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Behavioral Biases in Capital Budgeting: An Experimental Study of the Effects on Escalation of Commitment Given Different Capital Budgeting Methods*

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Abstract. This study examines if decision-makers using less sophisticated capital budgeting methods, such as Net present value and Payback, display a higher level of escalation of commitment to a failing project, compared to decision-makers using more sophisticated capital budgeting methods, such as Real options. Past studies advocates superiority in decision-making when incorporating more sophisticated models into a company's capital budgeting. The findings coincide with previous studies; that decision-makers explicitly using Real options display a lower escalation of commitment compared to decision-makers using Net present value. However, no difference in escalation of commitment was recorded between decision-makers using Payback and decision-makers using Real options.

Аннотация. Это исследование рассматривает особенности использования более простых методов бюджетирования капитала — таких как чистая приведенная стоимость и окупаемость — в сравнении с более сложными методами, такими как реальные опционы. Предшествующие исследования доказывают преимущества использования более сложных моделей при принятии решений. Результаты совпадают с предыдущими исследованиями: руководители, использующие в явном виде реальные опционы, показывают меньший рост эскалации обязательства по сравнению с теми, кто принимал решения на основе чистой приведенной стоимости. Однако разницы в эскалации обязательства не было отмечено между руководителями, принимающими решения на основе метода окупаемости, и теми, кто использовал реальные опционы.

Key words: Real options, Net present value, Payback, capital budgeting, escalation of commitment.

1. INTRODUCTION

This study examines if decision-makers using less sophisticated capital budgeting methods, such as Net present value and Payback, display a higher level of escalation of commitment to a failing project, compared to decision-makers using more sophisticated capital budgeting methods, such as Real options. The definition of escalation of commitment is when decision-makers continue to dedicate resources to a failing project influenced by previously invested resources (Staw, 1976).

In previous research, Denison (2009) conducted an experiment testing the effects of escalation of commitment to a failing course of action, by comparing investment recommendations between participants using explicitly Net present value and Real options. Denison's results of the experiment indicated that participants using Real options were less likely to exhibit escalation of commitment compared to participants using Net present value, and were also more likely to abandon unprofitable projects.

Advocates arguing to incorporate Real options in capital budgeting claim that more sophisticated capital budgeting leads to superior decision-making compared to less sophisticated capital budgeting methods (Antikarov and Copeland, 2001). The superiority of sophisticated capital budgeting methods derives from the higher quality of information being available to the decision-makers (Denison, 2009). Less sophisticated capital budgeting methods, such

* Поведенческие отклонения в бюджетировании капитала: экспериментальное исследование эффектов эскалации обязательства с учетом различных методов бюджетирования.

as discounted cash flow models, serve as appropriate valuation methods for cash cow businesses, but fall short when implementing substantial growth opportunities, R&D expenditure, intangible assets and abandonment value in valuation analysis (Myers, 1984). With discounted cash flow models understating the option value attached to growing, profitable businesses (Myers, 1984), the information used in these methods is presumed inferior to the information used in real options analysis. Studies have claimed that by exclusively using Real options analysis, the option of project abandonment becomes more cognitively accessible to decision-makers (Denison, 2009), and helps overcome "antifailure bias" (McGarth, 1999). This would suggest that decision-makers using Real options in their capital budgeting would be likely to display a lower level of escalation of commitment in failing projects compared to decision-makers using Net present value and Payback.

Regardless of theoretical superiority of incorporating a higher sophistication in capital budgeting, empirical findings suggest that in real life, managers oppose incorporating real options into capital budgeting (see Pike, 1996; Graham and Harvey, 2001; Sandahl and Sjögren, 2003; Block, 2007; Brunzell, Liljeblom and Vaihekoski, 2011). Block's (2007) findings suggest that inadequate understanding of real options in top management, and not wanting to shift decision-making to mathematicians and decision scientists, makes managers oppose the usage of real options, and instead rely on discounted cash flow and payback models, which they understand.

Irrational behavior due to escalation of commitment exists according to Friedman *et al.* (2007) in the real world on a grand scale. Decision-makers justify continuous resource spending into failing projects with the amount of resources already been spent, instead of considering abandonment. A few real world examples of escalation of commitment behavior can be illustrated with the Coke and Pepsi wars, Campeau auction, Maxwell House and Folgers advertising war and NASA's space shuttle Columbia, all resulting in an unnecessary spending of resources (Friedman *et al*., 2007). If instead decision-makers would become aware of the irrational behavior because of the escalation of commitment bias, it could potentially prevent project cost overruns. The purpose of this paper is to examine if more sophisticated capital budgeting methods lead to lower escalation of commitment, thereby preventing project cost overruns and leading to more profitable investment decisions.

To answer the research question, an experiment was conducted in which participants used one of three capital budgeting methods: Real options, Net present value, or Payback. By evaluating a project using the assigned capital budgeting method, the participants' recommendations to continue an unprofitable project were measured. Since in the experiment, a uniform decision should have been made regardless of capital budgeting method used, deviating behavior between capital budgeting methods was due to behavioral effects.

The difference between this study and previous studies (see Denison, 2009) is the inclusion of the capital budgeting method Payback. Payback is included in this study because of its historically persistent extensive use in capital budgeting (see Pike, 1996; Graham and Harvey, 2001; Sandahl and Sjögren, 2003; Brunzell, Liljeblom and Vaihekoski, 2011), and low sophistication.

The findings in this paper indicate that participants using Real options were not only more aware of a potential project failure compared to Net present value and Payback participants, but were also more likely to abandon a failing project compared to Net present value participants. However no difference was recorded in the likelihood of project abandonment between participants explicitly using Real options compared to participants explicitly using Payback. The lower escalation of commitment in Real options compared to Net present value participants was recorded even though all participants were provided the same information about cash flows, abandonment value and sunk costs.

The remainder of this paper is structured as follows. Section 2 presents relevant literature related to the behavioral biases escalation of commitment and sunk cost fallacy, followed by a review of the three capital budgeting methods used in the experiment. Section 3 formulates and presents the hypothesis. Section 4 describes the methodology of the experiment and statistical methods used. Section 5 presents and analyzes the results of the experiment, provides limitations of the study and concluding remarks.

2. THEORY

2.1. BACKGROUND

Expected utility theory (EUT) suggests that rational investors pursue utility maximization in their investments. In 1979 Daniel Kahneman and Amos Tversky found human behavior violating the axioms of EUT, and proposed an alternative model for determining decision-making under risk. Kahneman and Tversky's (1979) prospect theory motivates that a person's behavior is changing depending on if the person is winning or losing. If a person is winning (situated in the

gain domain) the person will display risk aversion behavior (favor certainty before uncertainty), while if the person is losing (situated in the loss domain) the person will display risk seeking behavior (favor uncertainty before certainty). Further research based on prospect theory (see Thaler, 1980; Statman and Caldwell, 1987) developed behavioral theories such as mental accounting, behavior enhanced with emotions of pride/regret and escalation of commitment, which all influence abandonment decisions in executive management.

Statman and Caldwell (1987) argued, based on Kahneman and Tversky's idea, that: "Behavioral finance provides a framework, supported by experiments, that is consistent with the tendency to resist project termination". Managers opposing project abandonment will overinvest in projects, thereby diverging from profit maximization decisions.

The two main behavioral biases discussed in this paper, which influence abandonment decisions, are Escalation of commitment and Sunk cost fallacy. Both behavioral biases emerge from mental accounting, introduced by Thaler (1980) and exemplified by Statman and Caldwell (1987).

2.2. MENTAL ACCOUNTING

While making decisions of abandonment or continuation, managers are faced with making choices based on uncertain cash flows. Managers that follow the net present value analysis, frame the cash flows according to economic accounting (Statman and Caldwell, 1987). But instead of using economic accounting managers use mental accounting to frame future cash flows, thereby including sunk costs in their decision-making (Statman and Caldwell, 1987).

Kahneman and Tversky's (1979) prospect theory divides the decision-making process into two phases. Firstly the manager frames the project by establishing mental accounts. Secondly the manager evaluates the project given the mental accounts created.

Consider the following example:

A project has lost $2,000 and the manager is given two options:

1) Continue the project with equal probability to gain $2,000 or gain nothing.

2) Abandon the project and gain $1,000 for sure.

Depending on if the manager ignores the sunk costs or not, it will either put the manager in the loss domain (include sunk costs) or gain domain (ignore sunk costs) of the value function.

According to economic accounting the initial loss of $2,000 should be considered a sunk cost, meaning that the account should be closed with a realized loss of $2,000. The options should then be considered as a 50–50 gamble of $2,000 or nothing for alternative 1, or $1,000 for sure for alternative 2. According to prospect theory a person displays risk aversion behavior in the gain domain (if ignoring sunk costs), and option 2 should therefore be chosen, as certainty is favored before uncertainty.

Conversely, if the manager is reluctant to realize losses, the first account will not be closed but instead it will be evaluated with the two options. When including sunk costs in the decision-making, the manager frames the alternatives in the loss domain of the value function. This leads the manager to frame the options as either a sure loss of $1,000 if option 2 is chosen, or a 50–50 gamble of outcome 0 or a loss of $2,000 if option 1 is chosen. According to prospect theory people are reluctant to realize sure losses and will instead display risk-seeking behavior in the loss domain in hopes of turning the loss into a gain or at least to get even. This type of behavior usually leads to even greater losses and was named "get-evenitis" by Shefrin (1999), and defines the behavior of holding on to a failing investment in hopes of getting even.

2.3. BIASES AND HOW THEY RELATE TO EXIT STRATEGIES

Kahneman and Tversky's (1979) prospect theory and Statman and Caldwell's (1987) mental accounting theory provide explanations to behavioral biases displayed by managers in project termination decisions. Horn *et al.* (2006) divides the decision-making process for project termination into three steps: An analysis step, a decision step and a step to proceed

Figure 1. 3-step decision-making process for project termination by Horn *et al.* (2006) including behavioral biases. In the first step the company analyzes if their projects are meeting expectations or not. If not, in the second step the company decides if they should terminate the project or continue with it. If a termination decision occurs, in the third step, the executive management works out the details around the project termination (for example the price of the project if it will be sold).

with the abandonment. In Figure 1 the three steps toward project termination and behavioral biases affecting each corresponding step are presented.

This study focuses on step 2, the decision step of project termination, and the effects of the behavioral biases escalation of commitment on project abandonment decisions.

