Economic Outlook states that this figure is only going to grow. This is good news for everybody, as it gives new opportunities to developed economies and has the potential to bring stability to the global economy.

A plurality of experts agree with the fact that the Chinese market is extremely attractive and has a lot of potential, and the charts above make it clear that China is in the lead across the board. Its GDP was growing at the average rate of 9% from 1979 to 2007, and, together with considerable economic and social changes, it swiftly brought the country to the economic level that other countries needed decades or even centuries to achieve. China's expenditure, speedy progress, efficient use of numerous state-of-the-art technologies and optimal financial innovations all contributed to the growing attention from foreign investors.

In this study, we will look at the capital structure of companies in BRIC countries, but the emphasis will be on the results of companies in the Chinese market. This is due to the dominant role of the Chinese market, its development prospects, and the ability to apply the benefits of the experience in the Chinese market to other companies in developing countries.

Emerging markets are a crucial part of the global economy today, and they are likely to have even more influence in the years to come. Every one of them, however, has its own growth rate defined by a given country's political, social and economic circumstances. China is currently in the lead, with competition from India, Brazil, Russia, South Africa and Korea.

As previously mentioned, the greatest contribution to the evolution of attitudes in the formation of capital structure was made by foreign scientists. However, the findings of their work focused more on the analysis of companies operating in developed markets, the terms of which differ significantly from markets of developing countries.

Today there are many lists of emerging markets that were compiled by leading companies in the financial services market. They are, for example, S&P, MSCI, FTSE Group, Dow Jones & Company. However, all the lists are consistent in asserting the fact that countries such as Brazil, India, Russia and China are the most significant countries with developing capital markets. These are referred to as the 'BRIC' group of countries (the first letters of the names of the countries).

The debt level of emerging economies is coming closer to that of developed countries. However, conclusions made for the latter do not apply to capital structure issues in emerging markets, as we cannot say with certainty that companies in both markets use the same strategies when deciding upon capital structure. According to a number of researchers, capital structure is considerably influenced by country-specific laws and regulations, corporate tax rates and taxation systems for individuals, and corporate governance, which means that each emerging economy should be studied separately. In order to understand the situation with Chinese companies, we need to study the Chinese economy, which is now the second largest in the world (with the US in the lead), as an independent case. The maturity of the Chinese market makes a case for exploring the capital structure determinants of Chinese companies.

The subject of the research is the capital structure of large companies in developing countries. The data sample includes information for companies operating for the period 2012 to 2016. This time period was selected as it avoids distortion associated with features of the economic situation and economic policy in a particular year. For example, the considered period includes the global financial crisis, which had significant negative impact on the living standards of the general population, as well as the period preceding the global economic crisis and post-crisis period.

The research goal is to investigate the determinants of capital structure using a cross-section sample of companies listed on stock exchanges in the period of 2012-2016.

The research question to be investigated is: What determines the capital structure in the big companies of emerging markets? In essence this is a test of the applicability of some of the findings in earlier studies in other countries.

In order to find an answer to the question above, we need to develop a suitable research design, which would support our objectives, determine information sources and establish analytical principles to be used with the data collected.

At the first level of research design, we apply a deductive approach (as opposed to an inductive one). This involves data collection to help identify a given phenomenon or to create a theory, and begins with proposing a hypothesis based on prior research (in our case, studies on capital structure in developed economies). This is then tested by the gathering of data, the determination of relationships and the provision of relevant reasoning. We also employ the quantitative method because most of the information is obtained from BRIC firms' annual statements. This data is used to test our hypothesis, which is a common practice when the deductive approach and the qualitative method are used together.

At the level of research strategy, our chosen format is that of an experiment intended to keep track of how independent variables change, wherein we will note the effect such changes have on the dependent ones – in other words, it shall help us determine if there is a significant relationship between them. Obtaining information from annual reports also means that our study focusses on historical data.

As for data collection, we use both primary and secondary sources. While our literature overview focusses on prior research of capital structure and other relevant materials

published in books and journals, the empirical part is based on information obtained from financial reports and annual statements released from 2012 to 2016.

To summarise, in this article we employ a quantitative research design involving a combination of quantitative analysis and the deductive approach, which are used in the format of an experiment. Our research objective is explained with the use of historical data, which has to be processed and turned into analytical data. This, in turn, defines our objectives for the next year: we need to develop a data analysis methodology, explain variable measurement, and work on model estimation.

Literature review

The aim of this review is to systematise the main findings which appeared in the literature on capital structure. This involves an analysis of theories of capital structure based on their division into static and dynamic theories. First, we considered the static theory of capital structure, the traditionalist approach of D. Durand, the fundamental theory of F. Modigliani and M. Miller, the trade-off theory and the theory of hierarchy. In the second part we discuss the dynamic models, which can be divided into two types: signalling and compromise. The signal model appeared first, but in recent years it has actively aided in the development of the concept of dynamic trade-off capital structure. We will present the theories in chronological order of their publication, which allows to allocate the basic stages of development of the theory of capital structure, and identify how this theory was supplemented by new factors and conditions. Further, this literature review will outline the basic assumptions and postulates of the theories and their benefits.

In general, the capital structure is usually defined as the ratio of owned and borrowed capital of the company as it corresponds to its long-term development strategy. There are disputes among researchers about what to include in the composition of equity and debt when calculating these indicators. Equity usually includes the company's shares (ordinary and preferred) [5], and sometimes includes retained earnings [6].

With regard to borrowed funds in the composition of capital structure, some authors attribute them to part of the long-term debt of the company [7]; [8]. However, accounting only for long-term borrowings may not reflect the entire debt capital, as some companies can be partly financed by short-term debt. Therefore, several studies into the calculation of the capital structure suggest that short-term debt (excluding accounts payable) should be considered a permanent component thereof [6].

From the definitions given by many previous researchers, capital structure can be referred to as "the combination of sources of funds a firm uses". Maintaining an appropriate capital structure is a critical consideration for any business organisation. According to Simerly and Li [9] the decision is important not only because of the need to maximise returns to the shareholders, but it is also important because of the impact of such decisions on an organisation's ability to deal with its competitive environment.

Previous research suggests that empirical studies of capital structure determinants mainly focus on the US and other developed economies, while the topic is clearly under-researched when it comes to developing countries. A recent example of the latter studies is the work by Booth [10], where the author attempts to find factors influencing capital structure in developing countries by analysing a sample of 10 developing countries. Booth concludes that factors that are relevant for developed countries apply to developing ones as well, regardless of institutional differences. Bhaduri's empirical study on corporate borrowing [11] focusses on the Indian market. The author claims that the optimal capital structure is normally chosen with such factors in mind as earnings growth, a company's size and cash flow, as well as product and industry features.

Kumar's paper [12] focusses on the capital theory and offers an overview of prior research. The article covers the period from 1972 to 2013, and the author is the first to attempt to identify 'blind spots' in the research of capital structure determinants, making suggestions for further investigations. The paper also includes a statistical summary of the results of the existing empirical research on the topic.

There are several reasons why the topic of capital structure in developing economies has grown in popularity. First, the rate of capital borrowing has the potential to greatly influence a company's profitability [13]. Second, it has been determined that decisions concerning corporate financing depend on a large number of policy-related issues [14], which affect security prices and interest rates, the development of the capital market, corporate government development, firm development, profitability, and the stability of exchange rates and inflation.

The diversity of empirical research into the capital structure of companies in developing countries is well-represented by the breadth of studies devoted to the analysis of the determinants and empirical testing of theories of structure formation of capital (the theory of financing order, trade-off theory, theory of market timing, agency, signalling). Mitton [15] made a research of long-term trends of capital structure on the data of 34 emerging markets. The author showed that a significant increase in the debt burden in the period 1980-2004 in emerging capital markets can be explained to a large extent by corresponding changes in the fundamental determinants of companies (the size of the capital of the company, the profitability of total capital, growth opportunities, and asset structure of the company). The significance of the traditional determinants was identified by [13] and [16] by analysing a sample of companies from Malaysia and Hungary respectively. However, the traditional list of determining factors influencing capital structure in developing countries is not limited. Booth and co-authors [10] revealed the importance of macroeconomic factors influencing the ratio of owned and borrowed capital.

Regarding BRIC countries, the study cited at [17] focussed on a comparative analysis of static trade-off theory and the theory of financing order. The study on the sample of companies from BRIC countries showed that the most significant factors affecting the capital structure are traditional determinants of developed countries, such as the structure of assets of the company, the amount of capital, and the return on capital of the company. The result of the study was that the determinants of capital structure in BRIC countries had no country differences. However, the motives for the formation of capital structure in these countries differ.

The process of testing of the existing concepts of capital structure formation in emerging capital markets is represented by comparatively fewer works.

For example, a study aimed at the empirical testing of the theory of financing order in emerging markets came to the following results. Ivashkovskaya and Makarov [18] used data from European countries to show that the order theory of financing can explain a significant share of new borrowing on the markets of Central and Eastern Europe (CEE), with the sample of determinants identified by the authors speaking in favour of the importance of static trade-off theory. Tong and Green [19], in their study on a sample of the 50 largest companies of China for the period 2001-2003 showed that the behaviour of Chinese companies with respect to the choice of capital structure is largely consistent with the theory of financing order.

The papers of Alani and Alamri [20], Acaravci [21], Rahim [22], and Haron [23] provide reviews of the different views on the present situation in developed and emerging markets and common issues that arise in the previous research of different authors.

It has been established that a company's decision is based not only on the assessment of tax shield benefits and bankruptcy costs, but also on a comparison of the agency costs of equity with those of debt. The cost and benefit analysis for different capital structure plans may include many other factors, but the most important aspect here is that firms come up with an optimal capital structure and then, if it has not yet been reached, they make adjustments. There are a number of studies that confirm that companies make adjustments to reach target debt ratios, for instance, Acaravci [21], Rahim [22], and Haron [23].

Rahim and Saad [22] explore the relationship between sustainable growth, capital structure, and company performance in emerging markets, namely in Thailand, Malaysia, Singapore, and Indonesia. The authors analyse the data from each country over a certain period, and then compare the results. According to this study, most of the parameters are pretty much the same in each country; however, some indicators are significantly different. The divergent group includes ROA (return on assets) and EPS (earnings per share), which usually means that such markets require different conditions for optimal capital structure. Overall, this article has helped us to fine-tune the methodology of our study.

To summarise, all the materials we have analysed offer useful information that can help conduct further research. The works by Fama and French [24], Kemsley and Nissima [25], and Baker and Vurgler [26] have proven to be of value for the theoretical section of our study and have helped us to understand the diversity of capital structure theories. The works by Alani and Alamri [20], Acaravci [21], and Haron [23] present various perspectives of developed and emerging markets today and discuss issues found in previous studies. Studies that examine companies operating in different developing economies are particularly valuable for our purposes, as they can help to identify the features of emerging economies that should be examined more carefully. We discuss some of these features in the next two sections of this article.

Vo [27] contributes further details to the discussion of whether developing markets have different capital structure determinants by analysing a unique data set, which contains company-specific attributes for Vietnamese firms over the period from 2006 to 2015. With a GMM estimator used to control for endogeneity, Vo's findings show that there are different capital structure determinants for long-term and short-term indicators.

Finally, the most recent work devoted to testing the dynamic trade-off concept is the study by Clark and co-authors [28] conducted on the data of 21 developed and 19 developing countries. This research allowed for establishing that the formation of capital structure in all markets can be described by the dynamic trade-off concept. Kokareva [29] in her research of the capital structure of companies from emerging financial markets came to the conclusion about the importance of the dynamic trade-off concept in the selection of the ratio of own and borrowed capital. It was found that traditional determinants of capital structure identified in the data of developed capital markets also has an impact on the target level of debt of companies in the BRIC countries and Eastern Europe. However, target financial leverage is also affected by factors reflecting the agent's motives, ownership structure, and corporate governance. The speed of adjustment to target debt depends on macroeconomic indicators (inflation rate, GDP growth rate) and determinants of the concepts of funding and tracking of the capital market.

It should be noted that the problem of choosing sources for external financing is relevant for any economy. In the case of the transition economy, China should take into account that the mechanisms of corporate financing are at the stage of formation. The system of corporate institutions is very specific. It should also be borne in mind that the parameters of financing are influenced by the ideological preferences of the state. In this case, a special tool is needed to analyse the financing policy of Chinese companies.

The debt financing institutions in developing countries and countries with economies in transition are developing more rapidly than fund-raising mechanisms. However, the Chinese stock market has been in existence for more than two decades, and its importance is growing in the

world of global corporate finance. In this regard, it is important to compare the logic of decision-making on financing from companies operating in the transitional economy of the BRIC countries and China, as although the stock market in each of these countries has been developing for approximately the same amount of time, the dynamics and characteristics remain notably different.

Thus, this paper aims to address a gap in the literature by empirically examining the relationship between the use of debt in the capital structure of companies in emerging markets and the relevant factors related to the capital structure.

The immediate goal of all development activities in this field is the identification of mechanisms for the choice of capital structure, the factors on which these mechanisms depend, and the impact of this choice on the value of the company. This is because an increase in cost reflects the welfare of the owners of the company, and therefore also indicates the status of progress in reaching the commercial targets of the managers working within it.

Attempts to explain the capital structure may be reduced to two approaches: the static (trade-off) approach and the dynamic approach. The first approach assumes that the firm should follow a certain policy with their capital as long as the marginal benefits of such actions are not reduced by the marginal costs (trade-off). This means that every company has a certain optimal capital structure which maximises its value.

Review of Chinese Market

Huang and Song [30] believe that in the case of Chinese companies the institutional environment is characterised by two factors. The first factor is a recognition that the Chinese economy is at a transitional stage. Being the world's second largest economy, it plays an important part in the global economic system. At the same time, the region lacks a modern financial system [31]; [32]. For example, the Chinese bond market is still developing, and treasury bills represent just 3% of corporate bond issuance [33]. Secondly, the majority of Chinese-listed companies are state-owned enterprises (SOEs) [34]. Unlike developed countries, China does not have effective financial supervision mechanisms and bankruptcy constraints, while SOEs are subject to soft credit constraint. The government controls most of the SOEs' stocks, and even after the split share reform of 2005, it still plays a major role in determining listed firms' capital structure [35]. Chen et al. [31] state that this increases the chances of agency conflicts happening between managers and investors, as the former have limited rights to make decisions concerning capital structure. Managers who own only a small percentage of the company's shares are more focussed on personal benefits than on maximising investors' wealth and firm value.

Chen [32] claims that Chinese companies use retained earnings for financing purposes more often; however, more recent evidence indicates a trend towards equity financing. 282 companies were registered on the stock market in 2011, with US$45.3 billion raised in new equity funds. It is significantly lower than the US$76.3 billion raised in 2010, but it is still better than the year 2009 where only 99 newly listed companies raised US$29.6 billion.

While there are many studies on capital structure determinants in China [36]; [37], none of them focus on foreign firms, whose presence may affect the overall situation. These articles offer an empirical analysis based on a large dataset covering more than 85 percent of China's total industrial output. The reason why there are no empirical studies of the impact of foreign companies on a firm's capital structure may be that there are no databases available. According to prior research on China, different financing decisions may depend on the type of company in question (public or private), which is why we investigate the impact of foreign presence on the capital structure of private, public and collectively owned firms separately.

Determinants of Capital Structure of Chinese Companies

A classic method of identifying the determinants of capital structure is based on the construction of linear regression. It is necessary to determine the number of potential determinants, the number of dependent variables, and the nature of their influence. A typical model, which is used to identify the determinants, can be formally written as a function of the debt burden from a number of factors:

$$L = \eta + \eta 1 Tax + \eta 2 Tangibility + \eta 3 Prof + \eta 4 Size + \\ + \eta 5 Risk + \sum \eta\, jXj + v \qquad (1)$$

where Tax – a variable responsible for the tax benefits of debt capital; Tangibility reflects the structure of the company's assets; Prof is a variable that reflects the profitability of the total capital of the company; Size - the size of the company; Risk is a variable reflecting the risk of the company; – is not that other as a vector of other determinants; $\Sigma \eta_j X_{j.}$ the vector of other determinants.

After determining dependent variables, it is useful to take into account the regional peculiarities of the markets of Latin America, Central and Eastern Europe, Asia, and Africa. Country risk and geographical location play very important roles in our model's construction.

The set of the independent variables is usually represented in empirical research by the following: non-debt tax shield, savings on income tax, quality of assets, and the market to book coefficient. The first variable, savings on income tax (Tax), is caused by interest payments on the debt, because companies can raise leverage to increase tax benefits by using the spending interest to reduce taxable profits. The study of Cespedes, Gonzalez and Molina [38] about companies in Latin America confirmed the importance of the tax savings factor. However, not all emerging capital markets studies show the importance of the tax factor. Secondly, it takes into account the savings on income tax of non-debt origin (non-debt tax shield – NDT), since there are other potential sources of such savings.

Thirdly, the quality of assets in the company can perform an important role in borrowing policy. Usually this parameter is linked to the proportion of long-term tangible assets (Tangibility) in total assets, as they can form the basis for collateral in case of borrowing. To reflect this, the proportion of fixed assets in total assets is commonly used: fixed assets/total assets or PPE/TA (property, plant and equipment to total assets). The higher the number of this coefficient, the more capacity the company has to increase borrowings. However, studies on emerging markets got contradictory results. For example, the expected direct impact discovered in the research on the data of Bahrain, Egypt, Qatar, Kuwait, UAE and Saudi Arabia [39]. But the opposite effect was revealed for Chinese companies [30]. Finally, in the test set of determinants, market-to-book, or the ratio of capitalisation shareholders ' equity to its book value is often included as a dependent variable. This ratio could reflect the growth opportunities of the company based on its strategic position and the prospect of development, because the numerator is based on the expectations of investors (market value of equity / book value of equity). But to account for the growth dynamics of a company, researchers use proxy variables of companies' growth rate.

The fact that immediately catches the eye in papers about emerging markets is the presence of variables responsible for agency conflicts in the company, which is extremely rare in models of companies in the U.S. To reflect the possible impact of the conflict there is a set of dummy variables responsible for the degree of information asymmetry in the models (agency dummies). For example, for Chinese companies, the shares which are not traded on the stock exchange (non-circulating share ratio) are used as an indicator, which is able to indirectly reflect the effect of agency costs on the overall cost [36].

To sum up information about emerging markets from different sources the following should be noted: the main determinants of capital structure remain important, although at times their effect is the opposite to that which is exhibited on Western European or American markets. However, some very interesting results accrue for Chinese companies, where obtained data do not agree with any of the above theories of capital structure. If the analysis of the determinants of the capital structure of companies from other emerging markets showed results similar to developed countries, for Chinese companies the dummy variables that are responsible for a qualitative shift in the estimation of parameters played an important distinguishing role.

Based on the variables discussed in our theoretical framework, we will propose hypotheses which are to be tested in order to address the objectives of this research. These hypotheses are intended to investigate firm-specific factors such as firm size, firm growth, tangibility of assets, depreciation to total assets, return on assets (ROA), and tax shield – each of which are significant determinants of the level of leverage in capital of Chinese companies. It is also assumed that the presence of the Chinese state in the management of the company has a significant impact. The hypotheses based on the literature review are: (1) return on assets (ROA) has a negative influence on leverage in emerging markets, as well as for Chinese companies, (2) firm size has a positive influence on same, (3) tangibility of assets has a positive influence, (4) tax shield has a positive influence, (5) growth has a positive influence, and (6) the presence of the state in the management of the company can ensure company sustainability.

Methodology

As was mentioned in the foregoing literature review, modern concepts of choice of capital structure includes the theory of compromise and the theory of financing order. A quantitative test of these theories is constructed using two models. The first model allows us to identify the determinants of capital structure to draw a conclusion about the logic of a decision on financing within the company on the basis of significance of multiple regression coefficients. The model is set out as follows:

$$L_{it} = \alpha + X_{it}\beta + \varepsilon_{it} \quad ,(2)$$

where L_{it} - the financial leverage in the i-th company in the year t; X_{it} – the matrix of the determinants of capital structure for the i-th company in the year t; α is a constant variable; β – coefficient of the determinants; ε_{it} - matrix of vectors of random variables for i-th company in the year t.

The dependent variable L can be expressed as the ratio of debt to value of total assets of the company or to the cost of equity capital. In general, debt capital includes long-term debts. For the evaluation of L one can use both the book and the market values. For this research we will use book value, because the value is reflected in the balance sheet at the time of raising funds and fairly reflects the balance of sources of financing used by the company.

The second model takes into account the specifics of the theoretical concepts of capital structure choice. As was mentioned above, the most popular theories nowadays are trade-off and the theory of financing order. We have chosen to focus on the latter theory, as it has been less studied. The theory of financing order implies that companies first use internal sources of financing, and then resort to external sources. It turns out that the size of the debt itself reflects the accumulated financial deficit, and the increment of the debt shows the finance deficit of the current period. Therefore, the second research model is presented as follows:

$$Debt_{it} = \alpha + \beta Deficit_{it} + \varepsilon_{it} \quad ,(3)$$

Where $Debt_{it}$ – the increment of the debt of the i-th company in year t; $Deficit_{it}$ – the current financial deficit of the i-th company in year t; α is a constant variable; the β – coefficient of variable of current deficit; ε_{it} – a matrix of vectors of random variables for i-th company.

If we look at the model, then we can assume that if the theory of the order of financing is correct, then the coeffi-

cient β is equal to 1, and the coefficient α is zero, and the financial deficit is covered by the value of the debt. The financial deficit is defined as the difference between cash flow from operating activities and cash payments for the period produced by companies. Data for both parts of the equation are taken from the income statement:

$$\text{Deficit}_{it} = DP_{it} + \text{CapEx}_{it} + \Delta\text{WC}_{it} + \text{Ref}_{it} - \text{OperCF}_{it}, (4)$$

where Deficit_{it} - current financial deficit of the i-th company in year t; DP_{it} - dividends paid out of the i-th company in year t; CapEx_it - capital costs of the i - th company in year t; ΔWC_{it} - increase in working capital of the i-th company in year t; Ref_it - portion of long-term debt payable in the current period of the i-th company in year t; OperCF_{it} - operating cash flow of the i-th company in year t.

As we can see, the resulting deficit variable takes both positive and negative values. It is believed that it is preferable to replace negative values with zero, on the assumption that early repayment of debt is uncharacteristic for firms and the negative value of the deficit has no logical justification.

The set of data that was used for this study contains observations for 195 non-financial companies in the five year period between 2012-2016. The sample contains companies from the following industries: heavy manufacturing, light manufacturing, agriculture, oil and gas equipment, oil and gas, and the metallurgical sectors. It should be noted that this sample includes companies adhering to the principles of IFRS or US GAAP. Initial data on companies were taken from the Thompson Reuters service database and in some cases is supplemented with data from officially published company reports. All data are presented (or translated at the official rate of the Central Bank of the Russian Federation) in terms of millions of US dollars. The final sample contains data on 57 China companies and 90 other companies. The ratio of total debt (TDR, total debt ratio) was used as a dependent variable, which is defined as the ratio of the total interest debt of the company to the total amount of its debt and the value of its share capital.

The independent variables are selected on the basis of studies on emerging markets outlined in the literature review of the paper. The description of the variables is presented in table 1, which shows that the participation of the state in the management of the company and the presence of foreign shareholders were taken as fictitious variables describing the qualitative characteristics for all countries. Based on existing studies on the selection of capital structure for companies in emerging markets, some assumptions were made to determine the concept of the choice of capital structure from the nature of the dependence of the variable described on the determinants (positive, negative or ambiguous, i.e. "-").

It should also be noted that all linear regressions were tested to fulfill the conditions of the Gauss – Markov theorem. Fulfilling the conditions of this theorem means that the model is correctly specified, the vector matrix determinant X_it is not random, and the mathematical expectation of all the constituent elements of the random variable vector- $E(\varepsilon_{it})$ - is zero:

$$E(\varepsilon_{it}) = 0 \quad (5)$$

In addition, the homoscedacity condition is fulfilled (the condition of equal variances-Var (ε_{it}) - in the constituents in the i-th equation):

$$E(\varepsilon_{it}^2) = \text{Var}(\varepsilon_{it}) = \sigma^2 \quad (6)$$

In all considered models of linear regression the condition of absence of autocorrelation is fulfilled:

$$E(\varepsilon_{it} * \varepsilon_{jt}) = \text{covariance}(\varepsilon_{it}; \varepsilon_{jt}) = 0 \quad (7)$$

Table 1. Description of independent variables for analysis.

Indicator	Description	The theory of financing order	The theory of compromise
Tangibility	Non-current assets to total assets ratio	Negative	Positive
ROA (Return on Assets)	Return on assets expressed as a ratio of net profit to total assets of the company	Negative	Positive
Growth	The ratio of capital to total assets of the company	Ambiguous	Negative
Tax	«Tax shield», expressed as the ratio of income tax paid to income before taxes	Ambiguous	Positive
NDT	«Non - tax shield, expressed as the ratio of depreciation to total assets	Ambiguous	Positive
Size	Normalised size of the company's capital (through the logarithm procedure)	Negative	Positive

Indicator	Description	The theory of financing order	The theory of compromise
Gov	Fictitious variable that reflects the presence of the state in the management of the company, and if the share of the state is equal to or more than 30%, the value is 1, if strictly less than 0	-	-
Foreign	A fictitious variable that takes the value investors in the company's share capital is between 10% and 25%, otherwise the value is 0	-	-

Source: [40]

Table 2. The results of assessing the determinants of capital structure of Chinese and another developing companies.

	TDR	
	Emerging markets	China
Tangibility	-0,1389	0,2207
ROA (Return on Assets)	-0,2587	-0,5998
Growth	0,1807	-0,0012
Tax	0,0030	0,0019
NDT	-0,0411	0,3420
Size	0,0180	0,0543
Gov	0,0924	0,0805
Foreign	0,0094	0,0907
Const	0,4065	-1,216
Number of observations	90	57
R-square	0,5112	0,2349
F - statistics	5,60	2,46
Probability > Fobserved	(0,000)	(0,000)

Due to the fact that the data are analysed not only for individual companies, but also for five years, we will use the panel data method. Based on the methodology of previous studies, the data obtained can be viewed from the perspective of the pooled regression (Fisher's Test) by the least squares method (LCM). The results for China and other countries are presented in table 2. The significance of variables was checked, with F – statistics evaluated at a 10% significance level.

Results and Discussion

The analysis of the data led to the following conclusions. First, there was a positive correlation between the share of non-current assets in total assets (Tangibility) and the financial leverage for Chinese companies. On the one hand, this dependence is quite understandable: non-current assets can be used as deposits when obtaining a long-term loan. On the other hand, in cases where agency costs are relevant, there is an asymmetry of information, which affects the low initial valuation of shares in the initial offering. As a rule, the availability of powerful and updated fixed assets, which occupy most of the non-current assets, can neutralise these negative effects. Thus, the two concepts of capital structure choice under consideration cannot be rejected.

It should be noted that the financial leverage of companies in developing countries has a negative dependence on the tangibility index. It may be connected with the low collateral value of long-term tangible assets, the presence of a large number of obsolete equipment, and limited service life. The question as to why the same situation is not observed in the China in this situation is quite logical: if we look at the results of the work of H. Li and L. Cui on Chinese companies in the period from 1994 to 2001 in the sectoral context, it can be seen that the metallurgical

sector showed results similar to those obtained for Russian companies [37]. According to the results of previous research (e.g. [13]; [36]) the tangibility of assets asserts a positive influence on financial leverage. Firms investing in intangible assets in countries with good creditor protections have better accessibility to leverage as evidenced by Pandey [13], Haron [23].

It should be noted that the inverse relationship was not obtained for all sectors - the oil and gas sector was the exception. All BRIC companies in this sector have shown positive dependence of variable L on Tangibility. It is no secret that for example Russian companies engaged in the extraction of natural resources have a sufficiently large debt burden. Nevertheless, the high cost of oil and gas equipment, fixed assets, and support from the state (most oil and gas companies in the sample in two countries have direct links with the state, as proven by the importance of the fictitious variable Gov), allows them to count on additional long-term loans if necessary.

Secondly, the inverse relationship between leverage and ROA was obtained for all countries. Such a result confirms that we should apply the concept of financing order. Now, if we recognise certain institutional features of the Chinese financial system, we can find more convincing reasons than the risk of underfunding investment projects put forward by the theory of financing order. Probably, although Chinese banks issue long-term loans to listed companies, their credit opportunities are not unlimited (even though budget constraints appear soft). At the same time, the corporate bond market is not developed. Due to the imbalance in the legal framework for trading and issuing shares, the rights of individual investors, the players who occupy the most part in the market, are affected, and this makes the issue of shares less binding to the fulfillment of obligations under the contract than the issuance of bonds. At the same time, there is no "tax shield" effect in China. In conclusion, the issuance of shares in certain situations is preferable than the attraction of debt funds.

Thirdly, the growth rate of the company has proved to be a significant determinant for the financial leverage of Chinese companies, but it has shown to be insignificant in the sample of BRIC companies. This observation can be explained by the fact that managers of fast-growing companies expect cash inflow in the future and do not hurry with debt financing. However, it is hardly to say unequivocally about the applicability of the theory of compromise to Chinese or BRIC companies. After all, the fact is that the majority of companies in the sample are representatives of such sectors as electricity, metallurgy, and mining. Fixed assets of such kind of company are near about 70% from total assets (Baosteel Group, Wuhan Iron & Steel Group, Hebei Iron & Steel Group, JSC "Evraz group", JSC "Severstal", JSC "NK Rosneft", with JSC "Gazprom" at a little more than 78%) [41], and other intangible assets occupy at least 5 – 7%. Narrowing opportunities for knowledge-based development hinders the growth prospects of companies.

Fourth, the indicator of the "tax shield" showed a low significance at the 10% level for all countries. If we pay attention to the nature of the impact of savings on income tax (not related to debt financing), we can reveal a positive relationship for BRIC companies, while Chinese companies showed the opposite result. If we look at the same indicator separately for each year, the situation remains the same for BRIC companies, and in China the sign of the coefficient in the determinant of NDT changes from positive to negative and vice versa. Most likely, the management annually corrects the financing policy, which is caused by the unstable situation in the market of metals, oil, jumps in the market of gold and coal, and the peculiarities of pricing in the electricity market.

In the coming years, we are likely to see higher debt ratios as a result of two trends: first, financial leverage is becoming more influenced by profitability, and second, profitability itself is on the decrease. This can affect Chinese companies' sustainable financial development in the future.

There is a significant positive association between firm size and financial leverage. Pandey [13] and Nivorozhkin [16] also came to the conclusion that company size has a positive impact on capital structure.

Under the conditions of China, the fictitious variable Gov turned out to be significant for the majority of companies in the oil and gas and metallurgical sectors in the sample. If we think about the institutional features of the financial system of China as soft budget constraints, underdevelopment of the corporate bond market, the underdeveloped legislative and regulatory framework for the balanced regulation of financial markets, and weak legally enforceable protection of creditors and shareholders, it becomes clear that major Chinese companies have the opportunity not on to take in debt and to answer for the loan in case of default, but also to collect large sums of money from the issues of shares. The relationship is also observed by previous empirical studies such as Chen [32], and Ding [1].

We can see that corporate leverage is restrained by profitability, and this influence has grown rapidly over the past few years. One of the reasons for that is a considerable decrease in lending rates after a large-scale stimulus program, which encouraged Chinese companies to borrow money instead of relying on retained earnings. This factor, along with lower profitability, has strengthened the association between capital structure and earnings.

In general, it can be noted that the results obtained for Chinese companies reflect the systemic features of the capital market in the country. The obtained differences in the results of the study between Chinese and BRIC companies reflect differences in the institutional structure of financing mechanisms in countries. The sample also did not show an unambiguous need to strictly follow to one of the classical concepts of capital structure choice, due to the multidirectional action of determinants. On the one hand, there is some evidence that Chinese companies put equity issuance above debt financing in the hierarchy. But, on the other hand, in absolute terms, lending, as was shown earlier in the paper, far exceeds equity financing.

Conclusion

This study identified the determinants that are considered significant to developed markets. They also remain relevant in the selection of capital structure by companies in emerging markets, although the impact for some Central and Eastern European countries is the opposite of that for Western European or American markets. The results are particularly interesting for Chinese companies: the data obtained do not agree with either the theory of the financing order or the compromise theory. In addition to the multidirectional influence of the indicators themselves, fictitious variables responsible for the qualitative shift in assessing the parameters of Chinese companies played an important distinctive role in the studies reviewed. As was discovered later, the main reason for such results was the peculiarity of the institutional structure of the Chinese economy, systemic risks and problems that are unusual for other developing countries.

Most of the hypotheses put forward in this work have been confirmed by the results of the study. In China, lending dominates joint financing. This is due not only to the fact that historically the debt market is formed faster than the equity financing market. As outlined above, there are a number of factors that support this imbalance in the Chinese economy: a distorted system of primary placement, a segmented structure of the stock market, and a limited admission of foreign investors to the stock financing market.

The findings on the development of mechanisms of direct corporate financing in China allowed for interpreting the data in the empirical analysis of the largest companies in BRIC and China. The analysis of the functioning of the capital market in China made it possible to assess the dependence of the variable financial leverage on the determinants of the capital structure more accurately.

The quantitative study confirmed the hypothesis that in some cases Chinese companies put the issue of shares above debt financing. On the one hand, the result contradicts the general situation of predominance of debt financing over equity financing. On the other hand, some companies are forced to resort to the issue of shares in view of the existing significant debt burden. Moreover, the underdeveloped corporate bond market also hinders the free issuance of debt instruments by large Chinese industrial companies. It turns out that at a certain stage, with the decrease in credit opportunities of large banks in China, there is an increase in the issuance of shares as more attractive instruments than debt financing.

The experience gained in the process of writing this work is ambiguous: on the one hand, it was possible to understand the basics of the stock market as a whole. On the other hand, the differences in the functioning of equity financing mechanisms in China were revealed, and the influence of the determinants of the capital structure for Chinese and BRIC companies was compared, which imparted certain knowledge necessary to understand the motives of Chinese investors.

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The Choice Between Public and Private Debt by Russian Companies at Different Stages of the Life Cycle

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 20-28 (2020)
DOI: https://10.17323/j.jcfr.2073-0438.14.1.2020.20-28
Received 11 February 2020 | **Peer-reviewed** 17 March 2020 | **Accepted** 20 March 2020

The Choice Between Public and Private Debt by Russian Companies at Different Stages of the Life Cycle

Abstract

The problems of formation of the company's capital structure to date have already been studied well. A large number of theoretical papers and empirical studies devoted to this issue have been published. However, managers are confronted not only with the question of the optimal balance between equity and debt capital, but also with the choice of debt structure in the presence of several of its sources, such as public and private debt. This is a new paradigm in corporate finance. On the one hand, companies are not always ready to issue listed securities at the initial stages of their activity. On the other hand, raising funds in open markets has several advantages. With the help of public debt, one can attract a sufficiently large amount of financial resources with a lower cost in comparison with private borrowing. At the same time, as a rule, the public debt is not secured by the assets in the proper amount.

According to the author's opinion, in dealing with this question, companies can take into account not only the current state of the company and its financial indicators, but also the stages of the life cycle, since each of them has its own development features. The purpose of this study is to analyze whether life cycle stages and other financial indicators of a company affect the choice of a source of borrowed capital (private or public debt), thereby to contribute to the development of this research direction. The objects of study are Russian companies. In the empirical part of the study, the binary choice model had been applied.

The sample size is 1,818 companies, the financial statements for three years were used. The stages of the organization's life cycle were calculated by the method of V. Dickinson. A number of control variables were also included in the model. The results of empirical analysis indicate that the company decides to issue public debt, regardless of the stage of the life cycle. This allows us to conclude that the company, when conceptually resolving the question about the structure of borrowed capital, relies on economic indicators such as profitability, size of the company, structure of assets and financial leverage. Understanding this fact can also help potential investors in making investment decisions to form conservative portfolios.

Keywords: borrowed capital, debt structure, public debt, private debt, stage of the life cycle of the company, choice of the debt structure, binary choice model

JEL classification: D15, D22, G31, G32

Introduction

Capital structure formation remains a major problem in corporate finance management. F. Modigliani and M. Miller (1958) are considered to be the founders of this theory and their paper is up to now, to a greater or lesser degree, the starting point for many researches in this sphere [1]. There is quite a number of theoretical and empirical studies dedicated to the problems of search for the optimal balance between equity and debt capital, finding and testing the factors which influence their balance [2; 3]. However, at present the most pressing issue is the choice of the borrowed capital source which structure is more complicated and heterogeneous and consists of several elements.

For many modern companies debt financing is virtually the main source of business development. However, in spite of the long period of its functioning this tooling is constantly developing and improving by taking new forms and ways of raising funds accommodating itself to the dynamically developing market. There is a series of papers which prove the importance of the borrowed capital source depending on the company size, its duration and other parameters [4; 5] etc. However, these papers are occasional, they use data from other countries and test mainly the choice between equity and debt capital. At the same time the number of researches dedicated to justification of the choice of the debt financing source, in particular for emerging capital markets, is almost negligible. Besides, the composition and structure of the debt capital differ in the researches rather significantly. For example, D. Denis and V. Mihov distinguish three sources of debt financing: bank private debt, nonbank private debt, public debt. The latter in this paper implies issue of debt securities [6]. A similar opinion was proposed in the paper by A.Marshall, L.McCann, P.McColgan [7]. A lot of researchers think that companies may raise debt capital by bond issuance, borrowing funds from banks and financial companies [8; 9; 10]. D.Rauh and A.Sufi give a wider classification of the debt issued by companies which comprises bank debts, bonds, private placement, convertible debt, debts against security of equipment and immovable property etc. [11]. K.Khan distinguishes six sources in the debt structure including without limitation long-term and short-term borrowings, secured and unsecured ones [4].

Further we will define two fundamental sources in the debt financing structure: private and public debt. Justification of their choice depends on the combination of factors of external and internal environment. This determined the topic of the present research.

State of Knowledge

Theoretical researches assign an important part to the debt source when decisions on the company capital structure are taken. According to the reputation theory, in D. Diamond's opinion, the companies first borrow and redeem private debts and repeat this procedure over and over again intentionally [12]. Acquiring and redeeming a private debt a company demonstrates to the market its financial capacities, ability to manage business thus creating a corresponding reputation in credit markets. Later on, this should result in reduction of the debt cost and after that the company starts acquiring public debts. Acquiring a bank debt has its benefits and drawbacks. As a rule, bank monitoring reduces the costs of information asymmetry for the companies which furnish less information to the market than the borrowers which use public debts. In this case credit institutions may analyze more thoroughly the financial and business operations of a company, control its money flows [13]. On the other hand, it is easier to reschedule a bank debt in case of money troubles because a bank has more information on the company's cashflows and investment opportunities which enables it to take a decision whether, for example, liquidation is the optimum resolution [14; 15]. Thus, the companies which wish to avoid an excessive bank control will try to acquire a public debt by issuing of bonds.

In their turn, Y.Altunbaş, A.Kara and D. Marques-Ibanez showed that large companies with a large financial leverage, a higher profit and bigger liquidating value choose, as a rule, syndicated credit. On the contrary, the companies with a lower debt and the ones perceived by the market as promising companies, with more opportunities for growth prefer the financing through corporate bonds. Syndicated credits are a preferable instrument when the companies are very large, profitable but have less opportunities for growth [16]. E.Morellec, P.Valta and A.Zhdanov obtained the results which confirm that the companies with more growth opportunities, higher ratings and bargaining power in case of a default, operating in more competitive markets and getting less credit offers are more likely to issue bonds [17].

The research made by C.Lin et all. indicates that the companies controlled by principal shareholders prefer financing of their operations using public debt instead of the bank one in order to avoid a thorough study of their business and to protect themselves from bank monitoring [18]. Quite opposite conclusions are given in the paper by S.Boubaker et all. Through the example of French companies the authors found out that dependence on the bank debt increases for the companies with multiple large shareholders. Moreover, the influence of MLS on the choice of debt is greater when agency problems between the controlling and minority shareholders are more serious [19].

A.Kreb, B.Eierle and I. Tsalavoutas in their paper reached the conclusion that there is a relation between investments used in the current year for R&D and the choice by the company of the source of debt financing for the next year. First, the companies investing in R&D in the current year tend to issue of bonds and do not incur private debts in the syndicated loans market the next year. Second, R&D investments of the current year influence the cost of debt by reducing it. The previous researches dedicated to the study of the consequences of investments in research and development in the debt market are focused

exceptionally on American companies and thus are based on the conditions under which the R&D discretionary capitalization cannot be observed [20].

A.Marshall, L.McCann and P.McColgan study the choice of the debt source between the public debt, syndicated bank loans, bilateral bank loans and nonbank private debt. On the basis of the selection of 400 nonfinancial companies for 2000–2012 the authors make the conclusion that larger companies borrow in the public debt markets more often. The companies which depend on banks borrow in the public debt markets less frequently and choose between the bank and nonbank private debt on the basis of the repayment period, security available to the creditors and other characteristic features of the company. These results are in line with the fact that the borrower's reputation is the principal factor which defines the debt source for the companies listed on the British stock exchange [7].

H.Chen and colleagues reached the conclusion that it is more likely that the companies with less allocable assets, less possibilities of opportunity application of capital outside of the company will borrow from banks rather than issue bonds. These conclusions accord with the fact that in case of a default risk or another unfavourable financial situation such companies will consider the opportunity of the bank debt restructuring instead of liquidation of assets in case of a default [5].

Accordingly, the problem of choice of the debt financing source is a currently topical managerial solution in the sphere of corporate finance. For example, K.Khan et all. found out that large Pakistan companies as well as small ones adopt a strategy of debt specification, however the reasons and factors are different [4].

In this regard we think that it is important to study the influence of the aggregate of financial determinants on the choice of the debt financing structure. Therein, in our opinion, the most interesting is the problem of making decisions on issue of bonds as public debt and analysis of the factors which influence such decision. In the authors' judgement, one of the significant factors which should be taken into account in this case is the stage of development of the company. In the considered researches the stage of development is defined using the time factor. R. Cole uses the period during which a company conducts business with the same management as a regressor. Therein this variable is significant at a high level [21]. C.Chang considered the time factor as the period which passed from the listing date. In some regressions this variable is significant in some – not [22]. J.Ramalho and J. da Silva define duration as an important factor and test corresponding hypotheses. Therein this regressor is significant only for individual groups of firms in different regressions [23]. F.Matias and Z.Serrasqueiro used an empirical analysis and found out the significance of the company duration at a high level in case of a joint and short-term debt for the companies of all regions and the significance just for the companies from some regions in case of a long-term debt. It follows that duration of a company is an controversial factor which influences the capital structure choice [24].

However inasmuch as market relations in some countries emerged relatively recently the time from the registration and re-registration date in compliance with new requirements cannot always be considered the company duration. Taking into account these specifics identical values of this variable will be characteristic of the biggest part of the selection, thus distorting the results of the research.

In the modern economic theory one of the concepts describing the company development stage is the company life cycle theory. Numerous research works proved that while following the life cycle trajectories the company evolutionizes changing approaches to management and decision making, overcoming certain difficulties.