2.3.1. Escalation of commitment and sunk cost fallacy

"Escalation of commitment and the sunk cost fallacy are essentially the same phenomenon: both lead decision-makers to exaggerate investments following previous commitment of resources. One distinction is that escalation may be associated with forms of commitment other than previous expenditures of economic resources, or sunk costs" (Camerer and Weber, 1999).

According to Statman and Caldwell (1987) commitment has both positive and negative behavioral sides in people. The positive side of commitment according to Statman and Caldwell (1987) is the persistence in pursuing goals, a motivator to work harder and accomplish more, and also to generate the force needed to complete difficult projects. Conversely commitment also entraps people in losing projects.

When evaluating a project, a manager committed to the project will take all costs into consideration when making the decision to abandon the project or not. In fact, variables such as sunk costs should be disregarded from the calculations. Statman and Caldwell (1987) argue that the tendency to become committed is deeply rooted in us, and that we lack a mechanism to turn it off or regulate it.

Few studies have been made examining the effects of capital budgeting methods on escalation of commitment, and if different capital budgeting methods result in a diverging level of escalation of commitment. Denison (2009) found indications of more sophisticated capital budgeting models, like real options (RO), resulting in a lower level of escalation of commitment in failing projects compared to less sophisticated capital budgeting models, like net present value. The effects of different capital budgeting methods on escalation of commitment are unclear, and apart from Denison's study, no other studies have examined the direct effects of capital budgeting methods on escalation of commitment.

2.4 Capital Budgeting

A variety of methods and techniques are available for managers to alleviate capital budgeting procedures (Horngren, Foster, and Datar, 1997). The use of these capital budgeting methods and techniques deviate between different managers (Brijlal, Quesada, 2011), or are by some ignored altogether in the decision-making process (McDonald, 2000). But over the past 3 decades companies have started to realize the importance of incorporating the possibility of project failure in capital budgeting decisions (Pike, 1996), thereby beginning to use more sophisticated capital budgeting methods to a higher extent. Some researchers argue that a higher degree of sophistication leads to optimal investment strategies (see Lander and Pinches, 1998; Block, 2007; Antikarov and Copeland, 2001), primarily by using RO. Other studies contradict the theory of more sophisticated capital budgeting methods being superior by arguing, "Empirical research has provided some, but very limited, support for the real-world applicability of real options models" (Chance and Peterson, 2002).

Regardless of the theoretical superiority of using RO in capital budgeting, in practice companies seem to continue using Payback (PB) and Net present value (NPV) as their main capital budgeting methods (see Pike, 1996; Graham and Harvey, 2001; Sandahl and Sjögren, 2003; Brunzell, Liljeblom and Vaihekoski, 2011). Block (2007) argues that sophisticated capital budgeting methods like RO are rarely used apart by certain industries such as, technology, energy, and utilities, where management is composed of specialists in science and math.

A brief description of each of the capital budgeting methods used in the experiment is provided in the following section.

2.4.1 Payback

Payback is a simplistic method calculating the number of periods required to pay back the net investment. A shorter PB period is considered superior to a longer one, since it allows the resources to be reused more quickly (Farris *et al*., 2010).

Academic literature has repeatedly illustrated problems associated with simple capital budgeting techniques such as PB, as it leads to non-firm value maximization investment decisions (Hatfield *et al.,* 2011). The 2 main problems emerging from PB analysis in capital budgeting, are that firstly it neglects time value of money, and secondly that it disregards cash flows generated by the investment after the PB period.

A common problem with PB analysis is that projects with a high cash flow in the beginning of the project are preferred, because of a shorter PB ratio, to projects with stable cash flows over a long period of time, regardless of their discounted cash flow value. If projects with lower value are chosen because of their shorter PB ratio, the company is not maximizing shareholder value. Regardless of the critique, the

usage of these simple methods is justified by easily interpreted results and calculations, requiring little or no knowledge in finance (Bower and Lessard as cited in Hatfield *et al.*, 2011).

No research has been made examining the relationship between PB and behavioral biases such as escalation of commitment. However, assuming PB being a hurdle rate whether to accept a project or reject it, research claims that self set hurdle rates by decision-makers result in lower escalation of commitment, compared to organization set hurdle rates (Cheng *et al.,* 2003).

An approach to decrease escalation of commitment in decision-makers that use the capital budgeting method payback would be to let the decision-maker set his own hurdle rate for when a project should be accepted or rejected (Statman and Caldwell, 1987; Cheng *et al.,* 2003).

2.4.2 Net present value

Net present value incorporates time value of money and presents the difference between the sum of discounted cash inflows and the sum of discounted cash outflows. Therefore if NPV is positive the project should be undertaken, whereas if NPV is negative the project should be abandoned. Variations of NPV calculations also take into account the abandonment value often comparing it to the NPV of the cash flows to determine if a project should be continued or abandoned (Denison, 2009). If the NPV of cash flows is greater (lower) than the abandonment value, the project should be undertaken (abandoned). This NPV variation resembles real options valuation discussed further below.

Literature suggests that NPV in theory is superior to other capital budgeting methods, since it consistently chooses the projects that maximize firm value and thereby shareholders' wealth (Hatfield *et al.,* 2011). Primary critique against NPV is that contrary to RO it does not take into account managerial flexibility in project valuation and assumes the cash flows being fixed. This undervalues the projects by not taking into consideration the options value.

Past research claims that decision-makers using NPV in capital budgeting display a higher level of escalation of commitment compared to decision-makers using RO. The higher level of escalation of commitment from using NPV derives from the inferior quality of information available to decision-makers (Denison, 2009). Myers (1984) argues that the type of information used in NPV valuations neglects the value of abandonment, growth opportunities and intangible assets. Neglecting the abandonment value in capital budgeting further leads to a lower construct accessibility of a possible project abandonment in managers, thereby leading to a higher level of escalation of commitment (Denison, 2009).

2.4.3 Real options

The term of real options was introduced by Myers (1977) and defined as real options are growth opportunities for a firm whose value depends on the firm's future investments. This would divide the value of a firm into the value of the firm's assets and the value of the firm's growth options (Collan and Kinnunen, 2009). RO determines firm value by taking into account the variety of possible management options (managerial flexibility) in an investment opportunity. The RO valuation incorporates options such as expansion or abandonment of the investment in the calculated value, where the highest of the possible values is chosen. Denison (2009) explains, "The use of real options in capital budgeting basically involves considering possible decision points that could arise as a project unfolds and the best response of management at each of these decision points. The value of the project should management choose the best option at each of these points is calculated, and a weighted average of these possible outcomes is taken based on their probability of occurrence".

A potential shortfall in RO is the level of sophistication the model requires. Complicated mathematical models intimidate managers whose choice is to instead use simplistic capital budgeting models that they feel comfortable using and interpreting (Lander and Pinches, 1998). Additionally the assumptions required for performing RO modeling are often violated in practice (Lander and Pinches, 1998).

2.5 HYPOTHESIS

Accessibility of cognitive constructs, such as personality traits, attitudes and choice options, is defined by psychology as the ease with which these constructs can be brought to mind (Higgins, 1996). The construct accessibility can be increased through repetition (Higgins and King, 1981) or through task instructions (Higgins and Chaires, 1980)

By failing to incorporate RO in the decision phase, executive management ignores the value of managerial flexibility of early project termination. However managers that do incorporate RO models in their capital budgeting, will repeatedly be exposed to the option of early abandonment in contrast to managers that only use NPV or PB. This will result in RO users having an increased construct accessibility of early project abandonment due to the construct of early project termination being activated more frequently through written instructions in RO participants compared to NPV or PB participants (Higgins *et al.,* 1982).

Additionally Posavac *et al.* (1997) states that when decision alternatives are salient, the decision-maker will be more likely to choose the preferred alternative. However, if the decision alternatives are left unspecified, the decision-maker will have to access the construct from memory, which potentially leads to a complete negligence of the preferred alternative. The negligence of the preferred alternative occurs according to Posavac (1997) when the accessibility is insufficient to retrieve the preferred alternative from memory.

Since the preferred alternative in this experiment is early project abandonment, decision-makers using the capital budgeting method RO, which has task instructions and salient decision alternatives about early project abandonment, should display a lower level of escalation of commitment compared to decision-makers using NPV or PB.

Hypothesis 1:

Project abandonment decisions in the case of unprofitable projects will be more probable when Real options are used explicitly for project decision-making compared to solely using Payback or Net present value.

Hypothesis 2:

Project abandonment decisions should not vary between capital budgeting methods Payback and Net present value, which do not take into account early project abandonment value in their calculations.

3. METHODOLOGY

The experiment was a quantitative study conducted through an online survey. In order to constrain unauthorized people from having access to the experiment, the survey was only accessible to selected participants at Gothenburg School of Business, Economics, and Law chosen prior to the experiment.

A potential shortfall of the experiment is the simplified experimental setting used, distant from capital budgeting situations in reality. This should not have an effect on the results, as there is a close similarity between experimental surveys and realistic field studies in research on organizational behavior (Locke, 1986). Additionally Griffin and Kacmar (1991) argue that experimental surveys provide a valid and useful approach in many situations.

3.1 Participants

The participants consisted of 293 past and current MSc Finance, MSc Economics, and Bachelor students with Corporate Finance major from University of Gothenburg School of Business, Economics, and Law in Gothenburg, Sweden.

The distribution of participants was 147 Corporate Finance students (50.17%), 107 Finance students (36.52%) and 39 Economics students (13.31%). The participants were chosen because of their theoretical knowledge of the capital budgeting methods used in the experiment. Use of students as subjects is consistent with the recommendations in Gordon *et al.* (1987) and is justified by the findings of Ashton and Kramer (1980) displaying similar results with students and nonstudents in decision-making studies.

A total of 48 students completed the experiment, yielding a 16.38% response rate and were divided accordingly among each capital budgeting method: 16 NPV responses, 15 RO responses, and 17 PB responses. The average age of the 48 participants completing the experiment was 23.46 years and 39.58% were female.

3.2 CASE GIVEN TO PARTICIPANTS, APPENDIX B

The case provided to each participant regarded a development of a new cell phone hard drive. This new hard drive had a higher storage capacity while maintaining production costs and dimensions constant compared to current cell phone hard drives. Each of the participants played the role of a controller for Ericsson AB who was responsible for project evaluations, and was given an example with calculations of how to use their assigned capital budgeting method. The example provided was given to the participants to guarantee an understanding on how to solve the case, and the participants could at any time refer back to the example while performing their own calculations. Furthermore the participants received information about the forecasted cash flows, project lifetime, probability of success/failure and abandonment value of the Ericsson cell phone HDD project. PB participants received exclusive information about a historical average accepted payback period of 3 years for past projects undertaken by Ericsson to use as a reference point in their investment recommendations.

Performing the calculations correctly for the Ericsson Cell Phone HDD project, NPV and RO calculations yielded values of positive $26,000,149.51 and $29,091,031.42 respectively, while PB yielded a payback period of 2.27 years. Correct calculations by the participants should therefore unambiguously lead to funding the project regardless of capital budgeting method used.

After performing the initial project evaluation, additional information explaining a project setback was presented to all case participants. The setback was due to an unexpected competitor entering the market with a superior product. All participants received information about current level of project completion, sunk costs and modified forecasted cash flows based on new demand. Forecasted cash flows became

definite after the project setback and the calculations for NPV and RO yielded the same positive project value of $42,272,795.23, while the payback period for the project increased to 5 years. Simultaneously Ericsson AB could sell the project for 65% of invested capital, thereby yielding an abandonment value of $55,250,000, being $12,977,204.77 higher compared to the calculated NPV and RO value. Correct calculations would indicate an abandonment being more profitable compared to a project continuation, which therefore should lead to an unambiguous choice of project abandonment in NPV and RO participants. The calculated payback period would exceed the average accepted payback period of 3 years, and, correspondingly to NPV and RO, should lead to project abandonment.

3.3 PROCEDURE FOR CASE STUDY

The participants were randomly assigned one of the three capital budgeting methods (RO, NPV and PB), and contacted by email inviting them to participate in the experiment. In the email, participants were asked to take part in an experiment by solving a case study explicitly using the assigned capital budgeting method.

After having read the Ericsson Cell Phone HDD case, each participant was asked to value the project by using the appropriate capital budgeting method. Based on the project value each participant provided a recommendation of whether to fund the project or not on a 10-point scale (1 not likely at all and 10 extremely likely) and a short motivation (1–2 sentences) defending their choice. Because of the apparent decision to accept the project, recommendations below 5 indicated a lack of understanding of the capital budgeting method used or incorrect calculations. 2 participants using RO calculations (4.17% of total, 13.33% of total RO participants) answered with recommendation values below 5, and therefore their values were excluded from the future analysis.

After the initial recommendation the participants were informed about a setback in the project. They were asked to revalue the project by using the same capital budgeting method as for their initial valuation, and provide a recommendation whether to continue the project or not on a 10-point scale (1 not likely at all and 10 extremely likely) and a short motivation (1–2 sentences) defending their choice.

3.4 MANIPULATION CHECK AND DEMOGRAPHIC QUESTIONS

Following the project valuation and investment recommendations participants were asked to answer a series of manipulation check questions and statements. The answers were measured on a 10-point scale with 1 being "Strongly disagree" and 10 being "Strongly agree". The questions were "To what extent do you agree that the firm uses the given capital budgeting method to evaluate its investment decision?", "I considered the possibility that the cell phone HDD project could fail before making my recommendation about whether to undertake the project", "I considered the possibility that the cell phone HDD project could fail before making my recommendation as to whether to continue developing the project", "The case was difficult to do", and "The case was very realistic" defining variables Eval, PFail1, PFail2, Diff and Rea respectively.

Following the manipulation check questions, all participants were asked the same demographic questions to determine the focus of study, previous work experience, age, gender and theoretical knowledge and practical usage of the three capital budgeting methods.

3.5 STATISTICS

The experiment was a repeated measure design where participants were assumed to be the same across the three capital budgeting methods. The between-subjects variable was the capital budgeting method (CapBud), which was manipulated at three levels (RO, NPV, PB). The within-subjects variable, time of recommendation (Time), was manipulated at two levels (Time1 and Time2).

CapBud, the first independent variable, was manipulated at three levels. Participants were randomly assigned to one of the three capital budgeting methods used and asked to explicitly use the assigned method (PB, NPV, or RO) in their investment calculations. The second independent variable, Time, was manipulated at 2 levels. Participants were asked to provide investment recommendations at two points in time, the first being the initial investment decision (Time 1) and the second deciding whether to continue the project after the setback or not (Time 2).

The dependent variable to test both hypotheses is the recommendation to continue the project (RCP) and is measured at two different times. At Time 1, RCP was measured to validate knowledge of the participants and to eliminate potential outliners skewing the results, and at Time 2 measuring the degree of escalation of commitment. A higher RCP score at Time 2 would indicate a higher degree of escalation of commitment due to opposition of project abandonment by the participant.

The most common method of measuring escalation of commitment is in monetary commitment. In this experiment, similarly to Kadous and Sedor (2004)

and Denison (2009), escalation of commitment is measured on a scale indicating the likelihood of recommending a project continuation.

3.6 BIAS AND OTHER DATA ISSUES

Due to a low response rate two tests were run to investigate possible non-response bias. To do this an additional email was sent out to all participants asking those that did not participate in the case to answer two questions. The questions established age and determined knowledge in the three capital budgeting methods RO, NPV and PB.

Assuming only participants not having done the case study replied to the email a total of 86 (29.35% of total number of participants) new replies were recorded. The answers from both groups (those having done the case and those that did not do the case) were statistically compared to each other to determine if the sample was a good representation of the population. The questions to establish age and determine knowledge in the capital budgeting methods used were the same for both groups.

No difference was recorded between the knowledge in NPV and PB since all participants (100% of those that did the case and those that did not do the case) answered they were familiar with the two capital budgeting methods. A statistical comparison was therefore only made for age and familiarity with RO.

The answers from the follow-up email defined two variables: The variable RO was as a dummy variable measuring if they had previous knowledge about RO (1 had knowledge or 0 did not have knowledge) and Age measuring the age of the respondents. The two variables were compared between groups (those having done the case and those that did not do the case) to test if the sample of students having done the case was a good representation of the population.

The results showed that both tests were not significantly different from each other and therefore indicated that the sample was a good representation of the population (RO p=0.721 and Age p=0.422).

4. EMPIRICAL RESULTS

4.1 MANIPULATION CHECK QUESTIONS

4.1.1 Manipulation check questions results

The results in Table 1 show the mean value for each of the manipulation check questions and Table 2 shows the significance between the different capital budgeting methods for each question. The manipulation check questions displayed significant differences in three out of five questions (see Table 2). Variables Diff (p=0.168) and Rea (p=0.454) measuring: How difficult the case was, and How realistic the case was, were between the capital budgeting methods not significantly different from each other (see Table 2). The p-value for variable Diff and Rea indicates that the participants found the case of equal difficulty and equally realistic, independent of capital budgeting method assigned.

Table 1. Mean values for Manipulation check questions.

Mean	**RO**	**NPV**	**PB**
Eval	9.46	7.94	6.06
PFail1	9.15	6.06	5.00
PFail2	8.85	6.19	4.53
Diff	2.62	1.88	2.71
Rea	7.69	7.06	7.71

Mean value of manipulation check questions on a 10-point scale labeled (1 "Not likely at all" and 10 "Extremely likely") for capital budgeting methods RO, NPV and PB. Definition of variables: Eval "Evaluation of capital budgeting method", PFail1 "Awareness of project failure at Time 1", PFail2 "Awareness of project failure at Time 2", Diff "Difficulty of the case" and Rea "Realism of the case".

Variables Eval, PFail1, and PFail2, measuring the evaluation of capital budgeting method used and awareness of project failure at Time1 and Time2, each had a significance of $p<0.05$, thereby indicating a difference between the three capital budgeting methods (see Table 2).

Since a rejection of the null hypothesis (H_0: $m_1=m_2=m_3$, where m_1= Mean of RO, m_2= Mean of NPV and m_3= Mean of PB) in Table 2 only indicates a significant difference between three variables, but not between which variables, a *post hoc* test is required to determine which variables are significantly different from the rest. A *post hoc* Bonferroni test was used to identify which capital budgeting method (s) the significance derived from (see Table 6 Appendix A)

Table 6 indicates that RO (p=0,00) and NPV (p=0,042) were considered as significantly better capital budgeting methods compared to PB for project evaluation. Regarding variable PFail1 the participants demonstrated a higher awareness of project failure in their initial calculations by using RO compared to NPV (p=0,00) and PB (p=0,00). For PFail2, awareness of project failure after the setback was again significantly higher in participants using RO compared to NPV (p=0,00) and PB (p=0,00), but also between NPV and PB (p=0,008).

4.1.2 Manipulation check questions analysis

A significant difference in variable Eval was anticipated. This can be explained through academia arguing

Table 2. One-way ANOVA for Manipulation check questions.

		Sum of Squares	df	Mean Square	F	Sig.
Eval	Between Groups	86.999	2	43.500	9.788	.000
	Within Groups	191.109	43	4.444		
	Total	278.109	45			
PFail1	Between Groups	132.783	2	66.392	19.739	.000
	Within Groups	144.630	43	3.363		
	Total	277.413	45			
PFail2	Between Groups	137.744	2	68.872	30.732	.000
	Within Groups	96.365	43	2.241		
	Total	234.109	45			
Diff	Between Groups	6.600	2	3.300	1.858	.168
	Within Groups	76.356	43	1.776		
	Total	82.957	45			
Rea	Between Groups	4.242	2	2.121	.805	.454
	Within Groups	113.236	43	2.633		
	Total	117.478	45			

One-way Anova output. The table displays between group significance in manipulation check question variables. Statistically significant difference between capital budgeting methods when Sig > 0,05.

that more sophisticated capital budgeting methods yields superior results (Lander and Pinches, 1998; Block, 2007; Antikarov and Copeland, 2001), and students influenced by academia support the same opinion. Surprisingly there was no significant difference between RO and NPV (p=0.178), meaning that the participants rated both as equally good methods for project evaluation.

The RO results for both PFail1 and PFail2 validated previous research indicating a higher construct accessibility of the possibility of early project abandonment when incorporating RO in capital budgeting (see Denison, 2009). This means that the RO participants, by including the abandonment value of the project in their calculations, increased their construct accessibility of early project termination through written task instructions, in contrast to NPV and PB participants.

The higher awareness of project failure between NPV and PB might derive from NPV yielding a negative value at Time 2 for certain participants (section 4.3.1). The negative NPV would indicate that the project has failed, thereby increasing NPV participants' awareness of project failure at Time 2 compared to PB participants.

4.2 RECOMMENDATION OF CONTINUING PROJECT

4.2.1 Recommendation of continuing project Results

The two-way Anova test results in Table 3, display the variable Time (p=0.000) and the interaction between Time and CapBud (p=0.001) both being significant between capital budgeting methods RO, NPV and PB. The interaction between Time and CapBud suggests that the change in RCP between Time 1 and Time 2 was significantly different between the capital budgeting methods.