Besides, a different degree of uncertainty and unequal development and growth opportunities are characteristic of each stage. Accessibility of financial markets, investors is also different. At the "creation" stage a company is unknown or little-known and its opportunities for growth are unmanifest. It has a small market segment, has no credit rating and, as a rule, no collateral. All managerial, organizational and financial decisions are taken by the entrepreneur/owner.

At the "maturity" stage, on the contrary, the company already has a stable market and lean business processes, however, the influence of bureaucratization and agency conflicts on financial, investment and other management decisions increases. Reduction of the total cashflow is characteristic of this stage and it decreases the prospects of the company development. The owner already has a vague image of the real business environment. In this regard raising debt capital and choice of its type depend greatly not only on the cashflow which is difficult to predict and is incidental to all stages, the company financial standing but on the manager's confidence. So, M.Pfaffermayr and colleagues proved that levers of influence on the corporate capital structure change throughout its life cycle [25]. In some papers it is also shown that a company life cycle is the explanatory factor of its financing structure [26; 27]. Besides, there is still no answer to the question which parameter should be used to measure the company duration. M.Pfaffermayr understands duration as the time since the date of registration. The results of his research show that younger companies demonstrate higher debt ratios and face great difficulties with fund raising sources [25].

In this regard the authors of this paper admit use of the corporate life cycle stage as a variable characterizing the company development level because, on the one hand, legislative regulations have no influence on them and on the other – they show the true state of affairs. It is assumed that young companies which have no reputation borrow in the bank sector (private debt) more often and later, when they become more serious, achieve certain indicators including the market position and capitalization they may take a decision on issue of public debt. This approach is

presented in the papers which consider certain aspects of business operation [26; 27; 28]. E.Suyono, S.Yarram and R.Riswan conducted a research verifying the significance of the life cycle stages of a company in relation to interconnection between the capital structure and the company performance indicators. It was established that the creation and growth stages play a moderately important role in increase of influence of the capital structure on the corporate operating results while at the maturity and slowdown stages influence of the capital structure on the company performance diminishes [29]. It should be noted that this factor was considered in the abovementioned researches only when analyzing the capital structure in totality. As for the debt capital structure, the influence of the life cycle stages on it has not been studied sufficiently.

In this research we will test whether the life cycle stage influences the choice of debt financing source (public and private debt). According to this the offered hypothesis is stated as follows:

H0: companies are more likely to issue public debt at more advanced stages of the life cycle.

Methodology

The choice problem justifies the use of binary logit model. The dependent variable y assumes the value of 1 if the company issued bonds and 0 – otherwise.

The binary choice model may be represented using a latent variable

$$y_i^* = \alpha + \beta LC_i + \gamma X_i + \varepsilon_i, \quad (1)$$

where LC is the column vector of the life cycle for the company компании i; X is the column vector for the control variables of the country i; γ is a corresponding row vector of parameters of control variables of the regression; β is a row vector of the life cycle parameters.

Thus,

$$y_i = 1 \text{ if } y_i^* \geq 0 \quad y_i = 0 \text{ if } y_i^* < 0.$$

In order to define the life cycle stages of a company the method of V.Dickinson is often used in researches because of deficit of available information [22; 23]. In this paper we in the same way distinguish three stages using V.Dickinson's method (creation, growth and maturity):

Creation (Stage_1), if OCF < 0, ICF < 0 and FCF > 0.

Growth (Stage_2), if OCF > 0, ICF < 0 and FCF > 0.

Maturity (Stage_3), if OCF > 0, ICF < 0 and FCF < 0.

Uncertainty / turbulence stages were not taken into consideration in the model. In this case, taking into account the component of the vector of the life cycle stages, equation (1) is presented as follows:

$$y_i^* = \alpha + \beta 1 \times Stage\_1_i + \beta 2 \times Stage\_2_i + \\ + \beta 3 \times Stage\_3_i + \gamma X_i + \varepsilon_i \quad . \quad (2)$$

Therein if the company is at a certain life cycle stage its corresponding variable assumes the value of 1 while the variables which characterize other stages have the value of 0.

Control variables

The authors presume that the indicators which determine the capital structure in general may influence the choice of the types of borrowing: private and public. So, S.Titman and R.Wessels used the following indicators as regressors: pledge value of assets, growth, industry affiliation, company size, profitability and some others [2]. R.Rajan and L.Zingales included the following in the basic regression as a dependent variable: the share of fixed assets in the company assets; market-to-book correlation (balance sheet assets after deduction of the book equity plus the market value of equity capital, and all the above is divided by the balance sheet assets); sales logarithm; profitability [3]. Similar indicators are presented in papers by other authors [30; 31; 32]. Using West European countries as an example K.Jõeveer distinguished four main factors which influence the choice of the capital structure: income, asset profile, assets logarithm, median value of the financial leverage in a certain industry [33]. In some studies a share of paid dividends is taken as a variable [31; 34]. Summary statistics for the determinants of the capital structure taken as explicative variables is represented in the paper by F.Matias and Z.Serrasqueiro [24].

On the basis of review of these and other papers the following indicators were included as control variables.

- Return on assets (ROA) is a ratio of net income (loss) to the total cost of assets.
- Return on equity (ROE) is a ratio of net income (loss) to the amount of equity and reserves.
- Return on sales (ROS) is a ratio of net income (loss) to sales revenue.
- Company size (Log_Assets) is calculated as the base logarithm of assets.
- Dividend ratio (Div_Ratio) is calculated as a ratio of dividend payouts when distributing profits to the owners to net income (loss).
- Asset profile (Tangibility) is defined as a ratio of the difference between the noncurrent assets and intangible assets to total assets.
- Rate of growth (Growth) is defined as a ratio of the purchased items of fixed assets, income-bearing investments in tangible assets and intangible assets to total assets (balance-sheet total).
- Financial leverage (Leverage) is calculated as a ratio of short-term and long-term obligations to equity and reserves.

The regression also comprises dummy variables indicating a year (Y_2014, Y_2015, Y_2016) to control fixed effects.

Database

The database contains 4,226 observations. The number of companies amounts to 1,818, accounting statements for 2014, 2015 and 2016 were used. The companies belong to various industry sectors (fuel and energy, transportation, trading, metallurgical and chemical industry, commu-

nications, automobile, construction, food, pharmaceutical, housing and utilities sector, machinery and metal working, agriculture, aircraft industry etc.). There are 1,009 observations for the companies at the creation stage, 1,368 – for the ones at the growth stage and 1,849 – at the maturity stage. Descriptive statistics of the variables which are not slack ones is presented in table 1.

The obtained results (table 1) show that the average value of the return on assets (ROA) amounts to approximately 5%, while the return on equity (ROE) exceeds 10%. Consequently, companies raise a lot of borrowed funds in order to provide additional returns for the owners and this confirms the ratio of the borrowed capital and equity. On average the share of tangible assets (tangibility) in the balance-sheet total amounts to 48% although the selection comprises nonfinancial companies which are not characterized by this feature but have debt obligations.

Table 1. Descriptive statistics

	Mean	Median	S.D.	Min	Max
ROA	0.04634	0.02855	0.1392	−2.962	2.165
ROE	0.1065	0.1379	2.852	−66.15	51.96
ROS	−0.0998	0.0263	3.877	−139.6	40.09
Log_Assets	16.57	16.37	1.522	10.23	23.35
Div_Ratio	0.2156	0	3.142	−135.6	81.45
Tangibility	0.4779	0.493	0.2795	0	0.9923
Growth	0.06153	0.03267	0.08797	0	0.8953
Leverage	10.35	1.948	64.69	−1,021	961.1

Results and Conclusions

The results of the empiric analysis are represented in table 2.

On the basis of the existing data the proposed hypothesis was not confirmed. Consequently, we can make the conclusion that the probability that a company enters stock exchange in order to issue bonds does not depend on the life cycle stage. Moreover, the return on assets, the company size, asset profile and the financial leverage are significant factors.

Therein it should be noted that the chances of bonds issuing increase with decrease of the return on assets and advance of the financial leverage level. This may mean that public debt is more attractive for a company due to various reasons: lower interest rates, long loan term, no monitoring by credit institutions etc. The obtained results do not accord with the conclusions made in the paper by Y.Altunbaş, A.Kara and D.Marques-Ibanez [16], however, they confirm the conclusions of E.Fama [13], T.Chemmanur and P.Fulghieri [14], O. Yosha [15].

The company size has a positive impact on the probability of borrowing by issue of public debt and this is in line with the results obtained by A.Marshall, L.McCann and P.McColgan [7]. The company which issues bonds has certain issue and transaction costs and a significant part of them does not depend on the size of the issue. Consequently, the bigger the issue size the lower such unit costs are. In its turn, a small company which has no certain reputation yet is highly unlikely to place a bond issue which exceeds greatly the size of the assets with an expected yield to maturity.

The asset profile, namely a share of tangible assets, has also a positive impact on making a decision of bonds issue because most likely the company is interested in the bond buyers with a large share of noncurrent assets which, in their turn, may be the subject of pledge or guarantee of loans.

So, if a company is rather large, its financial leverage is significant, it has a large share of tangible noncurrent assets and its profitability decreases such company is highly likely to enter the bond market irrespective of its life cycle stage.

The obtained results do not contradict D.Diamond's theory [12] which contemplates significance of the borrower's reputation when entering the financial market, however, when taking decisions on the choice of the debt financing source it is reasonable if Russian companies' managers pay attention to the life cycle stages of companies because each company has its own characteristic features, risks and opportunities. Otherwise the existing strategy oriented toward disregard of the business development stages, in the authors' opinion, may result in an unfavourable financial situation in future.

At present large, less profitable Russian companies which already have large amounts of borrowed funds prefer the strategy of public debt increase, thus trying to reduce operational risks, minimize expenses of bond issue and costs of debt. This may be explained by specific features of the emerging financial market ready for the issuer's elevated risks as well as by the fact that companies are forced to look for a cheaper funding source when income is low or other factors which require an additional study.

Table 2. Results of the empirical analysis

	Coefficient	Statistical error	Z	P-value	Marginal effect for average
Const	−9.61930	0.755777	−12.73	4.15e-037***	
Stage_1	0.0959031	0.193226	0.4963	0.6197	0.00386663
Stage_2	0.0713751	0.164069	0.4350	0.6635	0.00284465
ROA	−1.58607	0.454044	−3.493	0.0005***	−0.0624773
ROE	0.00859381	0.0169647	0.5066	0.6125	0.000338520
ROS	0.0326664	0.0387466	0.8431	0.3992	0.00128677
Log_Assets	0.363362	0.0447726	8.116	4.83e-016***	0.0143132
Div_Ratio	0.00140074	0.0247533	0.05659	0.9549	5.51765e-05
Tangibility	0.809868	0.305741	2.649	0.0081***	0.0319016
Growth	−0.891645	0.936959	−0.9516	0.3413	−0.0351229
Leverage	0.00394032	0.000678087	5.811	6.21e-09***	0.000155214
Y_2014	0.168375	0.177193	0.9502	0.3420	0.00681454
Y_2015	0.149215	0.175598	0.8498	0.3955	0.00601961

McFadden R square = 0.085764.

Likelihood ratio criterion: chi-square (12) = 150.74 [0.0000].

*** – significance at the 1% level; ** – significance at the 5% level; * – significance at the 10% level.

Conclusion

Summing up, we conclude that a company tends to take a decision of the public debt issue irrespective of the life cycle stage. It means that the degree of the business development and its possible opportunities for growth in future have no influence on the management's decision as regards debt specification and structuring from the point of view of its tooling. It indicates that a company may issue bonds taking into consideration only statutory restrictions instead of life cycle stages and their characteristics. This bears additional risks for investors.

It should be noted among positive aspects that Russian companies which issue and tend to issue public debt take into consideration not just the amount of the balance-sheet total but existence of physical long-term assets, which guarantee the obligations de facto, as well. On the other hand, the conducted research confirmed that the larger the share of the debt capital and the lower the profitability, the greater is the tendency to acquire public debt instead of the private one.

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Financial Effects of Corporate Social Responsibility and Information Transparency (the research for the pharmaceutical industry)

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 29-38 (2020)
DOI: https://10.17323/j.jcfr.2073-0438.14.1.2020.29-38
Received 22 January 2020 | **Peer-reviewed** 17 February 2020 | **Accepted** 10 March 2020

Financial Effects of Corporate Social Responsibility and Information Transparency (the research for the pharmaceutical industry)

Abstract

The article is devoted to research and evaluation of the usefulness of information disclosed in reports of pharmaceutical companies. The main purpose of the study was to assess the transparency of the metric, inter-firm comparability of non-financial reporting data, and to identify the usefulness of the disclosed information for international pharmaceutical companies. The methodological basis of the research is the harmonization of the requirements of business practice standards with financial reporting standards. The paper uses the method of proportional-typical selection of stable structured performance indicators of companies. The authors were not limited to information requests from investors in one country, individual companies, or priority areas of interests of interested and involved persons. The study approach implemented for the multilateral consideration of the views of stakeholders. The research database was compiled by reports of five companies, such as Johnson & Johnson, Novartis AG, Merck KGaA, Sanofi, and Takeda Pharmaceutical Co. Ltd. from the Global Reporting Initiative Database and financial reports of 20 pharmaceutical companies of the Access to Medicine Index System in 2014 and 2016. The result of the study is that the total position of 5 companies moved up from the 8th to the 6th rank. The result of the ratio of growth rates of their total revenue, capitalization and long-term capital is positive when compared with the growth rate of the quality of their disclosure of non-financial indicators. Such relationship is the strongest in attracting long-term capital, followed by growth in capitalization and it is the smallest in growth in revenue. The format of the minimum required set of harmonized indicators helps to increase the confidence of stakeholders in the financial and non-financial information of socially responsible companies. The novelty of the results obtained consists in using a metric expression of the quality of reporting indicators to assess their usefulness in the business practice of companies with a production profile. The results obtained in the course of the study allow us to make a generalized conclusion that useful information generated on the basis of harmonization of structured data from financial and non-financial statements contributes to increasing the level of business activity and its comprehensive performance of all parties involved in the company's affairs.

Keywords: non-financial reporting, corporate responsibility, information transparency, sustainable development, business practices harmonization

JEL: F610, G300, Q56

Social and ecological problems cause a heightened stir in the society because the assessment of building trust towards a company, loyal relationships between a company and its prospective customers (buyers), investors (including lenders) and partners should be beyond a purely financial measurement. Piecewise requirements and recommendations of IASB Board as regards generation of additional non-financial and nonmonetary information in its own platform do not satisfy the existing information requests. So, in September 2015 general public was scandalized by the facts reported by mass media which concerned overpollution of the environment by Volkswagen's (VW) cars from 2009 to 2015. Later it affected adversely the concern capitalization. As a result of the scandal the stakeholders urged to provide transparency of non-financial information along with financial one.

Against the background of the stakeholders' request for measuring the companies' impact on the planet applying a reliable and unified method, in the way their revenues are calculated at present, there are report forms of multiple and poorly harmonized voluntary non-financial standards beyond the bounds of financial information. Therein an increasingly greater number of decision makers from companies' management think it strategically important to pursue the concept of corporate social responsibility because the community demands more and more to establish fair and ethical business practices.

In his full-fledged analysis of business practices of international and American companies and organizations Barukh Lev [1] distinguishes the key sectors for which the traditional accounting and financial statements model no longer meets the requirements of stakeholders. Apart from the financial sphere and mass media sector the author identified so called capital-intensive segments: pharmaceutical, oil and gas, chemical and power-producing industry. It is the companies with a significant part of capital tangible assets on the books which release great amounts of hazardous substances into the atmosphere, water, soil.

A great number of papers offer conclusions on positive interrelation of meeting CSR by a company and customer behavior which is shown by the customers' loyalty. Stakeholders' loyalty to socially responsible business is confirmed by researches in the banking sector [2; 3], retail business [4], mass media and entertainment [5; 6] and insurance [7]. But we found a drawback in such studies for the abovementioned capital-intensive economic sectors the companies of which should make commitment to CSR principles a priority managerial task.

Therein one of the problems is how one can convey in a short and brief way valuable information on its activity to all concerned parties using communication channels and platforms which they prefer at reasonable expense [8]. A lot of organizations do not disclose certain key performance indicators as, for example, the International Integrated Reporting Council (IIRC). However, the standard reads that quantitative and monetized indicators "are extremely beneficial when explaining how an organization generates value, uses various types of capital and influences them" [9, p. 10].

In 2014 the European Union passed Directive 2014/95/EC in implementation of which Guidelines on Non-Financial Reporting 2017/C215/01 (Methodology for Reporting Non-Financial Information) were published for the reports made by company management. In accordance with the Guidelines companies should disclose the business practices formats they followed because it improves transparency and comparability. But although the Guidelines mention and *offer the companies to base themselves upon* KPI they virtually offer to the companies of various global economy sectors no way of selecting KPI and no instrument for quality assessment of non-financial information.

In Russia the Concept of Development of Public Non-Financial Reporting in Russia indicates the relevance of making a list of performance indicators. The Concept contemplates "defining the list of minimum essential basic indicators for disclosure of information on the performance results of a company in the economic, environmental and social spheres…" [10, p 13].

The research conducted by the pharmaceutical company Johnson & Johnson showed that implementation of CSR concept into business strategy of social and environmental aspects advances attaining financial goals of development [11]. Improvement of financial results is especially notable for the companies of business-to-customer sector which compete on the basis of their reputation and brand and at the same time use natural resources widely [12]. Cooperation with stakeholders and transparency in CSR are manifested in the companies' access to debt capital (reduction of its cost, easier access). Simplification of access to financing is accounted for reduction of information asymmetry due to activities' transparency and saving of agency costs for stakeholders due to increase of their involvement [13].

In our turn, we put forward the hypothesis that improvement of quality of disclosure of significant non-financial information by companies from capital-intensive sectors, which comply with corporate social responsibility requirements, causes increase of stakeholders' loyalty: buyers (as growth of the total market share of sales), lenders (who provide accessibility of long-term funding sources) and investors (who manifest their confidence in company's opportunities for growth through being active in making deals while shares' cost increases).

We think that it is possible to assess company's commitment to CSR concept and programs on the basis of measuring/metric approach. The following approaches are widely spread now:

- testing of the model of structural equation based on the assessment of perception by stakeholders' groups of companies' social responsibility. Aggregation of similar CSR researches makes it possible to make a checklist of CSR definitions where respondent's feedback ranges within a 7-point Likert-type scale [2];

- assessment of reputation, for example, review of corporate reputation by Fortune Magazine [14]. The assessment is made by industry sector analyzers and people with knowledge of the matter who prepare ratings for companies. Therein the magazine does not disclose assessment for all aspects presenting just an average rating - Fortune's MAC Rating in the range of 1 to 10 points;
- use of independent ratings, for example, responsible investment indexes: FTSE4Good Index, the Dow Jones Sustainability Indices (DJSI), MSCI KLD 400 Social Index, Calvert Social Index etc. [15; 16];
- direct data collection from company reports, published materials, interview with the management and its quantitative (availability of indicators, parameters) and qualitative analysis (data ranking) [17; 18].

In our paper we develop the last-mentioned approach finding out financial effects of expanded non-financial information disclosures. In the study of six largest (according to revenues) global pharmaceutical companies [17] the authors relied just on interviews with managers conducting only the quantitative analysis of commitment to CSR programs. At the same time the research [18] of non-financial reports of international pharmaceutical companies covers presence of KPI from the Global Reporting Initiative (GRI) as well as qualitative analysis of the degree of their disclosure. But the criteria of company selection are not transparent, the authors have not substantiated the number of KPI and the applied ranking system is falling behind similar systems [19] which have been elaborated more thoroughly.

In Russia some authors also have their requirements to building of the company indicators system, that is: data should not be collected by means of complicated, expensive and labour-intensive work; a systemic approach is necessary to choose indicators; the number of indicators should be sufficient but, if possible, minimal, and all indicators should be transparent, independent and complementing each other [20]. Therein the indicators offered by the authors are, as a matter of fact, just the lines of social, environmental and economic development set by them without offering any certain metrics.

From the point of view of the quantitative analysis A.D.Sheremet developed an approximate content of the indicators of social and environmental conditions of business operations [21, p 7], pointing out that such system of indicators should be stated taking into consideration the specifics of the types of companies' business operations. In our opinion social and environmental indicators should comprise companies' operating results instead of conditions; the indicators taken from provided standards of business practices, their interrelations instead of selected indicators alone.

We defined the organizations which offer measurable indicators of efficiency:

- Global Reporting Initiative [22; 23];
- Sustainability Accounting Standards Board [24];
- European Federation of Financial Analysts Societies [25];
- The Intergovernmental Working Group of Experts on International Standards of Accounting and Reporting of the United Nations Conference on Trade and Development [26].

Here we list the main characteristic features of the above-mentioned standards:

- GRI standards are a well-developed information platform represented as a set of KPI for all sectors of global economy;
- SASB standards were developed from the perspective of the investors' view of the format of non-financial reporting. We used KPI of SASB for the pharmaceutical industry;
- EFFAS standard was developed for listed companies and bond issuers. It inspires the capital market players to implement their KPI in their assessment models. We used KPI of EFFAS (version 3.0) for the pharmaceutical industry;
- UNCTAD facilitates investments, economic stability and sustainable development by means of encouraging the best practices of corporate transparency and accounting.

Applying the proportionally-typical selection for the purpose of ensuring the selection representativeness we offer a uniform set (table 1) of 15 significant performance indicators for the companies of the capital-intensive pharmaceutical industry (our numeration from 1E to 15S). We are not limited by stakeholders from one country, company or sphere of interest, we rather rely on the approach of multi-sided consideration of opinions of concerned parties (multi-stakeholder approach) with reference to which the four abovementioned standards were developed.

The indicators were added to the set if they were present simultaneously in two or more standards of the four ones mentioned above. We indicated them in short-hand form – from new GRI Standards which entered into force on July 1, 2018 and we found their exact matches to KPI of the previous standard GRI G4 (General Standard Disclosures).

Table 1. A set of key performance indicators using companies from the pharmaceutical industry as an example

№	GRI G4	Codes of harmonized standards	Name in accordance with GRI Standards
1E	EN2	301-2, HC0102-26	Share of materials which are recycled or reclaim waste materials

№	GRI G4	Codes of harmonized standards	Name in accordance with GRI Standards
2E	EN3	302-1, E01-01, HC0102-23	Power consumption within the organization
3E	EN8	303-1, E28-01, E28-02, E28-03, HC0102-24	Total amount of water taken in with breakdown according to sources
4E	EN15	305-1, E02-01	Direct GHG emissions (coverage area 1)
5E	EN16	305-2, E02-01	Indirect GHG emissions (coverage area 2)
6E	EN23	306-2, E06-01, HC0102-26	Overall amount of waste with breakdown according to types and disposal methods
7E	EN32	308-1,HC0102-30, V28-03, V28-04, V28-05, ISAR4	New suppliers assessed against ecologic criteria
8L	LA1	401-1,HC0102-14, HC0102-16, ISAR5, ISAR7, S01-01, S03-01	Share of new employees and staff turnover
9L	LA6	403-2, S04-03, S04-04, HC0102-17, HC0102-18, ISAR13	Types and frequency rate of industrial injuries, occupational health problems, lost workdays and workplace absence as well as number of fatalities related to work
10L	LA9	404-1, S02-02, HC0102-15, ISAR10	Average number of hours of training per year per one employee
11S	SO1	413-1, ISAR8,ISAR15, S08-03	Engagement with local communities, impact evaluation and development programs
12S	SO5	205-3,HC0102-27, ISAR16, V02-01	Proven acts of corruption and actions taken
13S	SO6	415-1, G01-01, ISAR14	Donations for political purposes
14S	SO8	419-1,HC0102-09,HC0102-22,V01-01, S05-02	Disregard of law and legislative instruments in the social and economic spheres
15S	SO9	414-1,HC0102-29, V28-03, V28-04, V28-05, ISAR4	New suppliers assessed against the criteria of social impact

Source: compiled by the authors

We offer practical implementation of the approach to ranking taking into consideration business practices of preparing non-financial reports (using energy companies as an example) as an instrument of handling non-financial information. Points are assigned as follows [19]: 0 points – the stated indicator is not shown, 1 point – there is a short mentioning of the indicator in the report; 2 points – the report presents valuable information expressed in figures; 3 points – the information is clear, there are diagrams and their analysis; 4 points – the issue is described completely.

Use of the mechanism of business practices standards harmonization and the data ranking instrument helps to appraise the obtained KPI set using pharmaceutical companies as an example. The database of our research comprises reports of sustainable development of companies from the rating system Access To Medicine Index (AMI) which describes the best practices of functioning of 20 most innovative pharmaceutical companies [27]. We considered reports of companies from AMI list for 2014 and 2016 where we used the following criteria:

- reports should be entered into a corresponding database [28];
- reports should be in accordance with GRI G4 Reporting Guidelines;
- reports should be made in English or Russian.

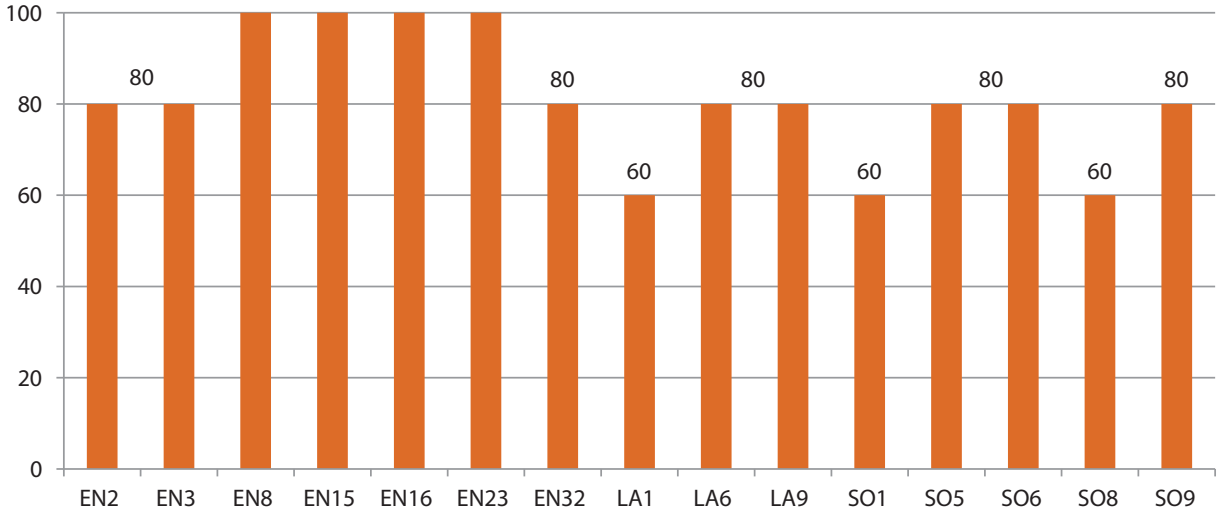
Russian pharmaceutical giants were not included in the lists of Access to Medicine Index. Though subsidiaries of some companies of the rating publish in Russia some KPI reports, they are Novo Nordisk AC from Denmark, Abbott Laboratories from America, Takeda Russia (Japan)

and Group Sanofi-Russia (France) while we are interested only in consolidated reports on KPI. The fact that we used GRI G4 report by Johnson & Johnson for 2015 is an assumption to some extent because since 2016 this company makes reports in accordance with GRI Standards. Five out of 20 companies declare openly (table 2) of their commitment to the principles of sustainable development and social responsibility.

So, there arises the question: are modern companies ready (in our case pharmaceutical ones) to disclose non-financial information which we indicate? We answer this question analyzing reports of five socially responsible pharmaceutical companies which published (unlike other 15 companies) KPI reports in GRI Database: Johnson & Johnson, Novartis AG, Merck KGaA, Sanofi, Takeda Pharmaceutical Co. Ltd.

Proceeding from the quantitative analysis of representation of KPI for the five abovementioned companies in 2016 on the basis of the developed unified set (table 1) we found out that the overwhelming majority of indicators are already mentioned frequently at present. The average frequency of their mentioning is 81.3%.

Figure 1. Representation of a set of key performance indicators for pharmaceutical companies for 2016, %



Source: compiled by the authors

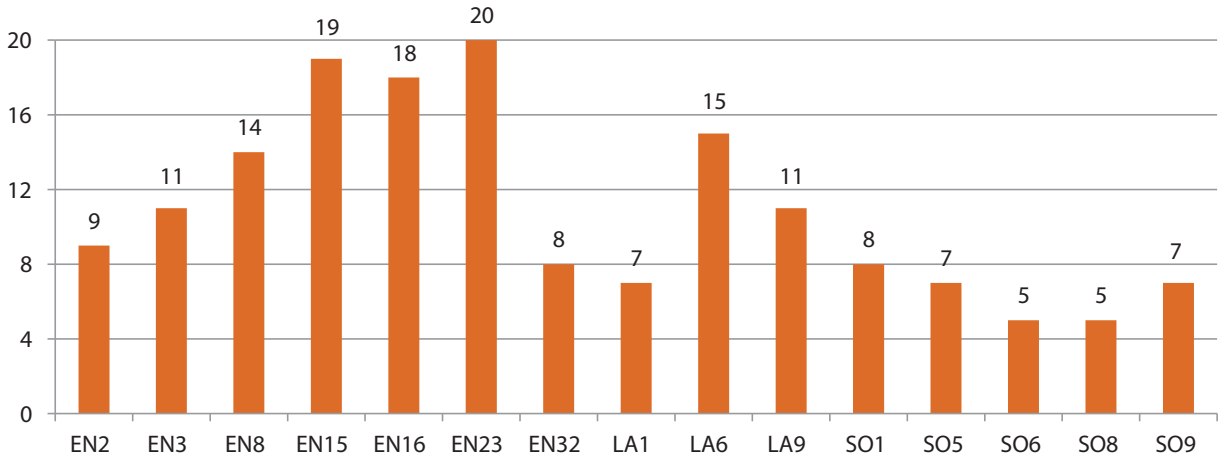
Table 2. Quality of disclosed indicators by socially responsible companies in the pharmaceutical industry

№	Company	Johnson & Johnson		Novartis		Merck KGaA		Sanofi		Takeda		Total	
	Code	2014	2016	2014	2016	2014	2016	2014	2016	2014	2016	2014	2016
Environmental indicators													
1E	EN2	1	1	0	2	0	4	3	0	0	2	4	9
2E	EN3	4	4	3	3	3	3	3	0	1	1	14	11
3E	EN8	2	2	3	3	0	4	3	2	3	3	11	14
4E	EN15	3	3	4	4	4	4	3	4	4	4	18	19
5E	EN16	3	3	3	3	4	4	3	4	4	4	17	18
6E	EN23	3	4	4	4	4	4	3	4	4	4	18	20
7E	EN32	1	2	0	0	2	2	3	2	0	2	6	8
Social indicators													
8L	LA1	2	2	2	2	3	3	3	0	3	0	13	7
9L	LA6	4	3	4	4	4	4	3	0	3	4	18	15
10L	LA9	1	1	2	4	4	4	3	2	0	0	10	11

№	Company	Johnson & Johnson		Novartis		Merck KGaA		Sanofi		Takeda		Total	
	Code	2014	2016	2014	2016	2014	2016	2014	2016	2014	2016	2014	2016
Indicators of corruption and engagement with local communities													
11S	SO1	1	1	2	3	0	0	3	4	0	0	6	8
12S	SO5	1	1	2	2	3	3	0	1	1	0	7	7
13S	SO6	2	1	2	2	1	1	0	1	0	0	5	5
14S	SO8	1	1	0	0	3	3	0	1	0	0	4	5
15S	SO9	1	1	0	0	2	2	0	2	0	2	3	7
Total		30	30	31	36	37	45	33	27	23	16	154	164

Source: compiled by the authors

Figure 2. Quality of disclosed performance indicators by pharmaceutical companies for 2016, points



Source: compiled by the authors

The compound quality improvement rate of disclosure by the five companies of performance indicators amounted to (164/154 – 1)·100% = 6.5%. Stakeholders who get an opportunity to access significant non-financial information disclosed by socially responsible companies will most probably be more ready to credit such companies and more tending to purchase their shares or products than those of informationally closed, "non-transparent" companies. It should be noted that since 2014 to 2016 the aggregate position of the five socially responsible companies (Johnson & Johnson, Novartis AG, Merck KGaA, Sanofi, Takeda) in the list of Access to Medicine changed moving from the 8th up to the 6th position.

Analysis of the compound quality of disclosure by the abovementioned five companies of each set of indicators developed by us (from 0 to 4 points) for 2016 is shown in fig. 2.

In spite of the high average value of representation of indicators of corruption combating – 76%, their quality of disclosure is the lowest in comparison with environmental and social aspects. Such undeveloped business practices of disclosure of corruption issues jeopardize sustainability of development and require closer attention of management. The obtained results indicate that the set of indicators for the pharmaceutical industry we offer is sought-after, it is included in the existing formats of non-financial reports, hence it is quite justifiable that it may be implemented in the existing systems of financial regulation.

Non-financial reports were in fact published by companies in GRI Database in the calendar year which follows the reporting year, therefore we are interested in financial results of companies' operation according to their accounting records as per IFRS as of the end of 2015 and 2017 (we used Bloomberg, Wall Street Journal and Investing.com databases). It should be noted that for Japanese companies the financial year ended on March 31, 2016 and March 31, 2018, respectively. Fewer than all companies in the rating are listed ones and fewer than all used long-term debts.

Table 3. Financial data of firms from Access to Medicine Index list, million U.S. dollars

AMI 2016	Company	AMI 2014	Revenue		Long-term credits and loans		Capitalization (average per year)	
			31.12. 2015	31.12. 2017	31.12. 2015	31.12. 2017	2015	2017
1	GlaxoSmithKline plc	1	35,260	40,763	22,517	19,262	101,510	91,740
2	Johnson & Johnson	3	70,074	76,450	12,857	30,675	277,880	341,890
3	Novartis AG	4	50,258	51,449	17,733	27,892	233,940	205,380
4	Merck KGaA	6	10,204	13,445	10,444	9,648	12,350	13,670
5	Merck & Co. Inc.	7	39,498	40,122	23,829	21,353	147,400	154,920
6	Sanofi	8	37,863	43,481	14,206	17,206	110,740	104,730
7	AstraZeneca plc.	15	24,708	22,465	20,795	21,012	87,340	78,430
8	Gilead Sciences Inc.	5	32,639	26,107	21,075	30,795	127,060	93,120
9	AbbVie Inc.	9	22,859	28,216	29,240	30,953	98,860	126,400
10	Novo Nordisk A/S	2	15,703	18,017	-	-	120,060	107,160
11	Eisai Co. Ltd.	11	4,867	5,646	1,808	1,480	15,610	16,990
12	Bayer AG	10	50,053	42,053	17,303	14,722	112,090	98,000
13	Bristol-Myers Squibb	13	16,560	20,776	6,550	6,975	104,360	97,810
14	Pfizer Inc.	16	48,851	52,546	28,740	33,538	188,560	204,320
15	Takeda Pharmaceutical	20	16,054	16,659	5,702	9,308	36,460	38,790
16	Boehringer Ingelheim	14	16,072	21,685	-	-	-	-
17	Eli Lilly & Co.	17	19,959	22,871	7,972	9,941	83,150	85,720
18	Daiichi Sankyo Co.	19	8,762	9,035	1,647	2,461	12,320	16,470
19	Roche Holding AG	12	48,049	54,695	17,062	16,250	192,230	168,910
20	Astellas Pharma Inc.	18	12,193	12,235	-	-	29,250	27,470
Total			580,486	618,716	259,480	303,471	2,091,170	2,071,920

Source: compiled by the authors

Results of analysis of financial data indicate that the aggregate share of the group of five socially responsible companies in the total revenue of all 200 companies for a corresponding financial year increased from 184,453/580,486·100% = 31.8% up to 201,484/618,716·100% = 32.6%. By means of similar calculations we showed growth of long-term borrowed funds in the total amount from 23.5 to 31.2% and growth of capitalization of these five companies in comparison to the 20 companies of the rating from 32.1 to 34%. The sensitivity coefficient introduced by us evaluates influence of non-financial performance indicators on financial and economic performance indicators:

$T_{fin} = k_s \cdot \tau_{non\text{-}fin}$.

This coefficient equals $k_s = 0.38$ when comparing the revenue growth rate of (32.6%/31.8% – 1)·100% = 2.5% to the rate of quality improvement of disclosure of non-financial indicators of (164 point/154 point – 1)·100% = 6.5%, $k_s = 5.0$ and $k_ч = 0.91$ when comparing with the rate of growth of long-term capital raising (32.8%) and capitalization (5.9%), respectively. The stronger the studied relation the greater the value of the sensitivity coefficient. The obtained results suggest that the most pronounced financial effects of stakeholders' loyalty to socially responsible business manifest themselves in providing by investors of long-term debt capital to companies and purchase of shares, and the least pronounced effect manifests itself in revenue growth.

The offered mechanism of business practices standard harmonization may be applied to any sector of global economy on the basis of proportionally-typical selection of key performance indicators of operations. Sufficiency of the set of indicators should be considered from the point of view of existence of inter-company comparability of enterprises of a certain industry sector. The format of a minimal set of indicators for such case facilitates the quantitative and qualitative analysis of non-financial information disclosures and makes it possible to assess loyalty of concerned parties to socially responsible business. Therein introduction of an obligatory mode of preparation of non-financial reports should provide for a better information disclosure which, together with calculation of non-financial indicators, may result in improvement of efficiency in the spheres which are most important for the shareholders, other concerned parties and the society in general.

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Total Quality Management in an Insurance Company: Use of Balanced Scorecards to Meet the Interests of Stakeholders

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 39-54 (2020)
DOI: https://10.0.67.171/j.jcfr.2073-0438.14.1.2020.39-54
Received 11 February 2020 | **Peer-reviewed** 17 March 2020 | **Accepted** 20 March 2020

Total Quality Management in an Insurance Company: Use of Balanced Scorecards to Meet the Interests of Stakeholders

Abstract

The insurance company is a financial intermediary between stakeholders - a set of participants in the insurance process and those who have received the right to insurance payment, as well as insuring parties who purchase insurance coverage and shareholders whose capital is involved in its guarantee. Satisfaction of stakeholders creates a company's free access to exchanged resources, thereby optimizing operations and increasing the efficiency of capital use. The implementation of the Total Quality Management (TQM) system, which could help achieve the goal, is complicated in insurance companies by dividing the personnel who create the insurance service, by the factor of time, since it is possible to check the quality only after the client has used it, which does not always arise in insurance, and often by the factor of location of units at geographically different points, which makes it virtually impossible for the simultaneous and equal participation of personnel in production processes, that requires innovative management tools.

The purpose of this study is to study the effect of introducing a Total Quality Management (TQM) system and a balanced scorecard (BSC) on the activities of an insurance company, including the one aimed at achieving the satisfaction of its stakeholders.

Using the methods of induction and synthesis of freely available data of SOGAZ, Rosgosstrakh, and ROSNO companies, a complex of dependent corporate goals was identified that were ranked relative to the organizational level.

The results of the study allow concluding that the concept of balanced indicators allows to indicatively monitor the quality of meeting the interests of the main stakeholders of the company, which creates new effective tools for improving resource exchange and does not allow distortions in management. The integration of strategic planning and TQM opens up new market growth opportunities for insurance companies in the context of a limited portfolio of services for a strictly limited audience. The paper provides specific recommendations for organizations to resolve problems that impede the successful implementation of TQM.

The results of this study can be used by officials of insurance companies in developing strategies and tactics for their development, including the implementation of BSC and TQM, as well as scientists for a deeper study of the results of the implementation of BSC and TQM, both in the insurance industry and other sectors of the economy.

Key words: standardization and compatibility, information and product quality, insurance, insurance companies, competitiveness, stakeholders, quality management standards
JEL classification: G22, I13, L15

Introduction

Risk accompanies any human activities: personal, social and economic ones [1]. Insurance as a phenomenon performs several functions: it transfers financial risk from individual persons and legal entities to insurance companies, by means of insurance rates it indicates the risk level in various economy segments, it induces risk mitigation by developing the incentives of insurance premiums reduction and also it helps to accelerate recovery of destroyed and impaired assets and to return people to their usual activity and the companies – to routine operations by means of provision of financial resources [2].

The insurance market is the link between the government, private companies and individual persons [3]. Therefore, this market, as well as other financial markets such as banking and stock market is of vital importance for the sustainable economic growth of the country [4].

Operating in the complex and boundless business world modern insurance companies are focused on improvement of their competitive advantages in order to ensure growth of income and reduction in expenditures [5], at the same time dealing with risks requires that their operating results were maintained at a high level [6].

An insurance company is a financial intermediary between its main principals - a set of participants in the insurance process and those who have received the right to insurance payment, as well as insurers who purchase insurance coverage and shareholders whose capital is involved in its guarantee. The insurance company's income depends directly on concernment of the individuals or entities which resources participate in exchange and on including such resources in the insurance activities [7]. Satisfaction of stakeholders provides a company's free access to exchanged resources, thereby optimizing operations and increasing the efficiency of capital use. Therefore, interaction with stakeholders is the foundation stone of modern business although there are difficulties related to the absolute interaction [8]. Therein in all fairness it should be noted that recently the idea that organizations incur more obligations than just serving the interests of their stakeholders has been gaining popularity [9].

Stakeholders are concerned parties which exchange their resources into results of their including in the activity of an insurance company, consequently, it is the quality of commercial insurance activity which is the main criterion of satisfaction for each concerned group [10]. The stakeholders of an insurance company which influence its activity and are interested in its performance are the shareholders (owners), management, employees, clients, competitors (other insurance companies), partners and service providers (including contractors, medical treatment facilities and physicians, service stations), banks and financial institutions, investors – state authorities, local communities, consumer protection groups and organizations, special interest groups, mass media and trade union organizations. Besides the last four categories may be classified as minority stakeholders of the insurance company [11–13]. This research is, first of all, focused on the issues of serving the interests of the four stakeholders' groups which are interested most of all in the insurer's performance: shareholders (owners), clients (insuring parties), top managers and employees.

It should be noted that the organizations which identify their stakeholders are more transparent and disclose non-financial information about themselves and their financial performance is often better than the one of the organizations which do not identify them. The companies which do not identify their concerned parties almost don't disclose non-financial information [14].

The company's degree of access to necessary resources may be a measure of correspondence of the implemented strategy to the interests of the concerned parties [15].

Thus, there arises the need among the goals of the insurance company management system to make the procedure and performance correspond to demands of all concerned parties. Therein management should approach the problem of stakeholders management and quality of relations with them in its entirety taking into consideration both the interests of the company and those of concerned parties [9]. This contemplates preliminary definition of interests of both the company and stakeholders in order to determine distinct goals depending on the company strategy [16].

Reduction of costs for search for effective solutions of creating such strategy and successfulness of its implementation is logically ensured on the basis of the principles of philosophy of the Total Quality Management.

The Total Quality Management (TQM) is a business strategy aimed at quality improvement of all organizational processes where "Total" means involvement of employees from all levels, production chains, corporate networks and product life cycle, "Quality" is a concern for providing to the client the goods which meet its requirements to the maximum extent, and "Management" is represented as a step by step organizing of corporate processes.

Improvement of the clients' satisfaction from the point of view of quality means that the organization may meet the clients' needs better by means of reducing the number of drawbacks in providing services by monitoring the process of the (insurance) product or service formation and also controlling the quality of the product or service [17]. Satisfaction of the consumers with the insurance company services is an important factor which defines further use of the company products [18].

The indicator of quality improvement is the consumers' satisfaction and getting benefit by all concerned parties (employees, owners, suppliers) and the company in general [19]. The Total Quality Management is a continuous process of revealing, reducing and elimination of errors in manufacturing, optimization of supply chain management, improvement of the quality of service. The Total Quality Management is aimed at making all the parties participating in the production process responsible for the total quality of the end product or service.

Implementation of this concept in insurance companies is complicated by dividing the personnel who create the insurance service, by the factor of time since it is possible to check the quality only after the client has used it, which does not always arise in insurance, and often by the factor of location of units at geographically different points, which makes it virtually impossible for the personnel to participate in the production processes simultaneously and equally. It requires innovative management tools.

Implementation of the system of balanced indicators in insurance companies will ensure not just a high-quality management of inner corporate processes, but also a complete taking into consideration of the company stakeholders' interests through their engagement in strategic programs of the corporate development. Engagement of the concerned parties is considered to be the best way of management and a more successful means of reaching a consensus among the stakeholders [20].

At the same time, it is necessary to remember that practice and strategy of stakeholders' engagement or non-engagement imply adaptation of the stakeholders management strategy to the changing circumstances. In other words, it is applying an adaptive and balanced approach to stakeholders management with the possibility to go from their engagement to non-engagement under the changing circumstances. Besides, both engagement and non-engagement may be used for the same stakeholder with added value at different time [8].

Research Methodology

In the research in order to determine the cause-and-effect relationships we used the induction method (stage of defining the related items complex) and Mind Meister program (state of defining the relation formation vector) and the data synthesis method when clusterizing the disconnected goals of units when creating the balanced goals tables using Smart Draw. The qualitative market specifics of insurance companies' activity in Russia was presented as a diagram on the basis of analysis of freely available data of insurance companies SOGAZ, Rosgosstrakh, and ROSNO where applying the deduction we defined a complex of dependent corporate goals and ranked them relative to the organizational level.

As long as access to the data and information of medium and small insurance companies is often limited significantly the research was focused on the data of the largest insurance companies. All necessary information about them is publicly available.

Literature Review and the Research Hypotheses

The goals of the Total Quality Management are consonant with the goals of ensuring the company competitiveness as a characteristic feature of its economic security and sustainability of development [21–23]. Quality is an aggregate of the item's characteristic features related to its ability to satisfy the established and anticipated requirements of any party concerned with it [7].

In this context one can raise the issue of the requirements that should be met by the insurance company which determines its strategic guidelines as ensuring competitiveness by means of quality management.

This issue is of high relevance because each stakeholder understands quality through various indicators since the interests of the insurance company stakeholders are not homogeneous and often are opposite. The most widespread indicators of the main stakeholders are as follows [13; 24; 25]:

- the insurance company clients: the offered service meets the set of the insuring parties' requirements including the price and quality of the insurance product, servicing, payments, company procedures in engaging services of external companies and approving of payments, quality of providing services by contracting organizations (hospitals, physicians, service stations, etc.);
- the company management: the process of creation of insurance products and rendering of the service within the term of insurance meets the quality assurance requirements imposed by the management; each employee has been trained the skills of high-quality service of the insuring party and is oriented toward this standard. There are also financial indicators of the company performance (net profit, EBITDA, working capital indicators and capital expenditures (CAPEX)), availability of funds for investments in the company development and remuneration (bonuses), authority, power, prestige among the management's interests;
- stakeholders (owners): the financial standing of the company has a high quality from the point of view of stability and profitability which manifests itself in certain financial indicators: return on equity (ROE), return on assets (ROA), cashflow indicators (FCF), EBITDA, EBIT, net profit, working capital indicators and capital expenditures (CAPEX), economic value added (EVA), dividends per share (DPS) etc.;
- staff of the insurance company: decent and safe working conditions, fair labor compensation and rate of its growth, career and professional development, social guarantees and benefits, sustainable development of a company and social stability;
- partners (contractors): timely payment for the services, long-term partnership relations, stability of the insurance company's activity for planning of work, payments approval procedure, increase of the scope of rendered services and payment for them;
- competitors: equal opportunities when participating in a tender for the right to conclude insurance contracts (government-owned companies and institutions, corporations), fair and transparent rules of operating in the market (no price dumping), cooperation in mutually-beneficial spheres, reduction

of the scope of rendered services including exit from the market, offer of employment of high-potential and high-performance managers and specialists;

- government and state authorities: taxes, employment, reporting (including reports on vacancies), legal compliance, raising social responsibility of companies to the community etc.;
- banks and financial organizations (creditors): interest, repayment of credit resources, safety of investment;
- investors: sustainable development of an economic entity and its equilibrium growth, improving the profitability of operations, return of investments, safety of investment;
- community-based organizations: provision of legitimacy of manufacture and sale of goods, works and services, observing the equality of citizens when obtaining socially important services, assistance in development of business of community-based organizations and extensive, comprehensive co-operation of economic entities with community-based organizations, joint attainment of socially important results in order to maintain the citizens' social security.

All these requirements are fulfilled in corporations by establishing a unified consistent system. The basis for such system is assurance of quality of all processes related to making insurance products and their rendering as insurance services. The foundation of the system is analysis of information on all processes and procedures taking place in the company operations in order to provide for control of their quality. In accordance with GOST R ISO 9000-2015 P.3.4.1 the process is defined as "an aggregate of interrelated and interacting types of activity which transforms the company inlets and outlets" [26]. Besides, in accordance with this Standard not just processes but all procedures GOST R ISO 9000-2015 P.3.4.5 are subject to documenting as an "established means of carrying out activities or a process" [27]. Therein it is important to take into consideration each and every procedure performed by each employee of an insurance organization.

International standards of series ISO 9000 and corresponding national analogues developed on their basis present for the management general requirements of building the company accounting and management system which guarantee functioning of the production system in accordance with the requirements of the quality system [27]. The standards cannot ensure a guaranteed quality of insurance services but are intended to ensure elimination of drawbacks of the production process which influence significantly such quality, i.e. to ensure the "most probable quality" or the so called "expected quality" [28].

Applying the tools offered by the management standards one may reveal all processes which influence significantly the quality of produced insurance services and then, first, provide a documented description of the rules of execution for each process; second, appoint a person individually responsible for fulfillment of the rules; third, provide constant monitoring of conformance of the real processes to the documented requirements.

The importance of documenting of the processes consists in the fact that an effective interference with the production technology and its management is possible only if there is an opportunity to ascertain with exactitude on the basis of a formalized description of production processes how one or another process proceeds in real life. Such possibility may be called "traceability" of processes. However, the measures listed above related to establishing the quality parameters for controlled processes and procedures as well as their monitoring for conformance to the established parameters make sense only from the point of view of their target goal.

The advantage of use of the tools of the balanced scorecards system (BSC) in a company comes to the possibility of transfer of the corporate mission and strategy into the system of interrelated indicators [29]. As long as the development strategy in the insurance business comprises the key aspects of activity: finance, client interaction, business processes, staff training – implementation of BSC concept produces the effect of corporate rehabilitation.

The basic idea of BSC concept is to present to top managers the information for indication control of the company strategy implementation concisely and in a structured form [30]. Since the company development prospect is related to business continuity an effective implementation of BSC concept helps to achieve forecastability of the company state in future by means of integration of financial and non-financial issues into the integrated management system which links the goals of corporate stability with actions and operating results [31]. It is highly esteemed in the financial services market where customer confidence, hence the future market volume and its demand, depend on the company stability.

The performance measurement matrix gives an idea of the most important corporate success factors. BSC concept ensures the operational balance in two ways. First, it maintains the proper combination of productivity indicators for the whole company for achievement of operational excellence, i.e. it guarantees that none of the groups of indicators predominates in the assessment process. This may result in distortions in reporting of the company activity. Second, the balanced indicators system helps the companies to reduce the pressure on the production processes responsible for a product or service in the nearest periods focusing the operational attention on long-term corporate needs which may jeopardize the company future results unless they are accounted for properly [32].

Research Results

Providing links inside consistent goals of all levels of the insurance company business is an analytical process of immense complexity. Advantages of such tool of strategic analysis and planning as the balanced scorecards system are evident in terms of implementation of such process.

BSC concept ensures a transparent integration of subjective and objective strategic operations. By creating a cause-consequence network and forming on its basis of further company strategy the decision maker (director), "transformer" (manager) and each individual participant of the organization may monitor which operations are of strategic importance and how the strategy is implemented at individual stages. Using the scorecards system one may compare the past, present and future status of implementation where regular "BSC audits" organize planning of a continuous improvement process.

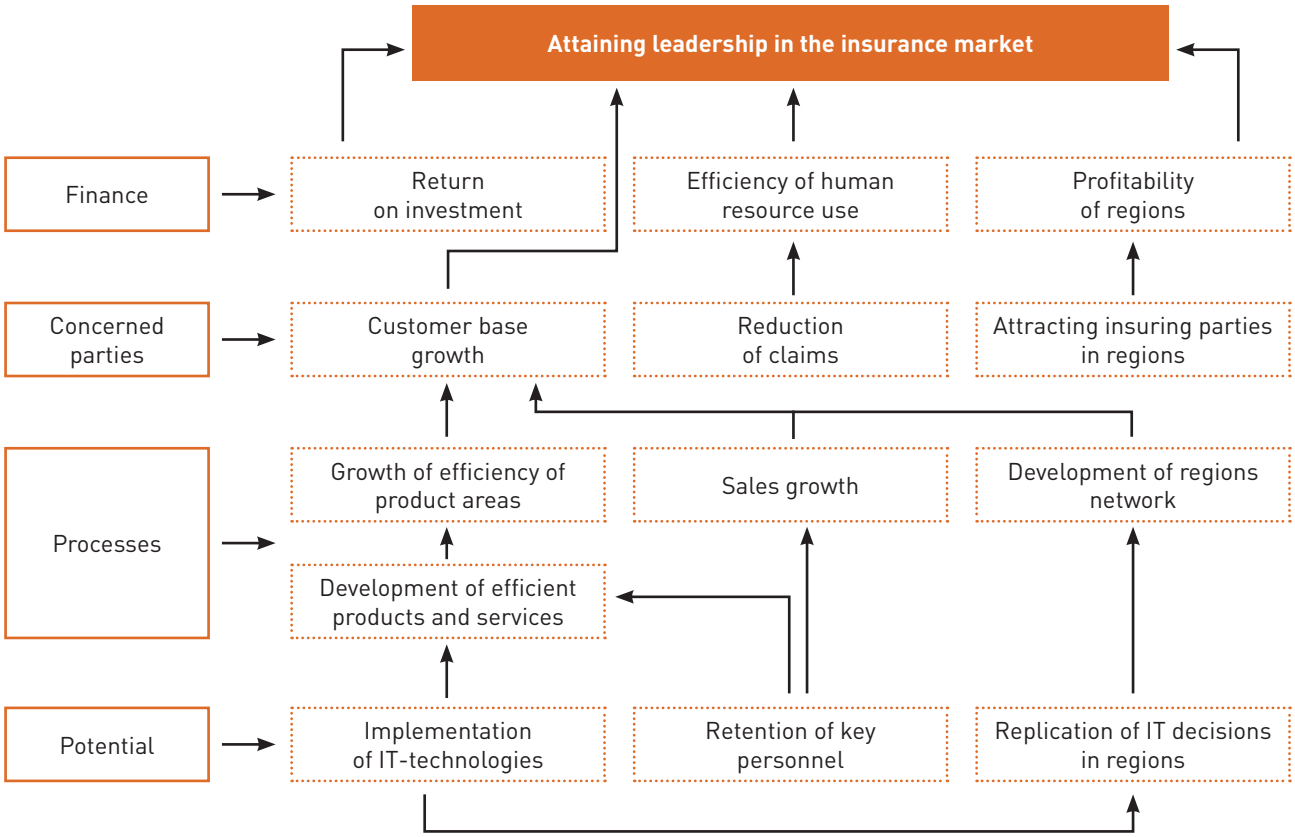
Expenses for ensuring of the processes' correspondence to the conditions of adaptation to the balance of interests of the company owners and managers (business), insuring parties (civil society actors) to the environmental conditions (government), in our opinion, should be an indicator and criterion of regulation of the level of achievement by the company of the established goals. Consequently, such correspondence should be taken into consideration at the stage of the company activity planning.

The corporate sustainable development strategy stated in BSC system provides for a tractable reaction to change of conditions of activity at the stage of strategy creating and determination of target values as well as at the stage of implementation of this strategy because discretion as regards decisions is limited only by the goal, rather than by the ways of achieving it, and this is a principle of process approach to management on the basis of TQM.

At present almost all insurance companies in the market have a development strategy. It may be widely paraded as well as kept "for official use only".

We analyzed publicly available information on strategies of the largest companies in the Russian insurance market [33; 34]. After structuring the obtained data using the balanced scorecards system we developed a generalized card of operational targets (fig. 1)

Figure 1. Target map for large companies in the Russian insurance market



Source: presented by the author on the basis of publicly available information: SOGAZ, Rosgosstrakh, ROSNO.

The above target map represents interrelation of all main targets of the company in the processes characteristic of each group (potential, processes, concerned parties, finance) in order to achieve the end goal – acceleration of the company value growth.

However, the strategy presented in this way doesn't give an opportunity to control the quality of the company operations aimed at satisfaction of individual groups of stakeholders.

TQM philosophy extended to the level of quality assurance of the processes of communication with stakeholders means that each of them becomes a kind of consumer of the results of corresponding processes.

Having accepted this concept one may make such target map in accordance with which BSC projections are chosen, and each of them has target quality indicators for each stakeholders' group.

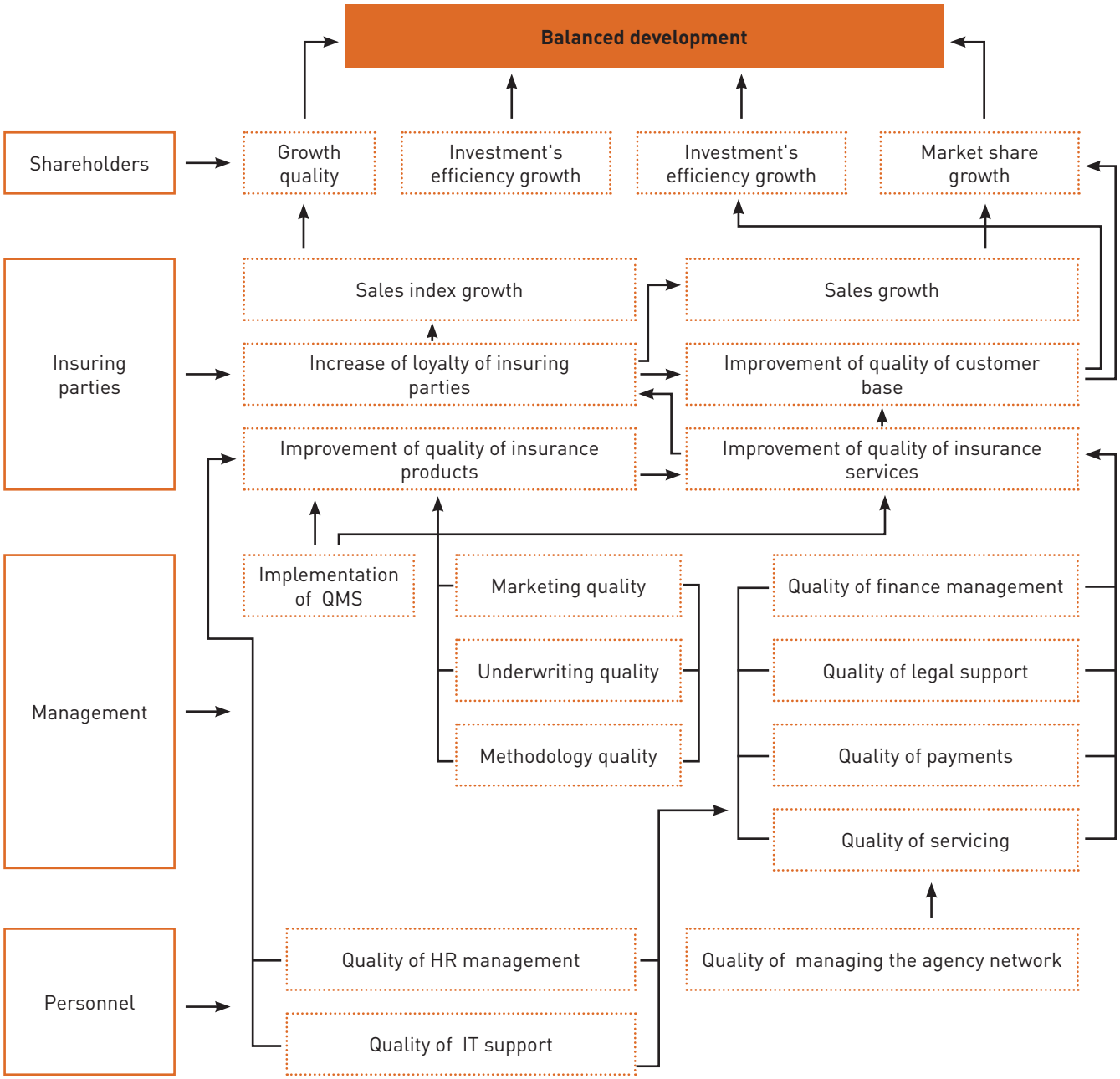
In a generalized way these projections may be defined as follows:

- control of financial indicators provides for shareholders' satisfaction;
- quality control of insurance services meets the interests of insuring parties;
- quality control of the core business processes is within the scope of functions of top managers;
- control of the personnel development level and the infrastructure which creates the personnel's activity preserves satisfaction of personnel with the quality of interaction with the insurance company.

As long as BSC may serve as the basis for creation of the insurance company development strategy based on the goal of assurance of steady quality of communications with all stakeholders' groups, this tool in particular is used to build the complex of key performance indicators which helps to plan and balance them, hence, it guarantees consistency of the company operations in a long-term period. When using the balanced scorecards system it becomes impossible, for example, to reduce expenditures as a result of refusal from training the staff because this will produce a quick short-term effect which will result in deterioration in quality of the employees' performance and losses in future.

When solving the problem of building the company development strategy in accordance with TQM philosophy, in our opinion, the target map should look as in fig. 2.

Figure 2. Target map of the insurance company implementing the TQM strategy



Source: offered by the author.

When using BSC for the purpose of strategic analysis the corporate strategy is defined at the level of the company top managers and is approved of by the general director. Our vision of such description in accordance with the target map in fig. 1 is presented in table 1.

Table 1. Strategic development map of the insurance company in accordance with Quality Management Standards

Target	Indicator
Prospect "Shareholders"	
Growth quality	Index of the premiums rate of growth to the rate of growth of the number of contracts
Market share growth	Relative share of premium income in the income of the target segment (all-Russian income). Relative share of the number of contracts against the size of the target segment
Insurance operations efficiency	Profitability of insurance products. Profitability of insurance areas. Growth index of solvency margin. Net assets growth index
Investment efficiency	Return on RUB 1 of the average asset value for a period
Prospect "Insuring parties"	
Improvement of quality of insurance products	Reduction in work time expenditures for conclusion of one contract. Reduction in the number of applications for unjustified payments
Improvement of quality of insurance services	Reduction in the number of refusals to pay. Reduction of time spent on settlement of losses. Index of payments to income not lower than the one taken into account in the tariff
Increase of loyalty of insuring parties	Increase of the share of renewed contracts. Increase of the share of premiums under renewed contracts
Improvement of quality of customer base	Increase of the customer base. Growth of profitability per a customer. Reduction in the number of insured events. Reduction in the number of insurance fraud cases
Sales index growth	Index of premium per one sale
Sales growth	Index of growth of the total amount of the collected premium. Index of growth of the number of contracts
Prospect "Management"	
Marketing quality	Growth of the sales share in the target segment
Underwriting quality	Index of improvement of the underwriting result. Index of payments to income

Target	Indicator
Methodology quality	Reduction of time spent on training of an agent / employee in relation to a new product
Servicing quality	Reduction of the number of complaints
Quality of payments	Reduction of the number of evidence-based documents for the insuring party
Quality of legal support	Reduction of the index of initiations of legal action
Quality of finance management	Index of time spent on making payments
Prospect "Personnel"	
Development of IT support	Index of IT-support of processes. Index of use of the IT solution uniform for the company
Retention and development of personnel	Index of staff turnover. Index of submitted innovative proposals of the process improvement
Motivation, retention and training of agents	Index of agents' turnover. Index of training time spent on one agent

Source: compiled by the author.

Table 2. An example of the most common strategic goals for the HR unit and their respective indicators

Goal	Indicator
Prospect "Customers"	
Increase of the number of new insuring parties. Preserving of the tried and tested customer base	Number of new insuring parties. Share of the number of insuring parties which renew contracts
Anticipation of insuring parties' needs as regards quality of satisfaction of insurance needs	Time spent on negotiations with key customers in order to reveal their insurance needs. Number of new projects based on key customers' needs.
Implementation of products in the segments of new insurance needs	Number of new market sectors where sale of core products started. Amount of premiums in the market with new insurance needs
Prospect "Operations Management"	
Achieving employees' broad specialization	Staff performance. Number of offered improvements
Creating new insurance products (as quality improvement of the core products)	Number of new insurance projects or concepts submitted for development. Frequency of creation of new insurance products
Position of an expert in a certain profession	Existence of strategically competent persons at key positions of research and development

Goal	Indicator
Active use of new developments of the scientific, insurance and IT community	Number of valuable new ideas obtained from outer sources. Internal audit of scientific and technological capabilities
Strengthening of innovative culture	Index of offers from employees as regards improvement of products and processes
Creation of the customer-oriented servicing culture	Number of customers' comments and complaints
Prospect "Personnel"	
Increase of employees' satisfaction	Index of personnel satisfaction (on the basis of a poll). Index of staff turnover
Achievement of a high level of professional competence and creativity of employees	Number of employees who raised their qualification. Period in days/hr. spent on staff training / retraining
Improvement of the motivation system	Share of employees who have a clear understanding of functioning of the corporate motivation system (on the basis of polls)
Increase of employees' engagement	Number of min./hr. of improper spending of working hours
Prospect "Top Managers"	
Development of mechanisms of encouragement of top managers to solve the issues of personnel motivation	Share of the bonus of each employee satisfied with the motivation system (on the basis of a poll)
Providing a high level of motivation for top managers to solve the problem of the employees' performance	Percentage of assignments not fulfilled by employees
Building and functioning of the system of management statements including the section of Employees' Motivation	Amount of information on the needs and values of employees

Source: compiled by the author.

On the basis of the system of strategic targets functional strategies are developed where the corporate strategy is detailed in particular directions which describe the targets and indicators in more detail.

In operational strategies measures aimed at achieving the targets are defined. The targets are decomposed until they correspond to measurement units, results and responsible persons.

After development of targets and the indicators corresponding to them for corporate BSC the process of BSC development for individual business units starts "cascading" corporate strategic targets into business units' targets. When "cascading" the strategic targets system "inward" processes and their results at the level of individual business units which in the long run ensure the quality of the company functioning are made specific.

In order to define the target map of a business unit, in our opinion, the following action plan is optimal:

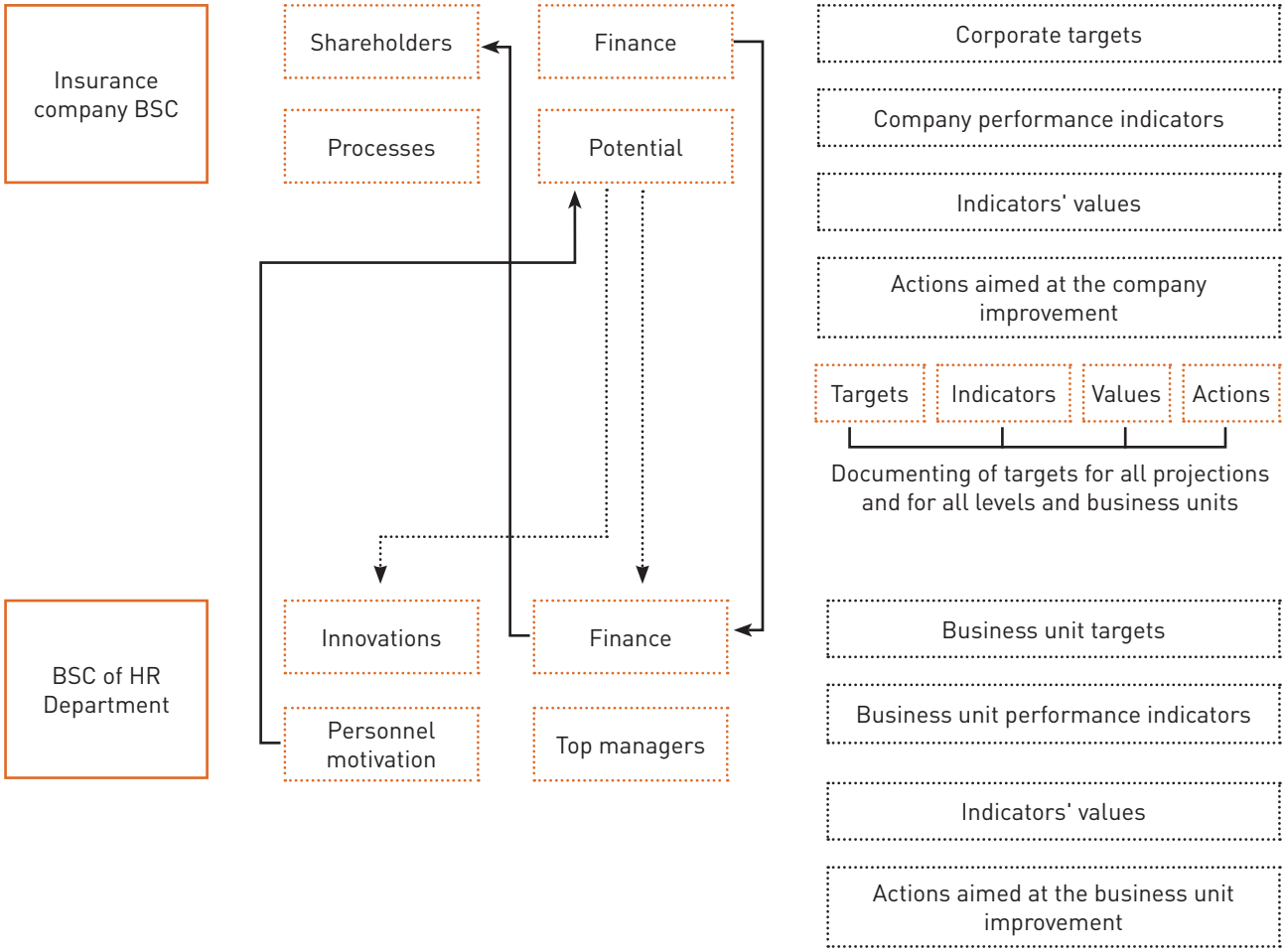
The targets of a business unit are formalized individually, thus providing means for creating the target map for it.

When developing the targets formalization is carried out in accordance with the targets of the whole insurance company.

A strategic map of the business unit itself is made where all strategic targets are divided into two groups: the strategic targets aimed completely at achievement of the insurance company targets and the strategic targets related to such business unit only.

We offer to consider the "cascading" process architecture in accordance with the diagram presented in fig. 3.

Figure 3. The process of achieving the best result of the work of the HR department



Source: developed by the author.

Among the corporate requests of BSC implementation the target of staff development as the key resource of an insurance company is of special popularity [35], and in the service sector it is extremely valuable because any service is fraught with an extremely high level of the service executor's (representative's) personality factor.

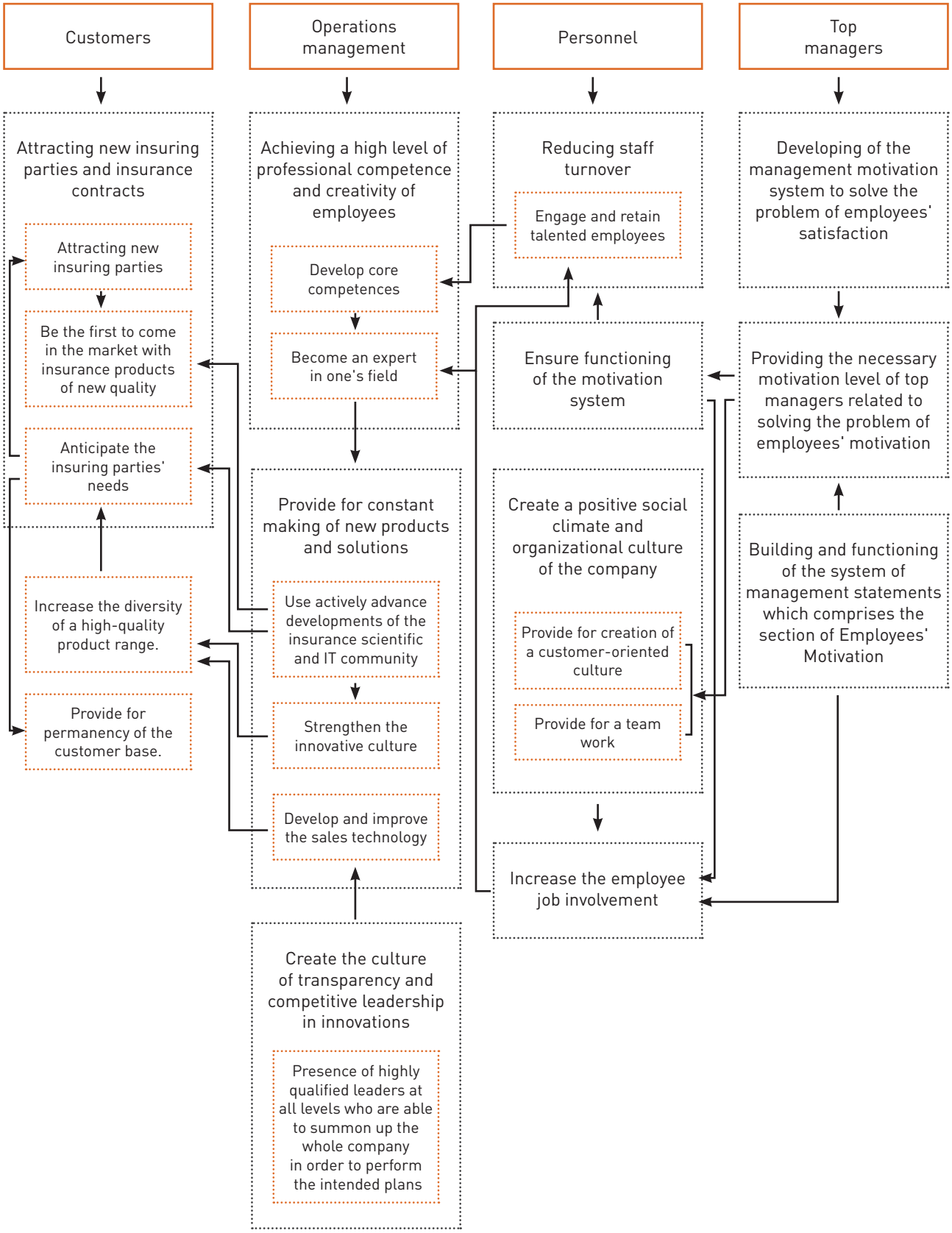
For this reason, for insurance companies we represented by a diagram structuring of the target map as exemplified particularly by examination of the request for an efficient human resource management (fig. 4).

When the stage of formation of the target package is completed the top managers of the functional business unit define the indicators of change control. The key objective here is to cover to the maximum extent stakeholders' interests. For convenience of control the indicators are divided into groups (see example in table 2). Control is performed through measuring of the actual state of the indicator and its changes at established time slots also defined by top managers of functional business units.

At the theoretical stage of the research it is in general unreasonable to establishe target values on the basis of indicators because the list of strategic goals, rates and boundaries of their achievement adapt to the interests of stakeholders of a certain insurance company and specifics of its operational processes. The existing researches of implementation of TQM and BSC in the service sector put emphasis on it.

For this purpose, first stakeholders of a certain insurance company, their interests including the ones expressed in quantitative and qualitative indicators are defined and segmented. After that using integration of strategic planning, TQM and BSC a system of goals and measures aimed at satisfaction of stakeholders' interests is developed based on certain quantitative and qualitative indicators which are monitored later.

Figure 4. Target map based on the example of the HR department



Source: developed by the author.

In the four stakeholders' groups considered as an example in this research based on insurance business one may define the following indicators:

- **stakeholder: Shareholders (owners):**
  - Index of the growth rate of premiums to the growth rate of the number of contracts;
  - relative share of premium income in the income of the target segment (all-Russian income);
  - relative share of the number of contracts against the size of the target segment;
  - profitability of insurance products;
  - profitability of insurance areas;
  - growth index of solvency margin;
  - net assets growth index;
  - return on RUB 1 of the average asset value for a period;
- **stakeholder: Customers (insuring parties):**
  - index of growth of the total amount of the collected premium;
  - index of payments to income;
  - index of premium per one sale;
  - profitability per a customer;
  - index of growth of the number of contracts;
  - size of the customer base;
  - share of renewed insurance contracts;
  - share of premiums under renewed contracts;
  - number of new market sectors where sale of core products started;
  - amount of premiums in the market with new insurance needs;
  - reduction in the number of refusals to pay;
  - time spent on settlement of losses;
  - number of applications for unjustified payments;
  - number of insured events;
  - number of insurance fraud cases;
  - work time expenditures for conclusion of one insurance contract;
- **stakeholder: Management:**
  - staff performance;
  - share of sales in the target segment;
  - index of payment to income;
  - number of customers' comments and complaints;
  - number of initiations of legal action;
  - index of time for making payments;
  - number of evidence-based documents for the insuring party;
  - index of improvement of the underwriting result;
  - time spent on training of an agent / employee in relation to a new product;
  - number of offered improvements;
  - number of new insurance projects or concepts submitted for development;
  - share of the bonus of each employee satisfied with the motivation system;
  - percentage of assignments not fulfilled by employees;
  - amount of information on the needs and values of employees;
- **stakeholder: Personnel:**
  - index of personnel satisfaction;
  - index of salary growth within a company;
  - index of social payments' growth within a company;
  - index of staff turnover;
  - index of agents' turnover;
  - index of training time spent on one agent;
  - index of time (days/hr.) spent on staff training / retraining;
  - share of employees who have a clear understanding of functioning of the corporate motivation system;
  - number of min./hr. of improper spending of working hours;
  - number of employees who raised their qualification;
  - index of submitted innovative proposals of the process improvement;
  - index of IT-support of processes;
  - index of use of the IT solution uniform for the company.

It should be noted that the above list of indicators is approximate and non-exhaustive. Other indicators may be added to it and a separate list of indicators may be made depending on the specifics of activity of a certain insurance company and its stakeholders.

After implementation of TQM and BSC the insurance company adjusts its business operations to stakeholders' needs completely. Later it will influence directly the company's income and stakeholders' satisfaction will create a free access of the company to exchanged resources, will optimize business operations and increase efficiency of capital use [7; 8]. A well-balanced satisfaction of all concerned parties, an upward trend of certain indicators by which satisfaction of certain stakeholders of a certain insurance company will be assessed will also be indicative of the balanced development of such company.

The system approach to orientation to stakeholders' interests starts from collection and analysis of information which in accordance with TQM should come in regularly from many sources and be integrated in the process

which helps to obtain accurate and justified conclusions as regards stakeholders' needs and expectations as applied to the existing market situation.

There are several problems which should be eliminated in a company for a successful implementation of TQM. Negligent attitude to elimination of these problems can not just impede applying of TQM, but also destroy gradually the company itself [36]:

- management of the main line only. Managers should know the process, be involved in it, understand the trouble spots and offer examples of solving the problems to their subordinates;
- assessment of operations on the basis of the system of quantitative indicators only where the reports, ratings or annual reviews of achievements often result in the factors which cause unsound competition, which impede team work in the company. Managers should make comments in person as regards individual work of employees in order to help them to improve it instead of use of such systems;
- emphasis on short-term benefits;
- absence of a unified for all business units, constantly implemented strategy;
- staff turnover. The management should take measures to make the employees feel as an important part of the team.
- Therein the advantages of implementation of TQM are as follows [36]:
- growth of stakeholders' satisfaction and, as a consequence, improvement of resource exchange;
- optimization of image and company goodwill in the market;
- increase of customers' loyalty and the share of repeat purchases (insurance companies implement it through a packaged insurance services rendered to households);
- increase in labour productivity which often takes place automatically as soon as the employees become partners in implementation of TQM;
- growth of personnel involvement;
- improvement of financial indicators as a cumulative result of realization of previously mentioned advantages.

Conclusions

The balanced scorecards system produces a beneficial effect only after implementation of strategic measures. Strategic measures help to make specific the strategic goals and link the strategy to operational goals of employees from functionally separate and geographically distant business units. Thus, the fundamental idea of implementation of a well-balanced system of indicators in an insurance company – transformation of corporate strategy of development of insurance services into certain actions of business operations is implemented.

The balanced scorecards concept helps to monitor on the basis of indicators the quality of satisfaction of interests of the main company stakeholders. This creates new effective tools for improvement of resource exchange and prevents distortions in management (including those caused by private ends and motives of managers and insuring parties). The integration of strategic planning, ISO principles and TQM opens up new market growth opportunities for insurance companies in the context of a limited portfolio of services for a strictly limited audience which are characteristic of the insurance market.

Clusterization of uncoordinated targets systemizes the goals of business units of different levels and their functional responsibilities into the unified plan of implementation of the corporate strategy which will unite the interests disconnected in time of implementation (at various stages of production chains) of all stakeholders' groups of the insurance company.

The quality of omnichannel communication with concerned parties is ensured by translation of the results of implementation of stakeholders' resources into business operations, and this becomes an extra incentive for increase of the company performance. The necessity to minimize technical errors and to mitigate the human factor in the gap between the "plan" and "fact" of the insurance operations, permanent goals duplication, correlation of results between functionally non-connected business units motivates the companies to look for innovative approaches to corporate management. The identical origins of the implemented tools and international standards guarantees correspondence of Russian managerial realias to global management trends and its best practices and also emphasizes the high relevance and efficiency of solving corporate requests of business in the insurance sphere by implementation of the Total Quality Management and the Balanced Scorecards System.

This research is limited to the publicly available data of the largest insurance corporations SOGAZ, Rosgosstrakh, and ROSNO. So, applicability of its methods and conclusions to medium and small insurance companies, access to information of which is often limited significantly, is assumed on the basis of similarity of specifics of business and procedures. Nevertheless, the influence of implementation of the Total Quality Management system and the Balanced Scorecards System (BSC) on the operations of medium and small insurance companies should be studied in another research paper.

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Two-Parametric / Game-Theory Model of a Service Concession in the Communal Heating Sector[1]

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 55-68 (2020)
DOI: https://10.0.67.171/j.jcfr.2073-0438.14.1.2020.55-68
Received 22 January 2020 | **Peer-reviewed** 17 February 2020 | **Accepted** 10 March 2020

[1] The research has been conducted with financial support from the Russian Foundation for Basic Research and Government of Novosibirsk Region as part of scientific project 18-410-540002\19.

Two-Parametric / Game-Theory Model of a Service Concession in the Communal Heating Sector

Abstract

In this study, we propose to model the operation of a service concession arrangement in the economic area of municipal heat supply utilities. We offer a scheme of interaction between the concedent and concessionaire in this concessionary arrangement. Currently, the existing regulations regarding the temperature of coolant focusses on the daily average outdoor temperature, and the determination of a "normative" demand for heat energy. On any day of the heating period, this demand is a random variable, whose distribution can be described through the distribution of daily average air temperature.

In our model, heat energy is paid for at a fixed price, and the concessionaire pays a penalty for each unit of unsatisfied normative demand. The price and penalty values are the concession parameters, and are determined by the concedent. The concedent's goal is to minimise the thermal energy cost; the concessionaire's purpose is to maximise profit. The interaction is formalised as a two-move game model. First, the concedent determines the price and the value of the penalty. Then the concessionaire selects the capacity to be created. The concession's parameters should be set so that the individual rationality and incentive compatibility conditions are met.

Our results prove the existence of Stackelberg equilibrium, and we derive the relevant formulas for computing its parameters. In equilibrium, the optimum capacity for the concessionaire provides a sufficient probability of meeting demand. The price of thermal energy is minimal under this condition. We also formulate a one-parameter model (thermal energy price as a parameter), which is based on a typical concession scheme. In the two-parameter model, the equilibrium capacity and price do not exceed the corresponding parameters of the one-parameter model. The main advantage of the two-parameter model is an "embedded" economic mechanism that prevents the concessionaire's opportunistic behaviour. By contrast, in the one-parameter model there is no such mechanism.

The proposed approach can be applied to a concession for the production of any good or service, provided the concerned parties are interested in the availability and reliability of meeting a corresponding need, which may be described as a random variable. However, typical concession schemes do not penalise unsatisfied demand, so the implementation of our two-parametric model is possible only after modification of the pertinent concession legislation.

Keywords: concession, heating, game-theoretic model, economic mechanism, Stackelberg equilibrium, opportunistic behaviour

JEL classification: C62, G38, L32, L38, Q41

Introduction

In public-private partnership (PPP) agreements the choice of the regulation type (contractual and (or) administrative) exerts a strong influence on the probability of the project implementation and its efficiency [1; 2]. This is particularly so in the case of government service concessions, that is, concessionary deals in regulated infrastructure sectors. Where the regulation of heat supply is concerned, such projects may combine the tariff (or restriction of price), requirements to capacity and process characteristics of the concession subject, and the investment returns norm, etc. The experience of projects focusing on modernising the heat supply system in the Novosibirsk Region (implemented in accordance with concession agreements) shows that such service concession arrangements can be effective in small municipal entities. The project participants noted specific risks arising when preparing and implementing such projects. Significant risks are related to inconformity in terms of a contrast of budgetary, tax-related, and concession-related regulatory documents, with the practice of tariff regulation - which does not prompt power-generating companies to reduce expenses and increase energy efficiency [3, p. 54]. To a great extent a project's success is predetermined at the stage of contract preparation when the legal and financial obligations of the parties are defined.

In this paper, we will consider a building, operation, and transfer (BOT) concession for the development and operation of heat producing capacity. When entering into such a concession, one of the main risks is related to the probability of the concessionaire's opportunistic behaviour. The concessionaire may (in order to reduce capital costs) develop a capacity insufficient for a consistent heat supply. Also, if the capacity is sufficient, the concessionaire may (in order to reduce current costs) decrease delivery of heat energy. We therefore seek to propose an economic mechanism which makes opportunistic behaviour disadvantageous for the concessionaire.