Table 4 presents the mean RCP2 value for all three capital budgeting methods used. Since, in the case of the experiment, the economically profitable decision was to abandon the project, a higher RCP2 value indicated a higher degree of escalation of commitment. According to Table 4, NPV participants displayed the highest level of escalation of commitment (4.688) among the three capital budgeting methods, followed by PB (3.588) and RO (2.077) participants.

Table 5 displays the results of the one-way Anova *post hoc* Benferroni test, measuring differences in RCP2 given different capital budgeting methods. The results presented in Table 5 show that RO par-

Table 3. Two-way ANOVA within-subjects effect.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	680.421	1	680.421	211.711	.000
Time * CapBud	49.019	2	24.510	7.626	.001
Error (Time)	138.198	43	3.214		

Two-way Anova within-subjects effect output. Determining significance of Time and Time*CapBud between capital budgeting methods using RCP for Time 1 and Time 2.

Table 4. Average RCP for initial and continuing decision.

Capital Budgeting		Mean
RO	*RCP2*	2.077
NPV	*RCP2*	4.688
PB	*RCP2*	3.588

Average RCP value at time 2 (RCP2) for RO, NPV and PB.

ticipants displayed a significantly lower level of escalation of commitment compared to NPV participants (p=0.008) but not compared to PB participants (p=0.200). No significant difference in RCP2 was noted between NPV and PB participants (p=0.465).

4.2.2 Recommendation of continuing project analysis

The results for Time being a significant variable (Table 3) suggest that the participants were aware of a decrease in profitability after the project setback. As a result, the participants lowered their investment recommendation for project continuation compared to their initial investment recommendation. The result strengthens the validity of the experiment as it indicates a non-random difference in RCP between Time 1 and Time 2.

Combining the results from Table 5 and Table 2 indicates that RO participants not only had a higher awareness of project failure, but also were more likely to abandon an unprofitable project compared to NPV users. These findings are consistent with the findings of Denison (2009) and Posavac *et al.* (1997), which advocate higher construct accessibility given salient decision alternatives. PB participants, who were least aware of the possibility of a project failure (see Table 1), did not display a significantly higher level of escalation of commitment compared to NPV (p=0.465) or RO (p=0.200) participants. The insignificant difference in RCP2 between RO and PB indicates that no difference in escalation of commitment exists among the participants using RO and PB, which potentially could explain the extensive use of PB by companies (see Pike, 1996; Graham and Harvey, 2001; Sandahl and Sjögren, 2003) and leads to a rejection of hypothesis 1. The statistically insignificant difference between PB and RO could potentially derive from the inclusion of sunk costs by all PB participants. When case participants included sunk costs in their calculations of RCP2, it resulted in negative RO and NPV valuations and a payback ratio exceeding the average accepted payback ratio for the project, thereby informing the participant to terminate the project. The reason why more participants using PB included sunk costs in their calculations compared to participants using NPV and RO could derive from the lack of academic support (Hatfield *et al.,* 2011) for PB, resulting in a lower construct accessibility of sunk costs for PB calculations in the case participants.

4.3 CALCULATIONS AND SHORT MOTIVATIONS OF INVESTMENT RECOMMENDATIONS

4.3.1 Calculated project value

For each of the capital budgeting methods the participants were asked to calculate the value of the project (for NPV and RO) and the payback period (for PB).

For variable RCP2, 31.25% (5) of NPV and 23.08% (3) of RO participants included sunk costs in their calculations of the project value, thereby yielding a negative project value. For NPV 68.75% (11) and for RO 76.92% (10) of the participants did not include sunk costs in their calculations, thereby yielding a positive project value.

All of the PB participants included the sunk cost in their calculations, which resulted in a PB of 5 years.

4.3.2 Statements defending RCP recommendation

Results

The participants provided short motivations formulated in 1–2 sentences defending their investment recommendation. The results provided are a summary of the comments defending the participants' investment recommendations for RCP2. Real values are provided within brackets.

For RO 61.54% (8) argued that the abandonment value was greater than the project value and the project should therefore be abandoned, 23.08% (3) argued for an abandonment of the project because of negative project value, and 15.38% (2) did not provide any arguments for their investment decision.

For NPV 37.50% (6) did not provide a motivation, 31.25% (5) argued that the NPV is positive and the project should therefore be undertaken, 18.75% (3) claimed that the NPV was negative and the project should be abandoned, and 12.50% (2) argued for abandoning the project due to the abandonment value being higher than the NPV.

For PB 35.29% (6) argued for a project abandonment by pointing out that the calculated PB ratio exceeded the average accepted payback ratio given in the case, 29.41% (5) argued that it might be more beneficial to abandon the investment and sell it but provided no calculations, 29.41% (5) provided no motivation, and 5.88% (1) wrote that the investment should be continued because of no other investment opportunities were presented.

Analysis

An incorrect calculation of the project value for RO (23.08%) and NPV (18.75%) resulted in the participants claiming the project value being negative and argued for an abandonment of the project. The negative project value was calculated when including sunk costs in the project value and using the initial investment value of $100,000,000 instead of the remaining investment required of $15,000,000. Including sunk costs in the project value calculations for this experiment resulted in contradiction of the escalation of commitment bias (See Statman and Caldwell, 1987). Statman and Caldwell (1987) state that due to mental accounting a manager will be more likely to continue investing in a failing project if previous investments into the project have been made, whereas in the case of Ericsson cell phone HDD project, including sunk costs in the calculation leads to the opposite action among the participants. The contradiction of Statman and Caldwell's (1987) theory might potentially derive from the participants not being fully committed to the project investments. The participants' lack of commitment to the project could be because of the fictitious experimental setting, and therefore no real risks in the case of making a wrong decision.

Table 5. *Post Hoc* Bonferroni Significance of CapBud on RCP 2.

(I) Capital Budgeting		Sig. RCP2
RO	*NPV*	.008
	PB	.200
NPV	*RO*	.008
	PB	.465
PB	*RO*	.200
	NPV	.465

Statistical significance (Sig.) between capital budgeting methods for dependent variable RCP at time 2 (RCP2).

4.4 RESULTS LINKED TO INITIAL HYPOTHESIS

4.4.1 Test of Hypothesis 1:

Hypothesis 1 was rejected based on the results from the experiment. A *post hoc* Bonferroni test (see Table 5) proved that the difference in RCP2 (measure of escalation of commitment) between the different capital budgeting methods was significant at 5% for RO and NPV (p=0,008) but not significant at 5% for RO and PB (p=0.2). The results therefore lead to a rejection of the initial hypothesis 1, which presumed RO being a superior method in decreasing escalation of commitment compared to both NPV and PB. The results additionally contradicted theories (see Pike, 1996; Lander and Pinches, 1998; Block, 2007) stating that more sophisticated capital budgeting models lead to superior results, and instead gave justification of empirical findings of PB being the most widely used capital budgeting method in companies (Pike, 1996; Graham and Harvey, 2001; Sandahl and Sjögren, 2003).

A possible explanation for escalation of commitment not being significantly higher in PB participants compared to RO participants might stem from PB's inclusion of sunk costs. All PB participants included sunk costs in their calculations and concluded that a payback of 5 years (calculation after setback) was longer than the company's average accepted payback ratio of 3 years, and therefore chose to abandon the project. A similar trend was observed in the NPV participants. Participants explicitly using NPV that included sunk costs in their calculations argued

similarly to PB participants for an early project termination. In the case of this experiment, including sunk costs in the calculations resulted in an indication of early project abandonment, which also was the preferred decision case participants should have made. However, PB participants demonstrated a rigid and low construct accessibility of sunk costs inclusion, which could act in their disfavor given a different experimental setting.

4.4.2 Test of Hypothesis 2:

Hypothesis 2 stated that: since neither PB nor NPV took into account abandonment value in their calculations for the examples provided with the case, participants using PB or NPV should not display different levels of escalation of commitment to a failing project. The hypothesis 2 was not rejected with a p-value of 0.465, and the results of the experiment displayed no difference in escalation of commitment between PB and NPV participants.

4.5 LIMITATIONS

A higher degree of escalation of commitment might have been displayed in NPV participants simply because they were following the case example instructions. The case example portrayed only one course of action, which was evaluating the project and recommending a continuation or not. Since the calculations for NPV yielded a positive project value at Time 2, participants following the instructions might have recommended a continuation of the project simply basing it on the case instructions informing them to do so. If instead a comparison between two options, continuation or abandonment, would have been made, it could have potentially lead to a lower escalation of commitment among NPV participants.

Similarly a lower escalation of commitment might have been recorded in PB participants. Since the instructions did not inform the participants to neglect sunk costs at Time 2, the calculated PB ratio violated the average accepted PB ratio for the company. Participants following the instructions provided would therefore abandon the project. However, all the information necessary to compare the two options of project abandonment or continuation to each other was provided to all participants. It was the participants themselves who decided whether to ignore the information or to include it in their calculations.

The participants were also a limitation of the study. Although students should display the same behavioral biases as managers, it is unclear if the results would have been the same. Additional experiments are necessary to establish a potential difference.

Another limitation to the study is the simplicity of the experiment. The case provided to the participants is distant and simplified compared to actual capital budgeting situations in reality. The psychological effects should be assumed the same in reality and in the experiment, but additional unknown factors might affect the results.

5. CONCLUSION

The aim of this study was to examine if decision-makers using less sophisticated capital budgeting methods, such as Net present value and Payback, lead to a higher level of escalation of commitment in a failing project, compared to decision-makers using more sophisticated capital budgeting methods, such as Real options. The results indicated that participants explicitly using Real options were more aware of the possibility of project failure, both during their initial calculations and also after the project setback, compared to participants using Net present value and Payback. Additionally participants using Real options displayed a lower level of escalation of commitment to a failing project compared to participants using Net present value, but not to participants using Payback.

Similar findings that indicate lower levels of escalation of commitment in students using Real options compared to students using Net present value were presented by Denison (2009). Consistent with Denison's (2009) study the superiority of Real options derived from a higher construct accessibility of early project termination, stemming mainly from the case instructions and resulting in a lower level of escalation of commitment. Neglecting early project abandonment leads to a higher RCP2 value for Net present value and Payback participants and was interpreted as a higher level of escalation of commitment. The negligence of the preferred alternative, in this case project abandonment, was consistent with Posavac *et al.*'s (1997) findings of decision-making with unspecified decision alternatives, and indicates that capital budgeting methods with salient decision alternatives yield superior results.