Our proposed model features the following assumptions and special characteristics:

1) In order to provide for a high quality heat supply, the concedent establishes the norms of the coolant's temperature, depending on the daily average outdoor temperature. In this way the "normative demand" for heat energy is created. This demand is a discrete random variable, the distribution for which is easy to define, knowing the distribution of average daily temperature of outdoor air.
2) The concedent can calculate the minimal power z_1, which ensures meeting the norm demand at an admissible probability. In order to incite creation of sufficient power and its use to satisfy the demand – that is the incentive compatibility condition – the concedent determines the price of heat energy p and penalty q for each unit of unsatisfied demand.
3) Customers pay for heat energy. Serving their interests, the concedent strives to minimise the price of heat energy. However, this price should provide to the concessionaire a non-negative operating profit (taking into consideration heat losses in the supply system) and, for the whole term of the concession, a non-negative cumulative net present value (NPV) – the individual rationality condition.
4) We formalise the interaction of the parties as a two-move game. The concedent (leader according to Stackelberg) makes the first move selecting the values of parameters p and q. Knowing these parameters, the concessionaire makes the second move choosing the target capacity z in a way that maximises the revenue.
5) Our proposed model provides for the opportunity of the concessionaire's participation in financing of modernisation of the heat-transmitting system, related to the concession subject (hereinafter referred to as the "transmitting system project", TSP). For this reason, unlike article [13], we do not postulate the non-negative characteristic of q. If the concessionaire's expenses for modernisation of the heat-transmitting system are significant, the parameter of q in equilibrium is negative. Additionally, as other characteristic features of equilibrium it helps to calculate the concedent's payments which ensure the concessionaire's guaranteed minimum income.

The novelty and main advantage of the offered model consists in the fact that an economic mechanism which makes the concessionaire's opportunistic behaviour unprofitable for it is "embedded" in the model (there is no such mechanism in the typical model of concession). With the recommended choice of p and q (price and penalty) parameters, the concessionaire will earn the maximum profit if it develops exactly the amount of power preferable for the concedent, and uses it to satisfy the normative demand to the maximum extent. The distinctive feature of this model is the fact that the concessionaire does not maximise some "governmental" benefit, but rather minimises the heat energy price. As far as we know, such concession models have not been described in the previous literature.

The article is presented as follows. Section 2 comprises our literature review. In Section 3 we set a problem and substantiate the main assumptions. In Section 4, we formalise the problem: we describe the concession game-theoretic model (a two-parameter model). In Section 5 we prove the existence and define the parameters of Stackelberg equilibrium. In Section 6, we develop and analyse the simplified model, close to the generally accepted concession schemes (one-parameter model). Section 7 compares the abovementioned models, and outlines the advantages of the two-parameter model. Finally, the article concludes with the presentation of our results and conclusions.

Literature Review

Game theory, and the economic mechanisms theory, provide an adequate language for modelling economic entities' interaction while making and fulfilling conces-

sion agreements. In particular, paper [4] is dedicated to the opportunities of applying game theory to public-private partnership problems. Papers [5; 6] describe the game-theoretic model of choice between delivery of a service by a state enterprise (regulated monopoly), concession and procurements in the free market. Papers [7; 8] offer models which substantiate the choice of the winner in a tender for participation in PPP and a reasonable reimbursement to those who fail to win the contract. Publications have also analysed the following problem: when a concessionaire suffers financial difficulties (for example, there is a threat of bankruptcy) under which conditions it is reasonable (from the concedent's point of view) to provide additional financing of the project, and under conditions it is reasonable to renew the agreement (see [5; 7]). In paper [9] it is observed that in construction, opportunistic bidding often causes financial difficulties for the contractor. In such cases, when striving to win the contract, the contractor undervalues the estimated cost, expecting that in future the customer will be reimbursed for the losses (because it needs to complete the project or on the basis of a legal action). A standard BOT concession contract has little protection from such opportunistic behaviour.

Paper [10] describes the model of the closed first-price auction for a public contract. A tenderer (agent) is interested in an increase of the contract value, while the customer (principal) strives to minimise it. An economic mechanism which reconciles the interests of the customer and the executor was created. Under these parameters, it is unprofitable for the agent to undervalue the announced expenses (in comparison with the genuine ones) for the sake of winning the tender, as in this case the victory will result in losses. Taking into consideration some additional assumptions, an equation was derived which is satisfied by the value of the key parameter of the optimal contract, which minimises the expected expenses of the customer. The customer (as the leader according to Stackelberg) fixes this value of this parameter, thus "switching on" the sought economic mechanism.

Papers [11; 12] are dedicated to concessions for natural resource utilisation with the assumption that both concedent and concessionaire strive to maximise NPV. Paper [11] considers the possibility of the concessionaire's withdrawal from a BOT concession as a real option, which influences the duration of the contract term. The parties' interests are reconciled as follows: in each single period the concedent (leader according to Stackelberg) chooses the values of the concession payment, and the concessionaire chooses the term of the concession. A corresponding Stackelberg equilibrium is derived. Paper [12] considers manufacturing projects from a certain selection defined by the government as the concession subject. The government also makes public the list of infrastructure and environmental projects, which support manufacturing projects. It is anticipated that infrastructure projects are implemented at the expense of the budget and environmental ones – through PPP. On the basis of this information an investor chooses the projects to participate in. The search for Stackelberg equilibrium is formalised as a problem of double level mixed integer linear programming. An approximate solution algorithm was offered.

The model of concession for the manufacturing of a public good is offered in article [13]. The authors presume that the good is free of charge for the end-use customers, and the demand is described as a random variable with the differentiable distribution function. The concedent pays for the satisfied demand at the price of p, and the concessionaire pays the penalty q for each unit of unsatisfied demand. The concessionaire maximises the expected NPV during the concession term. The concedent chooses p and q in such a way that the optimal capacity for the concessionaire (which manufactures the public good) provides a sufficient expected level of demand satisfaction. With this provision, it minimises the expected discounted costs. The existence of Stackelberg equilibrium is therefore proven, and its parameters are defined.

Statement of the Problem

Let us assume that the concession subject is heat generating capacity in the municipal heat supply system. It may be a new facility or an operating enterprise. In the first case, design and construction are usually assigned to the concessionaire. In the second case, the terms of the concession may contemplate modernisation (e.g. reconstruction, expansion) of the enterprise. In any event, the concedent is a competent authority (central or municipal).

The concedent is interested in the development and support by the concessionaire of a heat generating capacity which provides a consistent heat supply to consumers in accordance with norms and at a minimum price. The normative demand for heat energy on each day of the heating season depends on the average daily temperature on such day and, consequently, is a random variable, which distribution may be derived out of meteorological statistics and rules of calculation of the normative demand for heat energy.

In the pre-plan period, the concessionaire, at its own expense (or with partial budgetary financing) designs and expands (e.g. modernises, reconstructs) the enterprise capacity up to the chosen level within the planned period (term of the concession), and bears corresponding operational and productive costs. The concessionaire's costs should be reimbursed (in case of normal revenue) by the consumers' payments, the concedent may subsidise these payments (for all or some consumers).

The concession agreement may provide for modernisation (at the concessionaire's expense or with partial budgetary financing) of the heat-transmitting system related to the concession subject. In accordance with the Federal Law of 17.08.1995 No. 147-FZ Concerning Natural Monopolies (art. 4), the market of heat energy transmitting services belongs to the natural monopoly sphere. The actual generation of heat energy, on the other hand, is not a monopoly type of activity either legislatively, or *ad rem*. Managing a heat generating enterprise and a heat supply system, the

concessionaire would have achieved significant power in the market. The possible consequence, however, is an increase in the cost of heat energy for the consumers, and this contradicts the concedent's purpose. In light of the above, we presume that the heat supply system is not the concession subject.

The higher the heat energy losses during transmission, the greater should be the generating power able to satisfy consistently the normative demand. As this trend develops, capital costs increase correspondingly. The necessity to reimburse for the heat energy losses increases current costs as well, and as a result, the cost of heat energy for consumers rises, which contradicts the concedent's purpose. If the metering station is located on the boundary of balance sheet attribution of the heat supply system, the consumers pay only for the delivered heat energy. In such a situation, the generator's current costs will be proportionate to the generated energy, and therefore implementation of the TSP is beneficial for the concessionaire as well. The concedent, in acting in the interests of consumers, may initiate the development of the TSP. In doing so, the concedent may therefore determine a transfer to the concession of the generating capacity, where the concessionaire participates in the financing of the TSP.

In order to ensure alignment of interests of the concession parties, we offer to introduce a penalty which the concessionaire has to pay to the concedent for each unit of unsatisfied demand for heat energy. That is to say, we presume that the concessionaire gets from the consumers the payment $p \geq 0$ for each unit of satisfied demand, and pays to the concedent the penalty q (probably, negative) for each unit of unsatisfied demand (payments are made at the end of the year). With this provision, the concessionaire chooses the capacity z in order to maximise the expected NPV within the planned period.

The concedent chooses the value of the concession parameters p and q. The concedent's purpose at the minimal price for heat energy p is to ensure sufficient consistency of satisfaction of daily demand for heat energy. First, the generated capacity should be sufficient to make the probability of satisfaction of demand on each day of the planned period not less than the specified value. Second, at any average daily temperature within the considered range, the concessionaire's operating profit should be positive in order to eliminate the latter's motivation to stop heat generation (the lower the temperature, the larger the losses in heat energy transmission, and so generation may become unprofitable).

Below we will formalise the described situation as a dynamic game with perfect information, prove the existence of equilibrium in this game, and state the method of its calculation.

Formalisation of the Problem

Demand for Heat Energy: Satisfied and Unsatisfied

For each local heat supply system, a heat supplier develops a 'Schedule of Qualitative Regulation' of water temperature in the heating system[1]. This document indicates specified values of the temperature of the supplied and returned water in the heating system at the boundary of balance sheet attribution of the heat supplier and consumers, depending on the average daily outdoor temperature. With knowledge of the temperature of the cold water added to the system and the weight of the heat carrier medium, one can[2] calculate the normative daily demand for heat energy at an average daily outdoor temperature t. Inasmuch as the average daily temperatures are random variables, the daily demand for heat energy each day should be considered a discrete random variable with known distribution.

Designation and Definitions

τ_i – average daily temperature at the day i of the heating season, a random variable.

$t_1 > \ldots > t_n$ – values of the average daily temperature t for which the 'Schedule of Qualitative Regulation' of the considered heat supply system defines the normative temperature of the heat carrier medium.

d_j – normative daily demand for heat energy corresponding to the temperature of t_j, $d_1 < d_2 < \ldots < d_n$.

η_i – normative demand for heat energy on day i of the heating season, a discrete random variable.

$t(\tau)$ – the value t_j nearest to τ on the right, if $\tau \leq t_1$, otherwise $t(\tau) = t_1$.

We introduce a discrete random variable $\xi_i = t(\tau_i)$ and assume that $a_{ij} = P(\xi_i = t_j)$.

$\lambda(\tau) \in (0, 1)$ – the share of heat energy losses in the system (up to the boundary of balance sheet attribution of the heat supplier and consumers) at the ambient temperature τ. We suppose that $\lambda_j = \lambda(t_j)$ and replace the function $\lambda(\tau)$ with the step approximation: $\lambda(\tau) = \lambda_j$, if $t(\tau) = t_j$.

c – cost of production of one gigacalorie of heat energy.

z_0 and z (Gcal per day) – enterprise capacity before and after reconstruction.

$x_i(z)$ – quantity of heat energy generated per one day i of the heating season at the capacity of z.

$D_k = d_k / (1 - \lambda_k)$ – minimal capacity which at the average daily temperature τ, ensures the normative demand for heat energy d_k provided $t(\tau) = t_k$.

[1] Rules and Standards of Operation of Housing Resources MDK 2-03.2003: approved by order of the State Committee for Construction of the Russian Federation of 27.09.2003 No.170). M.: State Unitary Enterprise Centre of Construction Design Products, 2004.

[2] Method of defining the quantity of heat energy and heat carrier medium in water systems of municipal heat supply MDS 41-4.2000: approved by order of the State Committee for Construction of the Russian Federation of 06.05.2000 No. 105. M.: State Unitary Enterprise Centre of Construction Design Products, 2000.

Previous definitions have taken into account the possibility that during the heating season the average daily temperature will go beyond the range of $[t_n, t_1]$: if $\tau < t_n$, $\xi_i = t_n$ and $\eta_i = d_n$; if $\tau > t_1$, $\xi_i = t_1$ and $\eta_i = d_1$. It is clear that $\xi_i \in \{t_1, \ldots, t_n\}$ and $\eta_i \in \{d_1, \ldots, d_n\}$, and also $P(\eta_i = d_j) = P(\xi_i = t_j) = a_{ij}$.

When the ambient temperature decreases the normative demand and heat losses increase, therefore $\lambda_k < \lambda_{k+1}$ and $D_k < D_{k+1}$ for all $k < n$. With respect to z and z_0 we assume the following natural assumptions: $z \geq z_0 \geq 0$ and $z \in [D_1, D_n]$.

The concessionaire chooses the value of $x_i(z)$ on each day i of the heating season, maximising the current profit. It is clear that $0 \leq x_i(z) \leq \min\{z, D_j\}$, if $t(\tau_i) = t_j$. It is desirable that the concessionaire uses to the maximum extent the existing capacity to satisfy the demand and this is equivalent to the choice of $x_i(z) = \min\{z, D_j\}$. We will prove that the concedent can incite such choice with admissible values of parameters p and q.

Theorem 1. Let us assume that $t(\tau_i) = t_j$ at the heat producing capacity z. in this case the concessionaire will choose $x_i(z) = \min\{z, D_j\} > 0$, if $(p + q)(1 - \lambda_j) \geq c$, and otherwise $x_i(z) = 0$.

Proof. Under the hypotheses of the theorem $\xi_i = t_j$, $\lambda(\tau_i) = \lambda_j$ and $\eta_i = d_j$. The concessionaire's profit at the day i at the production value of x_i will be written as: $\pi(x_i) = p\min\{x_i(1 - \lambda_j), d_j\} - q\max\{0, d_j - x_i(1 - \lambda_j)\} - cx_i$. If $x_i \in [D_j, z]$ then $x_i(1 - \lambda_j) \geq d_j$, from which $\pi(x_i) = p(1 - \lambda_j)D_j - cx_i$ and $\max\{\pi(x_i) \mid x_i \in [D_j, z]\} = [p(1 - \lambda_j) - c]D_j = \pi(D_j) = \pi(\min\{z, D_j\})$. If $x_i \in [0, D_j]$ then $\pi(x_i) = [(p + q)(1 - \lambda_j) - c]x_i - qd_j$. If $(p + q)(1 - \lambda_j) < c$ then $\max\{\pi(x) \mid x \in [0, D_j], x \leq z\} = \pi(0) = -qd_j$; if in this case $z \geq D_j$, then $\max\{\pi(x_i) \mid x_i \in [D_j, z]\} = [p(1 - \lambda_j) - c]D_j < -q(1 - \lambda_j)D_j = -qd_j$; consequently, $x_i(z) = 0$. If however $(p + q)(1 - \lambda_j) \geq c$, then $\max\{\pi(x) \mid x \in [0, D_j], x \leq z\} = \pi(\min\{z, D_j\})$. (1)

The hypothesis $(p + q)(1 - \lambda_j) \geq c$ means that at the average daily temperature t_j the heat energy unit generated "for expected demand" will give the consumer $1 - \lambda_j$ of energy and the concessionaire will get payment for delivery and will "save" on the penalty for short-delivery of this quantity; wherein the concessionaire's total benefit should be less than the cost of production. Inasmuch as values of λ_j do not diminish as j it is necessary and sufficient to ensure the following inequation:

$$(p + q)(1 - \lambda_n) \geq c. \quad (1)$$

If this hypothesis is not met, the concessionaire is incited to decrease the heat energy at low temperatures.

Designations. $\mu_i(z)$ and $\nu_i(z)$ – satisfied and, respectively, unsatisfied normative demand for heat energy on the day i of the heating season at the capacity of z.

The value of $x_i(z)$ depends on the average daily temperature; the values of $\mu_i(z)$ and $\nu_i(z)$ depend on $x_i(z)$ and normative demand η_i. Consequently, $x_i(z)$, $\mu_i(z)$ and $\nu_i(z)$ are random variables. The following lemma indicates their expected values.

Lemma 1. If the hypothesis (1) is met and $z \in [D_k, D_{k+1})$ then

$$\mathrm{E}x_i(z) = \sum_{j=1}^{k} D_j a_{ij} + z \sum_{j=k+1}^{n} a_{ij}, \quad \mathrm{E}\mu_i(z) =$$

$$= \sum_{j=1}^{k} d_j a_{ij} + z \sum_{j=k+1}^{n} (1 - \lambda_j) a_{ij},$$

$$\mathrm{E}\nu_i(z) = \sum_{j=k+1}^{n} [d_j - z(1 - \lambda_j)] a_{ij}$$

Proof. Granted that $\xi_i = t_j$. Then $\lambda_j = \lambda(\xi_i)$, $d_j = D_j(1 - \lambda_j) = \eta_i$, theorem 1 implies that $x_i(z) = \min\{z, D_j\} = \min\{z, \eta_i / [1 - \lambda(\xi_i)]\}$. Hence $\mu_i(z) = \min\{d_j, x_i(z)(1 - \lambda_j)\} = \min\{d_j, z(1 - \lambda_j)\}$ and $\nu_i(z) = \max\{0, d_j - \mu_i(z)\} = \max\{0, d_j - z(1 - \lambda_j)\}$. If $\eta_i = d_j \leq z(1 - \lambda_j)$ then $D_j \leq z$, $x_i(z) = D_j$, $\mu_i(z) = d_j$ and $\nu_i(z) = 0$. However, if $\eta_i = d_j > z(1 - \lambda_j)$ then $D_j > z$, $x_i(z) = z$, $\mu_i(z) = z(1 - \lambda_j)$ and $\nu_i(z) = d_j - z(1 - \lambda_j)$. The lemma statement follows from the fact that $P(\xi_i = t_j) = a_{ij}$ and while $z \in [D_k, D_{k+1})$ the inequation $D_j \leq z$ is equivalent to $j \leq k$.

Lemma 2. In the interval $[D_1, D_n]$ functions $\mathrm{E}x_i(z)$, $\mathrm{E}\mu_i(z)$ and $\mathrm{E}\nu_i(z)$ are continuous, whereby $\mathrm{E}\mu_i(z)$ and $\mathrm{E}x_i(z)$ do not decrease, and $\mathrm{E}\nu_i(z)$ does not increase.

Proof. Continuity of functions $\mathrm{E}x_i(z)$, $\mathrm{E}\mu_i(z)$ and $\mathrm{E}\nu_i(z)$ follows easily from the formulas of lemma 1. Therein $\mathrm{E}\mu_i(x)$ and $\mathrm{E}x_i(z)$ do not decrease, and $\mathrm{E}\nu_i(x)$ does not increase at each interval of $[D_k, D_{k+1})$ and, consequently, at $[D_1, D_n]$.

Concessionaire's Profit

The concessionaire gets payment p from the consumers for each unit of satisfied demand and pays to the concedent the penalty q (probably, negative) for each unit of unsatisfied demand. Payments are made at the end of the year.

Designation and Definition

$u = (p, q)$ – vector of parameters defined by the concedent.

$\pi_i(u, z) = p\mathrm{E}\mu_i(z) - c\mathrm{E}x_i(z) - q\mathrm{E}\nu_i(z)$ – expected operating profit of the concessionaire for the day i at the capacity of z (without operational costs, they will be accounted for in the annual profit).

Let us assume that $z \in [D_k, D_{k+1}]$. It follows from lemma 2 that formulas of lemma 1 are valid for $z = D_{k+1}$. Using lemma 1, we arrive at

$$\pi_i(z) = \sum_{j=1}^{k} \left[p(1 - \lambda_j) - c \right] D_j a_{ij} +$$

$$+ \sum_{j=k+1}^{n} \left[z\left((p + q)(1 - \lambda_j) - c\right) - qD_j(1 - \lambda_j) \right] a_{ij}. \quad (2)$$

Our immediate goal is to prove the concavity of function $\pi_i(u, z)$ in z.

Designation. For $r \in \{1, \ldots, n\}$ suppose

$$L(u,r,z)=\sum_{j=1}^{r}\left[p\left(1-\lambda_j\right)-c\right]D_j <_{ij} +$$

$$+\sum_{j=r+1}^{n}\left[z\left(\left(p+q\right)\left(1-\lambda_j\right)-c\right)-qD_j\left(1-\lambda_j\right)a_{ij}\right].$$

Theorem 2. Function $\pi_i(u, z)$ is continuous in z in the interval of $[D_1, D_n]$ and concave in z within this interval if hypothesis (1) is met.

Proof. Continuity of $\pi_i(u, z)$ follows from lemma 2. Let us assume that hypothesis (1) is met and $z \in [D_k, D_{k+1}]$. Then $\pi_i(u, z) = L_i(u, k, z)$. If $r < k$ then

$$L(u,r,z)-L(u,k,z)=-\sum_{j=r+1}^{k}\left[p\left(1-\lambda_j\right)-c\right]D_j a_{ij}+$$

$$+\sum_{j=r+1}^{k}\left[z\left(\left(p+q\right)\left(1-\lambda_j\right)-c\right)-qD_j\left(1-\lambda_j\right)a_{\supseteq j}\right]=$$

$$=\sum_{j=r+1}^{k}\left[\left(p+q\right)\left(1-\lambda_j\right)-c\right]a_{ij}(z-D_j)\geq 0,$$

as far as $(p + q)(1 - \lambda_j) - c \geq 0$ in (1) and $z \geq D_j$ when $j \leq k$. Similarly we prove that $L(u,r,z)-L(u,k,z)\geq 0$ when $r > k$. Consequently, $\min_r\{L_i(u, r, z)\} = \pi_i(u, z)$ for $z \in [D_1, D_n]$, and concavity of $\pi_i(z)$ follows from [15, theorem 5.5].

Designations

$\Pi_t(u, z) = \sum_i \pi_i(u,z)$ –

expected operating profit of the concessionaire for the year t of the planned period at the capacity of z.

$$\mathrm{E}x(z)=\sum_i \mathrm{E}x_i(z),\ \mathrm{E}\mu(z)=\sum_i \mathrm{E}\mu_i(z),$$

$$\mathrm{E}\nu(z)=\sum_i \mathrm{E}\nu_i(z).$$

Using the introduced designations and definition $\pi_i(u, z)$, we can write that:

$$\Pi_t(u, z) = p\mathrm{E}\mu(z) - c\mathrm{E}x(z) - q\mathrm{E}\nu(z). \quad (3)$$

We get a more detailed representation of $\Pi_t(u, z)$ using lemma 1.

Designations

$$b_j=\sum_i a_{ij};\ M_1(\mathrm{k})=\sum_{j=k+1}^{n}\left(1-\lambda_j\right)b_j;$$

$$M_2(\mathrm{k})=\sum_{j=k+1}^{n}b_j;M_3(\mathrm{k})=\sum_{j=1}^{k}\left(1-\lambda_j\right)b_jD_j;$$

$$M_4(\mathrm{k})=\sum_{j=1}^{k}b_jD_j;M_5(\mathrm{k})=\sum_{j=k+1}^{n}\left(1-\lambda_j\right)b_jD_j.$$

When $z \in [D_k, D_{k+1}]$, taking into consideration (2),

$\mathrm{t}(\mathrm{u}, \mathrm{z}) = z[(p + q)M_1(k) - cM_2(k)] + pM_3(k) - cM_4(k) - qM_5(k)$. (4)

If hypothesis (1) is met, from continuity and concavity of $\pi_i(u, z)$ (theorem 2) continuity and concavity of $\Pi_t(u, z)$ in z follow in the interval of $[D_1, D_n]$.

Designations

K_1 – concessionaire's contribution into TSP.

$K_2(z)$ – capital costs necessary to achieve the capacity of $z \geq z_0$, $K_2(z_0) = 0$.

$C(z)$ – annual operational costs at the capacity of $z \geq 0$ (including the costs necessary to maintain the capacity).

T (лет) – duration of the concession term, $[0, T]$ – planned period.

$\alpha = \sum_{t=1}^{T}(1+\delta)^{-t}$, where δ – discount rate per annum.

$A(z) = K_1 + K_2(z) + \alpha C(z)$ – the concessionaire's discounted costs for the TSP, generation of the capacity $z \geq z_0$ and its operation within the planned period.

$F(u, z)$ – expected NPV of the concessionaire for the planned period with the concession vector of parameters $u = (p, q)$ and capacity z.

Inasmuch as the value of $\Pi_t(u, z)$ does not depend on t,

$$F(u,z)=-A(z)+\sum_{t-1}^{T}\Pi_t(u,z)=-A(z)+\alpha\Pi_t(u,z). \quad (5)$$

If $z \geq z_0$ and $z \in [D_k, D_{k+1}]$ then from (4) and (5) we obtain:

$F(u, z) = -A(z) + \alpha[z((p + q)M_1(k) - cM_2(k)) + pM_3(k) - cM_4(k) - qM_5(k)]$. (6)

The Concedent's Purpose

Let us assume that the concedent fixes the value of $\sigma \in (0, 1)$ and tries to define p and q which satisfy the following conditions. First, inequality (1) should be satisfied in order to eliminate the concessionaire's impetus to stop generating energy at low average daily temperatures. Second, the capacity of z chosen by the concessionaire should ensure sufficient consistency of heat supply: $P(\eta_i \leq z) \geq \sigma$ for all i.Let us assume that condition (1) is satisfied. Then at the capacity of $z \in [D_k, D_{k+1})$ the normative demand for heat energy on the day i of the heating season is satisfied with the probability of

$$P(\eta_i = d_j \leq z(1 - \lambda_j)) = P(\eta_i = d_j \text{ and } D_j \leq z) = P(\xi_i = t_j \text{ and } j \leq k) = \sum_{j=1}^{k} a_{ij}.$$

Designations. $k(i) = \min\{k \mid \sum_{j=1}^{k} a_{i\text{стр}} \geq \sigma\}$;

$z_1 = \max_i\{D_{k(i)}\} = D_m$.

On day i the normative demand for heat energy is satisfied with the probability not less than σ at the minimal capacity of $D_{k(i)}$, and on any day of the heating season – at the minimum capacity of z_1. Assume the capacity which satisfies the minimal demand does not provide for sufficient consistency of heat supply ($D_1 < z_1$), and a decrease of the existing capacity is unacceptable ($z \geq z_0$). At the specified conditions the concedent minimises p.

Game-Theoretic Model

This is a two-move game. First, the concedent (leader according to Stackelberg [14, p. 56]) chooses the strategy $u = (p, q) \in \mathrm{R}_+ \times \mathrm{R}$ (further we will see that with big values of K_1 the value of q should be negative in order to repay to the concessionaire the investments with the contractual profitability of δ). Second, knowing u the concessionaire selects $z \in \{0\} \cup [z_0, D_n]$. Choosing $z = 0$ equals relinquishment of concession and choosing $z \geq z_0$ means a consent to enter into the concession, invest the amount of K_1 in TSP and to develop the capacity of z.

If $z < z_1$ (in particular, when $z = 0$) the concedent will fail to achieve its goal. Assume in this case its gain function takes on the of value of $-\infty$. The concedent's gain function (maximised) appears as follows:

$H_1(u, z) = -p$, if $(p + q)(1 - \lambda_n) \geq c$ and $z \in [z_1, D_n]$, otherwise $H_1(u, z) = -\infty$.

The concessionaire's gain function appears as follows: $H_2(u, z) = F(u, z)$ when $z \in [z_0, D_n]$ and $H_2(u, 0) = 0$.

The concessionaire's strategy is function $z(\cdot)$: $\mathrm{R}_+ \times \mathrm{R} \to \{0\} \cup [z_0, D_n]$ which indicates the concessionaire's response to any concedent's strategy $u = (p, q)$.

Designation. $R(u) = \mathrm{Argmax}\{H_2(u, z) \mid z \in \{0\} \cup [z_0, D_n]\}$ – representation of the concessionaire's response.

It is clear that the concessionaire will choose $z(u) \in R(u)$. As a matter of fact, sets $R(u)$ are not one-element sets but strategies $z(u)$ have the property that $z(u) \in R(u)$ with all $u \in \mathrm{R}_+ \times \mathrm{R}$ they are equivalent for the concessionaire. On this basis, let us assume that the concession parties can agree upon implementation of the capacity from the set of $R(u)$ which is preferable for the concedent, and let us accept the following definition.

Definition. Strategies $\overline{u} = (\overline{p}, \overline{q})$ and $\overline{z}(u)$ of the concedent and concessionaire respectively create *equilibrium* in the considered game if $\overline{z}(u) \in R(u)$ for all $u \in \mathrm{R}_+ \times \mathrm{R}$ and

$$H_1\left(\overline{u}, \overline{z}\left(\overline{u}\right)\right) = \max\left\{H_1\left(u, \overline{z}\left(u\right)\right) \middle| u \in \mathbb{R}_+ \times \mathbb{R}\right\}.$$

We call the proposed model a 'two-parametric' model, because the concedent defines two parameters p and q.

Analysis of the Two-Parametric Model

Let us phrase the assumptions of the cost functions used in the model.

$K_2(z)$ – does not decrease and is differentiable in $[z_0, D_n]$, $K_2(z_0) = 0$, $K_2(z) > 0$ when $z > z_0$.

$C(z)$ – does not decrease, is convex and is differentiable within the interval of $[0, D_n]$, $C(0) = 0$.

$A(z)$ – does not decrease, is convex and is twice differentiable within the interval of $[z_0, D_n]$.

Concessionaire's Response

For each concedent's strategy u the concessionaire obtains response $R(u)$ as a set of all solutions of the following problem: $H_2(u, z) \to \max$ when $z \in \{0\} \cup [z_0, D_n]$.

Designations. $Z(u) = \mathrm{Argmax}\{F(u, z) \mid z \in [z_0, D_n]\}$; $\pi^*(u) = \max\{F(u, z) \mid z \in [z_0, D_n]\}$.

Lemma 3. Let us assume that $u = (p, q) \in \mathrm{R}_+ \times \mathrm{R}$ and condition (1) is met. Then:

(a) function $F(u, z)$ is continuous and concave in z within the interval of $[z_0, D_n]$;

(b) function $F(u, z)$ is differentiable in z within $[z_0, D_n]$ everywhere, except for the points of D_k, and in these points is has one-sided derivatives in z;

(c) in point $D_k \in (z_0, D_n)$ the derivative of the function on the left $F(u, z)$ is not less than the derivative on the right.

Proof. (a) The continuity and concavity of function $\Pi_t(u, z)$ in $[z_0, D_n]$ follow from theorem 2 and the definition of this function. Then, assertion (a) follows from (5) and the assumption of characteristics of function $A(z)$. Differentiability of $F(u, z)$ within the interval of $(D_k, D_{k+1}) \cap [z_0, D_n]$ follows from (6). The existence of one-sided derivatives in point D_k and the correlation between them follow from [15, theorem 23.1 and 24.1]. Assertions (b) and (c) are proven.

It is clear that:

$R(u) = Z(u)$, if $\pi^*(u) > 0$; $R(u) = Z(u) \cup \{0\}$, if $\pi^*(u) = 0$; $R(u) = \{0\}$, if $\pi^*(u) < 0$. (7)

In the latter case, the concession cannot take place.

Designation. For $z \in [z_0, D_n] \cap [D_k, D_{k+1}]$ and $u = (p, q)$ assume

$g_k(u, z) = -A'(z) + \alpha[(p + q)M_1(k) - cM_2(k)]$.

The value of $g_k(u, z)$ is derivative of function $F(u, z)$ in z when $z \in (D_k, D_{k+1})$, derivative on the left in point D_{k+1} when $z = D_{k+1}$ and derivative on the right in point D_k when $z = D_k$ $(k < n)$.

Lemma 4. Let us assume that $u \in \mathrm{R}_+ \times \mathrm{R}$ and condition (1) is met. Then $z \in Z(u)$, if and only if one of the following conditions is met:

(a) $z = z_0$ and $g_l(u, z_0) \leq 0$, where l is defined by condition $z_0 \in [D_l, D_{l+1})$;

(b) $z \in (z_0, D_n] \cap (D_k, D_{k+1})$ and $g_k(u, z) = 0$;

(c) $z = D_k \in (z_0, D_n)$, $g_{k-1}(u, D_k) \geq 0$ and $g_k(u, D_k) \leq 0$;

(d) $z = D_n$ and $g_{n-1}(u, D_n) \geq 0$.

Proof. The concave function $f(x)$ reaches its maximum in point x, if and only if $0 \in \partial f(x)$, where $\partial f(x)$ – subdifferential of function $f(x)$ in point x (see the symmetric assertion for convex function in [15, p. 279]). When $u \in \mathrm{R}_+ \times \mathrm{R}$ the subdifferential $\partial F(u, z)$ equals: $[g_1(u, z_0), +\infty)$, if $z = z_0$ and $z_0 \in [D_l, D_{l+1})$; $\{g_k(u, z)\}$ when $z \in (D_k, D_{k+1})$; $[g_k(u, z), g_{k-1}(u, z)]$ when $z = D_k \in (z_0, D_n)$; $(-\infty, g_{n-1}(u, z)$ when $z = D_n$. Assertion of lemma follows from it.

Concedent's Problem

Designations. $S(u) = R(u) \cap [z_1, D_n]$, $U = \{u = (p, q) \in \mathrm{R}_+ \times \mathrm{R} \mid S(u) \neq \emptyset, (p + q)(1 - \lambda_n) \geq c\}$.

If $S(u) = \emptyset$ the concessionaire will choose $z < z_1$. When $(p + q)(1 - \lambda_n) < c$ condition (1) is not met and it is unprofitable for the concessionaire to generate heat energy at low

temperatures. In both cases, the concedent's benefit equals $-\infty$. Consequently, U is a set of all strategies acceptable for the concedent. In the language of the economic mechanisms theory $z \in R(u)$ is the condition of individual rationality while (1) and $z \geq z_1$ are the conditions of incentive compatibility, see [14, p. 57 and further]. If $U = \emptyset$ the concedent's goal is unattainable. However, if $u \in U$ then $H_1(u, z) = -p$ for any $z \in S(u)$. Taking equivalence into consideration for the concessionaire of all $z \in R(u)$, assume that in equilibrium $z(u) \in S(u)$ for all $u \in U$. Consequently, if the concedent's goal can be achieved ($U \neq \emptyset$), then its equilibrium strategy is defined on the basis of the following problem: $p \to \min$ under the condition of $(p, q) \in U$.

Equilibrium

Designation. $A_1(z) = A(z) - K_1 = K_2(z) + C(z)$.

Lemma 5. If $0 \leq z_0 \leq z' \leq z$, then $-K_1 \leq z'A'(z') - A(z') \leq zA'(z) - A(z)$.

Proof. It is known[1] that if function $f(x)$ is convex and differentiable in $X \subseteq \mathrm{R}$, then $f'(x)$ does not decrease in X and $f(x_2) - f(x_1) \geq f'(x_1)(x_2 - x_1)$ for any x_1, x_2 out of X, i.e.

$$x_1 f'(x_1) - f(x_1) \geq x_2 f'(x_1) - f(x_2). \quad (8)$$

Assume $z_0 \leq z' \leq z$. Applying (8) to the convex non-decreasing function $A_1(\cdot)$ when $x_1 = z$ and $x_2 = z'$, we obtain: $zA_1'(z) - A_1(z) \geq z'A_1'(z) - A_1(z') \geq z'A_1'(z') - A_1(z')$. Similarly, when $x_1 = z'$ and $x_2 = z_0$, taking into consideration that $K_2(z_0) = 0$ and $K_2'(z_0) \geq 0$, we have

$$z'A_1'(z') - A_1(z') \geq z_0 A_1'(z_0) - A_1(z_0) =$$
$$z_0[K_2'(z_0) + C'(z_0)] - [K_2(z_0) + C(z_0)] \geq z_0 C'(z_0) - C(z_0).$$

By assuming the function $C(z)$ is convex in $[0, D_n]$ and $C(0) = 0$, therefore it follows from (8) when $x_1 = z_0$ and $x_2 = 0$ that $z_0 C'(z_0) - C(z_0) \geq 0$. Hence $0 \leq z'A_1'(z') - A_1(z') \leq zA_1'(z) - A_1(z)$. Deducting K_1 from both sides of inequation and taking into consideration that $A_1'(z) = A'(z)$, we arrive at the desired result.

Designation. Assume $\Delta_k = [z_0, D_n] \cap [D_k, D_{k+1}]$.

When $k < n$ each $z \in \Delta_k$ let us compare the system of equations

$$(p + q)M_1(k) = cM_2(k) + A'(z)/\alpha, \quad (9)$$
$$pM_3(k) - qM_5(k) = cM_4(k) + [A(z) - zA'(z)]/\alpha. \quad (10)$$

Lemma 6. At any $z \in \Delta_k$ the system of equations (9), (10) has the unique solution:

$$p = \frac{\alpha c\left[M_2(k)M_5(k) + M_1(k)M_4(k)\right] + A'(z)M_5(k) + [A(z) - zA'(z)]M_1(k)}{\acute{a}M_1(k)\left[M_3(k) + M_5(k)\right]}, \quad (11)$$

$$q = \frac{\acute{a}c\left[M_2(k)M_3(k) - M_1(k)M_4(k)\right] + A'(z)M_3(k) + \left[zA'(z) - A(z)\right]M_1(k)}{\acute{a}M_1(k)\left[M_3(k) + M_5(k)\right]}. \quad (12)$$

If $u = (p, q)$ is the system solution, then $F(u, z) = 0$. If, apart from that, condition (1) is met then $z \in R(u)$.

Proof. Let us calculate the system determinant (9), (10):

$$\Delta = -M_1(k)[M_3(k) + M_5(k)] = -M_1(k)\sum_{j=1}^{n}\left(1 - \lambda_j\right)D_j b_j < 0.$$

Consequently, the system has a unique solution, which we designate as $u = (p, q)$. Applying Cramer's rule, we obtain formulas (11), (12).

Using formula (6) it is easy to verify that $F(u, z) = 0$, if p and q satisfy equations (9), (10). Assume p and q meet condition (1). Equation (9) is equivalent to $g_k(u, z) = 0$, therefore $z \in R(u)$ follows from lemma 4 using assertion (c) of lemma 3.

Designations. Assume $z \in \Delta_k$.

$u(z, k) = (p(z, k), q(z, k))$ – solution of the system of equations (9)–(10).

For $k < n$ assume $K_0(z, k) = \alpha c[M_2(k)M_3(k)/M_1(k) - M_4(k)] + A'(z)[z + M_3(k)/M_1(k)] - A_1(z)$.

Note that for $z = D_k \in (z_0, D_n)$ both $u(z, k)$ and $u(z, k - 1)$ are defined.

Consequence 1. Assume $z \in \Delta_k$. Then: (a) $q(z, k) < 0$ if and only if $K_1 > K_0(z, k)$; (b) $q(z, k) \geq 0$ when $K_1 = 0$; (c) $p(z, k) \geq c$.

Proof. The denominator of formula (12) is positive. In the equation which reflects negativeness of the numerator, let us replace $A(z)$ with $A_1(z) + K_1$. Solving the obtained inequation as regards K_1, we are left with assertion (*a*).

Values of λ_j do not decrease in j, therefore

$$M_2(k)M_3(k) = \sum_{j=k+1}^{n} b_j \cdot \sum_{j=1}^{k}\left(1 - \lambda_j\right)D_j b_j \geq \left(1 - \lambda_k\right)\sum_{j=k+1}^{n} b_j \cdot$$
$$\cdot \sum_{j=1}^{k} D_j b_j \geq \geq \sum_{j=k+1}^{n}\left(1 - \lambda_j\right)b_j \cdot \sum_{j=1}^{k} D_j b_j = M_1(k)M_4(k).$$

Besides, if $K_1 = 0$ then $A(z) = A_1(z)$ and $zA'(z) - A(z) \geq 0$ according to lemma 5, from which $K_0(z, k) \geq 0 = K_1$. Then $q(z, k) \geq 0$ according to assertion (*a*). Assertion (b) has been proven.

[1] See: Pshenichny B. N. Convex Analysis and Extremum Problem. M.: Nauka, 1980. Theorem 1.1.

Let us rewrite (11) as follows:

$$p = c\frac{M_2(k)M_5(k)+M_1(k)M_4(k)}{M_1(k)M_5(k)+M_1(k)M_5(k)}+\frac{A'(z)M_5(k)+\left[A(z)-zA'(z)\right]M_1(k)}{\alpha M_1(k)\left[M_3(k)+M_5(k)\right]}. \quad (13)$$

Note that $M_2(k) \geq M_1(k)$ and $M_4(k) \geq M_3(k)$, therefore the coefficient when c in the right side of the equation is (13) is not less than unity. It means that $p(z, k) \geq c$ if $A(z) - zA'(z) \geq 0$. Let us assume that $A(z) - zA'(z) = K_1 + A_1(z) - zA'(z) < 0$. Then $K_1 < zA_1'(z) - A_1(z) \leq K_0(z, k)$ and $q(z, k) \geq 0$ according to assertion (a). The quantity of generated heat energy cannot be less than the satisfied demand, therefore $E\mu_i(z) \leq Ex_i(z)$ for all i and z (it can be easily proved formally, using lemma 1). If $p(z, k) \leq c$ then $\Pi_t(u(z, k), z) \leq 0$ in (3) and $F(u(z, k), z) < 0$ in (5), and this contradicts lemma 6. Consequently, $p(z, k) \geq c$ in all cases and assertion (c) has been proven.

Designation

For $z \in \Delta_k \setminus \{D_k\}$ assume $k(z) = k$ and $h(z) = p(z, k) + q(z, k)$.

Let us assume that $B = \{z \geq z_1 \mid h(z)(1 - \lambda_n) \geq c\}$ and z^* is the greatest lower bound of set B.

Lemma 7

(a) Function $h(z)$ is continuous in the interval of $\Delta_k \setminus \{D_k\}$ and does not decrease in $[z_0, D_n]$.

(b) $(z^*, D_n] \subseteq B \subseteq [z^*, D_n]$.

(c) If $u \in U$ and $z \in S(u)$ then $z \geq z^*$.

Proof. For $z \in \Delta_k \setminus \{D_k\}$ we obtain the following out of (9)

$$h(z) = cM_2(k) / M_1(k) + A'(z) / \alpha M_1(k). \quad (14)$$

Continuity of $h(z)$ in $\Delta_k \setminus \{D_k\}$ follows from (14). Function $k(z)$ does not decrease in z and $M_1(k)$ does not increase in k, therefore $M_1(k(z))$ does not increase in z. According to the assumption that $A(z)$ is a convex function, therefore $A'(z)$ does not decrease. Consequently, the addend in the expression for $h(z)$ does not decrease. The augend does not decrease either. In point of fact,

$M_2(k - 1) / M_1(k - 1) \leq M_2(k) / M_1(k) \leftrightarrow M_2(k - 1)M_1(k) \leq M_1(k - 1) M_2(k) \leftrightarrow$

$$\sum_{j=k}^{n} b_j \cdot \sum_{j=k+1}^{n} \left(1-\lambda_j\right)b_j \leq \sum_{j=k+1}^{n} b_j \cdot \sum_{j=k}^{n} \left(1-\lambda_j\right)b_j.$$

$$\sum_{j=k+1}^{n} \left(1-\lambda_j\right)b_j \leq \left(1-\lambda_k\right) \sum_{j=k+1}^{n} b_j.$$

The last inequality holds because $\lambda_j \geq \lambda_k$ for $j > k$. Consequently, $h(z)$ is a nondecreasing function within the interval of $[z_0, D_n]$ and assertion (a) has been proven.