This study contributed to validating Denison's findings and contributed to the escalation of commitment literature by integrating a broader range of capital budgeting methods and their effect on escalation on commitment, compared to previous studies. The findings of this experiment additionally contradicted theories supporting a negative correlation between sophistication of capital budgeting methods and level of escalation of commitment, and contributed to justifying the extensive usage of payback in capital budgeting by managers.

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7. APPENDIX

7.1 APPENDIX A

Table 6. *Post Hoc* Bonferroni for Manipulation check questions.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
Eval	RO	*NPV*	1.524	.787	.178
		PB	3.403	.777	.000
	NPV	*RO*	-1.524	.787	.178
		PB	1.879	.734	.042
	PB	*RO*	-3.403	.777	.000
		NPV	-1.879	.734	.042
PFail1	RO	*NPV*	3.091	.685	.000
		PB	4.154	.676	.000
	NPV	*RO*	-3.091	.685	.000
		PB	1.063	.639	.311
	PB	*RO*	-4.154	.676	.000
		NPV	-1.063	.639	.311
PFail2	RO	*NPV*	2.659	.559	.000
		PB	4.317	.552	.000
	NPV	*RO*	-2.659	.559	.000
		PB	1.658	.521	.008
	PB	*RO*	-4.317	.552	.000
		NPV	-1.658	.521	.008

Post hoc Bonferroni results to determine difference between capital budgeting methods for variables Eval, PFail1 and PFail2. Statistically significant difference between capital budgeting methods when Sig > 0,05.

7.2 APPENDIX B: CASE GIVEN TO PARTICIPANTS

Initial project:

A new project proposal is put on your table for a new cell phone hard drive (Cell phone HDD) that's able to increase current storage capacity by up to 100 percent while retaining costs and dimensions to their current level. The product has already been developed by the R&D department, but the project will require an additional $100,000,000 to build the production technology. This production technology can be sold at 65 percent of the value invested to date at any point during project development if the project is discontinued. The marketing department has reported that the project's expected cash will depend upon demand. There is a 60 percent chance that demand for the product will be high, with net cash flows of $60,000,000 per year, and a 40 percent chance that demand will be low, with net cash flows of $20,000,000 per year (learning which outcome will occur as soon as development is complete). Thus, the expected cash flows for the project are $44,000,000 per year (0.6 * $60,000,000 + 0.4 * $20,000,000). The project is expected to last 5 years and Ericsson's required rate of return is 22 percent, yielding a discount factor of 2.8636.

PB calculations:
Investment/Expected cash flow = 100,000,000/44,000,000 = **2.27 years**

NPV calculations:
Expected cash flow * Discount factor — Investment = 44,000,000*2.8636–100,000,000 = **25,998,400**

RO calculations:
High cash flow: High cash flow * Discount factor = 60,000,000 * 2.8636 = *171,816,000*
Cash flow low: Low cash flow * Discount factor = 20,000,000 * 2.8636 = *57,272,000*
Abandonment value: Amount invested * Abandonment value = 100,000,000 * 0.65 = *65,000,000*
Since the abandonment value is higher than the Cash flow low, the project should be abandoned in the case of a low cash flow from the project.
Total value: High cash flow * Probability of occurrence + Abandonment * Probability of occurrence — Investment = 171,816,000 *0,6 + 65,000,000 * 0,4–100,000,000 = **29,089,600**

Setback:
The initial prediction about the cell phone hard drive development project has proven inaccurate. An unexpected competitor has developed a superior product, thereby changing the expected cash flows for the project. New market research shows that the project will have a lifetime of 5 years with a certain cash flow of $20,000,000 per year. As of today we are approximately 85% into the project and need to re-evaluate the decision. We need to decide whether to continue this project as planned or abandon it.

PB calculations:
Investment/Expected cash flow = 100,000,000/20,000,000 = **5 years**

NPV calculations:
Expected cash flow * Discount factor — Investment = 20,000,000 * 2.8636–100,000,000 * (1–0.85) = **42,272,000**

RO calculations:
Because of certain cash flows the calculations for RO will yield the same value as for NPV above.
Expected cash flow * Discount factor — Investment = 20,000,000 * 2,8636–100,000,000 * (1–0.85) = **42,272,000**

Abandonment value:
Investment made * Abandonment value = 100,000,000 * 0.85 * 0.65 = **55,250,000**
Since the abandonment value is greater than the RO and NPV value, the participants should choose to abandon the project in order to maximize firm value.

Moscow Energy Strategy in the Framework of the Russian Energy Strategy*

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Abstract. In this article we focused on the assessment of energy-efficiency promoting policy mixes for Moscow Region from multicriteria perspective with an emphasis on greenhouse gas (GHG) emission reduction. For this purpose we analyzed the energy balances of the city of Moscow for the period 2005–2013. Then official documents of the city of Moscow and the Russian Federation, which affect or may affect the energy efficiency of the city, were analyzed. Based on these documents, forecasts were prepared. On the basis of these materials we obtained three scenarios that describe the possible trends of Moscow energy development: business-as-usual, optimistic and pessimistic. Scenarios are calculated for the period until 2025. Scenarios are modeled in Long-Range Energy Alternatives Planning (LEAP) environment. The results are long-term forecasts of greenhouse gas emissions in the city of Moscow. The analysis done shows that the best scenario in terms of reduction of greenhouse gas emissions is the optimistic scenario.

Аннотация. В данной статье анализируется эффективность политики города Москвы в области повышения уровня энергоэффективности. Основным критерием оценки политик выбран уровень сокращения выбросов парниковых газов в атмосферу. Для этого сначала анализируются энергетические балансы города Москвы за период 2005–2013 гг. Далее рассматриваются законодательства города Москвы и Российской Федерации, которые влияют или могут повлиять на энергоэффективность города. Анализ законодательства дополняется прогнозами, взятыми из официальных государственных и международных источников. На основании данных материалов строятся три сценария, которые описывают возможные траектории развития энергетики города Москвы: базовый, оптимистичный и пессимистичный. Сценарии рассчитываются на период до 2025 г. Моделирование сценариев осуществляется в программе Long-Range Energy Alternatives Planning (LEAP). Результатом моделирования являются долгосрочные прогнозы выбросов парниковых газов в городе Москве. Проведенный анализ свидетельствует о том, что наилучшие показатели по сокращению количества выбросов имеет оптимистичный сценарий.

Key words: Long-range energy alternatives planning (LEAP), energy policy, energy efficiency, GHG emissions.

INTRODUCTION

Moscow is one of the biggest cities in the world and the biggest one in the Russian Federation in terms of area and population. Moscow provides 21% of retail trade, 30% of turnover in wholesale trade of food products, 14% of foreign trade, and has 25% of the total volume of paid services to the population. Moscow's share in the total volume of Russian investments in fixed assets is 12%. Average annual growth of gross regional product, since 2000, amounted to 108%, industrial production — 115.6%, real disposable income — 110.4%, investment in fixed assets — 106.7%, retail trade turnover — 106.1%, turnover in wholesale trade of food products — 105.5%[1].

Currently, there are positive trends in demographic development: growth of fertility, mortality reduction, and increased life expectancy.

On the other hand, problems are exacerbated in the development of transport, engineering and social infrastructure.

However, sustainable growth of Moscow economy still directly depends on energy efficiency of various region industries. The energy sector of Moscow is complex because of a number of factors:

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* Московская энергетическая стратегия в рамках энергетической стратегии России.

[1] Law of the City of Moscow № 47 of 26.10.2011 «On General Plan of the City of Moscow».

• energy, being an ingredient for any Moscow industry, its availability or lack of it affects the society and consequently, there are greater societal concerns and influences affecting the sector;

• the energy sector of Moscow is influenced by interactions at different levels (international, regional, national and even local);

• the constituent industries tend to be highly technical in nature, requiring some understanding of the underlying processes and techniques for a good grasp of the economic issues;

• each industry of the sector has its own specific features, which require special attention.

Energy sector is one of the main foundations of the whole economy. Therefore, efficiency of the economy depends directly on the sustainable development of the energy sector[2]. On the other hand, the sustainability of the energy sector depends on the government policies and climate changes, and non-effective government policy mixes may lead to serious environmental problems, such as increase of greenhouse gas emission. Thus, improving the energy efficiency of Moscow economy is among top priorities for both Moscow and Russian policy makers.

STRUCTURE OF FINAL ENERGY CONSUMPTION IN MOSCOW REGION

In order to estimate Moscow energy strategy scenarios, let me analyze the latest final energy consumption data that is available.

In 2012 final energy consumption in Moscow is 31 712 thousand tons of fuel equivalent. There is a growing trend in 2010–2012.

Table 1. Final energy consumption in Moscow in 2010–2012, thousand tons of fuel equivalent.

Year	Coal and other fuels	Oil	Oil products	Natural gas	Hydro-power	Electricity	Heat	Total
2010	26	0	8 345	3 297	0,0	5134	12 130	28 932
2011	22	0	9 581	3 224	0	5334	12 064	30 224
2012	51	0	9 724	3 600	0	5455	12 882	31 712

Average growth rate in this period was on 4,5–5% annually. The highest growth rate is observed in Coal and other fuels, but their share in total energy consumption is insignificant. The highest growth in absolute numbers is observed in Heat. However, an important assumption is that energy consumption growth in 2012 is mainly connected with the inclusion of new territories in the territory of Moscow, which occurred on the 1 June 2012 after the decree of the President of the Russian Federation.

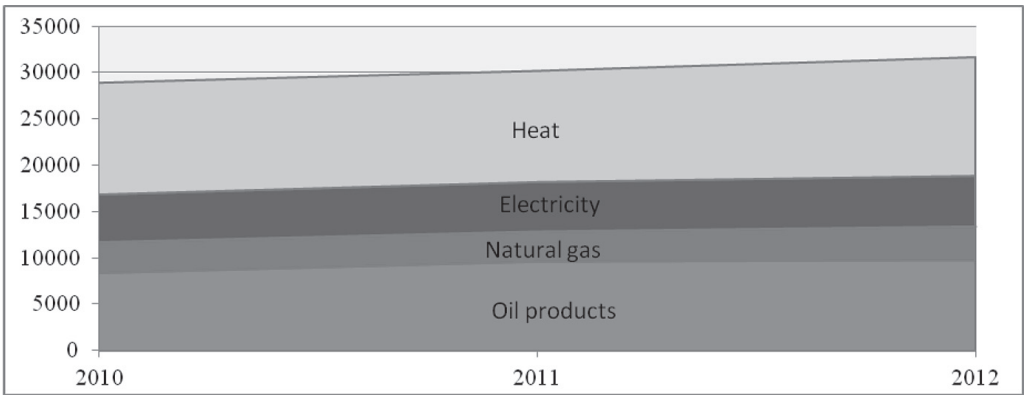

Figure 1. Changes in energy consumption by types of fuels in 2010–2012, thousand tons of fuel equivalent.