By convention $k(D_n) = n - 1$ and according to (14)

$h(D_n) = cM_2(n - 1) / M_1(n - 1) + A'(D_n) / \alpha M_1(n - 1) = c / (1 - \lambda_n) + A'(D_n) / \alpha b_n \geq c / (1 - \lambda_n)$.

Hence, $D_n \in B$. Then assertion (b) follows from assertion (a).

Let us assume that $u = (p, q) \in U$ and $z \in S(u)$. Then $p + q \geq c / (1 - \lambda_n)$. If $z \in (D_k, D_{k+1})$ then according to lemma 4 $g_k(u, z) = 0$ follows from $z \in S(u) \subseteq R(u)$, and taking into consideration (9) it equals $h(z) = p + q$. Hence $h(z) \geq c / (1 - \lambda_n)$ and $z \geq z^*$. Assume $z = D_k$. Inasmuch as $D_n \geq z^*$ it is sufficient to consider the case of $k < n$. In this case according to lemma 4 it follows out of $z \in S(u)$ that $g_k(u, z) \leq 0$. Using (9) we obtain $p(z, k) + q(z, k) \geq p + q \geq c / (1 - \lambda_n)$. But $p(z, k) + q(z, k) = \lim_{y \to z+0} h(y)$, therefore taking into consideration assertion (a), $h(y) \geq c / (1 - \lambda_n)$ for $y > z$. Then it follows from the definition of z^* that $z \geq z^*$. Assertion (c) has been proven.

It follows from lemmas 6 and 7 that the concedent may, by choosing $u = u(z, k(z))$, stimulate generation of any capacity $z \in B$. Assertion (b) of lemma 7 describes set $B \setminus \{z^*\}$. Exogenous parameters of the model define whether z^* belongs to set B. Let us show that the concedent's optimal strategy $u^* = (p^*, q^*)$ makes strategy z^*, in particular, optimal for the concessionaire and let us find the values of p^* and q^*. The next lemma shows some properties of point z^*.

Lemma 8

(a) If $z^* \in (D_r, D_{r+1})$, then $p(z^*, r) + q(z^*, r) = c / (1 - \lambda_n)$ and $z^* \in B$.

(b) If $z^* = D_r \in B$ and $z^* > z_1$, then $p(z^*, r - 1) + q(z^*, r - 1) = c / (1 - \lambda_n)$.

(c) If $z^* = D_r \notin B$, then $1 < r < n$ and there exists number $\gamma \in (0, 1]$ with the property that

$(1 - \gamma)[p(z^*, r - 1) + q(z^*, r - 1)] + \gamma[p(z^*, r) + q(z^*, r)] = c / (1 - \lambda_n)$.

Proof. According to the choice of z^* we have $h(z) < c / (1 - \lambda_n)$ for $z < z^*$. Assume $z^* \in (D_r, D_{r+1})$. According to assertion (b) of lemma 7 $h(z) \geq c / (1 - \lambda_n)$ for $z \in (z^*, D_{r+1})$. Then $h(z^*) = c / (1 - \lambda_n)$ follows from assertion (a) of lemma 7. Now assume $z^* = D_r$. By assumption $z_1 = D_m > D_1$, therefore $r > 1$. If $D_r \in B$ and $D_r > z_1$, then $h(z^*) \geq c / (1 - \lambda_n)$ and $h(z) < c / (1 - \lambda_n)$ for $z < z^*$. Hence, taking into consideration assertion (a) of lemma 7 it follows that $h(z^*) = c / (1 - \lambda_n)$. If $D_r \notin B$, then $r < n$, as far as $D_n \in B$ according to assertion (b) of lemma 7. Therein $h(z^*) = p(z^*, r - 1) + q(z^*, r - 1) < c / (1 - \lambda_n)$, and it follows from (9) and assertion (b) of lemma 7 that $p(z^*, r) + q(z^*, r) = \lim_{z \to z^* + 0}[p(z, r) + q(z, r)] \geq c / (1 - \lambda_n)$. Consequently, the equality indicated in assertion (c) holds for some number γ, which is easily calculated out of this equality.

Lemma 9. Let us assume that $z \in \Delta_k$, $u = (p, q) \in R_+ \times R$, $F(u, z) \geq 0$ and $g_k(u, z) \geq 0$. Then $p \geq p(z, k)$.

Proof. If it is granted that conditions of lemma are met and $p < p(z, k)$. Then $q > q(z, k)$, as far as $g_k(u, z) \geq 0$ implies $p + q \geq cM_2(k) / M_1(k) + A'(z) / \alpha M_1(k) = p(z, k) + q(z, k)$ in (9). Hence, using (5) and (3) we obtain $F(u, z) - F(u(z, k), z) = \alpha[(p - p(z, k))\cdot E\mu(z) - (q - q(z, k))\cdot Ev(z)] < 0$.

But $F(u(z, k), z) = 0$ according to lemma 6, it means that $F(u, z) < 0$, contradiction.

Lemma 10. (a) Function $p(z, k)$ does not decrease in Δ_k. (b) If $1 < s < n$ and for the concedent's strategy $u(D_s, s)$ condition (1) is met then $p(D_s, s-1) \le p(D_s, s)$.

Proof. In accordance with (11), minimisation of $p(z, k)$ by Δ_k is equal to minimisation of function $f(z) = A'(z)M_5(k) + [A(z) - zA'(z)]M_1(k)$. Let us find $f'(z) = A''(z)[M_5(k) - zM_1(k)]$. From convexity $A(z)$ it follows that $A''(z) \ge 0$. If $z \le D_{k+1}$ then

$$M_5(k) - zM_1(k) = \sum_{j=k+1}^{n} (1-\lambda_j) b_j (D_j - z) \ge 0.$$

It means that $f'(z) \ge 0$ in Δ_k and assertion (a) has been proven.

Let us assume that the set $u = u(D_s, s)$ meets condition (1). Then $F(u, D_s) = 0$ and $D_s \in R(u)$ according to lemma 6. Hence, $g_{s-1}(u, D_s) \ge 0$ according to condition (c) of lemma 4. It means that when $k = s - 1$ and $p' = p(D_s, s)$ conditions of lemma 9 and $p(D_s, s) \ge p(D_s, s-1)$ are met.

It follows from lemma 10 that function $p(z, k(z))$ does not decrease in the interval of $(D_1, D_n]$. Now let us define the concedent's strategy $u^* = (p^*, q^*)$, the optimality of which will be proven below.

Designations and definition. Assume $u^* = u(z^*, r)$, if $z^* \in (D_r, D_{r+1})$, and $u^* = u(z^*, r-1)$, if $z^* = D_r \in B$ (in particular, if $z^* = D_n$). However, if $z^* = D_r \notin B$, then $u^* = (1 - \gamma) u(z^*, r-1) + \gamma u(z^*, r)$, where γ is the number indicated in assertion (c) of lemma 8.

Theorem 3. Assume $z(\cdot)$ is the concessionaire's strategy such that $z(u) \in R(u)$ for all $u \in \mathrm{R}_+ \times \mathrm{R}$ and $z(u^*) = z^*$. Then $z(\cdot)$ and the concedent's strategy u^* create equilibrium in the considered game.

Proof. Assume $z^* \in \Delta_r$ and $u^* = (p^*, q^*)$. On the basis of (7) and lemma 3 we make the conclusion that $R(u) \ne \emptyset$ at all $u \in \mathrm{R}_+ \times \mathrm{R}$. The definition of u^*, taking into consideration assertion (c) of consequence 1, guarantees that $u^* \in \mathrm{R}_+ \times \mathrm{R}$ and condition (1) is met for u^*. If $u^* = u(z^*, r)$, then $z^* \in R(u^*)$ according to lemma 6. However, if $u^* \ne u(z^*, r)$, then $z^* = D_r < D_n$. In this case it follows from (9) that $g_{r-1}(u(z^*, r-1), z^*) = g_r(u(z^*, r), z^*) = 0$, it means that $g_r(u(z^*, r-1), z^*) \le 0$ and $g_{r-1}(u(z^*, r), z^*) \ge 0$ according to assertion (c) of lemma 3. Function $g_k(u, z)$ with fixed z and k is linear in u, therefore $g_{r-1}(u^*, z^*) \ge 0$, $g_r(u^*, z^*) \le 0$ and $z^* \in R(u^*)$ according to condition (c) of lemma 4. So, $z^* \in R(u^*)$ in all cases, therefore $u^* \in U$, and therefore concessionaire's strategies with the properties indicated in the theorem exist, and we assume $z(\cdot)$ is one of them.

If $u \notin U$, then $H_1(u, z(u)) = -\infty < -p^* = H_1(u^*, z^*)$. Let us assume that $u = (p, q) \in U$. Then $S(u) \ne \emptyset$ and $(p + q)(1 - \lambda_n) \ge c$. Let us show that $p^* \le p$. Assume $z(u) = z \in \Delta_k$. As long as all strategies from $R(u)$ are equivalent for the concessionaire we can think that $z \in S(u)$. Then $F(u, z) \ge 0$ in (7) and $z \ge z^*$ according to assertion (c) of lemma 7. At the same time if $z \in [z^*, D_{r+1}]$, then it follows from $z \in S(u) \subseteq R(u)$ according to lemma 4 that $g_r(u, z) \ge 0$. Then $p \ge p(z, r) \ge p(z^*, r)$ according to lemmas 9 and 10.

Granted that $z \in \Delta_k$ for $k > r$. If $z \in (D_k, D_{k+1}]$ then $g_k(u, z) \ge 0$ according to lemma 4. Using lemmas 9 and 10 we obtain $p \ge p(z, k) \ge p(D_k, k)$. Therein $p(D_k, k) + q(D_k, k) = \lim_{y \to D_k + 0} h(y) \ge c/(1 - \lambda_n)$, because $D_k > z^*$. Then $p(D_k, k) \ge p(D_k, k-1)$, according to assertion (b) of lemma 10. According to assertion (*a*) of this lemma $p(y, k-1)$ does not decrease in y in Δ_{k-1}. Hence, $p(D_{k-1}, k-1) \le p(D_k, k-1) \le p(D_k, k)$. Repeating the reasoning let us prove that $p \ge p(D_k, k) \ge p(D_{k-1}, k-1) \ge \ldots \ge p(D_{r+1}, r+1)$. Note that $F(u(D_{r+1}, r+1), D_{r+1}) = 0$ according to lemma 6 and $g_{r+1}(u(D_{r+1}, r+1), D_{r+1}) = 0$ in (9), therefore applying lemma 9 when $k = r$, $u = u(D_{r+1}, r+1)$ and $z = D_{r+1}$, we obtain $p(D_{r+1}, r+1) \ge p(D_{r+1}, r)$. Finally, according to assertion (a) of lemma 10, $p(z^*, r) \le p(D_{r+1}, r) \le p$.

Thus, if $z^* \in \Delta_r$, then $p(z^*, r) \le p$ for any concedent's strategy $u = (p, q) \in U$. If $z^* \in (D_r, D_{r+1})$ or $r = n - 1$ and $z^* = D_n$, then $p^* = p(z^*, r) \le p$. Assume $z^* = D_r$ and $r < n$. Then it follows from assertion (b) of lemma 7 that $p(D_r, r) + q(D_r, r) = \lim_{y \to D_r + 0} h(y) \ge c/(1 - \lambda_n)$, and according to assertion (b) of lemma 10, $p(z^*, r-1) \le p(z^*, r) \le p$. Now from definition p^* follows $p^* \le p$. So, for any concedent's strategy $u = (p, q) \in U$ we obtain $p^* \le p$. We proved above that $u^* \in U$, therefore $p^* = \min\{p \mid (p, q) \in U\}$.

Theorem 3 demonstrates that if the concedent declares a concession with parameters p^* and q^*, then z^* is included in the concessionaire's response, and it will have no grounds to refuse to create this particular heat generating capacity. Therein the concedent's goal is achieved in the equilibrium at the minimal tariff.

Consequence 3. In the equilibrium the concessionaire's NPV is zero.

Proof. By convention u^* is one of strategies $u(z^*, r)$ and $u(z^*, r-1)$ or their linear combination. Then $F(u^*, z^*) = 0$ follows from lemma 6 in the first two cases and from linearity $F(u, z)$ in u – in the third case.

One-Parametric Model

The concession mechanism offered above with $q > 0$ implies penalisation of the concessionaire for each unit of unsatisfied demand. Let us examine the results which may be obtained from a one-parametric model which has no (equals zero) parameter q.

As before, we assume that the concessionaire develops the capacity of z, and then on each day i of the heating season it chooses the rate of its usage $x_i(z)$, maximising the current profit. The concedent makes the first move defining the tariff $p \ge 0$, and the concessionaire makes the second move choosing the capacity $z \in \{0\} \cup [z_0, D_n]$. An analogue of condition (1) which in the two-parametric model guarantees that the concessionaire does not stop heat supply even at the minimal temperature, in the one-parametric model is the inequality $p(1 - \lambda_n) \ge c$. (15)

If it holds then at the capacity of z average daily temperature t_j on the day i of the heating season the concessionaire will choose $x_i(z) = \min\{z, D_j\}$.

Concedent's gain function is: $H_1^1(p, z) = -p$, if $z \in [z_1, D_n]$ and $p(1 - \lambda_n) \ge c$, otherwise $H_1^1(p, z) = 0$.

The net present expected profit of the concessionaire is written as

$$F_1(p, z) = -A(z) + \alpha[p\mathrm{E}\mu(z) - c\mathrm{E}x(z)]. \quad (16)$$

It follows from (3), (5) and (16) that

$$F_1(p, z) = F(u, z) + \alpha q\mathrm{E}v(z), \text{ where } u = (p, q), \quad (17)$$

where $F(u, z)$ – the concessionaire's expected NPV within the planned period in the two-parametric model. If condition (15) is met, then analogues of assertions of lemma 3 hold: function $F_1(p, z)$ is continuous in z within the interval of $[D_1, D_n]$ and concave in z within this interval; it is differentiable in z in $[z_0, D_n]$ everywhere, except for points D_k, and in these points it has one-sided derivatives in z.

When $z \in \Delta_k$ from (16) and lemma 1 follows that

$$F_1(p, z) = -A(z) + \alpha[z(pM_1(k) - cM_2(k)) + pM_3(k) - cM_4(k)] =$$

$$-A(z) + \alpha\left[z\sum_{j=1}^{k} D_j b_j\left(p\left(1-\lambda_j\right)-c\right) + \sum_{j=k+1}^{n} b_j\left(p\left(1-\lambda_j\right)-c\right)\right]. \quad (18)$$

Designation. For $z \in \Delta_k$ assume $g_k^1(p, z) = -A'(z) + \alpha[pM_1(k) - cM_2(k)]$.

The value $g_k^1(p, z)$ – derivative of function $F_1(p, z)$ in z when $z \in (D_k, D_{k+1})$, left-side derivative when $z = D_{k+1}$ and right-side derivative when $z = D_k$. If $u = (p, q)$, then $g_k(u, z) = g_{\text{ж}}^1(p, z)$.

The concessionaire's gain function: $H_2^1(p, z) = F_1(p, z)$, if $z \in [z_0, D_n]$, and $H_2^1(p, 0) = 0$.

The concessionaire's strategy is function $z(p)$ which indicates the concessionaire's response to any concedent's strategy p.

Definition and Designations

$Z_1(p) = \mathrm{Argmax}\{F_1(p, z) \mid z \in [z_0, D_n]\}$, $R_1(p) = \mathrm{Argmax}\{H_2^1(p, z) \mid z \in \{0\} \cup [z_0, D_n]\}$.

The pair of strategies $\bar{z}(p)$ and $\bar{p}$ is a equilibrium if $\bar{z}(p) \in R_1(p)$ for all $p \geq 0$ and

$$H_1^1\left(\bar{p}, \bar{z}\left(\bar{p}\right)\right) = \max\{H_1^1\left(p, \bar{z}\left(p\right)\right) \mid p \geq 0\}.$$

Let us assume that $P = \{p \mid p \geq c/(1 - \lambda_n), R_1(p) \cap [z_1, D_n] \neq \emptyset\}$.

For $z \in \Delta_k$ assume $p_1(z, k) = cM_2(k)/M_1(k) + A'(z)/\alpha M_1(k)$.

$R_1(p)$ – representation of the concessionaire's response. If $z \in Z_1(p)$ then $z \in R_1(p)$ is equivalent to $F_1(p, z) \geq 0$. The concedent looks for the minimal value of p out of P. At any $p > 0$ the concessionaire chooses $z(p) \in R_1(p)$. All $z \in R_1(p)$ are equal for the concessionaire, therefore let us assume that $z(p) \in Z_1(p)$ if $p \in P$. Both $p_1(z, k - 1)$ and $p_1(z, k)$ are defined for $z = D_k \in (D_1, D_n)$. An analogue of lemma 4 with replacement of $Z(u)$ with $Z_1(p)$ and $g_k(u, z)$ in $g_k^1(p, z)$ holds.

Lemma 11. Assume $z \in \Delta_k$.

(a) $g_k^1\left(p_1\left(z, k\right), z\right) = 0$ and $p_1(z, k) = p(z, k) + q(z, k)$. If $z \in (D_k, D_{k+1}]$ then $p_1(z, k) = h(z)$.

(b) $z \in Z_1(p)$ if and only if one of the following conditions is fulfilled: $z = D_1$ and $p \leq p_1(z, k)$; $z \in (D_k, D_{k+1})$ and $p = p_1(z, k)$; $z = D_{k+1} < \mathrm{D_n}$ and $p_1(z, k) \leq p \leq p_1(z, k+1)$; $z = \mathrm{D_n}$ and $p \geq p_1(z, n - 1)$.

Proof. Assertion (a) follows from definitions $g_k^1\left(p_1\left(z, k\right), z\right)$, $p_1(z, k)$, $u(z, k)$ and $h(z)$. Function $g_k^1(p, z)$ does not decrease in p, therefore any relation between $g_k^1(p, z)$ and zero (less than, equal or greater than) is equivalent to the identical relation between p and $p_1(z, k)$. Now assertion (b) follows from the analogue of lemma 4 for one-parametric model.

6. Comparison of Equilibrium in the One-Parametric and Two-Parametric Models

Let us assume that $u^* = (p^*, q^*)$ and $z(u)$ are equilibrium strategies of participants in the two-parametric model, $z^* = z(u^*) \in (D_r, D_{r+1}]$. Let us also assume that p_1 and $z_1(p_1)$ are equilibrium strategies of participants in the one-parametric model where $z_1(p_1) = z_1^* \in (D_s, D_{s+1}]$.

Theorem 4. $z_1^* \geq z^*$ and $p_1 \geq \max\{p^*, p^* + q^*\}$.

Proof. If it is granted that $z_1^* < z^*$. Then $p_1 \in P$ and $z_1^* \in Z_1(p)$. From assertion (a) of lemma 7 follows $\mathrm{h(y)} < c/(1 - \lambda_n)$ for $y \in [z_1^*, z^*)$. If $z_1^* \neq D_{s+1}$ then $p_1 = h\left(z_1^*\right)$ according to 11. If $z_1^* = D_{s+1}$ then from $z_1^* < z^*$ follows $D_{s+1} < D_n$ and using lemma 11 we obtain

$$p_1 \leq p\left(z_1^*, s+1\right) + q\left(z_1^*, s+1\right) = \lim_{y \bullet z_1^*} h\left(y\right) < c/(1 - \lambda_n).$$

In all cases $p_1 < c/(1 - \lambda_n)$, which contradicts $p \in P$. Consequently, $z_1^* \geq z^*$, hence $k(z_1^*) = s \geq r = k(z^*)$. If $q\left(z_1^*, s\right) \geq 0$ then from lemma 11 follows $p_1 \geq p_1\left(z_1^*, s\right) = h\left(z_1^*\right) \geq p\left(z_1^*, s\right)$. Let us assume that $p_1\left(z_1^*, s\right) = h\left(z_1^*\right) \geq p\left(z_1^*, s\right) < 0$. Then with $p_1 < p_1\left(z_1^*, s\right) = h\left(z_1^*\right) \geq p\left(z_1^*, s\right)$ we have:

$$F_1\left(p_1, z_1^*\right) = p_1 E\mu\left(z_1^*\right) - cEx\left(z_1^*\right) <$$

$$p\left(z_1^*, s\right)E\mu\left(z_1^*\right) - cEx\left(z_1^*\right) - q\left(z_1^*, s\right)Ev\left(z_1^*\right) =$$

$$= F\left(u(z_1^*, s), z_1^*\right) = 0,$$

And this contradicts the condition of $z_1^* \in R_1(p_1)$. It means that $p_1 \geq p_1\left(z_1^*, s\right)$ in all cases.

Function $p(z, k(z))$ does not decrease in z (see lemmas 9 and 10), therefore from $z^* \neq D_{r+1}$ it follows that $p^* = p(z^*, r) \leq p_1\left(z_1^*, s\right)$. If $z^* = D_{r+1}$ then $s > r$; from definition of p^* and lemma 10 we obtain $p^* \leq p(z^*, r + 1) \leq \mathrm{p(z_1^*, s))}$. In all cases $p_1 \geq p^*$ because $p_1 \geq p_1\left(z_1^*, s\right)$.

It is obvious from definition of u^* that either $p^* + q^* = c/(1 - \lambda_n)$, or $g_r(u^*, z^*) \leq 0$. Consequently, if $p < p^* + q^*$ two variants are possible : $p < c/(1 - \lambda_n)$ or $g_r^1\left(p, z^*\right) < g_r^1\left(p^* + q^*, z^*\right) = g_r\left(u^*, z^*\right) \leq 0$.

Function $g_k^1(p,z)$ does not increase in Δ_k, and for concave function $F_1(p, z)$ the left-hand derivative in any point of z is not less than the right-hand derivative, therefore $g_r^1(p,z^*) < 0$ implies $g_s^1(p,z^*) < 0$. In both cases we have a contradiction with $z_1^* \in R_1(p_1)$. In means that $p_1 \geq p^* + q^*$.

Thus, in the two-parametric model the equilibrium capacity and equilibrium price of heat energy do not exceed the corresponding indicators of the one-parametric model.

The following result shows that $z_1^* = z^*$ and $p_1 > p^*$ under "normal" conditions (when $q^* \geq 0$).

Consequence 2. If $q^* \geq 0$ then in the one-parametric model there is equilibrium with the following parameters $z_1^* = z^*$ and $p_1 = p^* + q^*$.

Proof. Let us assume that $p = p^* + q^*$. Inasmuch as $p_1 \geq p^* + q^*$ (theorem 4) it is sufficient to prove that $p \in P$ and $z^* \in R_1(p)$. If $p' = p + q$ and $u = (p, q)$ then $g_k^1(p',z) = g_k(u, z)$ for all k and $z \in \Delta_k$. Then from $z^* \in Z(u^*)$ of lemma 4 and its analogue for one-parametric model it follows that $z^* \in Z_1(p)$. From $z^* \in R(u^*)$, (17) and $q^* \geq 0$ follows $F_1(p, z^*) \geq F_1(p^*, z^*) \geq F(u^*, z^*) \geq 0$, therefore $p_1 \in P$.

In the two-parametric model the expected NPV of the concessionaire in equilibrium equals zero. In the one-parametric model this indicator may be positive (which means that the aggregate expected discounted costs of the community party (the consumer) exceed the expected discounted costs of the concessionaire). For example, $F_1(p_1, z^*) > F_1(p^*, z^*) > F(u^*, z^*)$ in the situation described by consequence 2 with $q^* > 0$.

Results and Conclusions

In the two-parametric model the concedent defines the required consistency of heat supply σ and chooses parameters p and q (tariff and penalty for failure to fulfill normative delivery of heat). With these parameters the concessionaire, maximising NPV, chooses z (the enterprise capacity), and defines the amount of generation of heat energy each day. We have proven the existence of, and found the method of creating Stackelberg equilibrium. The properties of this equilibrium are as follows: a capacity of z^* ensures sufficient consistency of heat supply; the concessionaire utilises the full extent this capacity to satisfy the normative demand; the price p^* of heat energy covers its price cost c; the net present expected profit of the concessionaire is zero; and finally, p^* is the minimum price at which the abovementioned conditions may be fulfilled.

If the concessionaire's expenses for the modernisation of the heat supply system K_1 are too high the "penalty" q^* becomes negative. Inasmuch as $p^* \geq c$ the concessionaire's lost profits correspond to the unsatisfied demand. If $q^* < 0$ this short-received profit is reimbursed by the concedent which pays $|q^*|$ for each unit of unsatisfied demand. Reimbursements to the concessionaire are included in many real concession agreements as a "guaranteed minimum income" (GMI). Our model indicates in which cases such payments are necessary, and helps to define their amount. It is true that if $z^* \in \Delta_r$ then $u^* = u(z^*, r)$, or $u^* = u(z^*, r - 1)$, or $u^* = (1 - \gamma)u(z^*, r - 1) + \gamma u(z^*, r)$. For the first two cases, assertion (a) of consequence 1 indicates the concessionaire's maximum expenses for the transmission system project with which $q^* \geq 0$. It is easy to calculate such threshold value for the third version of definition u^* as well. In particular, $q^* \geq 0$ if the concessionaire does not invest in modernising heat supply systems. By reducing the concessionaire's contribution towards modernisation of the heat supply systems one can always ensure non-negativeness of the penalty in the equilibrium.

The concessionaire's expected NPV in equilibrium equals zero, nevertheless it is possible to ensure normal entrepreneurial profit for it by choosing the discount rate δ, i.e. the price of investments. However, it follows from (11) that when δ increases p^* grows as well, whereby the consumers' payments may be socially unacceptable.

Conclusion

As shown in section 6 the two-parametric model is more beneficial for the community party / consumers in terms of value indicators. An important advantage of this model, in our opinion, is that it is better protected from the concessionaire's opportunistic behaviour, and makes violation of the agreement unprofitable for it. If the concessionaire develops the capacity of $z < z^*$ then with equal equilibrium values of parameters (p^* and q^*) its net present expected profit will not be positive (as a rule, it will be negative).

The one-parametric model does not possess such a property. With the equilibrium value of heat energy (p_1) and capacity $z < z_1^*$, the concessionaire's profit may be positive (though not maximal). If that is granted, for example, the initial capacity z_0 is positive and $z_0 \in \Delta_k$. Then with $z = z_0$ and price p_1, in accordance with (18) the concessionaire will have the following profit

$$F_1(p_1, z_0) = -A(z_0) + \alpha[z_0 \sum_{j=1}^{k} D_j b_j (p_1(1-\lambda_j) - c) +$$

$$+ \sum_{j=k+1}^{n} b_j (p_1(1-\lambda_j) - c)]. \quad (19)$$

From the definition of equilibrium follows the proposition $p_1(1 - \lambda_n) \geq c$, and so the expression in square brackets is non-negative. If it equals zero then $F_1(p_1, z) < 0$ for all $z > 0$, and this contradicts the condition $p_1 \in P$. Hence, the addend on the right side of formula (19) is positive. In such a circumstance, an unscrupulous concessionaire may get a positive profit without making any investments or having necessary operating expenses, but selling heat energy at price p_1. In the two-parametric model such concessionaire would have gone bankrupt paying penalties for short-delivery of heat energy, and in the one-parametric model the concedent may simply resort to administrative and legal remedies. This all goes to say that an economic mechanism which inhibits the concessionaire's opportunistic behaviour is "embedded" in the two-parametric model. There

is no such mechanism in the present generally accepted one-parametric model. Therefore, practical implementation of the two-parametric model is possible only after modification of the concession legislation.

A simplified version of the model was tested successfully in the master's thesis by S.A. Klimentieva (Novosibirsk State University, Faculty of Economics, 2018, advisor – A.B.Khutoretsky), using construction of a boiler-house in the microdistrict of Razdolny, in the town of Berdsk, as an example (at the time of writing, the project has not been implemented). The calculated price of heat energy turned out to be 9.6% less than the current actual price, and 7.5% less than the design price, and the design capacity and capital costs 12% less than corresponding project parameters.

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The Impact of Domestic Mergers and Acquisitions on the Operating Profit Margins of Companies in Russia

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 69-79 (2020)
DOI: https://10.0.67.171/j.jcfr.2073-0438.14.1.2020.69-79
Received 11 February 2020 | **Peer-reviewed** 17 March 2020 | **Accepted** 20 March 2020

The Impact of Domestic Mergers and Acquisitions on the Operating Profit Margins of Companies in Russia

Abstract

This research paper studies the impact of domestic Russian mergers and acquisitions on the operating profit margin of companies participating in deals. The goal of the research is to evaluate the changes in operating profit margin, and to analyse the significance of factors affecting operating profit margin after deals have been concluded.

The main scientific contribution of this research is the development of a methodology to analyse the effect of mergers and acquisitions on operating profit margins that takes into account the idiosyncratic features of the Russian market, and which can be used with limited information for analysis of private companies. The proposed methodology is based on benchmarking the operating profit margin of companies participating in a deal against the same variable for a portfolio of similar companies.

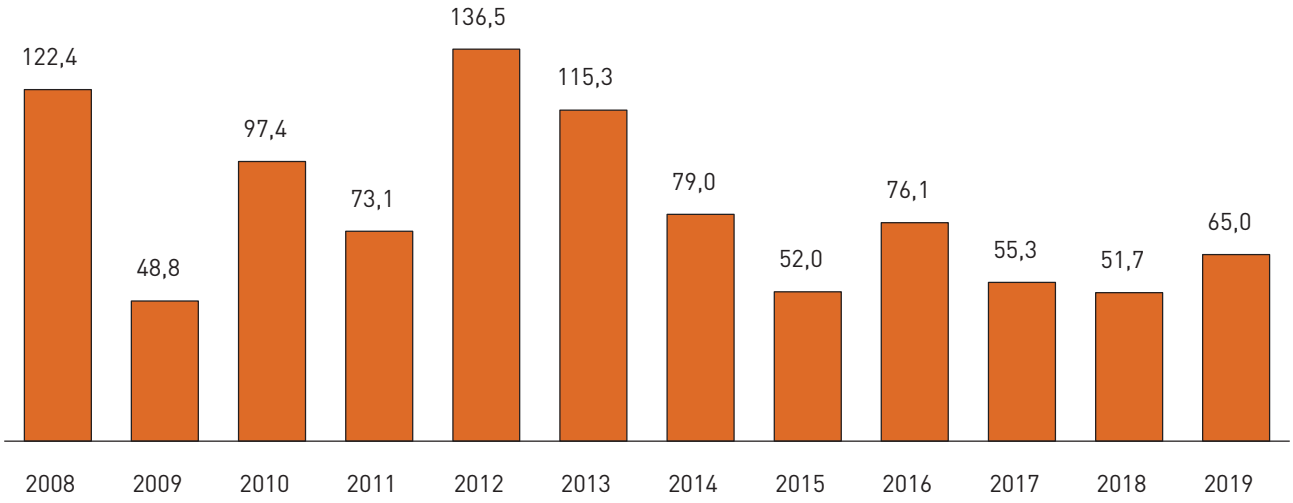
Based on the analysis of recent studies, several explanatory variables were proposed to explain the changes in operating profit margin after the deal. Among these were included real GDP growth, type and value of the deal, book value of assets of the target company, as well as a number of control variables. A random effects model with robust standard errors was used to test the significance of factors affecting operating profit margin. This methodology was applied to a sample of 73 domestic Russian deals observed in the period 2012-2019.

This research makes several practical contributions to the literature. In the studied sample, deals lead to an increase of operating profit margin by 4.6% relative to the period before the deal, and 2.5% relative to the benchmark portfolio. The highest growth of operating profit margin relative to the benchmark portfolio is observed 2 years after the deal. This growth is increased by the purchase of large companies in the same industry. There is a significant negative effect of the deal value and a strong indication that buyers tend to overpay for the target companies relative to their fair value.

This research will be of practical use for persons in management positions to estimate the value of prospective deals, and for academic researchers interested in the analysis of mergers and acquisitions in emerging markets.

Keywords: mergers; acquisitions; synergy; operating profit margin; market power, economies of scale; emerging markets
JEL: G34

Figure 1. Russian M&A market in 2008-2019, billion USD



Source: Author's analysis based on KPMG data

Introduction

Every year, a significant amount of assets is involved in mergers and acquisitions (M&A). In 2019, the global M&A market amounted to USD 4.1 trillion (-0.5% y/y).[1] Despite the decline in global M&A activity in 2019, companies continue to use M&A to strengthen their business, enhance the scale of their operations and better position themselves in the global market.

The Russian M&A market stagnated in the last 5 years. The economic sanctions against Russia adopted in March 2014 resulted in a decrease in domestic activity due to limited access to capital for many Russian companies. Low oil prices and the devaluation of the ruble at the end of 2014 further limited M&A activity. In 2019, the Russian M&A market amounted to USD 62.8 billion (670 deals)[2], which was over two times lower than in 2012 in terms of value.

The market is traditionally dominated by domestic deals, which accounted for 64% of market value in 2019. 33% of the market accounted for the purchases of Russian assets by foreign companies, and only 3% were the purchases of foreign assets by Russian companies.

For the ten year period preceding 2019, the Oil and gas industry has remained the largest industry in terms of value. This industry accounted for about a third of all Russian deals in 2019. Other major industries by the factor of total deal value are banking, IT, metals and mining, telecommunications, and media. More than 80% of all such deals were between private companies.[3]

Due to uncertainty about the future of the Russian economy, many M&A initiatives are currently postponed. In the current condition of the Russian M&A market, it has become increasingly important to analyse the prospects of potential M&A and, if possible, to better assess potential synergy. A topical research issue is the development of tools for empirical analysis of domestic deals, which takes into account the features of the national M&A market and which can be used with limited information about companies.

This study is devoted to the development and application of these tools on a sample of 73 domestic Russian deals observed in 2012-2019. The study also attempts to estimate the impact of several features of Russian M&A on operating profit margin. In this context, significant government involvement in the economy and high concentration of ownership in companies' equity capital (with control variables included in the econometric model), as well as the high share of domestic deals with the corresponding restriction are included within the sample.

Literature review

Shareholders expect the value of their company to increase as a result of M&A. This additional value can be driven by the improved performance of assets (higher revenue, lower expenses, etc.), reduced discount rate for future cash flows, or other reasons. Studying the performance after M&A is a simple approach to determining whether or not additional value was created.

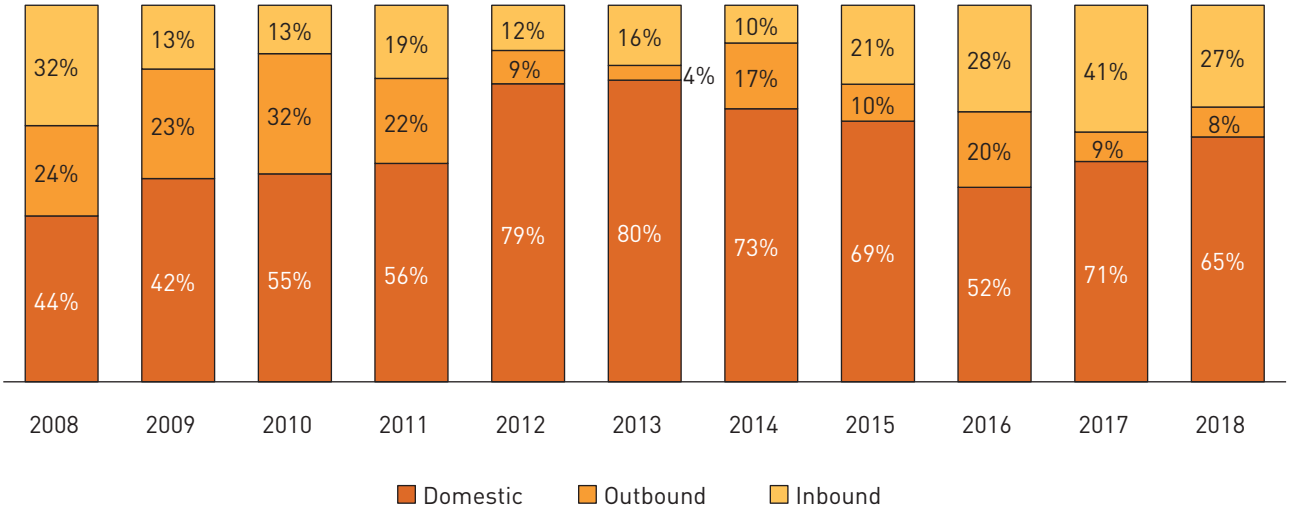
In the existing literature, there are several ways to examine specific changes in performance after M&A: first, examinations of ex-post stock price behaviour [1], [2]; second, studies of changes in specific characteristics of the firms [3]; third, studies of changes in operating performance [4], [5].

[1] J.P. Morgan 2020 Global M&A Outlook. Retrieved February 05, 2020, from https://www.jpmorgan.com/jpmpdf/1320748081210.pdf

[2] KPMG Russian M&A review 2019. Retrieved April 18, 2020, from https://assets.kpmg/content/dam/kpmg/ru/pdf/2020/02/ru-ru-ma-survey-2019.pdf

[3] Author's estimations based on Mergermarket.com data

Figure 2. Structure of the Russian M&A market in 2008-2019 by type, % of billion USD



Source: Author's analysis based on KPMG data

This study focuses on the analysis of changes in operating performance, in particular, changes in the operating profit margin of companies involved in M&A. The research design was similar to the one proposed in the recent paper by [5], which used return on assets and return on equity as the relevant performance indicators for analysis after the deal.

M&A can affect the profitability of companies involved in a deal in two ways. First, increased revenue with stable expenses indicates that a merged company strengthened its market power, and is thus able to set prices higher than marginal costs, or at another level allowed by the competition prior to the deal. Second, decreased expenses with stable revenue indicate that cost reduction synergies were achieved after the deal.

Market power in academic and applied research is usually measured with a market share or market concentration index (Herfindahl-Hirschman index).

Using market share as an indicator of market power, the research at [6] (for deals in the United States in 1997-2007) and [7] (for deals in Europe in 1996-2010) showed that a growth of market share leads to a significant increase in ROI while maintaining the same level of expenses.

Studies based on the PIMS database (Profit Impact of Market Strategy) confirm a positive correlation between profitability and market share. The first studies on this topic, for example, [8] showed that a 10% increase in market share leads to a 5% increase in profit margin before taxes. The study of recent PIMS data by [9] also noted a significant positive correlation between changes in market share and earnings.

Expenses can decrease after a deal due to the optimisation of production and duplicative business functions (HR, IT, accounting, procurement, administrative and other). The total output and revenue do not change. These cost economies are estimated, with the average costs, output elasticities, or cost elasticities considered.

A majority of studies confirm that consolidation and integration via M&A or other means lead to a cost reduction. This conclusion is supported by [10] in a study on international airports, [11] in European banking, and [12] for Russian natural monopolies.

This research attempts to estimate the significance of 4 variables that may explain the changes in operating profit margin after a deal. These variables are: changes in real gross domestic product (GDP), the type of deal (horizontal or vertical), the deal value, and the size of a target company.

Real GDP growth is correlated with the value of the national M&A market (see [13]), but may not affect M&A synergies. For example, [14] showed, on a sample of 132 M&A deals in the banking industry, that GDP growth is insignificant to the accumulated abnormal return of the buyer company's shares after M&A.

Horizontal transactions may increase operating profit margin by gaining greater market share and creating economies of scale. Vertical transactions aim to increase control over the value chain and increase operating profit margin by reducing the costs of products or services. Studies show that horizontal deals are more likely to increase operating profit margin. The research at [15], on a sample of 90 French listed companies M&A, and [16] on a sample of 434 Chinese M&A, both concluded that horizontal M&A lead to a cost reduction via economies of scale.

The increase in the deal value in most studies is associated with the destruction of synergy. For example, in [17] authors found a negative correlation between the size of the deal and the operating profit margin of the company after the deal. This may be explained by the systematic overpayment in the acquisition of large companies.

There are different views in the academic literature on the impact of the size of a target company on improving profitability after M&A. One hypothesis is that the acquisition of a large company may create economies of scale, market power, and other types of synergies. On the other hand, large transactions may reduce the operating profit margin

because of the complexity of integrating a large company into the overall business.

In the existing literature on the subject, the Russian M&A market is usually included in the samples of M&A projects in BRICS countries. Among examples in recent literature, [18] studies the impact of M&A on corporate debt, [19] – on companies' fundamental values, and [20] – on bidders' returns in financial sector.

Research hypotheses

After the analysis of relevant academic literature, 5 hypotheses related to the impact of M&A on operating profit margin were formulated and tested in this study (Table 1). The expected signs for hypotheses are based on the assumption that signs of explanatory variables are the same in the Russian M&A market as they are in other M&A markets, as studied in the existing literature.

Table 1. Research hypotheses

Hypothesis	Variable	Expected sign	Literature
1. Operating profit margin increases after M&A	Operating profit margin adjusted for a benchmark based on matching companies	Positive	[17]
2. Economic growth increases operating profit margin	Real GDP growth in Russia	Positive	[14]
3. M&A between companies in the same industry increase operating profit margin	Dummy variable (1 for horizontal deals)	Positive	[15], [16]
4. More expensive M&A reduce operating profit margin	Natural logarithm of deal value	Negative	[17]
5. M&A of larger companies increase operating profit margin	Natural logarithm of target company assets value	Positive	[21]

Source: Author's analysis

Data and methodology

In order to compile the sample for this research, information was taken from several commercial databases (Mergermarket, SPARK-Interfax, Bloomberg), open government data (Rosstat, Central Bank of Russia), as well as unstructured information from the websites of the companies involved in the relevant transactions.

Initial data on domestic M&A transactions were provided by the Mergermarket database. The total number of completed domestic transactions is 309. The initial sample includes all domestic deals in the database completed in the period under review. Transactions between companies in regulated industries and the financial industry were excluded from the initial sample due to the features of reporting and operating profit margin measures in these industries.

Data on the financial performance of companies involved in M&A were collected from SPARK-Interfax and Bloomberg databases. Financial data used to calculate operating profit margin included revenue and operating profit details. The primary sources of financial information for the SPARK-Interfax and Bloomberg databases were annual profit and loss statements.

The sample included financial indicators for 7 years: 3 years before M&A, in the year of M&A and 3 years after M&A. If during the 3 years after the deal one or both companies were involved in another M&A transaction, terminated operations, or did not publish data needed for the analysis, the time period was reduced to obtain comparable data.

The time period under review was at least three years (a year before M&A, a year of M&A and a year after M&A). It was assumed that the operating profit margin is affected within no more than three years from M&A completion date.

M&A deals where the book value of the target company's assets in the year of M&A was less than 5% of the buyer's assets were also excluded. Following the example of [22], it was assumed that M&A deals have a significant impact on the buyer's operating profit margin only under this restriction. The final sample contains 73 deals and 446 individual observations of operating profit margin in 2012-2019.

A detailed description of all reasons for excluding M&As from the general sample is provided in Table 2.

All deals included in the final sample involved an acquisition of the controlling stake. 23 deals also involved integration of businesses after a deal. The composition of the initial and the final samples is provided in Table 3.