Structure of final energy consumption corresponds with the economy of postindustrial benchmark regions. Non-production sector — population and services — consumes around 69% of energy resources, and together with transport and telecom, they occupy more than 82%. Production sector consumes only 15% of final energy consumption.

[2] Bhattacharyya, S.C. Energy Economics. Concepts, Issues, Markets and Governance / — London: Springer, 2011–645.

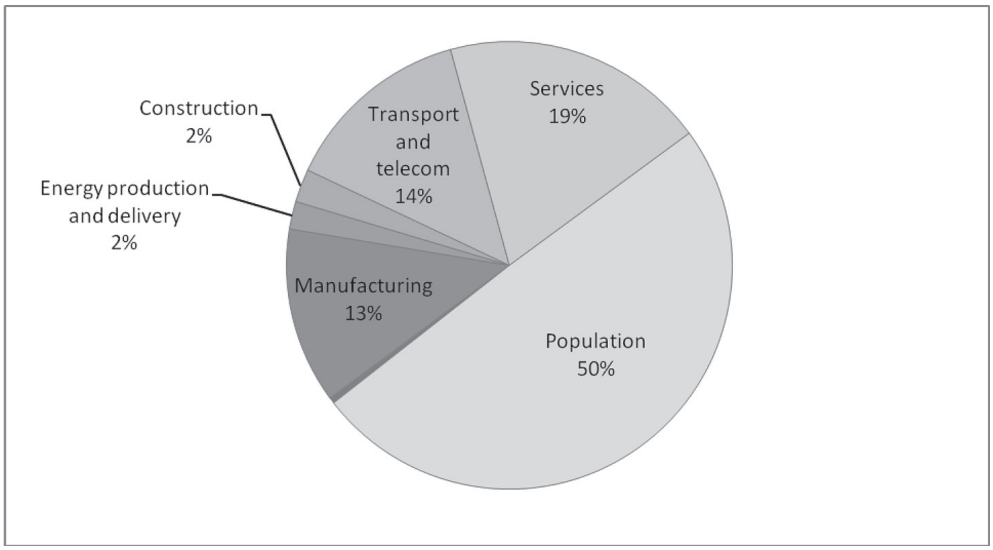

Figure 2. Structure of final consumption in Moscow in 2012.

In the structure of final consumption, heat occupies around 41% and is mainly consumed for heating and hot water supply for housing units (around 84% of total heat consumption) and less for production purposes. Oil products are mainly consumed by private automobiles, trucks and public service vehicles. Oil products occupy around 31% of final consumption, while electricity — 17%, natural gas — 11%.

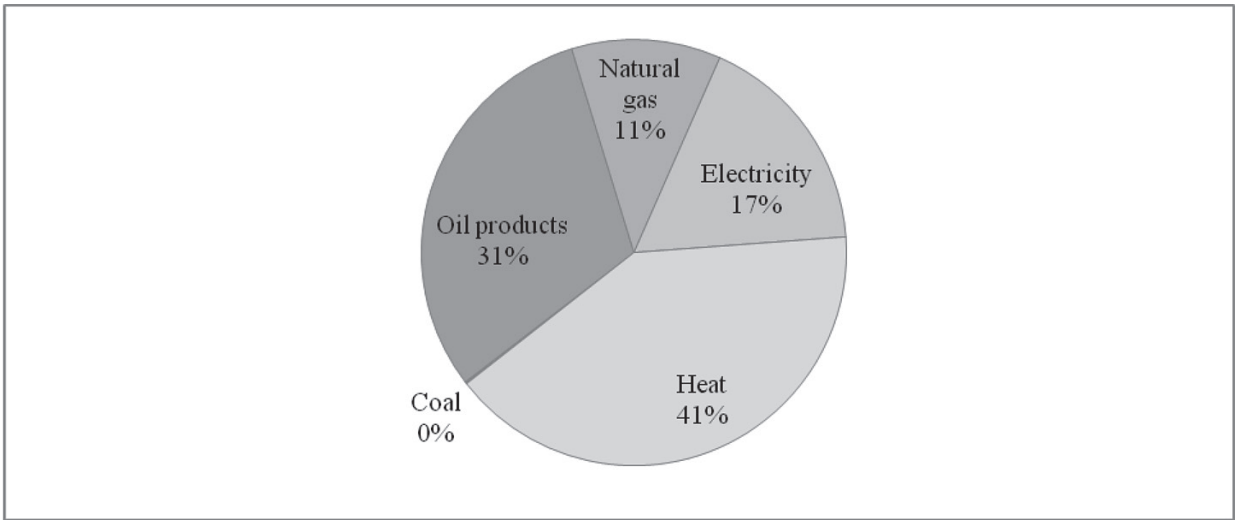

Figure 3. Fuel structure of final consumption in Moscow in 2012.

SCENARIO ANALYSIS OF MOSCOW REGION ENERGY STRATEGY

There are various ways of further development of Moscow, so I grouped them into three scenarios in order to simplify the analysis process. The scenarios are the following: Business-as-Usual, Optimistic and Pessimistic.

BUSINESS-AS-USUAL SCENARIO

Business-as-Usual (BAU) scenario is based on the policy portfolio effective as of October 26, 2011 and corresponds mainly with the General Plan of Moscow[3].

Several groups of assumptions, or key assumptions for BAU scenario, are of great importance for the correct estimation by the model, so they are described below.

[3] Law of the City of Moscow № 47 of 26.10.2011 «On General Plan of the City of Moscow».

Population

Population dynamics follows dynamics that is forecasted in the General Plan of Moscow. This forecast contains saving the current level of the number of births, reduction of the number of deaths and stabilization of the net migration at the level of 50–75 thousand people per year. Thus, total population of Moscow by the end of 2025 will exceed 12 million people. This will bepossible due to improvement of health, life capacity, fertility growth and migration mobility of population, including:

- Improving the health status of the population of working age;
- Strengthening and improving the health of children, adolescents and the elderly;
- An increase in life expectancy to 77–80 years;
- Reducing the gap in life expectancy between men and women up to 6–7 years;
- A decline in infant mortality;
- The creation of socio-economic conditions for the growth of fertility;
- The formation of positive public opinion on encouraging and increasing fertility, strengthen the family;
- Strengthening of differentiated social support for families, depending on the number of children, encouraging the birth of the second and third child;
- Regulation of the volume and structure of labor and non-labor migration flows on the basis of demographic needs of the city;
- Effective use of foreign and nonresident workforce, reduction of illegal migration, creating conditions for a socially useful adaptation and integration of migrants into the urban community;
- Creation of socio-economic conditions for adaptation and rehabilitation of the disabled.

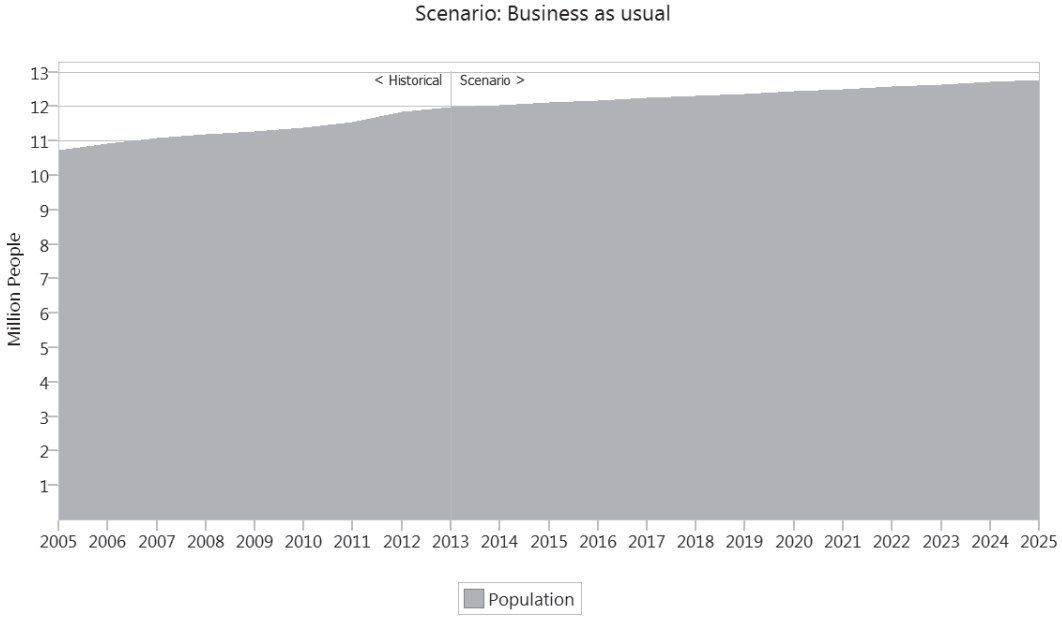

Figure 4. Demographics: population. BAU scenario.

Climate

Climate forecasts are based on the Roshydromet weather forecast reports and are results of a simple regression of the data gained analysis.

Economy

Real GRP as an indicator of an economic activity is the key factor for forecasting GHG emission in the BAU scenario. In Moscow, this interplay is even higher, moderated by low energy efficiency and significant role of energy sector in the economy. Real GRP dynamics, with energy-efficiency dynamics and structural change in the economy are, thus, key factors of energy demand and, accordingly — GHG emissions.

If the goals of the current policies would be reached, experts forecast that GRP growth rate would be 0.5% on average and, thus, would reach around 263 billion euro by 2025.

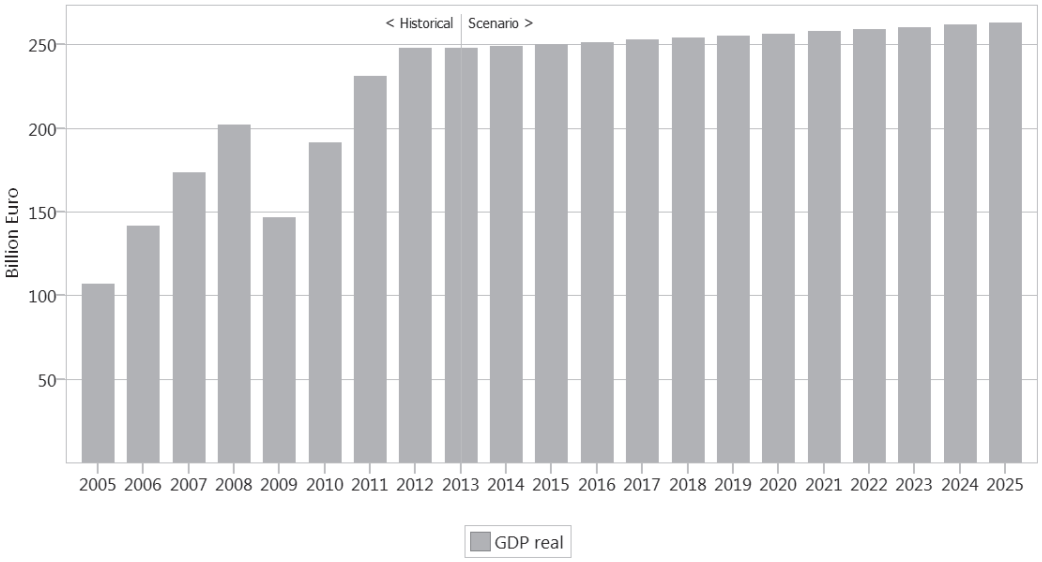

Figure 5. Economy: GRP real. BAU scenario.

Sectoral distribution of GRP will also follow the dynamics of total real GRP. However, the structure of GRP in 2025 differs from the one in 2013 as the share of services increases[4].

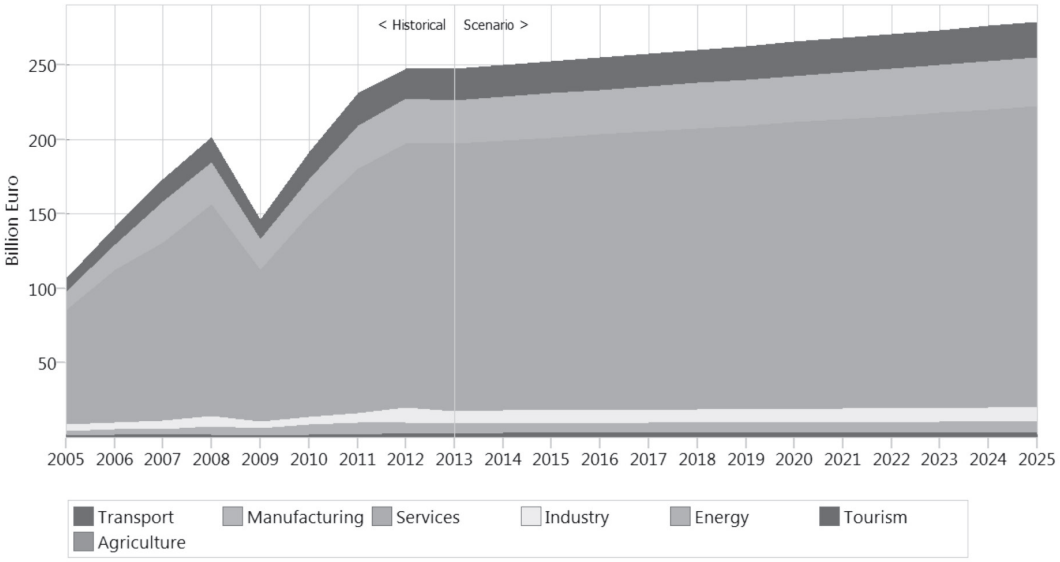

Figure 6. GRP distribution per sector. BAU scenario.

Energy Demand

In the BAU scenario the final energy demand in households sector will be decreasing as the result of energy saving policy of the Moscow government[5], which should allow consuming less heat and oil in this sector. Household sector, being the main consumer of total energy produced in Moscow, is thus of high importance in terms of GHG emission.

[4] The Government of Moscow. Report on the socio-economic development and implementation of the Moscow government programs in 2012, Moscow, 2013–133.
[5] Government Decree of the City of Moscow № 1075-ПП of 02.12.2008 «On the Moscow Energy Strategy until 2025»

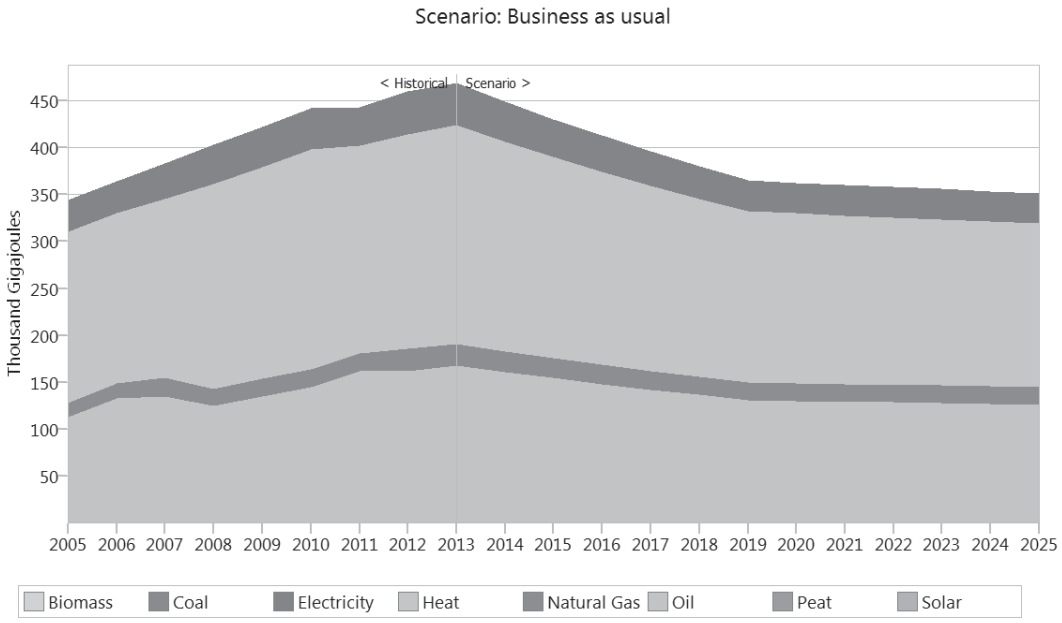

Figure 7. Final energy demand in household sector. BAU scenario.

Agriculture has a significant contribution to the national economy, but a small share in the final consumption of commercial energies. The assumption for the growth rate of energy demand in the BAU scenario is that it follows its respective growth rate as described earlier in the GRP distribution per sector. Fuel shares are considered to be almost the same across the years since no influencing policy instrument is applied.

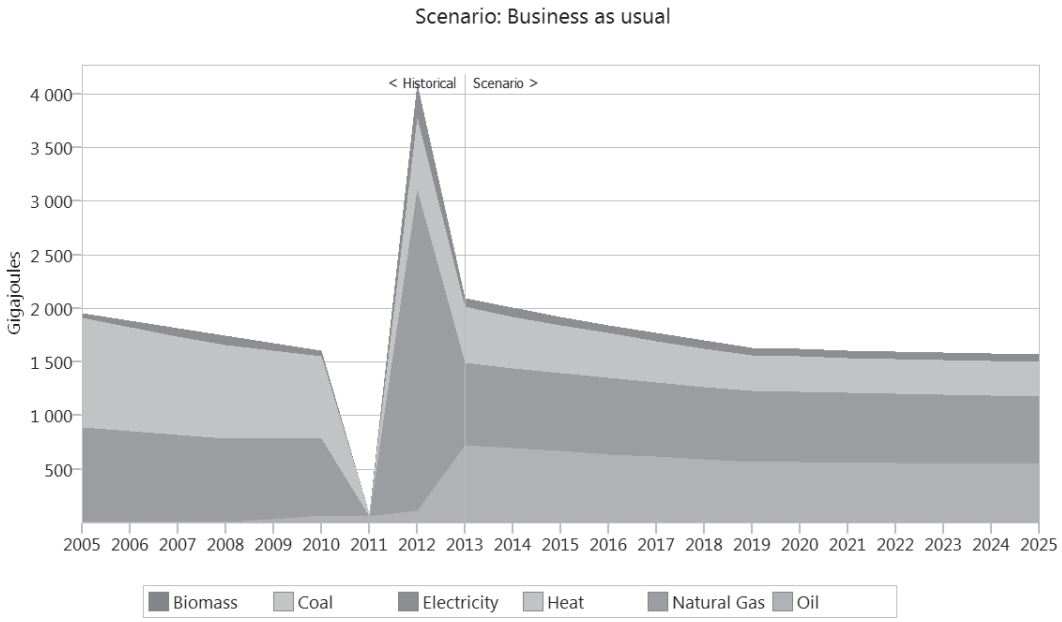

Figure 8. Final energy demand in agriculture sector. BAU scenario.

Due to lack of data for the activity level, the industrial energy demand structure (industry sector) was formed mainly by experts' evaluations and partly by GRP structure. The growth rate of activity level and the growth rate of energy demand are equal to its respective growth rate described earlier in the GRP distribution per sector section. Fuel shares are considered steadily since no policy instruments are applied.

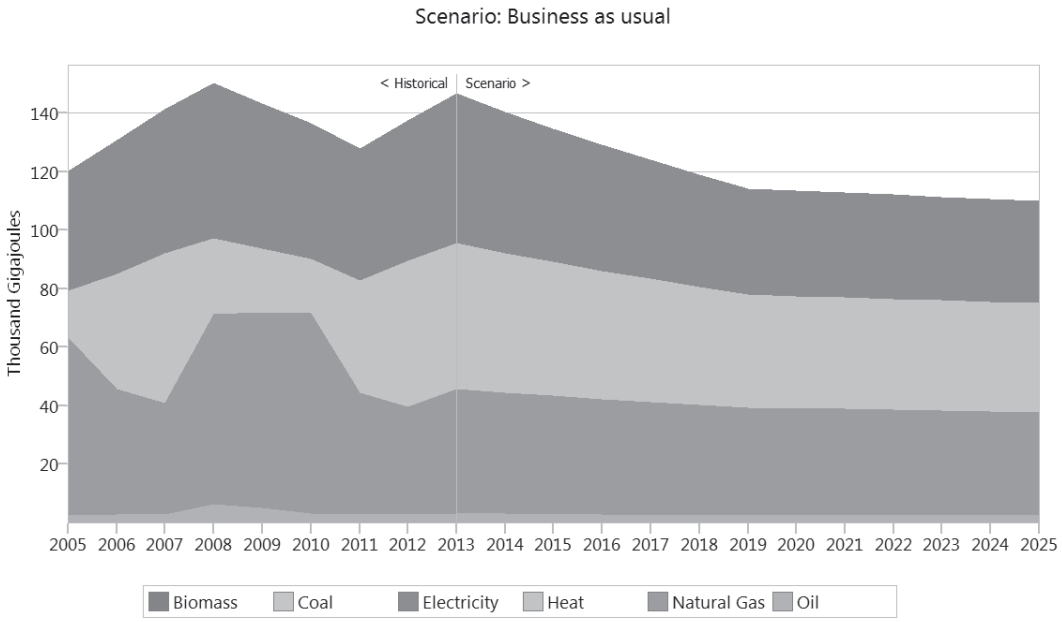

Figure 9. Final energy demand in industry sector. BAU scenario.