Table 2. Excluded deals and the final sample

Reasons of exclusion	Number of deals
Initial sample	309
No financial statements	59
Deals do not change the holder of the controlling stake	57
Deals between companies in the financial industry	43
Target company asset value is less than 5% of the buyer's assets value	24
Deals between companies in regulated industries	15
Cross-border deals	14
The buyer ceased operations within one year after M&A	9
Acquisition of separate assets	6
Other reasons (duplicates, lack of information about the buyer, etc.)	9
Final sample	73

Source: Author's analysis

Table 3. The composition of the initial and the final samples

	Initial sample	Final sample
Total deals	309	73
Payment		
Cash	128	28
Shares	9	2
No data	172	43
Primary industry		
Consumer and agriculture	53	13
Banking and insurance	40	0
Oil and gas	32	7
Telecoms and media	28	9
Real estate and construction	26	14
Manufacturing	24	9
R&D and technologies	18	2
Transport	17	8
Metals and mining	13	4
Other	58	7
Deal value, million USD		
Average	549	710
Median	112	133
Minimum	5	14
Maximum	11 270	8 411

Source: Author's analysis

The operating profit margin for every deal was measured as the sum of operating profit margins of buyer and target companies weighted by their revenue before and after the deal.

$$\text{Operating profit margin}_{it} = \frac{EBIT_{i,t,buyer}}{Revenue_{i,t,buyer}} \cdot \frac{Revenue_{i,t,buyer}}{Revenue_{i,t,buyer} + Revenue_{i,t,target}} + \frac{EBIT_{i,t,target}}{Revenue_{i,t,target}} \cdot \frac{Revenue_{i,t,target}}{Revenue_{i,t,buyer} + Revenue_{i,t,target}}$$

where i is the index of deals and t is the index of time (years of observation for each deal). These data were from the annual financial statements of buying and target companies. After the deal, if available, the consolidated financial statements of the buyer were used to calculate operating profit margin for both companies.

To account for the differences in operating profit margin in various industries, the operating profit margin of the benchmark portfolio of comparable companies for every deal was also calculated.

The benchmark portfolio included 4 companies in the same industry under the three-digit code of OKVED and with the closest revenues to the companies involved in the deal. On average, in the year of the deal, the average revenue of benchmark companies was 11.8% higher than the revenue of companies involved in the deal. For 9 out of 73 deals in the sample, the control group included 3 companies due to the lack of sufficient number of comparable companies.

If the companies involved in the deal operated in different industries, a benchmark portfolio of companies was formed for both the buyer and the target for the most relevant comparison. The operating profit margin of the control portfolios was weighted according to the revenues of the companies involved in the deal. This approach to benchmarking is similar to the method used in [23].

For example, for a deal between a target company with 2 billion rubles revenue and a buyer company in a different industry with 3 billion rubles revenue the control portfolio consists of 8 companies. The first 4 control companies will match with the industry of the target company and 2 billion rubles revenue. The next 4 control companies will match with the industry of the buyer company and 3 billion rubles revenue. The weight in the portfolio of the first 4 companies will be (2 billion rubles / 5 billion rubles) = 40%, the second 4 companies (3 billion rubles / 5 billion rubles) = 60%. This calculation is made for each year of observation before and after the deal.

Summary statistics of explanatory variables are provided in Table 4.

Table 4. Summary statistics of variables in the baseline model

Variable		Mean	Std. Dev.	Min	Max	Observations
Operating profit margin of companies in M&A	overall	0.107	0.117	-0.051	0.332	N = 443
	between		0.100	-0.051	0.332	n = 73
	within		0.064	-0.127	0.294	T-bar = 6.110
Real GDP growth in Russia	overall	0.011	0.020	-0.025	0.043	N = 446
	between		0.004	0.000	0.014	n = 73
	within		0.019	-0.029	0.039	T-bar = 6.110
Dummy variable for horizontal M&A	overall	0.706	0.457	0.000	1.000	N = 446
	between		0.470	0.000	1.000	n = 73
	within		0.000	0.706	0.706	T-bar = 6.217
Natural logarithm of deal value in mln USD	overall	5.049	1.531	2.590	9.037	N = 226
	between		1.572	2.590	9.037	n = 38
	within		0.000	5.049	5.049	T-bar = 5.947
Natural logarithm of target company assets value in mln RUB	overall	8.764	1.721	3.481	13.291	N = 446
	between		1.692	4.457	13.001	n = 73
	within		0.395	7.301	10.332	T-bar = 6.041

Source: Author's analysis. Note: 35 deals had no information about the deal value

The significance of explanatory variables was assessed with a random individual effects data model. This model was chosen because of the presence of a time-independent dummy variable and was recommended by Breusch-Pagan and Hausman tests. Due to the presence of heteroscedasticity, the model was estimated using robust standard errors. No multicollinearity was found in the model with the variance inflation factor (VIF) test in Stata 14.

The general equation for the model is formulated as follows:

$$Operating\ profit\ margin_{it} = \alpha + \beta_1 \times hypothesis_{it} + \\ + \beta_2 \times control_{it} + u_i + \varepsilon_{it}$$

Where *hypothesis* is the set of explanatory variables for hypotheses testing, *control* is the set of control variables, u is the set of individual effects and ε is the random variable.

For robustness checks, the base model was estimated separately with three groups of control variables: characteristics of the deal, the target company and the buyer. The characteristic of the deal is the share in the equity of the target company after the deal. The characteristics of the target company are operating cash flow and capital expenditures. The characteristics of the buyer are operating cash flow, capital expenditures, the presence of a foreign shareholder in the equity capital and the presence of the government in the equity capital. This approach to robustness checks with groups of control variables is similar to the one proposed and used in [24].

Results

Median operating profit margin of the companies involved in the deal and the benchmark portfolio is provided in Figure 3.

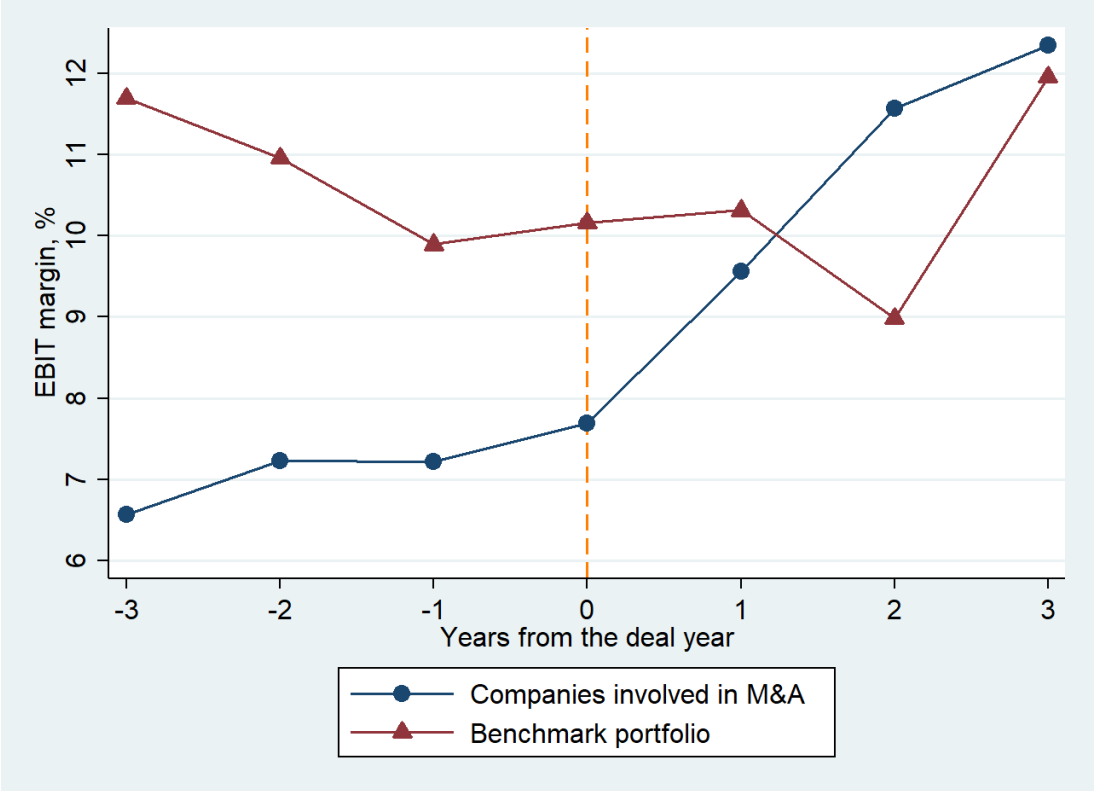
Before the M&A, the operating profit margin of the companies involved in the deal is lower than the benchmark portfolio. The difference ranges from -5.1% 3 years before the M&A to -2.2% in the year of the M&A.

M&A deals lead to a significant improvement in the operating profit margin. Over 3 years after M&A, operating profit margin increases from 7.7% to 12.3%. The greatest effect relative to the benchmark portfolio is achieved 2 years after M&A.

The improvement of operating profit margin occurs thanks to an abnormal increase in revenues in comparison to expenses. In the first year after M&A, companies' revenues grew by 8.6%, while operating expenses grew by 8.1%. In the second year, revenue grew by 7.0%, while expenses decreased by 0.8%.

At a significance level of 5% this supports the hypothesis that M&As create opportunities for the company to receive excessive profit, in comparison to the control group of companies. This hypothesis was tested with the Wilcoxon test [25] for the operating profit margins of the companies involved in M&A and operating profit margins of the matched benchmark portfolios.

Figure 3. Median operating profit margin for the companies involved in M&A and the benchmark portfolio



Source: Author's analysis

The results of econometric testing of research hypotheses 2-5 are provided in Table 5.

The results show that M&A between large companies in the same industry improve operating profit margin the most. According to the base model, horizontal M&A lead to 11.4% increase in operating profit margin compared to vertical M&A (10% significance level). A 1% increase in the target company book value of assets leads to a 5.7% increase in operating profit margin (5% significance level).

The decrease of operating profit margin is associated with the deal value: a 1% increase in the deal value leads to a 8.3% decrease in operating profit margin (1% significance level). In addition, the negative effect of the deal value is higher than the positive effect of the target asset value, which may indicate overpayment relative to the fair value by the buyers.

Models with three groups of control variables were additionally evaluated to test the robustness of the results. Robustness checks confirm the estimates obtained in the base model: signs and impact of significant variables in the base model do not change with the addition of control variables.

Thus, from the perspective of improving operating profit margin with domestic transactions, horizontal M&A with large companies are the most attractive targets. At the same time, it is necessary to accurately assess the fair value of the target so that the deal value does not absorb potential synergy.

Table 5. Econometric testing of research hypotheses

Variable	(1) Baseline model	(2) First group of control variables	(3) Second group of control variables	(4) Third group of control variables
Baseline model with 4 explanatory variables				
Real GDP growth	-0.517	-0.515	-0.532	-0.378
	(0.507)	(0.506)	(0.591)	(0.594)
Horizontal M&A	0.114*	0.106*	0.109	0.149
	(0.066)	(0.063)	(0.069)	(0.094)
Natural logarithm of deal value	-0.083***	-0.088***	-0.081***	-0.082***
	(0.027)	(0.028)	(0.029)	(0.027)
Natural logarithm of target company assets value	0.057**	0.059**	0.056**	0.040***
	(0.024)	(0.025)	(0.029)	(0.015)
Control variable for the deal				
Share in the equity of the target company after the deal	-	0,183	-	-
		(0,193)		
Control variables for the target company				
Natural logarithm of operating cash flow of the target	-	-	0.014	-
			(0.009)	
Natural logarithm of capital expenditures of the target	-	-	-0.005	-
			(0.006)	
Control variables of the buyer company				
Natural logarithm of operating cash flow of the buyer	-	-	-	0.022
				(0.019)
Natural logarithm of capital expenditures of the buyer	-	-	-	0.000
				(0.005)
Government in the buyer's equity capital	-	-	-	-0.121*
				(0.066)
Foreign shareholder in the buyer's equity capital	-	-	-	-0.106
				(0.077)

Variable	(1) Baseline model	(2) First group of control variables	(3) Second group of control variables	(4) Third group of control variables
Control variables	Not included	Included	Included	Included
Constant	-0,014 (0,121)	-0.171 (0.203)	-0,069 (0.122)	-0,027 (0,087)
Observations	446	446	446	446
Deals	73	73	73	73
Significance (chi-squared)	0,033**	0,056*	0,000***	0,000***
Overall R-squared	0,177	0,236	0,150	0,395

Source: Author's analysis. Note: figures in brackets are the robust standard errors.
Significance levels: *** p<0.01, ** p<0.05, * p<0.10. Significance levels were calculated with t tests.

Conclusion

The result of the study was an assessment of the impact of domestic M&A on operating profit margin and several explanatory factors according to the proposed methodology. The object of the study were Russian companies directly involved in domestic M&A.

Based on the existing research, an approach to operating profit margin assessment was proposed. Changes in operating profit margin were assessed during 7 years of monitoring of companies involved in M&A. An econometric model based on data with random individual effects was developed, the significance of explanatory factors was assessed.

The most salient result of the study is that there is a significant positive impact of M&A on operating profit margin. Our evidence supports the view that M&A can improve the operating performance of companies. In the domestic Russian M&A market, the operating profit margin of companies improves after horizontal deals between large companies, in line with previous research of other M&A markets ([15], [16], [17], [21]). However, in Russia, unlike many other countries (see [13]), real GDP growth does not impact the size of the national M&A market in value terms or the operating profit margin of companies after deals.

One of the directions for development of this research is the addition of other explanatory variables in the econometric model. The developed methodology can also be applied to M&A in other countries to analyse the features of other M&A markets.

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Assessment of Measures for Tax Regulation of Transfer Pricing from the Standpoint of National Welfare

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 80-90 (2020)
DOI: https://10.0.67.171/j.jcfr.2073-0438.14.1.2020.80-90
Received 18 February 2020 | **Peer-reviewed** 24 March 2020 | **Accepted** 27 March 2020

Assessment of Measures for Tax Regulation of Transfer Pricing from the Standpoint of National Welfare

Abstract

This article is devoted to development of mathematical models for resolving an actual scientific challenge in the field of corporate finance. This involves substantiating taxation policies for the counter-acting tax planning of multinational companies (MNC), and then devising and articulating the appropriate international taxation scheme, as evaluated from the position of national welfare policy. Based on an analysis of existing models of international taxation, and on the peculiarities of the actual mechanism of capital movement tax regulation, new models with equilibrium postulated have been developed.

The primary mechanisms of this research involve the following considerations: (1) examination of an approach targeted at the determination of the final outcomes of international taxation from the perspective of national economies; (2) measures of tax planning on the part of MNCs, and corresponding counter-acting measures to the tax planning applied by governments, are taken as a complex.

Our results indicate that because a government uses rules of controlled transactions, in order to counter-act MNCs' tax planning, for the government the final outcome from an application of these rules may be negative. This is due to a possibility of MNCs' development in convenient and offshore jurisdictions. This finding is illustrated by means of an approbation of models with a case study involving a three-tier structure.

Further to this point, instead of additional revenues, a government is at a risk of a shrinking tax base and a reduction in budget revenues; and moreover from the perspective of national welfare, the additional loss of revenues and capital of MNCs. Therefore there is a significant importance in forming rules for MNC taxation policies which would focus not on taxes as such, but would focus on trying to keep capital within the territory and/or would facilitate the return of earlier divested income. This could be attempted, for example, by using the secondary adjustment rule in conjunction with a minimum tax on return.

The novelty of this research resides in the specificity of our investigation and the applicability of our conclusions to the practical challenges of international taxation and national revenue policies. The peculiarities of this economic moment and the crucial challenges for national governments in dealing with MNCs and the digital economy underline the significance of this study. Our results expand and develop the existing literature in this ever-crucial area be of immediate use to policymakers, academics and administrators involved in national and international taxation, finance, economics, and analysis.

Keywords: international taxation, economic-mathematical modeling, multinational company, tax planning, rules of controlled transactions, withdrawal of revenues, return of revenues, transfer pricing, national welfare
JEL classification: C620, F230, H320, G17, G18

Introduction

The problems posed by the taxation of multinational companies (MNCs), and how to address these using economic-mathematical modeling, is constantly in the focus of scientists and practitioners. This entire area is naturally subject to the contingencies (and vagaries) of globalisation, with increased competition for capital, huge volumes of international trade [1, p. 10–11], transborder investment [2, p. 2] and influence of taxation policy on international capital flows all being significant influential variables. One of the recent examples of activity in this area is in the area of tax reform in the USA, which aims at providing conditions for repatriation of capital [3].

A range of empirical evaluations given in paper [4] shows that susceptibility to direct taxes is also a significant variable: a reduction in taxes by 1 percentage point results in an increase of foreign direct investment (FDI) by 3.72%. Consequentially, over the course of time, FDI becomes more susceptible to taxes [4, p. 12].

This means that taxation of capital and income of MNCs, along with other factors, is a valuable reason which defines their flow. Due to the digital revolution and the accelerated development of cyber physical enterprises, transborder business activity has risen sharply. It influences intangible assets, users and business functions, and the flexibility of corporate entities in choosing the location of resources and capital [5, p. 33–34]. As such, new opportunities have arisen for building more effective systems of international trade and MNC tax expenditure reduction. This induced various governments to take measures towards counteracting new methods of tax avoidance and distortions of competition [6; 18]. The purpose of this research is to substantiate (on the basis of the author's economic-mathematical models) the most efficient measures of government taxation policy intended to clamp down on tax avoidance by MNCs that use transfer pricing (TP), and to devise a favourable taxation scheme for both keeping capital inside the country and attracting capital into it. Unlike our predecessors, we assess the influence of tax regulation on MNCs from the point of view of national welfare, taking into consideration the behaviour of MNCs in the area of taxation.

Methods

Types of MNC Taxation Models

A variety of MNC taxation models exist based on the neoclassical investment theory. These models are of special interest from the standpoint of achieving our goal in this study. According to the method of determination of economic equilibrium, we distinguish calculable equilibrium models [4, p. 155–181; 7; 8] from postulated equilibrium models [9; 10; 11; 12]. According to the types of financial structure, there are bilateral (direct) holding structure models and three-tier structure models with an intermediary (usually offshore) [4, p. 129; 7, p. 91–100]. In the case of economic equilibrium, there are tax rate equilibrium models [10; 11; 12], company income equilibrium models [8; 9] and jurisdiction income equilibrium models [8].

H. Grubert [9] in his paper, uses a number of scenarios to simulate the events when the amount of payment of interest and royalty to the parent company is undervalued and the company's savings on tax is calculated. However, at the same time, the issue of shortfall in income of the home jurisdiction is not considered, and the possibility of income reverse adjustment by the government is not taken into consideration. The author does not analyse the possibility of company manipulation with active income. This makes it impossible to estimate the efficiency of the government counteracting the tax planning methods of MNCs from the point of view of the economic welfare of the country.

Paper [8] evaluates the influence of controlled company rules and thin capitalisation on the amount of MNC taxes and income from the standpoint of both the country's welfare and MNCs' welfare. However, this is approached as a common neoclassic assumption, i.e. of economic operators' maximising behaviour by means of differentiation on the basis of tax rates, and finding the extremum of the welfare function. There is no separation into active and passive income as concerns how different taxation approaches are applied. Besides, the formula [8, p. 10–12] does not take into account the fundamental rules of controlled transactions. For this reason, the model does not take into consideration the amount of divested and returned income and capital, thus impeding a realistic estimate of welfare concerns.

The fundamental research by the OECD [4] does not fully present the approach from the point of view of return of previously divested income. Six cases of tax planning are considered, mainly by means of in-company credit provision.

Our research develops the scientific-methodological approaches of D.W. Jorgenson [14], J. Whalley [10], H. Grubert [9], but it takes into consideration issues which have not been amply covered in their papers. The point at issue is an assessment of MNC tax planning countermeasures applied by governments of various countries. Against this background, we raise the problem of loyal jurisdictions, with taxation policy parameters that enable MNCs to avoid taxes divesting capital through their subsidiary companies.

In order to achieve the research goal, we offer to use postulated equilibrium simulation models analysing three-tier financial structures (comprising subsidiary companies in loyal jurisdictions and affiliated persons in offshores). This approach aims to help take better account of the institutional factors, and describe the business situation using rather simple formulas, which are easier to interpret economically. We start with income equilibrium models for enterprises after tax (as basic ones) and then pass on to more complicated models with jurisdiction income equilibrium. This choice is explained by the fact that our

approach aims at the correct determination of the final results of MNC taxation from the point of view of national economies when indicators of private and public sector of the economy are taken into consideration, characterising the total resources of economic development left in the country and those resources which are received from abroad.

Economic Statement of the Problem and Description of MNC Taxation Models

We analyse three tax jurisdictions: common - A (territory of the country from which the situation is estimated), loyal – B (with a weak anti-offshore legislation), and a tax haven – C. There is also a MNC – a parent company, resident of A's territory. This parent company opens a subsidiary company (the parent owns or controls more than 50% of its property) in a loyal jurisdiction *B*, which conducts active economic operations. We assume that tax planning methods of MNCs may change by means of using affiliated companies opened by the parent company (A) and the subsidiary company (B) (indirectly) in the tax haven C. The territory of C is used to conceal income and avoid taxes, and as such there are no real business operations here. Companies may apply (or not apply, or apply with limitations) common methods of tax planning including transfer pricing. At another point, governments may employ corresponding countermeasures categorised herein as *Special Anti-Avoidance Rules*: first of all, controlled transactions rules and secondary adjustment rules intended to counteract tax avoidance using transfer pricing [15; 16][1].

Let us introduce some designations. Assume that the net profit (income) margin of the parent company in country A is D_A, and the net profit (income) margin[2] of the subsidiary company in country B is D_B. The condition of economic equilibrium is observed if

$$D_A = D_B k_B; \quad k_B > 0.$$

In the general case, as long as we have a simulation model, $D_A \neq D_B$. Our goal is to study the influence of taxation policy, therefore we proceed to an analysis of the situation when $k_B = 1 \Rightarrow D_A = D_B$.

One of our research tools is *factors*. Arithmetically, they are a share of the total net profit (income) margin for which the company (applying transfer pricing) and the country (by means of controlled transaction rules) changes such income:

$$\Delta\varphi = (\varphi_c - \varphi_g),$$

where $\varphi_c = \frac{D'}{D}$ – the corrigent factor which defines the part of income (D'), divested by the company from tax with respect to the total amount of its taxable income D;

$\varphi_g = \frac{D''}{D}$ – the adjusting factor which defines the part of income (D''), returned by the government of the country to taxation against the total amount of the company taxable income D;

$\Delta\varphi$ – the resulting balance after such corrigent actions and adjustments (in the normal course of events $\varphi_c \geq \varphi_g \Rightarrow \Delta\varphi \geq 0$).

Let us define that hereinafter all *D* are the normal net income margin generated on the basis of market prices, which later may be corrected by MNCs by the value of D' and then corrected back by the value of D'' by countries.

Types of income:

economic operations D (comprises active and passive income taken into consideration in the formulas separately due to differences in their taxation);

passive income in the form of: dividends D_S, royalty D_R, interest D_I.

Tax rates:

t_{AA}, t_{BB} – effective (average) tax rates for net profit (income)[3] [17, p. 99];

t^n_{AA}, t^n_{BB} – nominal rates of corporate income tax;

$t_{S_{BAA}}$, $t_{R_{BAA}}$, $t_{I_{BAA}}$ – effective rates of passive income tax (in this case – taxes paid by a subsidiary company from the loyal country B to the parent company to country A subject to taxation in country A – see suffix number BAA); these tax rates are obtained as a result of change of nominal rates for some reasons $(t_{X_{BAA}} = f(t^n_{X_{BAA}}))$;

$t_{S_{BAB}}$, $t_{R_{BAB}}$, $t_{I_{BAB}}$ – nominal rates of tax on repatriation of dividends, royalty, interest, correspondingly, which is withheld at source (in this case in country B – see suffix number BAB);

$t^+_{I_{ACA}}$, $t^+_{S_{ACA}}$, $t^+_{S_{BAA}}$ – effective rates of supplementary taxes on some types of MNC income introduced by governments as tax avoidance countermeasures.

[1] The point of secondary adjustments is that the government tries to make up for losses related to retention of MNC income abroad, considering it as a kind of assets, and subject to taxation on imputed income.

[2] The net profit (income) margin may be expressed as relative values (as a percentage ratio of income from investments to the sum of such investments) and also as absolute values (as the sum of income earned on the preassigned sum of investments). For convenience of economic interpretation hereinafter we will interpret D as a certain sum of net profit (income) (for example, 100 y.e.) induced by such fixed investment amount.

[3] In this case, we understand the effective tax rate on net income as a certain equated percent of seizure of profits of a typical enterprise (enterprise-representative), under the influence of all taxes provided for in the national legislation (not just the corporate income tax). That is, in the interpretation of Paying Taxes: "Paying Taxes take into consideration all taxes and duties established by the government (at any level: federal, governmental or local), applied to standardised business and influencing its financial statements" [17, p. 99].

According to OECD specialists [7, p. 14], from the point of view of an empirical evaluation of tax influence on FDI, historic average effective tax rates (*AETR)* give more relevant values and are a better predictor than predicted marginal effective tax rates (*METR)*. They are all the more better than nominal tax rates established by law which do not take into consideration tax planning effects and special tax regimes. As such, the most general expression of the main tool used in modeling - *AETR* - becomes as follows:

$$AETR = \frac{D - D(1-\Delta\varphi)(1-t)}{D} = 1-(1-\Delta\varphi)(1-t),$$

provided that $D > 0$.

When comparing AET*R* of countries A and B the equilibrium formula may be represented as follows:

$$AETR_A = AETR_B,$$

$$1-(1-\Delta\varphi_A)(1-t_A) = 1-(1-\Delta\varphi_B)(1-t_B).$$

A similar formula was offered by H. Grubert [9], however in addition to the possibility of a correction of MNC income taken into consideration in his paper, we added the possibility of reverse correction of such income by the government. Further, we will compare not just tax rates in interacting countries (taking into consideration MNC correction and corrections made by governments) but rates of return (initially $D_A = D_B$) which remain available to enterprises of various countries:

$$D_A(1-\Delta\varphi_A)(1-t_A) = D_B(1-\Delta\varphi_B)(1-t_B).$$

This and subsequent equilibrium formulas may be used to calculate the effective tax rates of the actually earned income and to substantiate the conclusions on the policy directions. Further analysis is dedicated to evaluation of changes of underlying situations under the influence of tax planning methods of MNC and countermeasures taken by the governments – i.e. controlled transactions rules.

General Formula of Calculation of Income from the Standpoint of MNC Taking into Consideration Divested Income

In a general way the income of the parent company in country A (or a similar subsidiary company in country B) may be represented as follows:

$$D^c = D(1-\Delta\varphi)(1-t) = D - D\Delta\varphi \; -$$

$$-Dt + D\Delta\varphi\, t = D \; - F \; - T^g + T^{c+}.$$

The income of the company remaining in this country (D^c) is defined as total income (D) net of divested "grey" income (*F*) and tax paid (T^g) plus the sums saved by MNC by means of tax planning (T^{c+}) (in other words – government's losses).

From the point of view of MNC net income, formula (6) is incomplete, as it does not take into consideration the share of divested income of MNC. In order to make a more accurate calculation of the total income of MNCs, and to evaluate the economic equilibrium taking into consideration the offshore factor expression (6) should be increased by *F,* which characterises the share of income divested to offshore C:

$$D^c_{all} = D^c + F = D(1-\Delta\varphi)(1-t) +$$

$$+D\Delta\varphi = (D \; - F \;) - (T^g - T^{c+}) + F \; .$$

Income transferred to offshore C is actually MNC income divested from these countries in order to reduce the taxable base. Undervaluation by MNCs of the goods' market value by the part of the total income φ_{AC} when exporting from country A to country C helps to shrink the taxable base in the native country $D_A(1-\varphi_{AC})$, and to increase income in the offshore C by the same value $D_A\varphi_{AC}$, because the goods will be sold later at the market price and the non-taxable margin will stay in the offshore C. Even if we take into account that governments using controlled transaction rules may correct income for taxation purposes, the untaxed income will amount to $D_A\Delta\varphi_{ACA}$, where $\Delta\varphi_{ACA} = \varphi_{AC} - \varphi_{ACA}$, and φ_{ACA} – amount of correction of the divested income by country A.

Now such income may also be a "grey" income and (or) "grey" capital which does not return to the country's economy later, makes no positive contribution in the native country, and is in fact used in the economy of other countries. Consequently, application of the corrections methods within controlled transaction rules from the standpoint of national welfare may be ineffective, even if the government completely reestablishes the taxable base. In this case, corrections will be made only for the taxation purposes: $\Delta\varphi_{ACA} = \varphi_{AC} - \varphi_{ACA} = 0$, however from the point of view of counter-action, of income outflow, or its return, they are inefficient: $\varphi_{ACA} = 0$. Consequently, $\Delta\varphi_{ACA} = \varphi_{AC}$, and income outflows from the country in full. In such scenarios the non-returned "grey" income:

$$F_A = D_A\varphi_{AC} + D_A\varphi_{R_{AC}} + D_A\varphi_{I_{AC}} + D_{R_{CA}}\varphi_{R_{CA}} + D_{I_{CA}}\varphi_{I_{CA}}$$

is the result of application by MNCs of transfer pricing methods as regards active transactions $(D_A\varphi_{AC})$, as well as passive income $(D_A\varphi_{R_{AC}}, D_A\varphi_{I_{AC}}, D_{R_{CA}}\varphi_{R_{CA}}, D_{I_{CA}}\varphi_{I_{CA}})$.

Now the reasons why MNC operations have a negative impact on the economy of country *A* become clear: a significant part of capital is absorbed irretrievably into offshore *C,* and the income which remains in the country is reduced even more by the supplementary tax. Further we will consider a complicated situation taking into consideration repatriation taxes and passive income.

Explicit Model of Income Equilibrium from the Standpoint of MNC, taking Divested Income into Consideration Let us consider a more general scenario in which:

1) the parent company invested in tangible and intangible assets of a subsidiary company, and also disbursed a loan to it (purchased debt securities). The income earned by

the subsidiary company in country B is repatriated in the form of dividends D_S, royalty D_R and interest D_I to country A. The parent company may also get intangible assets and loans from the subsidiary company and, consequently, the parent company pays royalties and interests to the subsidiary;

2) the parent and a subsidiary company conduct active and passive transactions with affiliated companies opened in offshore *C*, but along with this they do not make direct investments in these companies, so the company in offshore *C* pays no dividends to companies in country A and B. All economic relations in combinations A-C and B-C are limited by crediting and transfer of intangible assets from the company from offshore *C* to the companies from countries A and B and, consequently, by payment of royalty and interests to offshore *C* as well as by back-to-back similar transactions of C-A and C-B;

3) the parent and a subsidiary company carry out economic operations using transfer pricing through an affiliated company in offshore *C*. This helps to correct the tax base for a certain part of the rate of return. The governments restore the taxable base. In this case, the tax equilibrium model becomes as follows:

$$D_A^{all} = D_B^{all}$$

or

$$D_A^m + D_{S_{AB}}^p + D_{CA}^p + F_{AC} = D_{S_{BA}}^m + D_{BA}^p + D_{S_{CB}}^p + F_{BC},$$

where $D_A^m, D_{S_{BA}}^m$ – the net income from active business operations of the parent and subsidiary company in countries A and B, respectively;

$D_{CA}^p, D_{S_{CB}}^p$ – the net passive income received, respectively, by the parent and subsidiary company from affiliated companies from offshore C;

$D_{BA}^p, D_{S_{AB}}^p$ – the net passive income received by the parent and subsidiary company, respectively, from each other;

F_{AC}, F_{BC} – the total amount of "grey" income divested by the parent and subsidiary company (from all active and passive transactions) to offshore *C* net of passive income repatriation taxes (see Note 1).

It is clear from the presented equilibrium model that the amount of divested passive income is reduced by its repatriation tax. The amount of income divested from country *A* to offshore *C* will be

$$F_{AC} = D_A\varphi_{ACA} + D_A\varphi_{R_{ACA}} + D_A\varphi_{I_{ACA}} +$$
$$+D_{R_{CA}}\varphi_{R_{CAA}} + D_{I_{CA}}\varphi_{I_{CAA}} -$$
$$-(D_A\varphi_{R_{AC}}t_{R_{ACA}} + D_A\varphi_{I_{AC}}t_{I_{ACA}}).$$

In this scenario, we proceed from the premise of the equilibrium of MNC income earned in countries A and B, regardless of the company which owns it (plus the income gained from offshore *C*). Further, we will consider the problem from another point of view – from the standpoint of national welfare of country *A*.

National Welfare Model in Case of Divestment of MNC Income to Offshore

All the models considered above are preliminary, they evaluate economic interests from the MNC point of view. National interests are much more than interests of economic operators from the private sector. Here, we should give consideration only to the income which pertains to the territory of a certain country acting as the source of wealth (e.g. financing of labour and capital, social sector etc.). Approaching the problem this way changes the logic of the mathematical modeling significantly. In the simplest case, the function of national welfare may be defined as follows:

$$D^{w} = D\ (1-\Delta\varphi)(1-t\ ) + D\ (1-\Delta\varphi)t\ = D^{c} + T\ .$$

The fundamental difference of this model from the basic model (5) consists in the fact that in this case, net income is taken into consideration along with taxes imposed by governments. In a more general situation, considering three countries as sources of income – A, B and C, the national welfare of country *A* is defined as follows:

$$D_{ABC}^{w} = D_{ABC}^{c} + T\ ,$$

where D_{ABC}^{c} – the sum of income gained from three countries (unlike previous scenarios where only the company income from the country of incorporation and offshore *C* was taken into consideration. The total income of country *A*, taking into consideration tax revenues of the government amounts to the following:

$$D_{ABC}^{\tilde{w}} = D_{ABC} + T =$$
$$= D_A^m + (D_{S_{BA}}^m + D_{S_{CB}}^p + D_{S_{AB}}^p + D_{BA}^p) + D_{CA}^p + T_{ABC}^g - T_{ABC}^{c+},$$

where income $D_{S_{BA}}^m, D_{S_{CB}}^p, D_{S_{AB}}^p$ are dividends received by the parent company from the subsidiary company (income is divided into component parts due to the specific character of its accrual).

Taxes collected by the government of country *A* consist of taxes imposed on the income gained in countries *A*, B and C, and of the taxes repatriated to countries B and C, reduced by the amounts saved by MNCs due to tax planning.

$$T = T_{ABC}^g - T_{ABC}^{c+} = (T_A^m + T_{ACA}^p + T_{ABA}^p) +$$
$$+(T_{S_{BAA}}^m + T_{S_{CBA}}^p + T_{S_{ABA}}^p + T_{BAA}^p) + T_{CAA}^p =$$
$$= [(T_{AC}^m - T_{AC}^{m+}) + (T_{I_{ACA}}^I + T_{R_{ACA}}^R) + (T_{I_{ABA}}^I + T_{R_{ABA}}^R)] +$$
$$+[(T_{S_{BAA}}^m - T_{S_{BAA}}^{m+}) + ((T_{S_{BAA}}^{I_{CB}} + T_{S_{BAA}}^{R_{CB}}) - (T_{S_{BAA}}^{I_{CB}+} + T_{S_{BAA}}^{R_{CB}+}) +$$
$$+(T_{S_{BAA}}^{I_{AB}} + T_{S_{BAA}}^{R_{AB}}) + (T_{I_{BAA}}^{I_{BA}} + T_{R_{BAA}}^{R_{BA}})] +$$
$$+[(T_{CA}^I + T_{CA}^R) - (T_{CA}^{I+} + T_{CA}^{R+})].$$

Thus, the national welfare model of country *A* becomes an equation:

$$D_{ABC}^{w1} = D_{ABC}^{w2}.$$

Its economic meaning is that the total incomes of country *A* earned from sources in countries A, B, and C in various case scenarios are compared on the basis of specific features of MNC tax minimisation methods and countermeasures taken by the governments.

Calculations and Results

Let us consider specific examples which show how the presented models function. We take Russia (RF) as the home country *A*. Assume that the parent company from RF works with the loyal territory *B* (Laos) where it has a subsidiary company. The parent and subsidiary company cooperate with affiliated offshore companies from country *C* - British Virgin Islands (BVI) which imposes no taxes on foreign income.

In Laos, the taxes are comprised of:

effective tax – $t_{BB} = 26\%$ [17];

tax on interests received from abroad – $t_{I_{ABB}} = t_{I_{CBB}} = 24\%$, royalty $t_{R_{ABB}} = t_{R_{CAA}} = 24\%$;

tax on dividends repatriation – $t_{S_{BAB}} = 10\%$, interest $t_{I_{BAB}} = t_{I_{BCB}} = 10\%$, royalty $t_{R_{BAB}} = t_{R_{BCB}} = 10\%$.

In RF the taxes consist of:

effective tax – $t_{AA} = 48\%$ [17];

tax on dividends received from a foreign company – $t_{S_{BAA}} = 13\%$, interest $t_{I_{BAA}} = t_{I_{CAA}} = 20\%$, royalty $t_{R_{BAA}} = t_{R_{CAA}} = 20\%$;

tax on dividends repatriation – $t_{I_{ABA}} = t_{I_{ACA}} = 20\%$, royalty $t_{R_{ABA}} = t_{R_{ACA}} = 20\%$.

We assume that the total rate of return in countries A and B is equivalent and amounts to 100 units. Taking into consideration the application in RF of the controlled transaction rule we presume that the government for the purpose of taxation restores 100% of divested taxes or $\varphi_g^A = 1$. The government of Laos does not apply the controlled transaction rule, hence, it does not correct taxes, i.e. $\varphi_g^B = 0$. Let us also assume that that the parent and subsidiary companies correct and divest in a "grey" way 20 units of active income to offshore *C*, and 5 units of royalty and interest in each of the following cases: from country *A* to country *C*, from country *B* to country *C*, from country C to country A and from country C to country B. Apart from that, we assume that 5 units of passive income (royalty, interest) are transferred from country C to A and the same amount - from country C to B. We presume that Laos and RF have signed a double taxation treaty. From the standpoint of an MNC, we insert values into (8) and obtain the following:

$$D_A^m + D_{S_{AB}}^p + D_{CA}^p + F_{AC} = D_{S_{BA}}^m + D_{BA}^p + D_{S_{CB}}^p + F_{BC} + \Delta;$$

$$(70,0-30,0-33,6)+(10,0-3,4)+(20,0-10,0-4,0)+$$

$$+(40,0-2,0)=(70,0-30,0-24,9+10,7)+(10-2)+$$

$$+(20-10-5,4+2,7)+(40,0-1,0)+\Delta;$$

$$6,4+6,6+6+38,0=25,8+8+7,3+39,0+\Delta;$$

$$19,0+38,0=41,0+39,0+\Delta$$

$$\Delta=-23,0.$$

The results of these calculations show that with such initial data it is obviously economically beneficial to invest in the subsidiary company in Laos because income after taxes is much greater than the income earned at home (41.0>19.0 units). When taking into consideration the "grey" income (38.0 and 39.0 units) delta remains almost unchanged (23.0 units while it was 22.0 units). The advantages of opening a subsidiary company in Laos are contingent upon the fact that the home jurisdiction, applying the controlled transaction rules, additionally imposes taxes on divested income of 16.4 units (or gives no opportunity to save on taxes, as is permitted in Laos) and there is a smaller effective tax rate in Laos. The amount of divested income is approximately equal (it was reduced insignificantly by the repatriation tax: in country A - by 2 units, in country B - by 1 unit). Due to the subsidiary company's manipulations with taxes the government of country *B* receives in its budget less than due taxes amounting to 12.7 units. Besides, the government of country *A* loses 0.7 units of the dividend tax. As a result, MNC saves 13.4 units, which amounts to almost 7% of all its income from three territories (total income is 200 units).

Thus, controlled transaction rules applied by the government of country *A* has no impact on the amount of income which remains with the parent company. The amounts of income divested by the company are approximately equal to the indicators of the subsidiary company in Laos, although its government does not introduce restrictive rules. The situation becomes even worse for the parent company due to additional taxation introduced by the government of country *A*.

Analysing the situation from the point of view of national welfare, one may draw substantially varying conclusions. Let us here make calculations with the parameters of variables identical to the previous scenario inserting them in (14) (see Note 1):

$$D_{ABC}^{w1} = D_{ABC}^{w2} + \Delta;$$

$$6,4+(25,8+7,2+6,6+8)+6+(44,5-0,7)=$$

$$=20,8+(25,8+7,2+6,6+8)+8+(44,5-17,1)+\Delta;$$

$$6,4+47,6+6+43,8=20,8+47,6+8+27,4+\Delta;$$

$$60,0+43,8=76,4+27,4+\Delta;$$

$$103,8=103,8+\Delta;$$

$$\Delta=0.$$

In the first case (if *A* applies the controlled transaction rules), the total income of country *A* from operations of the company in countries A, B, C amounts to 103.8 units including tax proceeds of the government of 43.8 units; and the parent company income amounts to 60,0 units (obtained from A – 6.4, B – 47.6 (including the dividends of 39.6), C – 6.0).

In the second case (if *A* does not apply the controlled transaction rules) the total income of country *A* from operations of the company in countries A, B, C has not changed in general and amounts to 103.8 units but it was redistributed between MNC and the government as follows: tax proceeds of the government of 27.4 units; and the parent company income amounts to 76.4 units (obtained from A – 20.8, B – 47.6 (including the dividends of 39.6), C – 8.0).

It is now becoming apparent that the controlled transaction rules from the point of view of national welfare of country *A* are inoperative because in general the income has not changed $(\Delta = 0)$. In both scenarios the total "grey" income divested into offshore C remained unchanged and amounted to 77.0 units (from A – 38.0, from B – 39.0). If country A had avoided losses or had returned income from offshore C its income from territories A, B and C would have been 180.8 units.

Calculations show that if the government of the home jurisdiction fails to return capital or prevent its divestiture, the total income of countries A and B net of taxes will amount to 60.0 and this is significantly fewer than "grey" income in offshore C of 77 units. Apart from that, governments of countries A and B lose 13.4 units of taxes (and this when the government of country *A* applies controlled transaction rules which restore the tax base to some extent but in general are ineffective as a method of return of "grey" income). Applying the controlled transaction rules, country *A* returned 16.4 units of income in the form of taxes, but this is out of proportion to the fact that country A lost 77 units of divested "grey" income (including the income not returned to country B which finally would have been received by country A as dividends). Eventually, the income of country *A,* in spite of the controlled transaction rules, is reduced by almost half (from 180.8 to 103.8 units). As a result of the problems in defining market prices and, correspondingly, with the efficiency of use of the controlled transaction rules for operations with intangible assets $\varphi_g^A \to 0$, in addition, country A may lose income consisting of restored taxes. This means that it is necessary to improve the controlled transaction rules for intangible assets.

Discussion

Our calculations show differences in the considered issues: from the point of view of MNCs, global net and "grey" MNC income is evaluated, whereas from the standpoint of national welfare only the income of MNC and governments which is aimed at satisfaction of the needs of such country is evaluated.

From the point of view of countries, the most important is the return of divested "grey" income. After all, from the standpoint of total income of MNC income is not just divested from tax but is also transferred to other countries. However, in this case MNC income is not reduced but rather increased by the amount of saved taxes. From the point of view of national welfare the income divested by MNCs decreases a country's income significantly and restored taxes (even in full) cannot reimburse for such losses.

Our predecessors (see for example [9, p. 23–24; 19; 20; 21; 22]) have already given substantiated recommendations for MNC taxation improvement, in particular, concerning application of the proportionate multijurisdictional taxation method [23]. However, in the majority of papers the main attention was focused on the problems of tax avoidance and the correction of income by companies. We have a different view, since the problem consists not so much in the government tax income as in the income and capital of MNC which is divested and fails to participate in improvement of national welfare.

The main conclusion of H. Grubert [9] stated that the strategies of MNCs, in using aggressive tax planning schemes (first of all, in operations with intangible assets), exercised a decisive influence on the effective tax burden for transborder investments. The determining approach in the behaviour of the receiving country may be the approach of governments in which imposing tax burden on various types of companies depends on their contribution to national welfare. We agreed with the author and moved on focusing the main attention on an assessment of MNC actions from the point of view of national welfare and considering the efficiency of tax planning countermeasures taken by governments (H. Grubert does not consider this issue).

From the standpoint of the approach we offer, we emphasise the importance of creating such rules of MNC tax planning counteracting which would not focus on taxes as such, but would rather stimulate the preservation of capital in a certain territory and (or) would facilitate return of previously divested income. In this context, it is reasonable to introduce in Russia the secondary adjustment rule in combination with minimal taxation when income is returned to the country.

Conclusion

One of the main problems of MNC taxation is a tax-free outflow of MNC capital and income as a result of their use of tax planning methods related to development of the digital economy. In order to substantiate the ways of MNC tax planning counteraction and to create a national taxation regime that is favourable for preserving and attracting capital, we developed economic-mathematical models which evolve the approaches of our predecessors. The main new special characteristics of the models we offer consist of the following:

1. The approach is intended to define the eventual outcome of international taxation from the standpoint of national economies, where indicators of the private (economic entities) as well as public (government) economy sectors (which characterise the total resources of economic development remaining in the country and received from abroad) are taken into consideration;

2. The measures of MNC tax planning as well as countermeasures taken by the government are taken into consideration together.

Approbation of the developed models, as exemplified by application of the controlled transaction rule which is fundamental for anti-avoidance measures taken against MNC, showed the following:1. From the standpoint of the economic interests of MNCs, the government's stern

measures (such as controlled transaction rules) may have a direct negative effect: the better the rules work, the less income is left at the company's disposal within the home jurisdiction, as it is redistributed in favour of the government in the form of taxes. Therefore, an MNC is interested in expanding its activities within the loyal of offshore jurisdictions to the disadvantage of the home jurisdiction. This helps to circumvent the controlled transaction rules. For the government, the eventual outcome of application of the controlled transaction rules may be negative: a shrinking tax base and revenue suppression. From the standpoint of national welfare, the outcome is even more negative, as the country may lose MNC income, capital, and tax proceeds.

The controlled transaction rules essentially work poorly with intangible assets, since it is very difficult to justify their "market" price within the conditions of a digital economy. MNCs may always find mechanisms which help to avoid taxation of a part of income applying the transfer pricing methods for intangible assets. Therefore, national welfare will decline for tax reasons too. It is necessary to consider carefully whether more strictly controlled transaction rules should be invented or significant tax preferences should be granted to certain types of business activity.

2. The national taxation policy as regards MNC depends strongly on taxation policies of other countries, so while loyal countries and offshores exist in the world, strict controlled transaction rules in the home country A (connective A-C) may fail because capital may go away, taking the route A-B-C. This puts the problem of global coherence of taxation rules front and centre in terms of international economic significance.

3. The problem is not only one of taxes as such, and their distribution among national jurisdictions. If, for example, taxes are assessed additionally for MNC in country A but the capital actually divested before was not returned to country A from countries B and C, it makes no economic sense. This is because it does not increase the national welfare of country A, but merely redistributes GDP between the private sector and the government in favour of the government.

4. In order to substantiate a taxation regime favourable for economic growth we should develop the offered approach from the point of view of national welfare, which requires taking into consideration the global income of MNC and its distribution among jurisdictions (including an application of the proportionate formular method). In the long run, taxes are not in and of themselves as important as the location where the real capital is situated, where it operates financially, and where employment opportunities are provided, innovations are generated etc.

Our conclusions are preliminary, and further studies are necessary. A common logic may consist in the expansion of parameterisation of models in order to carry out a set of computational experiments with different typical versions of change within the rules of governmental regulation of MNC taxation. In this context, emphasis should be placed, in particular, on income and capital flows and the relevant considerations of national welfare.

Note 1. Interpretation of Elements of Formulas in Equilibrium Models

$$D_A^m = D_{AC}^m - F_{AC}^m - T_{AC}^m + T_{AC}^{m+} =$$
$$= \{D_A(1-d_{R_{AB}} - d_{I_{AB}} - d_{R_{CA}} - d_{I_{CA}})\} -$$
$$-\{D_A\varphi_{AC} + D_A(\varphi_{R_{AC}} + \varphi_{I_{AC}})\} -$$
$$-\{[D_A(1-d_{R_{AB}} - d_{I_{AB}} - d_{R_{CA}} - d_{I_{CA}})]t_{AA}\} +$$
$$+\{D_A\Delta\varphi_{ACA}t_{AA} + D_A(\Delta\varphi_{R_{ACA}} + \Delta\varphi_{I_{ACA}})t_{AA}\};$$

$$D_{S_{AB}}^p = D_{S_{AB}}^p - T_{ABA}^p - T_{ABB}^p - T_{S_{BAB}}^{p_{AB}} - T_{S_{BAA}}^{p_{AB}} = [D_{S_{AB}}^I + D_{S_{AB}}^R] -$$
$$-[T_{I_{ABA}}^I + T_{R_{ABA}}^R] - [T_{I_{ABB}}^I + T_{R_{ABB}}^R] - [T_{S_{BAB}}^I + T_{S_{BAB}}^R] -$$
$$-[T_{S_{BAA}}^I + T_{S_{BAA}}^R] = \{D_{R_{AB}} + D_{I_{AB}}\} - \{D_{R_{AB}}t_{R_{ABA}} + D_{I_{AB}}t_{I_{ABA}}\} -$$
$$-\{D_{R_{AB}}t_{R_{ABB}} + D_{I_{AB}}t_{I_{ABB}}\} - \{D_{R_{AB}}(1-t_{R_{ABA}} - t_{R_{ABB}})t_{S_{BAB}} +$$
$$+D_{I_{AB}}(1-t_{I_{ABA}} - t_{I_{ABB}})t_{S_{BAB}}\} - \{D_{R_{AB}}(1-t_{R_{ABA}} - t_{R_{ABB}})t_{S_{BAA}} +$$
$$+D_{I_{AB}}(1-t_{I_{ABA}} - t_{I_{ABB}})t_{S_{BAA}}\};$$

$$D_{CA}^p = [D_{CA}^p - F_{CA}^p - T_{CA}^p] = [D_{CA}^I + D_{CA}^R] - [F_{CA}^I + F_{CA}^R] -$$
$$-[T_{CA}^I + T_{CA}^R] + [T_{CA}^{I+} + T_{CA}^{R+}] = \{D_{R_{CA}} + D_{I_{CA}}\} -$$
$$-\{D_{R_{CA}}\varphi_{R_{CA}} + D_{I_{CA}}\varphi_{I_{CA}}\} - \{D_{R_{CA}}t_{R_{CA}} + D_{I_{CA}}t_{I_{CA}}\} +$$
$$+\{D_{R_{CA}}\Delta\varphi_{R_{CAA}}t_{R_{CA}} + D_{I_{CA}}\Delta\varphi_{I_{CAA}}t_{I_{CA}}\};$$

$$F_{AC} = [(F_{AC}^m - T_{ACA}^p + F_{CA}^p)] = [(F_{AC}^m - (T_{I_{ACA}}^I + T_{R_{ACA}}^R) +$$
$$+F_{CA}^I + F_{CA}^R)] = \{[D_A\varphi_{AC} + D\ \varphi_{A\tilde{N}} + D\ \varphi_{A\tilde{N}}] -$$
$$-(D_A\varphi_{R_{AC}}t_{R_{ACA}} + D_A\varphi_{R_{AC}}t_{R_{ACA}})\} + \{D_{I_{CA}}\varphi_{I_{CA}}\} + \{D_{R_{CA}}\varphi_{R_{CA}}\}$$

$$D_{S_{BA}}^m = D_{BC}^m - F_{BC}^m - [T_{BC}^m - T_{BC}^{m+}] - [T_{S_{BAB}}^m - T_{S_{BAB}}^{m+}] -$$
$$-[T_{S_{BAA}}^m - T_{S_{BAA}}^{m+}] = \{D_B(1-d_{R_{BA}} - d_{I_{BA}} - d_{R_{CB}} - d_{I_{CB}})\} -$$
$$-\{D_B\varphi_{BC} + D_B\varphi_{R_{BC}} + D_B\varphi_{I_{BC}}\} -$$
$$-\{[D_B(1-d_{R_{BA}} - d_{I_{BA}} - d_{R_{CB}} - d_{I_{CB}})t_{BB}] -$$
$$-[D_B\Delta\varphi_{BCB}t_{BB} + D_B\Delta\varphi_{R_{BCB}}t_{BB} + D_B\Delta\varphi_{I_{BCB}}t_{BB}]\} -$$
$$-\{[D_B(1-d_{R_{BA}} - d_{I_{BA}} - d_{R_{CB}} - d_{I_{CB}})(1-t_{BB})t_{S_{BAB}}] -$$
$$-[D_B\Delta\varphi_{BCB}(1-t_{BB})t_{S_{BAB}} + D_B\Delta\varphi_{R_{BCB}}(1-t_{BB})t_{S_{BAB}} +$$
$$+D_B\Delta\varphi_{I_{BCB}}(1-t_{BB})t_{S_{BAB}}]\} -$$
$$-\{[D_B(1-d_{R_{BA}} - d_{I_{BA}} - d_{R_{CB}} - d_{I_{CB}})(1-t_{BB})t_{S_{BAA}}]$$
$$-[D_B\Delta\varphi_{BCB}(1-t_{BB})t_{S_{BAA}} + D_B\Delta\varphi_{R_{BCB}}(1-t_{BB})t_{S_{BAA}} +$$
$$+D_B\Delta\varphi_{I_{BCB}}(1-t_{BB})t_{S_{BAA}}]\};$$

$$D^p_{BA} = D^I_{S_{BA}} + D^R_{S_{BA}} - [T^I_{I_{BAB}} + T^R_{R_{BAB}}] - [T^I_{I_{BAA}} + T^R_{R_{BAA}}] =$$
$$= D_{I_{BA}} + D_{R_{BA}} - \{D_{I_{BA}} t_{I_{BAB}} + D_{R_{BA}} t_{R_{BAB}}\} - \{D_{I_{BA}} t_{I_{BAA}} +$$
$$+ D_{R_{BA}} t_{R_{BAA}}\};$$

$$D^p_{S_{CB}} = D^I_{CB} + D^R_{CB} - [F^I_{CB} + F^R_{CB}] - [T^I_{CB} + T^R_{CB}] +$$
$$+ [T^{I+}_{CB} + T^{R+}_{CB}] - [T^{I_{CB}}_{S_{BAB}} + T^{R_{CB}}_{S_{BAB}}] + [T^{I_{CB}+}_{S_{BAB}} + T^{R_{CB}+}_{S_{BAB}}] -$$
$$- [T^{I_{CB}}_{S_{BAA}} + T^{R_{CB}}_{S_{BAA}}] + [T^{I_{CB}+}_{S_{BAA}} + T^{R_{CB}+}_{S_{BAA}}] =$$
$$= D_{I_{CB}} + D_{R_{CB}} - \{D_{I_{CB}} \varphi_{I_{CB}} - D_{R_{CB}} \varphi_{R_{CB}}\} -$$
$$- \{D_{I_{CB}} t_{I_{CB}} + D_{R_{CB}} t_{R_{CB}}\} +$$
$$+ \{D_{I_{CB}} \Delta\varphi_{I_{CBB}} t_{I_{CB}} + D_{R_{CB}} \Delta\varphi_{R_{CBB}} t_{R_{CB}}\} -$$
$$- \{[(D_{I_{CB}} - D_{I_{CB}} t_{I_{CB}} - D_{I_{CB}} \Delta\varphi_{I_{CBB}}) t_{S_{BAB}}] +$$
$$+ [(D_{R_{CB}} - D_{R_{CB}} t_{R_{CB}} - D_{R_{CB}} \Delta\varphi_{R_{CBB}}) t_{S_{BAB}}]\} +$$
$$+ \{[(D_{I_{CB}} \Delta\varphi_{I_{CBB}} t_{I_{CB}}) t_{S_{BAB}}] + [(D_{R_{CB}} \Delta\varphi_{R_{CBB}} t_{R_{CB}}) t_{S_{BAB}}]\} -$$
$$- \{[(D_{I_{CB}} - D_{I_{CB}} t_{I_{CB}} - D_{I_{CB}} \Delta\varphi_{I_{CBB}}) t_{S_{BAA}}] +$$
$$+ [(D_{R_{CB}} - D_{R_{CB}} t_{R_{CB}} - D_{R_{CB}} \Delta\varphi_{R_{CBB}}) t_{S_{BAA}}]\} +$$
$$+ \{[(D_{I_{CB}} \Delta\varphi_{I_{CBB}} t_{I_{CB}}) t_{S_{BAA}}] + [(D_{R_{CB}} \Delta\varphi_{R_{CBB}} t_{R_{CB}}) t_{S_{BAA}}]\}$$

$$F_{BC} = [(F^m_{BC} + F^I_{CB} + F^R_{CB})] = [(F^m_{BC} - (T^I_{I_{BCB}} + T^R_{R_{BCB}}) +$$
$$+ F^I_{CB} + F^R_{CB})] = \{[D_B \varphi_{BC} + D_B \varphi_{R_{\tilde{N}}} + D_B \varphi_{I_{\tilde{N}}}] -$$
$$- (D_B \varphi_{R_{BC}} t_{R_{BCB}} + D_B \varphi_{R_{BC}} t_{R_{BCB}})\} + \{D_{I_{CB}} \varphi_{I_{CB}}\} + \{D_{R_{CB}} \varphi_{R_{CB}}\}$$

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Development of the 'Inner Assessment Model' of Long-Term Default Probability for Corporate Borrowers in the Trade Segment of the Economy in Accordance with IFRS 9

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Journal of Corporate Finance Research, Vol. 14, No. 1, pp. 91-114 (2020)
DOI: https://10.17323/j.jcfr.2073-0438.14.1.2020.91-114
Received 25 February 2020 | **Peer-reviewed** 24 March 2020 | **Accepted** 27 March 2020

Development of the 'Inner Assessment Model' of Long-Term Default Probability for Corporate Borrowers in the Trade Segment of the Economy in Accordance with IFRS 9

Abstract

This work is the next step in the research project of various authors in modeling credit risk for Russian banks, taking into account the requirements of IFRS 9. This standard has been implemented all over the world since January 1, 2018 (including in the Russian banking market), and in accordance with the relevant standards it is necessary to clarify the existing models for assessing credit risk. IFRS 9 is based on the expected credit loss (ECL) approach. This new business model radically changes the approach to reserves under the rules of IFRS 9, including the impact of macroeconomic indicators on reserve value.

The purpose of this article is to create a model for assessing the probability of default for corporate borrowers in the trade 'industry' over the course of the whole life duration of assets, in accordance with the requirements of IFRS 9.

In this paper, the life-time probability of default of a financial instrument (referred to as life-time PD, or Lt PD) is based on a parametric model, and two distinct classes of distributions (the two-parameter Weibull distribution and the modified Weibull distribution) were studied. The results of model development are presented in this report.

The development of the model in this paper is based on real bank1 data, so the results and methods used in this work can be applied by both commercial banks and regulatory authorities to model and implement the various requirements of IFRS 9. The practical value of this research also determines its scientific novelty, since this research is one of the first studies in the field of long-term probability of default using real data from Russian corporate clients of commercial banks.

Keywords: IFRS 9, expected credit losses, credit risk assessment stages, Weibull distribution
JEL classification: B40, G21, F65

[1] For confidentiality reasons, the authors do not disclose the name of the bank which portfolio data has been used, or the names of its clients.

Introduction

In the previous article under this research project, "Methods of Calculation of Expected Credit Losses under Requirements of IFRS 9" [1] and in other papers (e.g. [2]) we developed and presented the methodological concept of calculation of bank reserves for various types of assets, taking into consideration the specific character of requirements of IFRS 39. This article continues in the vein of the research papers written by the authors, studying the development of methods and approaches to credit risk modeling (i.e. assessment models of expected credit risk during the whole life-time of assets [3]). It is a project of development of the inner assessment model of the probability of default of corporate borrowers from the 'trade' segment of the economy for the whole life-time of the financial instrument, in accordance with requirements of IFRS 9.

This model has been developed on the basis of data from a real bank. Its results may be used from theoretical and practical points of view by commercial banks as well as by regulatory authorities when executing projects involving the implementation of IFRS 9 [4].

Defining Default

The conclusive evidence of a default is represented by the following circumstances:

- borrower's involuntary debt restructuring;
- payment delay for more than 90 days;
- assignment to the borrower of a rating of 10-default.

In general, when a customer approaches a bank for restructuring of a debt, the designated staff should first of all assign to the borrower a rating of 10-default, and then lift the default status, establishing that the customer is involved in the process of involuntary restructuring. Inasmuch as in practice there are cases of violation of this procedure, and that situations take place when the borrower is assigned a signal of involuntary restructuring without assigning the 10-default rating, it is generally accepted that the fact of involuntary restructuring is a conclusive evidence of default [5].

Description of the Approach to Development of the Model

At the time of development of the model evaluating the life-time probability of default of a financial instrument (Lt PD) of the trade segment of the economy (hereinafter the 'Trade segment') 36,213 observations were available (according to the key of entry "TIN + reporting date") concerning 1,507 borrowers since November 2011. When rating groups were made (see item 3.1), the number of observations in a rating group ranged from 716 observations concerning 22 borrowers to 7,557 observations concerning 159 borrowers (with the largest number of observations in "positive" rating groups and the smallest number of observations in "negative" rating groups). Besides this, there were a sufficient number of default observations for Lt PD modeling on the basis of empirical default rates (DR).

The approach to Lt PD modeling using a parametric model on the basis of internal data has the following advantages:

1) building of multiyear probability of default profiles on the basis of the observed default rates is an intuitive logical approach which does not require the articulation of additional suppositions as, for example, in the case of migration matrices;
2) the use of the approach helps (using the observed data) to extrapolate the results to any number of years (including nonintegrals) without overstating values of the last year's, which is characteristic of migration matrices. Therefore, this approach is preferable if default statistics are available for a sufficiently long period.

In view of these advantages, the approach to Lt PD modeling was chosen for the Trade segment on the basis of the parametric model, and under the scope of the project we studied two classes of distributions (the two-parameter Weibull distribution, and the modified Weibull distribution).

Stages of Modeling of Multiyear Probability of Default

Modeling of multiyear probability of default is based upon empiric (cumulative) default rates and existing probability of default (hereinafter: 'PD') (for 12 months) according to bank models.

The main stages of multiyear probability of default:

1) Obtaining cumulative default rates.
2) Building of multiyear cumulative through-the-cycle (TTC) PD profiles for each rating group on the basis of the Weibull distribution.
3) Converting to the master-scale, extrapolation and interpolation of the results of item 2.
4) Choice of macro parameters, and forms of dependence of default frequency on macro parameters.
5) Choice of scenarios for the modification of macro parameters.
6) Adjustment of TTC Lt PD obtained at the third stage, taking into consideration the macroforecast for defining marginal PD for the calculation of ECL.

Empiric Cumulative Default Rates

Annual default rate

The default rate (DR) was calculated for the first year, . This calculation was prepared with a breakdown into rating groups made for the purpose of modeling (see item 3.1). The equation is presented as follows:

$$DR(t) = \frac{\sum_{i=1}^{12} \text{New defaults}(t_{i-1}; t_i)}{\text{Non} - \text{default customers}(t_0)}, \quad (1)$$

where t – an annual period;

t_0 – date of the beginning of the period;

$(t_{i-1}; t_i)$ – i-th month of period t;

DR(t) – one-year default rate in the year t.

The DR of the first year is calculated for the period of 01.11.2011–01.10.2016 (as of the same date in each month). In order to calculate the final one-year DR of the first year using the data from the reporting dates of 01.11.2011–01.10.2016, DR as at each date of the month (60 observations) was averaged. Averaging was conducted by calculating the arithmetic mean. The final DR is further used to calculate the cumulative default rates [5].

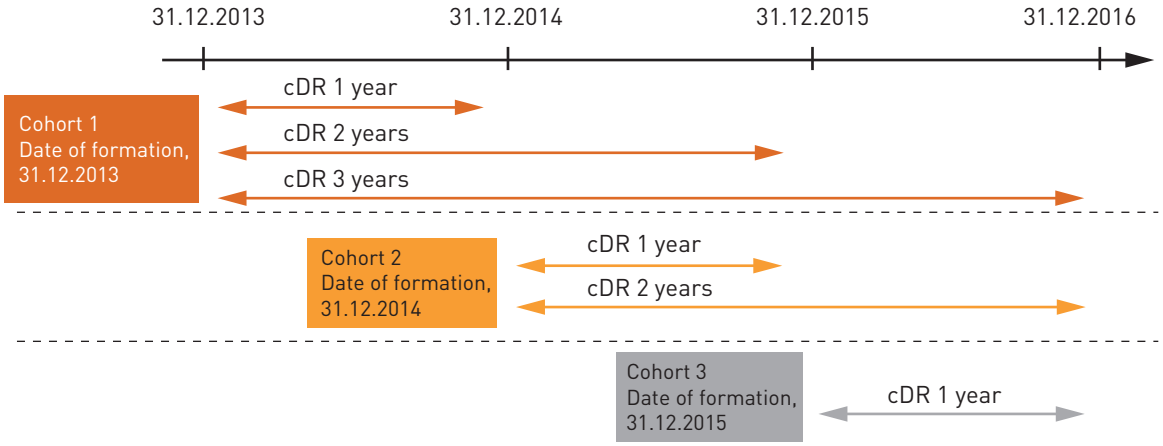
In a similar manner, we calculated the resulting DR for the second, third and fourth years. DR of the fifth year is not included in the further analysis due to a small number of observations (few customers stay in the portfolio till the fifth year, and the default rate of the fifth year tends toward zero).

Cumulative default rate

Cumulative default rates are calculated for each rating group for each year of the financial instrument life. Risk is assigned as at the date of the cohort formation.

Data is collected at the level of cohorts, where each cohort is formed as of the same date in each month. Examples of cohort formation are presented in Figure 1.

Figure 1. Cohort formation



Cumulative default rates are calculated on the basis of resulting DR as follows:

$$cDR_i = 1 - (1 - DR_1) \cdot (1 - DR_2) \cdot \ldots \cdot (1 - DR_i), \quad 2)$$

where cDR_i – cumulative default rate for i years;

DR_i – the final average one-year default rate in year i;

i – year.

Building of Multiyear TTC PD Profiles on the Basis of the Weibull Distribution [6]

Weibull distribution

The multiyear probability of default for the whole lifetime of a financial instrument is evaluated on the basis of the *Weibull distribution*.

The precondition for use of the Weibull distribution is the availability of data on historic default rates for the period of 3 to 8 years (in order to determine the distribution function parameters). This condition holds: data on four-year empirical cumulative default rates is available.

After obtaining empirical cumulative default rates, we calculate parameters k and λ of the two-parameter Weibull distribution function, or parameters α and β of the modified Weibull distribution.

Cumulative PDs are calculated on the basis of historic data on default.

In case of use of the Weibull distribution, the cumulative default rate cDR is described by the function of $F(\tau; \kappa, \lambda)$ – the two-parameter Weibull distribution function with parameters k and λ.

$$F(\tau; \kappa, \lambda) = \hat{e}DR(t, \lambda, \ ) = \begin{cases} 1 - e^{-\left(\frac{t}{\lambda}\right)^{\hat{e}}}, t \geq 0 \\ 0, \ t < 0 \end{cases}, \quad (3)$$

where k – the shape parameter;

λ – distribution function scale parameter;

t – period in years (integer, takes on the values of 1, 2, 3 etc.).

Parameters k and λ are defined for each rating group separately by linearisation of the dependency t and cDR_t:

$$cDR_t = 1 - e^{-\left(\frac{t}{\lambda}\right)^{\kappa}}$$

$$\ln(1 - cDR_t) = -\left(\frac{t}{\lambda}\right)^{\kappa}.$$

Substitution: assume $\kappa = b, \ \lambda = e^{-a/b}$

$$\ln(1-\mathrm{cDR}_t) = -\left(\frac{t}{e^{-a/b}}\right)^b$$

$$b\bullet\ln t + a = \ln\left(-\ln\left(1-\mathrm{cDR}_t\right)\right). \quad (4)$$

Parameters k and λ are assessed on the basis of a linear regression of the double logarithm of the survival function applying the least square method.

Parameters a and b of the linear regression are defined by the least square method:

$$\arg\min_{a,\,b}\left[\sum_{t=1}^{s}\left(y_t-\hat{y}_t\right)^2\right], \quad (5)$$

where $y_t = \ln\left(-\ln\left(1-\mathrm{cDR}_t\right)\right)$;

$\hat{y}_t = a + b\bullet\ln(t)$;

s – the maximum period in years within which the default data is available;

$\sum_{t=1}^{s}\left(y_t-\hat{y}_t\right)^2$ – the sum of squared deviations.

On the basis of the obtained parameters, multiyear PD curves (TTC) are constructed individually for each rating group. In case where the approach is applied on the basis of the Weibull distribution, the following formula is representative:

$$\mathrm{cPD}\left(t,\lambda_i,\kappa_i\right) = 1-e^{-\left(\frac{t}{\lambda}\right)^{\kappa}}, \quad (6)$$

where t – a period in years for which the probability of default is calculated (t = 1 is one year);

λ_i, k_i – Weibull distribution coefficients for rating group i.

The conditional probability of default PD(t) for year [t-1; t] is obtained from the cumulative probability of default using the following formula:

$$\mathrm{PD}(t) = \frac{\mathrm{cPD}(t)-\mathrm{cPD}(t-1)}{1-\mathrm{cPD}(t-1)}. \quad (7)$$

Modified Weibull distribution

In case of use of this modified Weibull distribution, the cumulative default rate cDR is described by the following function:

$$F(t,\alpha,\beta) = \mathrm{cDR}(t,\alpha,\beta) = \begin{cases} \dfrac{1-e^{-\left(e^{-(\alpha\cdot t^{\beta})}\right)}}{\left(1-e^{-1}\right)}, & t>0 \\ 0, & t\le 0 \end{cases} \quad (8)$$

where $\beta < 0$.

When using the modified Weibull distribution, the exponential approximation of the negative double natural logarithm of the survival function with the introduced coefficient and the natural logarithm of time is applied:

$$-\ln\left(-\ln\left(1-K\bullet\mathrm{cDR}_t\right)\right) = \alpha\bullet e^{\beta\cdot\ln(t)}, \quad (9)$$

where $K = 1-e^{-1}$.

The exponential approximation takes into consideration the nonlinear nature of time distribution of the cumulative probability of default (due to the cyclical nature of economy, debt repayment etc.). The introduced coefficient K converts the expression into the function for which all four properties of the distribution function hold:

1. The function is right-continuous.
2. The function is not decreasing.
3. $\lim_{x\to-\infty} F(x) = 0$.
4. $\lim_{x\to+\infty} F(x) = 1$.

The linear dependence is obtained due to taking the logarithm in base e of both sides of equation:

$$\mathrm{cDR}_t = \frac{1-e^{-\left(e^{-(\alpha\cdot t^{\beta})}\right)}}{\left(1-e^{-1}\right)}$$

$$K = 1-e^{-1}$$

$$K\bullet\mathrm{cDR}_t = 1-e^{-\left(e^{-(\alpha\cdot t^{\beta})}\right)}$$

$$-\alpha\bullet e^{\ln t^{\beta}} = \ln\left(-\ln\left(1-K\bullet\mathrm{cDR}_t\right)\right)$$

Substitution: assume $\alpha = e^A; \beta = B$

$$e^A\bullet e^{\ln t^B} = -\ln\left(-\ln\left(1-K\bullet\mathrm{cDR}_t\right)\right)$$

$$A + B\bullet\ln t = \ln\left(-\ln\left(-\ln\left(1-K\bullet\mathrm{cDR}_t\right)\right)\right). \quad (10)$$

Parameters A and B of the linear regression are defined by the least square method

$$\arg\min_{A,B}\left[\sum_{t=1}^{s}\left(y_t-\hat{y}_t\right)^2\right], \quad (11)$$

where

$y_t = \ln\left(-\ln\left(-\ln\left(1-K\bullet\mathrm{cDR}_t\right)\right)\right)$;

$\hat{y}_t = A + B\bullet\ln(t)$;

s – the maximum period in years for which default data is available;

$\sum_{t=1}^{s}\left(y_t-\hat{y}_t\right)^2$ – sum of squared deviations.

On the basis of the obtained parameters, multiyear PD curves (TTC) are constructed individually for each rating group.

In case of using the approach on the basis of the modified Weibull distribution the following formula is applied:

$$\mathrm{cPD}\left(t,\alpha_i,\beta_i\right) = \frac{1-e^{-\left(e^{-(\alpha_i\cdot t^{\beta_i})}\right)}}{\left(1-e^{-1}\right)}, \quad (12)$$

where t – a period in years for which the probability of default is calculated (t = 1 is one year);

α_i, β_i – modified Weibull distribution coefficients for rating group i.

The conditional probability of default PD(t) for year [t-1; t] is obtained from the cumulative probability of default using formula (7).

Reducing to the Master-Scale, Extrapolation and Interpolation of the Results

After obtaining the cumulative probability of default profiles, the deviation of empiric default rates from the obtained curves is evaluated. Prolonged periods not covered by the available data are extrapolated, taking into consideration the following prerequisites:

1) curves cPD for various rating groups should not intersect in any time interval (see Figure 3);
2) the curves should not be too plane or too convex. This assessment is based on an expert opinion.

If nonmonotonicity is observed in the obtained cumulative probability of default profiles the probabilities of default should be converted into marginal probabilities of default for further elimination of intersections. (For nonmonotonicity in this instance, the following condition should be met: the probability of default of the worst rating exceeds the probability of default of the previous rating). Adjustment is made by assigning the maximum probability of default of previous ratings to the rating in which the monotonicity condition is violated.

Then the obtained monotonous marginal probabilities of default are transformed into cumulative ones.

The cumulative probabilities of default are converted into conditional probabilities of default for further translation of TTC PD for the first year into the bank master scale, and calculation of conditional PD for each rating inside the rating groups applying the logarithmic interpolation.

On the basis of the conditional PD obtained in the previous stage, we calculate the final marginal PD (without taking into consideration the forecasting information). Values of marginal PD are corrected in order to eliminate intersections.

The above transformations of the probability of default profiles are made using the following formulas:The cumulative PD is defined as follows:

$$CPD_t = \begin{cases} CPD_{t-1} + (1 - CPD_{t-1}) \cdot PD_t, t > 0 \\ 0, t = 0 \end{cases}. \quad (13)$$

The marginal PD is defined as follows:

$$MPD_t = PD_t \cdot (1 - CPD_{t-1}) = CPD_t - CPD_{t-1}. \quad (14)$$

Choosing the Approach

In order to choose a more accurate evaluation method of the probability of default for the life-time, the values of the coefficient of linear dependences determination (5) and (11) are compared. When the coefficient of linear dependence determination (11) exceeds the coefficient of linear dependence determination (5) the choice is in favour of the modified Weibull distribution. If the coefficient of linear dependence determination (11) is lower than the coefficient of linear dependence determination (5) the choice is in favour of the two-parameter Weibull distribution.

Construction of Lt PD PIT Model Taking into Consideration Forecasting Macroeconomic Information

One of the main requirements of the new Standard is ECL evaluation at a point in time (PIT) which implies use of historic data, current information, and forecasting information (macroeconomic factors). TTC PD is an average PD for the whole economic cycle, which evaluation is based on all available information on default rates for the whole available observation period. TTC PD is stable in time and has no correlation with the economic cycle [6].

PIT calibration is made on the basis of the Bayesian formula, where the PD of an agreement / customer / rating group is scaled according to the forecasting default rate and PD portfolio.

In order to transform the conditional one-year values of PD for each year of the financial instrument life-time, the Bayesian formula is applied as follows:

$$PD_i^{New} = \frac{(1 - CDT) \cdot DR_{New} \cdot PD_i}{CDT \cdot (1 - DR_{New}) \cdot (1 - PD_i) + (1 - CDT) \cdot DR_{New} \cdot PD_i}, \quad (15)$$

where PD_i^{New} is a new PD of the rating grade i which corresponds to a new default rate DR_{New}, taking into consideration the macroforecast for a corresponding year;

PD_i is a conditional PD of the rating grade i for a corresponding year (for the first year it corresponds to the bank master scale);

DR_{New} is the forecasting default rate for a corresponding year;

CDT is an average one-year default rate calculated according to the economic cycle.

Results of TTC Lt Pd Modeling before Taking into Consideration the Forecasting Macroeconomic Information

In order to evaluate ECL for the whole life-time of the financial instrument T, marginal probabilities of default are assessed for each life-time period of the financial instrument. Further the algorithm of obtaining these evaluations is described [7–8].

Results of Calculation of Empiric Cumulative Default Rates

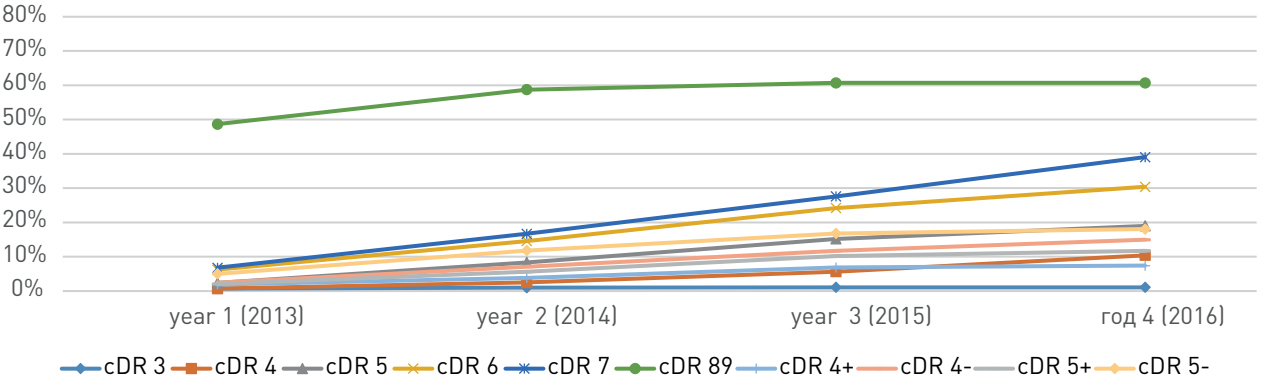
Cumulative default rates were calculated in accordance with formula (2):

- data from 01.11.2011 to 01.10.2016 (60 dates) was analysed; on the basis of the data Bank Default Register;
- DR in rating groups of the bank were calculated separately;
- for the Trade segment, the data was arranged into rating groups 3 (3+, 3, 3–), 4+, 4, 4–, 5+, 5, 5–, 6 (6+, 6, 6–), 7 (7+, 7, 7–), 89 (8+; 8; 8– and 9). The necessity to arrange the data into groups is explained by insufficient number of observations in individual rating grades (Table 1).

Table 1. Number of observations according to rating grades / groups.

Rating group	Rating grade	Number of observations in the rating grade	Number of observations in the rating group
3	1+	–	2,059
	1	–	
	1–	–	
	2+	1	
	2	–	
	2–	195	
	3+	149	
	3	485	
	3–	1,229	
4+	4+	2,450	2,450
4	4	2,791	2,791
4–	4–	3,784	3,784
5+	5+	4,120	4,120
5	5	4,237	4,237
5–	5–	4,268	4,268
6	6+	3,460	7,557
	6	2,461	
	6–	1,636	
7	7+	823	1,250
	7	295	
	7–	132	
89	8+	66	716
	8	519	
	8–	44	
	9	87	

Figure 2. Empiric cumulative default rates, Trade segment.



The initial ratings for the previous model (Corporate Customers, versions 2; 3.0; 3.1; 3.2) were counted (converted to the reference point of the Trade model – 4.4%). Therein we admit an assumption that the structure of the Corporate Customers models versions 2; 3.0; 3.1; 3.2 is similar to the structure of the Trade model, and such conversion calculation is admissible. The structure of the Corporate Customers model in version 1 differs significantly from the structure of the Trade model, and for this reason conversion calculation is impossible.

Figure 2 of Table 2 presents empiric cumulative default rates in the Trade segment.

Table 2. Empiric cumulative default rates for the Trade segment (%).

Rating group	Year 1	Year 2	Year 3	Year 4
3	0.68	0.96	1.07	1.07
4+	1.90	3.84	6.84	7.40
4	0.67	2.46	5.64	10.42
4–	2.41	7.08	11.71	14.95
5+	2.01	5.58	10.17	11.69
5	2.33	8.32	15.19	18.99
5–	4.99	11.79	16.78	18.06
6	6.23	14.57	24.19	30.37
7	6.77	16.67	27.57	39.04
89	48.64	58.73	60.70	60.70

Results of Construction of Multiyear Cumulative TTC PD Profiles on the Basis of the Weibull distribution and Choice of the Approach

In table 3–4, we present information on the obtained parameters of the function of the two-parameter Weibull distribution, and the modified Weibull distribution for the Trade segment in a bank calculated on the basis of the algorithm, described in section 2.

Table 3. Parameters of the two-parameter Weibull distribution function for the Trade segment.

Rating group	λ	κ
3	364 947.99	0.39
4+	39.91	1.07
4	12.64	1.97
4–	12.84	1.45
5+	15.54	1.42
5	8.95	1.71
5–	14.50	1.11
6	8.46	1.28
7	6.71	1.40
89	3.84	0.30

Table 4. Parameters of the modified Weibull distribution function for the Trade segment.

Rating group	α	β
3	5.44	–0.07
4+	4.42	–0.28
4	5.47	–0.47
4–	4.18	–0.44
5+	4.36	–0.40
5	4.21	–0.53
5–	3.44	–0.39
6	3.21	–0.51
7	3.13	–0.60
89	1.00	–0.29

Figure 3. Cumulative probabilities of default for the Trade segment.

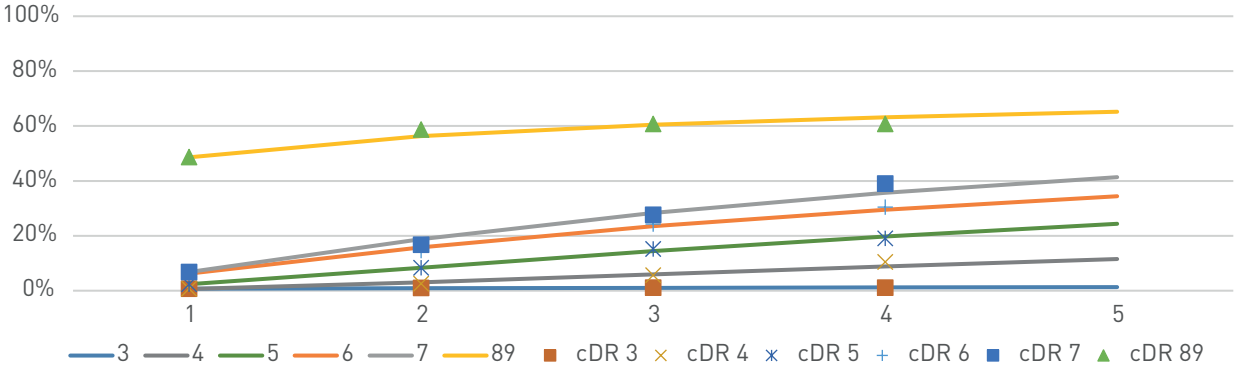


Figure 4. Comparison of the approach on the basis of the two-parameter Weibull distribution to the approach on the basis of the modified Weibull distribution using bank data (rating group "5-")

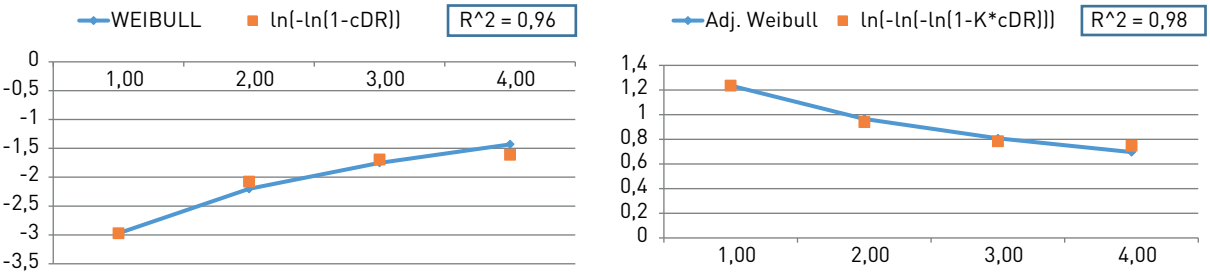


Figure 5. Marginal probabilities of default for the Trade segment, rating group "5-".On the basis of the obtained parameters we built multiyear PD curves (TTC) separately for each rating group (Figure 3).

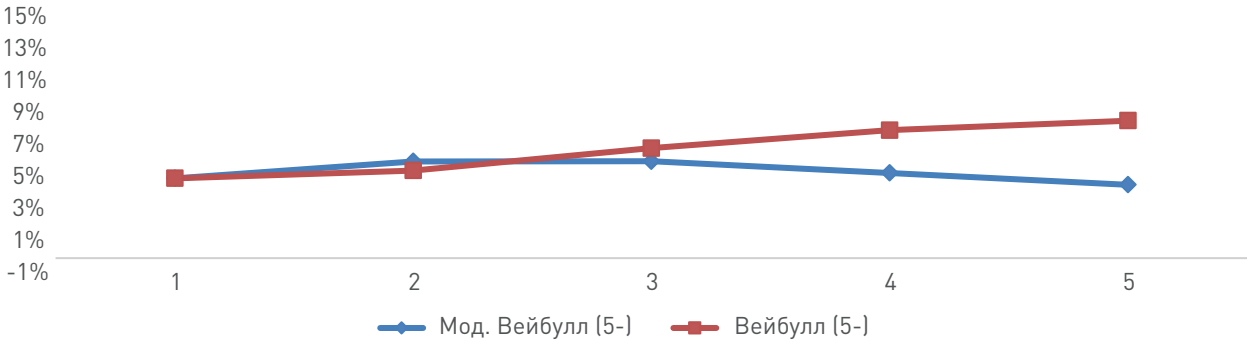


Figure 4 represents by a diagram comparison of two methods using rating group "5-" as an example (in the Trade segment it has a rather high concentration of borrowers).

As long as the determination coefficient for the two-parameter Weibull distribution is a little lower than the coefficient for the modified Weibull distribution (0.96<0.98) a decision was taken to choose the modified two-parameter Weibull distribution.

For rating groups 3, 4–, 5+, 5, 5– where the borrower concentration amounts to 57.7% the determination coefficient for the two-parameter Weibull distribution is lower than the coefficient for the modified Weibull distribution. So, on the basis of a comparison of the results of the two methods for other rating groups a decision was taken in favour of the modified two-parameter Weibull distribution.

Reducing to the Master-Scale, Extrapolation and Interpolation of the Results

It is evident from Table 5 that in the theoretical cumulative probabilities of default calculated according to formula (12) using the obtained parameters α and β non-monotonicity is observed (for example, probabilities of default for rating "4+" exceed the probabilities of default of rating "4", probabilities of default for rating "4-" exceed the probability of default of rating "5+").

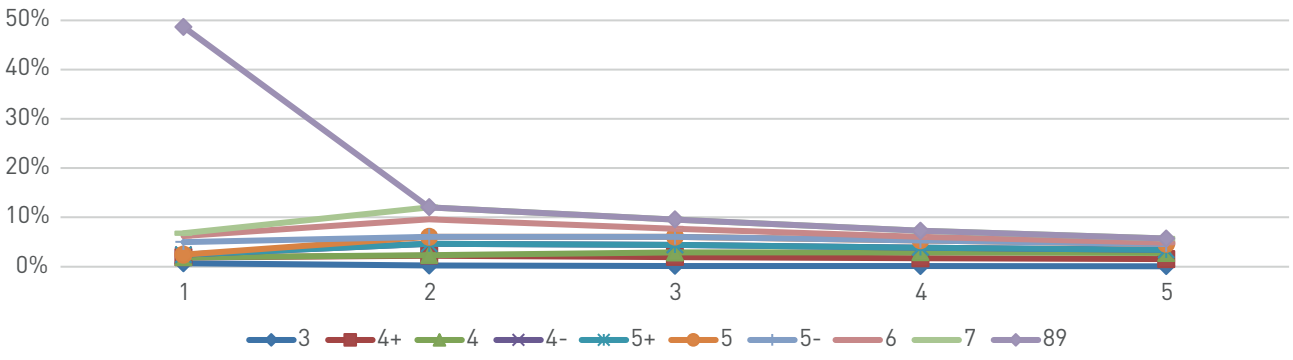
Table 5. Cumulative default rates for the Trade segment evaluated on the basis of the modified Weibull function (%).

Rating group	Year 1	Year 2	Year 3	Year 4	Year 5
3	0.68	0.90	1.04	1.16	1.26
4+	1.90	4.13	6.08	7.78	9.29
4	0.67	3.00	5.89	8.80	11.57
4–	2.41	7.05	11.44	15.31	18.70
5+	2.01	5.72	9.28	12.47	15.29
5	2.33	8.37	14.43	19.76	24.35
5–	4.99	11.04	15.94	19.93	23.27
6	6.23	15.81	23.49	29.54	34.40
7	6.77	18.81	28.36	35.65	41.34
89	48.64	56.30	60.44	63.20	65.23

Table 6. Marginal probabilities of default for the Trade segment after elimination of nonmonotonicity (%).

Rating group	Year 1	Year 2	Year 3	Year 4	Year 5
3	0.68	0.21	0.15	0.12	0.10
4+	1.90	2.23	1.95	1.70	1.51
4	1.90	2.34	2.88	2.91	2.77
4-	2.41	4.63	4.40	3.87	3.38
5+	2.41	4.63	4.40	3.87	3.38
5	2.41	6.04	6.06	5.33	4.59
5–	4.99	6.05	6.06	5.33	4.59
6	6.23	9.58	7.69	6.04	4.86
7	6.77	12.04	9.56	7.29	5.69
89	48.64	12.04	9.56	7.29	5.69

Figure 6. Marginal Probabilities of default for the Trade segment.



The following transformations have been consistently applied to the obtained cumulative probabilities of default for the Trade segment.

Step 1. Cumulative probabilities of default were converted into marginal probabilities of default (see formula (14)) for further elimination of intersections. Adjustment was made by assigning the probability of default of the previous rating to the rating in which the monotoneness condition is violated.

Marginal TTC profiles of multiyear probabilities of default were adjusted to eliminate intersections (for rating groups 4, 5+, 5– and 89 mPD they were fixed at the level of maximum mPD for rating groups 4+, 4–, 5 and 7, respectively).

Marginal probabilities of default after the adjustments are represented in Table 6.

Step 2. Marginal probabilities of default were transformed into cumulative ones (in accordance with dependency (13)).

Cumulative probabilities of default after adjustment are represented in Table 7.

Table 7. Cumulative probabilities of default for the Trade segment after elimination of nonmonotonicity (%).

Rating groups	Year 1	Year 2	Year 3	Year 4	Year 5
3	0.68	0.90	1.04	1.16	1.26
4+	1.90	4.13	6.08	7.78	9.29
4	1.90	4.24	7.12	10.03	12.80
4–	2.41	7.05	11.44	15.31	18.70
5+	2.41	7.05	11.44	15.31	18.70
5	2.41	8.45	14.51	19.84	24.43
5–	4.99	11.04	17.10	22.43	27.02
6	6.23	15.81	23.49	29.54	34.40
7	6.77	18.81	28.36	35.65	41.34
89	48.64	60.68	70.23	77.52	83.21

Table 8. Conditional multiyear probabilities of default for the Trade segment (%).

Rating group	Empiric PD TTC	Year 1 (PD according to the bank master-scale)	Year 2	Year 3	Year 4	Year 5
3	0.68	0.58	0.82	0.73	0.65	0.59
4+	1.90	0.96	2.28	2.03	1.81	1.64
4	1.90	1.23	2.38	3.01	3.13	3.08
4–	2.41	1.58	4.75	4.73	4.37	3.99
5+	2.41	2.03	4.75	4.73	4.37	3.99
5	2.41	2.61	6.19	6.62	6.23	5.73
5–	4.99	3.36	6.37	6.81	6.43	5.92
6	6.23	5.54	10.21	9.13	7.90	6.90
7	6.77	11.74	12.91	11.77	10.17	8.84
89 (8–)	48.64	31.97	42.20	24.30	24ю48	25.30

Step 3. Cumulative probabilities of default were transformed into conditional probabilities of default (in accordance with dependence (7)) for further conversion of TTC PD for the first year to the bank master-scale, and calculation of conditional PD for each rating inside rating groups by means of logarithmic interpolation (stage 4).

Moreover, as long as the conditional probabilities of default for rating group "3" in the second and subsequent years are significantly lower than in the first year (judged on the basis of the empiric selection data) they were adjusted for the correction factor of change of the conditional probability of default from year to year in rating group "4+".

The bank uses a fixed scale of the bank inner rating mapping with PD_{TTC}. The obtained probabilities of default for the first year were replaced in accordance with the bank master-scale (Table 8).

Step 4. Conditional PD for each rating inside rating groups 3, 6, 7, 89 were calculated by means of logarithmic interpolation.

Example of calculation of logarithmic interpolation for rating "3-" (year 2):

$$PD_{3-} = PD_3 \cdot \left(\frac{PD_{4+}}{PD_3}\right)^{1/2}, \quad (16)$$

where (1/2) – ratio of the distance (number of rating grades) between the target value PD3 and the known value PD3 (equals one) to the distance between two known values PD3 and PD4+ (equals two).

Conditional PD for ratings 1+, 1, 1–, 2+, 2 and 2– are fixed at the level of the bank master-scale (Table 9).

Table 9. Conditional multiyear probabilities of default for the Trade segment after applying logarithmic interpolation (%).

Risk category	Year 1	Year 2	Year 3	Year 4	Year 5
1+	0.01	0.01	0.01	0.01	0.01
1	0.02	0.02	0.02	0.02	0.02
1–	0.04	0.04	0.04	0.04	0.04
2+	0.08	0.08	0.08	0.08	0.08
2	0.16	0.16	0.16	0.16	0.16
2–	0.32	0.32	0.32	0.32	0.32
3+	0.45	0.49	0.44	0.39	0.35
3	0.58	0.82	0.73	0.65	0.59
3–	0.75	1.36	1.22	1.09	0.98
4+	0.96	2.28	2.03	1.81	1.64
4	1.23	2.38	3.01	3.13	3.08
4–	1.58	4.75	4.73	4.37	3.99
5+	2.03	4.75	4.73	4.37	3.99
5	2.61	6.19	6.62	6.23	5.73
5–	3.36	6.37	6.81	6.43	5.92
6+	4.31	8.06	7.88	7.13	6.39
6	5.54	10.21	9.13	7.90	6.90
6–	7.12	11.04	9.94	8.60	7.49
7+	9.14	11.94	10.81	9.35	8.14
7	11.74	12.91	11.77	10.17	8.84
7–	15.08	17.36	14.11	12.67	11.50
8+	19.37	23.34	16.91	15.78	14.95
8	24.89	31.39	20.27	19.66	19.45
8–	31.97	42.20	24.30	24.48	25.30
9	41.06	56.73	29.13	30.49	32.91

Step 5. On the basis of conditional PD obtained at step 4, marginal PD values were calculated (see formula (14)).

For ratings 1+, 1, 1–, 2+, 2 and 2– mPD were fixed at the level of the bank master-scale.

For ratings 5+, 8, 8– and 9 starting from the third year the values of marginal PD were adjusted to eliminate intersections.

The final mPD values (without taking into consideration forecasting information) are presented in Table 10.

Table 10. Marginal TTC profiles of multiyear probabilities of default for the Trade segment (%).

Rating group	Year 1	Year 2	Year 3	Year 4	Year 5
1+	0.01	0.01	0.01	0.01	0.01
1	0.02	0.02	0.02	0.02	0.02
1–	0.04	0.04	0.04	0.04	0.04
2+	0.08	0.08	0.08	0.08	0.08
2	0.16	0.16	0.16	0.16	0.16
2–	0.32	0.32	0.32	0.32	0.32
3+	0.45	0.49	0.43	0.39	0.35
3	0.58	0.81	0.72	0.64	0.57
3–	0.75	1.35	1.19	1.05	0.94
4+	0.96	2.25	1.97	1.72	1.52

Rating group	Year 1	Year 2	Year 3	Year 4	Year 5
4	1.23	2.35	2.90	2.93	2.79
4–	1.58	4.67	4.43	3.90	3.41
5+	2.03	4.67	4.43	3.90	3.41
5	2.61	6.03	6.04	5.32	4.58
5–	3.36	6.15	6.16	5.42	4.67
6+	4.31	7.72	6.94	5.78	4.81
6	5.54	9.65	7.74	6.09	4.89
6–	7.12	10.26	8.21	6.40	5.09
7+	9.14	10.85	8.65	6.67	5.26
7	11.74	11.40	9.05	6.90	5.38
7–	15.08	14.74	9.90	7.64	6.05
8+	19.37	18.82	10.45	8.11	6.47
8	24.89	23.57	10.45	8.11	6.47
8–	31.97	28.71	10.45	8.11	6.47
9	41.06	33.44	10.45	8.11	6.47

Construction of pit It pd Model Taking into Consideration Forecasting Macroeconomic Information

Choice of Macro Parameters and Forms of Dependence of Default Frequency on Macro Parameters for Further Analysis [10–12]

Choice of explicative variables

In order to analyse the macroeconomic information the integrated data as regards the Trade segment as well as Manufacturing and Service segments of the economy were used for the purpose of evening-out the high volatility of DR in one of the segments - Manufacturing and Services – which is not related to relevant macroeconomic factors.

Macroeconomic factors forecasted by the bank were used as independent variables. Analysis was carried out as at the dates of 01.01.2012 to 01.10.2016 (58 monthly dates).

"Long List" of explicative variables

In order to choose the parameter which demonstrates the maximum dependence as regards the default frequency, the following converted indicators were analysed:

- annual consumer price index for goods and services for the following 12 months from the reporting date, % (source: <www.gks.ru>) – CPI_1;
- increment of the annual consumer price index for goods and services for the following 12 months to the previous 12 months as of a date, % (source: <www.gks.ru>) – CPI_2;
- annual index of change of the interest rate of the Central Bank of the Russian Federation, as a % of the following 12 months from the reporting date (source: <www.cbr.ru>) – cb_rate;
- real disposable household income, as a % of the corresponding period of the previous year (source: <www.gks.ru>) – rdi_1;
- average annual index of the real disposable household income, as % for the last 12 months (source: <www.gks.ru>) – rdi_2;
- index of change of average annual prices for Brent oil, for the following 12 months from the reporting date, % (source: <finam.ru>) – oil_aver;
- increment of the average annual exchange rate of the US dollar, for the following 12 months from the reporting date, % (source: <finam.ru>) – dollar_aver;
- increment of the exchange rate of the US dollar as of the end of the period, for the following 12 months from the reporting date, % (source: <finam.ru>) – dollar_ep;
- increment of the average annual exchange rate of the Euro, for the following 12 months from the reporting date, % (source: <finam.ru>) – euro_aver;
- increment of the exchange rate of the Euro as of the end of the period, for the following 12 months from the reporting date, % (source: <finam.ru>) – euro_ep;
- average annual index – GDP deflator, for the following 12 months from the reporting date, % (source: <www.gks.ru>) – gdp_deflator;
- annual increment of GDP in roubles in constant prices, for the following 12 months from the reporting date, % (source: <www.gks.ru>) – gdp_1;
- annual increment of GDP in US dollars in constant prices, for the following 12 months from the reporting date, % (source: <www.gks.ru>) – gdp_2.

Although the GDP deflator index is not forecasted in the bank, this indicator was used for analysis because it illustrates very well the pattern of economic development of the Russian Federation, and the publicly-available forecast is based on it (Department of Macroeconomic Analysis and Forecasting of the Ministry of Economic Development of the Russian Federation[1]).

All indicators, except for rdi_1, rdi_2, are considered "for the following 12 months from the reporting date", and this corresponds to the period for which the default rates DR are calculated. Apart from that, for the purposes of

[1] URL: http://economy.gov.ru/minec/activity/sections/macro/prognoz/

taking into account macroeconomic information, the forecasting future values of the chosen explanatory factor are used. For the indicator of the "real disposable household income, as a % of the corresponding period of the previous year", the logic of "for the last 12 months" was preserved in order to obtain economically interpretable negative correlation ratios of indicators rdi_1, rdi_2 with the default rates DR.

In order to take into consideration the deferred influence of the factors the indicators with the lags of 1–18 months were considered.

Selection Procedure

Correlation Analysis

Linear interrelation ratios between variables (Pearson correlation) were calculated. The obtained results were analysed in order to select macroeconomic factors with the biggest linear interrelation value with the default rate.

In Table 11, the variables with the biggest correlation ratio with a dependent variable are presented.

Correlation was calculated as follows:

- by pairs between macroeconomic factors;
- between the dependent variable and macroeconomic factors;
- between the dependent variable and lag values of macroeconomic factors.

When selecting factors for further analysis we used the following criteria:

- coherence of the pair correlation sign with the economic sense of variables interrelation;
- pair correlation ratio of independent variables does not exceed 60% (in modulus);
- factor / factor lag correlation ratio with a dependent variable takes on the maximum value.

Table 11. Correlation ratios between selected variables from the list of factors and the default rate (in the segments of Trade, Manufacturing, and Services).

Variable	Variable description	Significant lag in months	Correlation with c DR, %
dollar_aver_lag4	Increment of the average annual exchange rate of the US dollar, for the following 12 months from the reporting date, %	4	93.3
CPI_1_lag6	Annual consumer price index for goods and services for the following 12 months from the reporting date, %	6	92.3
oil_aver _lag1	Index of change of average annual prices for Brent oil, for the following 12 months from the reporting date, %	1	–88.9
dollar_ep_lag8	Increment of the exchange rate of US dollar as of the end of the period, for the following 12 months from the reporting date, %	8	87.1
gdp_1	Annual increment of GDP in roubles in constant prices, for the following 12 months from the reporting date, %	0	–87.1

The results of these calculations show a strong linear interrelation between the default rates in the Trade segment and the Manufacturing and Services segment and five selected macroeconomic variables in the period of 01.01.2012 to 01.10.2016.

Graphical Analysis

The graphical analysis does not confirm a powerful influence of the consumer price index (CPI_1_lag6) and increment of US dollar exchange rate (dollar_ep_lag8) on the default rates (there are concentrations of points in two areas. Inside these areas there is no correlation relationship between indicators, or it has the sign opposite to the total correlation ratio). Thus, on the basis of the results of the graphical analysis, the following factors have been selected: 1) GDP annual increment; 2) increment of the average annual US dollar exchange rate; 3) index of change of average annual prices for Brent oil. In graphical analysis, these indicators show a high correlation with the default rates and a well-defined linear trend. These macroeconomic indicators also have a good interpretability with regard to influence on the default rates.

See below dependence diagrams according to DR type (macro factor) (figures 7–11).

Figure 7. Increment of the average annual exchange rate of the US dollar, for the following 12 months from the reporting date, %

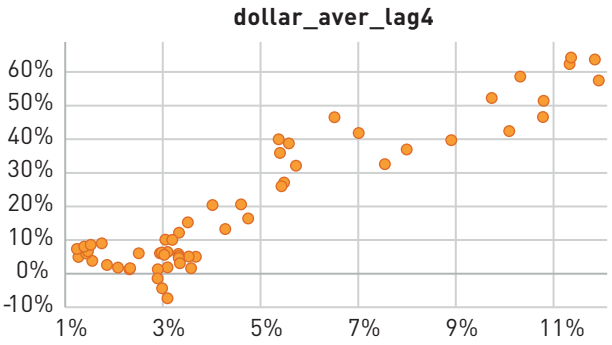


Figure 8. Annual consumer price index for goods and services for the following 12 months from the reporting date, %

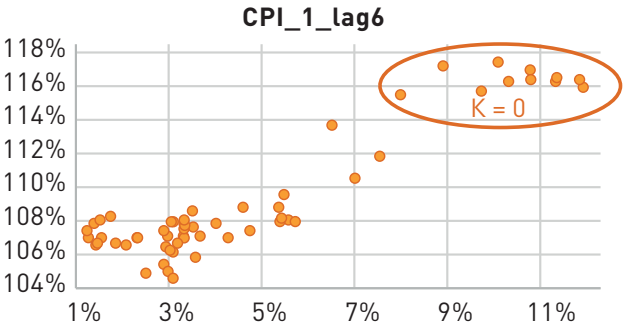


Figure 9. Index of change of average annual prices for Brent oil, for the following 12 months from the reporting date, %

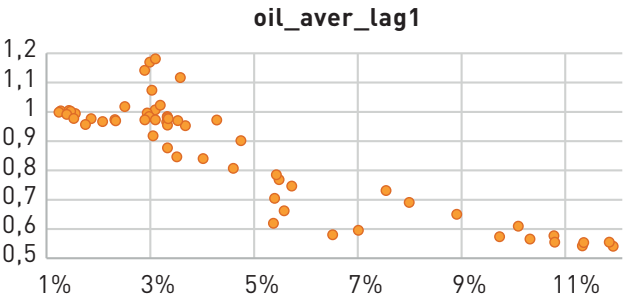


Figure 10. Increment of the exchange rate of the US dollar as of the end of the period, for the following 12 months from the reporting date, %

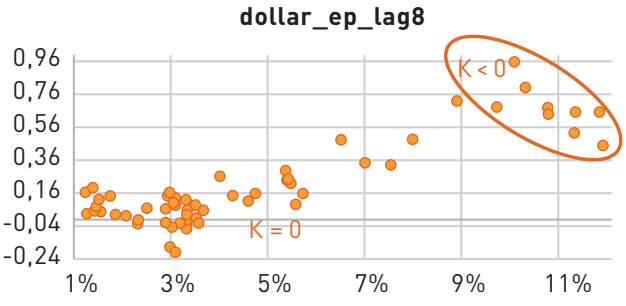
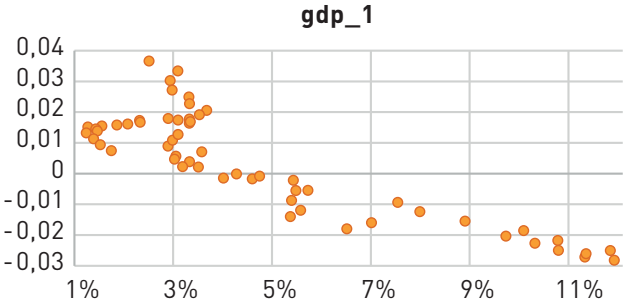


Figure 11. Annual increment of GDP in roubles in constant prices, for the following 12 months from the reporting date, %



"Short List" of explicative variables:

- annual increment of GDP in roubles in constant prices, for the following 12 months from the reporting date, % (source: <www.gks.ru>) – gdp_1;
- increment of the average annual exchange rate of US dollar, for the following 12 months from the reporting date, % (source: <finam.ru>) – dollar_aver;
- index of change of average annual prices for Brent oil, for the following 12 months from the reporting date, % (source: <finam.ru>) – oil_aver.

Econometric Analysis

Stage 1. Construction of One-Factor Models

Due to existence of high correlation factors with an independent variable, the following one-factor models were constructed: linear, log-linear and Vasicek models. The following models showed the greatest forecast power:

1) Vasicek model with the variable dollar_aver_lag4 (R^2 = 88.8%);
2) Vasicek model with the variable gdp_1 (R^2 = 88.3%);
3) log linear regression model with the variable dollar_aver_lag4 (R^2 = 87.4%).

The Vasicek model with the variable dollar_aver_lag4h showed the greatest forecast power, a similar model with the variable gdp_1 showed a slightly smaller forecast power (R^2 is less by 0.5%). After discussion a study group defined that the model on the basis of the factor of increment of the average US dollar exchange rate is less interpretable than the model with the GDP increment rate variable. Taking into consideration the results of the graphical analysis, the Vasicek model with the GDP increment rate variable was chosen as the best model on the basis of an analysis of all one-factor models.

Stage 2. Construction of Two-Factor Models

In order to verify whether it is reasonable to add the second factor to the model in order to strengthen its forecasting properties, the strongest two-factor models were built, taking into consideration the following limitations:

- correlation between the factor and default rate (in modulus) not less than 40% (substantiation of existence of influence on the default rate);
- correlation between factors (in modulus) not exceeding 60% (absence of multicollinearity);

- deviation of the correlation ratio between the factor and DR from the maximum correlation value of this factor with the optimal lag value not exceeding 0.1 (substantiation of choice of the lag length)[2];
- each factor in the model is statistically significant: p-value not exceeding 0.05;
- we excluded certain models based on the factors with poor properties on the basis of the results of the graphical analysis: dollar_ep, and CPI_1;
- we excluded the models in which the sign of the regression coefficient in front of the variable does not correspond to the economic sense of influence of the variable on the default rate: rdi2_lag18, rdi2_lag17 etc.

The model of log linear regression (R^2adj = 92.7%) with the variables: dollar_aver_lag2 (increment of the average annual US dollar exchange rate) and rdi_2_lag3 (average annual index of real disposable household income) showed the greatest forecasting power. The predictive power of this model is somewhat greater than that of the one-factor model with the variable gdp_1 (R^2 = 88.3%) but adding supplementary factors to the model did not result in a significant increase of its predictive power, and therefore is unreasonable.

Stage 3. Back Testing of the Model

We verified the results of one-factor models with the variable of "GDP growth rate" in the test selection (back testing) applying the following approach: distinguishing of an individual training selection for development of the model and a testing selection to verify its quality[3]. The final model should meet the following criteria:

- the model should have the highest determination coefficient;
- the relative reduction of R^2 in the testing selection should not exceed 5%.

The results of comparison of the approaches to analysis are presented in Table 12.

Table 12. Results of choice of the approach to building of the final model (%).

Model	R^2 in the selection:	
	Training selection	Testing selection
Vasicek model	89.3	86.7
Log linear regression	86.1	83.6
Linear regression	77.1	73.7

On the basis of the results of the analysis, we see that the Vasicek model represents most adequately the influence of the annual GDP increment rate on the default rate in the segments of Trade, Manufacturing, and Services. This model is highly efficient in the training selection, R^2 = 89.3%. In the testing selection the efficiency of the model is slightly lower, R^2 = 86,7%. Reduction in effectiveness of a selection within 5% is admissible.

Stage 4. Model Parameters Evaluation

The constructed Vasicek model is written as:

$$DR = N\left(\frac{N^{-1}\left(DR_{avg}\right) - \sqrt{\rho}\ Z}{\sqrt{1-\rho}}\right), \quad (17)$$

where $N()$ – standard normal distribution;

$N^{-1}()$ – inverse normal distribution;

DR – default rate;

DR_{avg} – average level of DR across the selection;

Z – standardised value of macroeconomic factor calculated by the following formula:

$$Z = \frac{X - \bar{X}}{\sigma},$$

where X – macro factor value as of the reporting date;

$\bar{X}$ – macro factor average value;

σ – standard deviation of macro factor;

ρ – model parameter characteristic of the level of the nonlinear dependence between the macro factor value and DR.

The value of parameter ρ was evaluated on the basis of the condition of maximisation of the total determination coefficient of the model (using the 'Solver' add-in in MS Excel). The stability of the predictive power of the model on the basis of indicator R^2 on an annual basis was thereby controlled. This approach helped to maximise the total R^2 up to88.3% and achieve a high predictive power of the model since 2013 (since 2013 $R^2 \geq 87.7\%$). The insufficient predictive power of the model using the data for 2012 may be explained by a high DR volatility in the segment of Manufacturing and Services in this year, not related to macroeconomic factors. Table 13 presents information on th estability of the R^2 indicator arranged by the years.

[2] This is about deviation in the correlation ratio value when a lag variable, for which correlation with DR is less than for the variable with the optimal lag length, is used in the model. For example, assume that the maximum correlation ratio between DR and macroeconomic factor is achieved with a lag of L1. When a two-factor model is constructed, the overall effectiveness of the model with lag L2 is greater than that of the model with lag L1 (although the variable correlation level with lag L2 with DR is slightly lower than the variable correlation with lag L1). In this case, choosing a variable with lag L2 it is necessary to ensure that the lag length is sufficiently interpretable. A deviation of 0.1 from the maximum correlation ratio of this factor with DR level is accepted as the interpretability measure.

[3] We used monthly points obtained by the linear interpolation method, and lying between quarterly observations as the training selection. In order to verify the quality of the model, the testing selection was built on the basis of quarterly observations.

Table 13. Values of indicator R^2 arranged by the years (%).

Indicator	2012	2013	2014	2015	2016	Total R^2
R^2	20.0	87.7	93.5	94.1	83.2	88.3

Table 14. Values of parameters of the Vasicek model (%).

ρ	DR_{avg}	$\bar{X}$	sigma
8.49	4.78	0.32	1.71

Table 15. Scenario values of change of the annual GDP growth rate and one-year DR (segments of Trade and Manufacturing and Services) (%).

Scenario of change of the annual GDP growth rate	Indicator	2018	2019	2020 et seq.
Basic (50%)	GDP growth rate	1.60	1.20	1.10
	DR_{New}	2.43	2.87	4.68
Optimistic (25%)	GDP growth rate	2.90	1.90	
	DR_{New}	1.38	2.14	4.68
Worst-case (25%)	GDP growth rate	0.90	−2.90	
	DR_{New}	3.24	12.14	4.68
Annual DR, weighed on the basis of scenarios probability	DR_{New}	2.37	5.01	4.68

Figure 12. Comparison of the actual dynamics of the default rate in the segments of Trade and Manufacturing and Services with the forecasted rate.

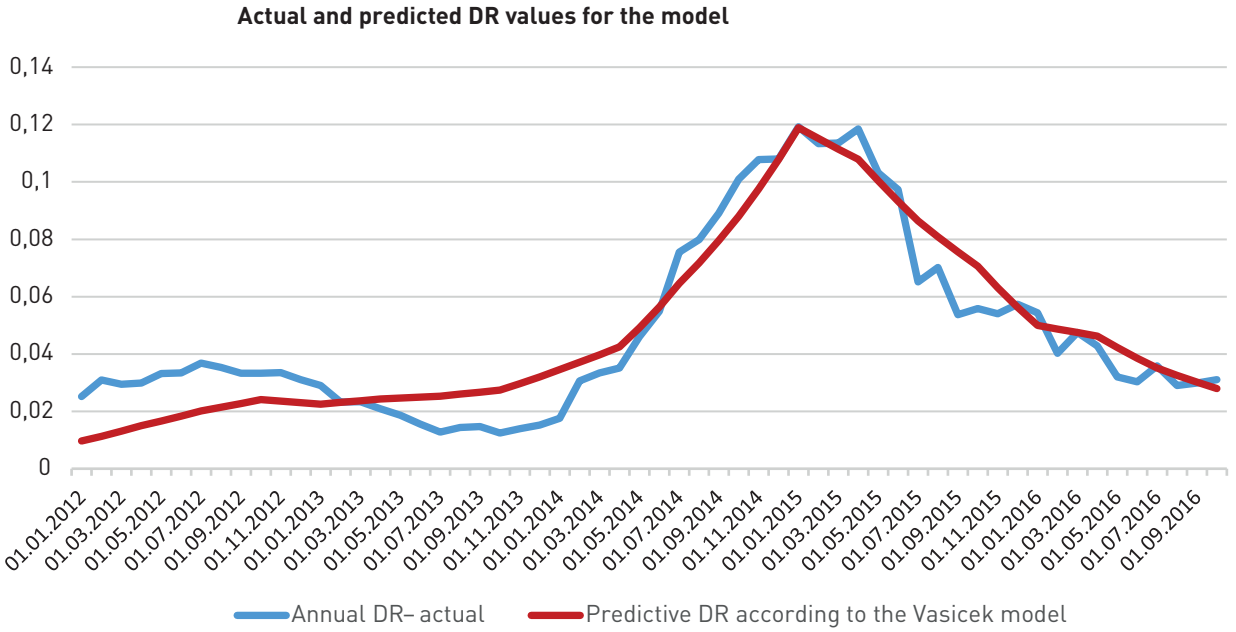


Table 14 presents information on the obtained values of parameters of the Vasicek model described in formula (17).

Graphically the comparison of the actual dynamics of the default rate in the segments of Trade, and Manufacturing and Services with the forecasting rate is presented as follows (Figure 12).

Choice of Scenarios of Parameters Change

In order to take into consideration the forecasting macroeconomic information for two years we took as the basic, optimistic and worst-case scenarios the forecasts of the annual GDP growth rate on the basis of statistics published by the Bank of Russia [12].

In accordance with the explanations given by the Impairment Transition Group (ITG), the ECL evaluation should take into account at least two macroeconomic scenarios if there is a significant non-linear interrelation between macro parameters in various possible scenarios and credit losses related to them. For the segments of Trade and Manufacturing and Services this interrelation is non-linear. It is expressed in the nonlinear nature of the type of DR dependence in the level of the annual GDP growth rate which, taking into consideration the actual data, shows a more intensive growth of DR level in an unfavourable economic environment. On the contrary, in a favourable economic environment DR decreases less intensively, approaching asymptotically 0% (Figure 13) [9].

The probability of alternative scenarios is chosen in accordance with an expert opinion of the bank taking into consideration the following rules:

- The probability of the optimistic worst-case scenarios should be less than the probability of the basic scenario;
- The sum of probabilities of all scenarios should be 100%.

In the general case the bank accepts the probability of optimistic and worst-case scenarios as equal. But asymmetrical scenarios are possible if, according to the bank's expert opinion one of the alternative scenarios of displacement against the basic scenario seems to be more probable: optimistic or worst-case scenario.

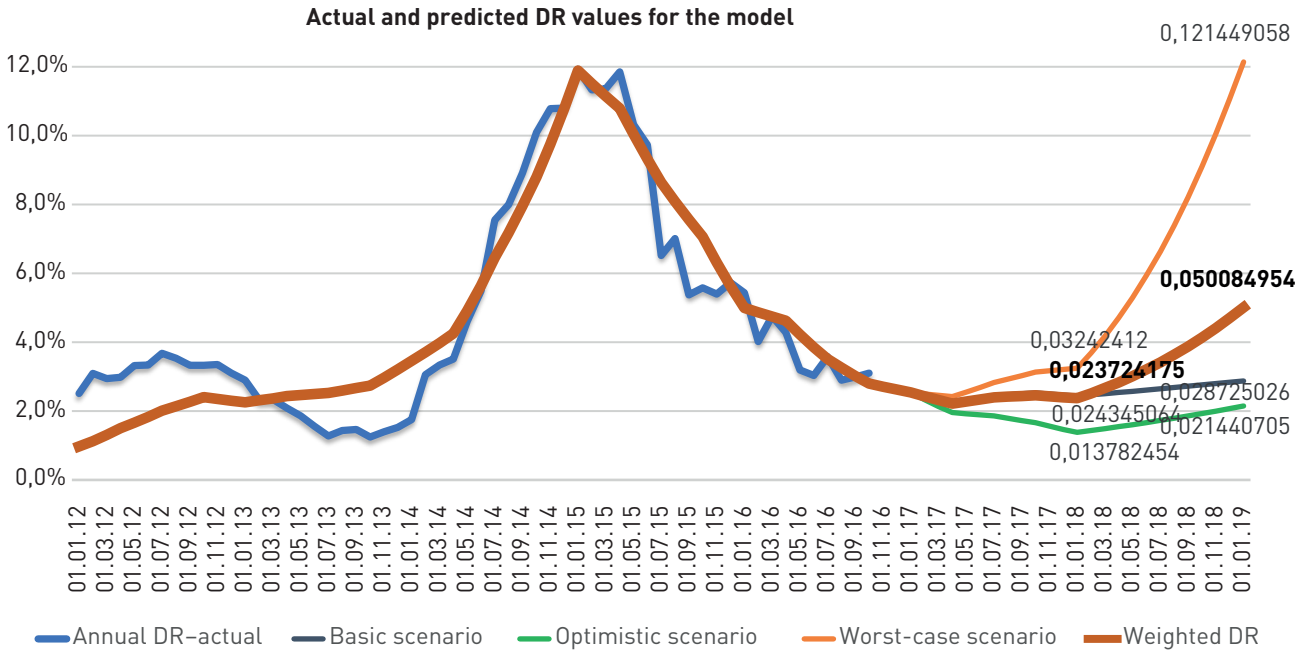
The probabilities of macroeconomic scenarios should be equal for all segments and macroeconomic indicators.

Calculations of the optimistic and worst-case forecasts of the GDP growth rate and corresponding forecast of DR for the segments of Trade and Manufacturing and Services built on the basis of the macroeconomic Vasicek model described in item 10.1.2 are represented in Table 15 and Figure 13.

The influence of macroeconomic factors is taken into consideration only for the first and second years. From the third year onwards, the value of the central tendency is used because PD PIT forecast for a period exceeding two years may be insufficiently reliable due to a decrease of the accuracy of macroeconomic forecasts when the forecasting horizon increases. In accordance with IFRS 9, an assessment of the expected credit losses does not require an obligatory detailed evaluation for periods reaching to the distant future. For such periods a company may extrapolate the existing reliable information [9].

For the purpose of defining Lt PD PIT, taking into consideration the predictive macroeconomic information, the average PD of the portfolio is accepted as 4.68% (average one-year DR in the segments of Trade and Manufacturing and Services, data from 01.11.2011 to 01.10.2016). The forecasting default rates weighed on the basis of scenarios probability for 2018 amounted to 2.37%, and for 2019 – 5.01%.

Figure 13. Graphical interpretation of macroeconomic scenarios



The offered macroeconomic model ensures a high stability of predicted values depending on the level of input from macroeconomic factors. This is provided by the choice of the type of the function of dependence of DR on GDP according to the Vasicek model which is close to the line function at medium and high DR but at the same time provides for a gradual asymptotic approximation of DR to zero when the GDP growth forecast is 3% and more. On the basis of testing results the predictive power of the model (presented as the determination coefficient R^2) is stable from year to year. This is confirmed by a small value of standard deviation of the determination coefficient R^2 which equals 5.2%.

Correction of TTC Lt PD for taking the macroforecast into consideration

The correction of the final TTC Lt PD (for the first and second year) presented in item 2.4 was effected in accordance with formula (15).

Table 16 represents the final one-year conditional PD which indicates the probability of default taking into consideration the influence of macroeconomic information.

Table 17 presents the final one-year marginal PD, which indicates the probability of default taking into consideration the influence of macroeconomic information and participation in ECL evaluation.

Table 16. The final one-year conditional PD, which indicates the probability of default taking into consideration the influence of macroeconomic information.

Scale	PD TTC	Forward PD (PD PIT for the 1st and 2nd year, PD TTC for the 3–5 years)				
		Year 1	Year 2	Year 3	Year 4	Year 5
1+	0.01	0.00	0.01	0.01	0.01	0.01
1	0.02	0.01	0.02	0.02	0.02	0.02
1–	0.04	0.02	0.04	0.04	0.04	0.04
2+	0.08	0.04	0.09	0.08	0.08	0.08
2	0.16	0.08	0.17	0.16	0.16	0.16
2–	0.32	0.16	0.34	0.32	0.32	0.32
3+	0.45	0.22	0.53	0.44	0.39	0.35
3	0.58	0.29	0.88	0.73	0.65	0.59
3–	0.75	0.37	1.46	1.22	1.09	0.98
4+	0.96	0.48	2.44	2.03	1.81	1.64
4	1.23	0.61	2.55	3.01	3.13	3.08
4–	1.58	0.79	5.08	4.73	4.37	3.99
5+	2.03	1.02	5.08	4.73	4.37	3.99
5	2.61	1.31	6.62	6.62	6.23	5.73
5–	3.36	1.69	6.81	6.81	6.43	5.92
6+	4.31	2.18	8.61	7.88	7.13	6.39
6	5.54	2.82	10.89	9.13	7.90	6.90
6–	7.12	3.66	11.76	9.94	8.60	7.49
7+	9.14	4.74	12.71	10.81	9.35	8.14
7	11.74	6.18	13.74	11.77	10.17	8.84
7–	15.08	8.08	18.41	14.11	12.67	11.50
8+	19.37	10.63	24.64	16.91	15.78	14.95
8	24.89	14.09	32.94	20.27	19.66	19.45
8–	31.97	18.87	43.95	24.30	24.48	25.30
9	41.06	25.64	58.48	29.13	30.49	32.91

Table 17. The final one-year marginal PD, which indicates the probability of default taking into consideration the influence of macroeconomic information (segment of Trade) (%).

Scale	PD TTC	MPD				
		Year 1	Year 2	Year 3	Year 4	Year 5
1+	0.01	0.00	0.01	0.01	0.01	0.01
1	0.02	0.01	0.02	0.02	0.02	0.02
1–	0.04	0.02	0.04	0.04	0.04	0.04
2+	0.08	0.04	0.09	0.08	0.08	0.08
2	0.16	0.08	0.17	0.16	0.16	0.16
2–	0.32	0.16	0.34	0.32	0.32	0.32
3+	0.45	0.22	0.52	0.43	0.39	0.35
3	0.58	0.29	0.88	0.72	0.64	0.57
3–	0.75	0.37	1.46	1.20	1.05	0.94
4+	0.96	0.48	2.43	1.97	1.73	1.53
4	1.23	0.61	2.54	2.92	2.94	2.80
4–	1.58	0.79	5.04	4.45	3.92	3.43
5+	2.03	1.02	5.03	4.46	3.93	3.44
5	2.61	1.31	6.53	6.10	5.37	4.62
5–	3.36	1.69	6.69	6.24	5.49	4.73
6+	4.31	2.18	8.42	7.05	5.87	4.89
6	5.54	2.82	10.58	7.91	6.22	5.00
6–	7.12	3.66	11.33	8.45	6.58	5.24
7+	9.14	4.74	12.11	8.99	6.94	5.47
7	11.74	6.18	12.89	9.53	7.27	5.67
7–	15.08	8.08	16.92	10.58	8.16	6.47
8+	19.37	10.63	22.02	11.39	8.83	7.05
8	24.89	14.09	28.30	11.69	9.06	7.23
8–	31.97	18.87	35.65	12.09	9.38	7.48
9	41.06	25.64	43.48	12.66	9.82	7.84

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Appendix 1. Bank Master Scale (%)

Scale of PJSC BANK XXX	Probability of default (PD)	Lower limit of the probability of default	Upper limit of the probability of default
1+	0.01	0.00	0.02
1	0.02	0.02	0.03
1–	0.04	0.03	0.07
2+	0.08	0.07	0.14
2	0.16	0.14	0.27
2–	0.32	0.27	0.38
3+	0.45	0.38	0.49
3	0.58	0.49	0.63
3–	0.75	0.63	0.81
4+	0.96	0.81	1.04
4	1.23	1.04	1.33
4–	1.58	1.33	1.71
5+	2.03	1.71	2.20
5	2.61	2.20	2.82
5–	3.36	2.82	3.63
6+	4.31	3.63	4.66
6	5.54	4.66	5.99
6–	7.12	5.99	7.69
7+	9.14	7.69	9.88
7	11.74	9.88	12.69
7–	15.08	12.69	16.30
8+	19.37	16.30	20.93
8	24.89	20.93	26.89
8–	31.97	26.89	34.54
9	41.06	34.54	100
10	100	100	100

Appendix 2. Glossary. Terms and Definitions

Probability of default	–	probability (in percent) of default occurrence as regards the customer's obligations within one year, defined by means of the model of the probability of default evaluation
Internal credit rating	–	indicator providing a comprehensive characteristic of the customer's/project's creditworthiness, calculated on the basis of the risk factor indicators
Default	–	failure to fulfill obligations of loan repayment by the borrower (default is taken into consideration in accordance with the definition stated in the article)
Cumulative probability of default (cPD)	–	probability of default at any moment within the period T (accumulated probability of default)
Marginal probability of default, mPD (t)	–	unconditional probability that default will occur within the future period t which is a part of the period T
Observation	–	data aggregate concerning a customer/project as of a certain date
Rating	–	In accordance with the Report on Development of the Inner Model of Evaluation of the Probability of Default of Corporate Borrowers in the Trade Segment
Rating group	–	an aggregate of several rating grades located in the rating scale at neighbouring positions unified in order to ensure a sufficient number of observations for a statistical analysis
Risk segment	–	a group of rating objects defined in accordance with inertial regulatory documents of the bank based on requirements of Basel Standards and Standards of the Bank of Russia
Conditional probability of default, PD (t)	–	the conditional probability that default will occur within the future period t which is a part of the period T, provided the default does not take place before the beginning of period t
Rating scale	–	Gradation rating scores in accordance with Appendix 1
Probability of default for the life-time of the instrument, Lt PD	–	Probability of default within the contractual validity term of a financial instrument

Designations and Abbreviations

cDR	–	cumulative default rate
cPD	–	cumulative probability of default
Dpd	–	days past due
DR	–	default rate
mPD	–	marginal probability of default
PD	–	probability of default
PD for 12 months	–	probability of default within 12 months after the reporting date
PIT (point-in-time)	–	calibration at the "point-in-time"
TTC	–	through-the-cycle
CPI	–	consumer price index
IFRS 9	–	International Financial Reporting Standards (IFRS) 9 Financial Instruments
ECL	–	expected credit losses
SP AACR	–	Software Package Accounting and Analysis of Credit Risks

APPENDIX 3. Calculation of influence of macroeconomic information based on integrated data in the segments of Trade, Manufacturing, and Services