Transport sector is one of the most discussed sectors by Moscow government, as it needs to become more modern and developed. Therefore, successful realization of transport strategy of Moscow is crucial not only for the population of Moscow, but also for the current management of Transport Department. Based on the experts' expectations on the successful transport strategy realization, final energy demand in transport sector is estimated.

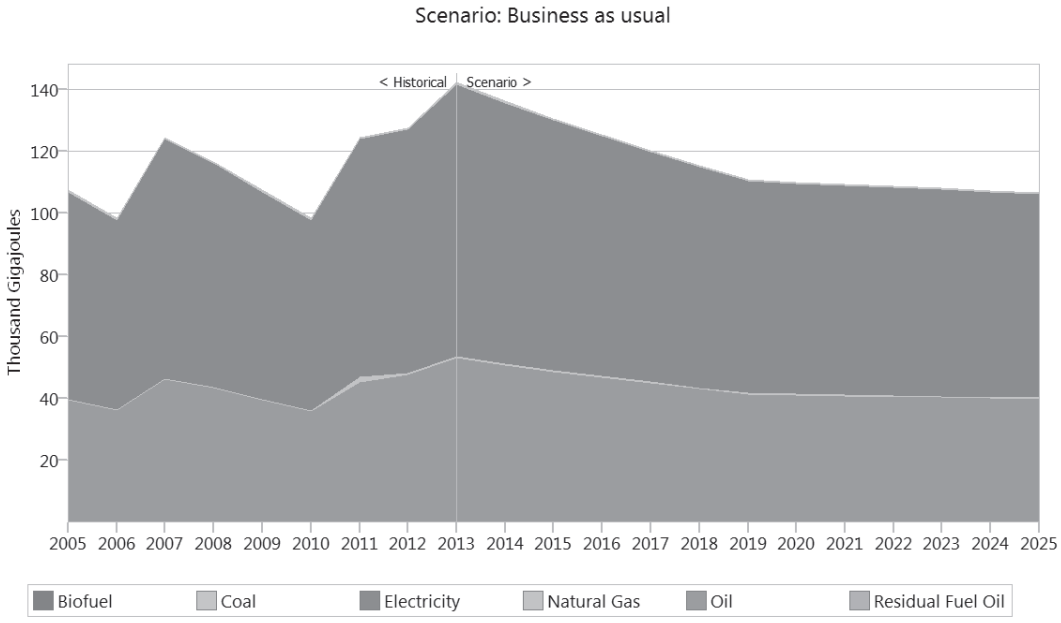

Figure 10. Final energy demand in transport sector. BAU scenario.

Transformation

Total transformation energy losses are over 28%. Most of the losses are connected with electricity and heat and each of them loses about 8% during transmission and distribution. Assuming that no modernization is planned that could influence this situation and that the equipment is slowly aging, the growth rate of transformation efficiency is close to zero.

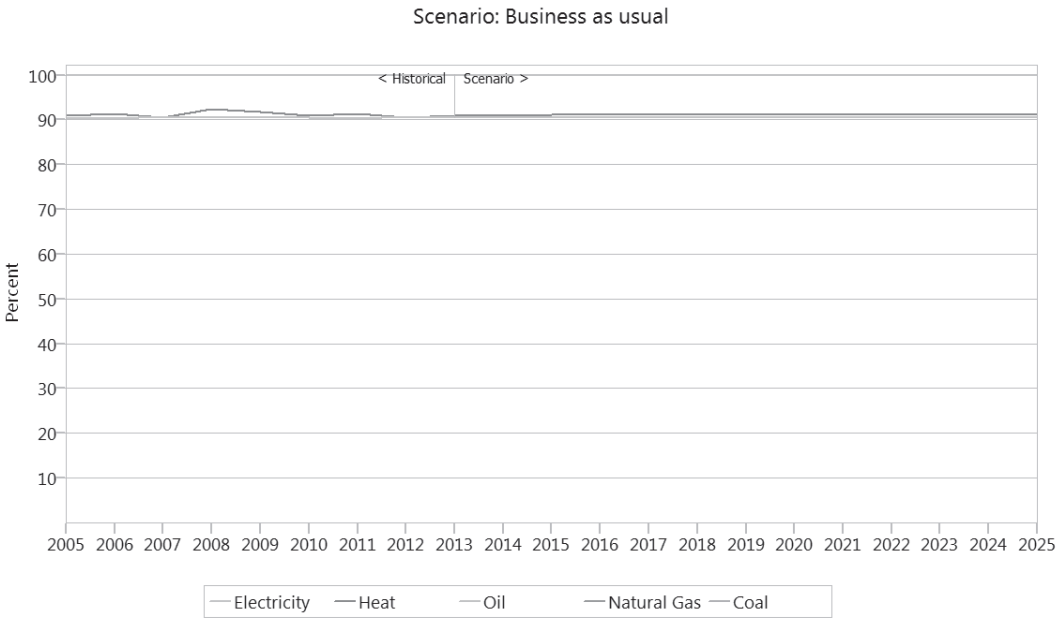

Figure 11. Transformation efficiency – transmission and distribution. BAU scenario.

Own use losses are less than that in transmission and distribution and equal about 10% (2% — heat and 8% — electricity). Assuming that no innovations would be implemented, own use losses are considered to remain steady.

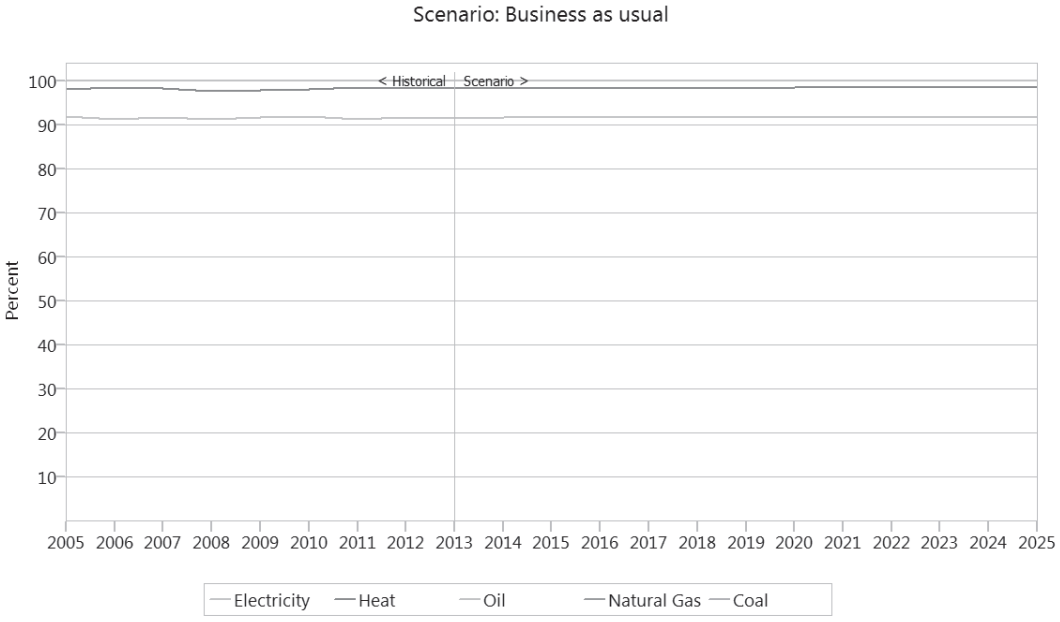

Figure 12. Transformation efficiency – own use. BAU scenario.

Global Warming Potential (GHG Emissions)

The BAU scenario shows us that comparing to 2013 the GHG emission will be reduced steadily and in 2015 will reach the reduction of 7%, in 2025 it will achieve the total reduction equal to 22%.

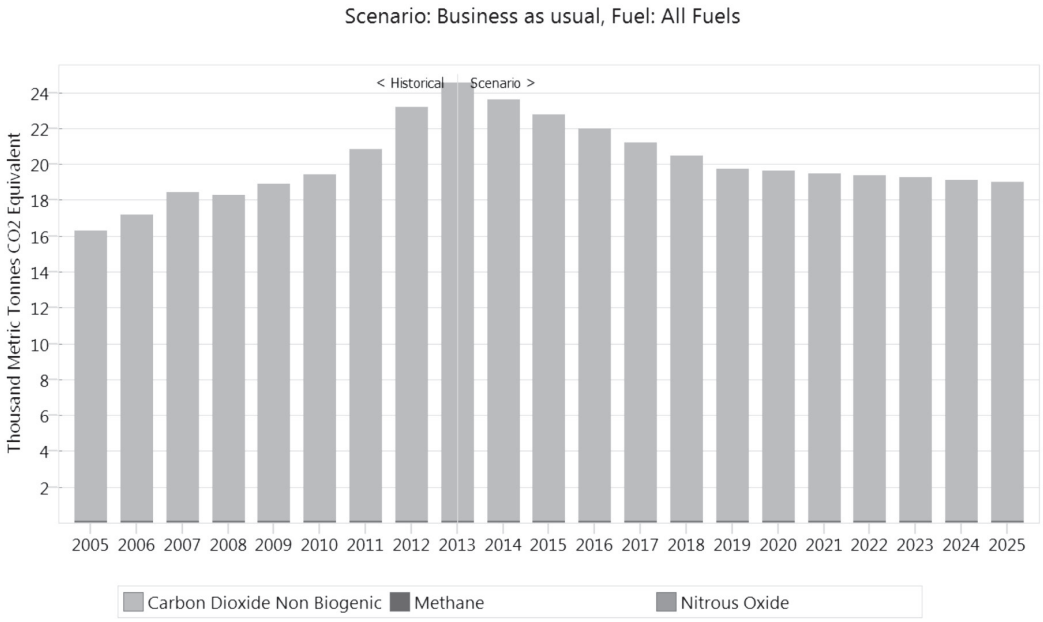

Figure 13. Global warming potential by GHGs. BAU scenario.

Optimistic Scenario

Optimistic (OPT) scenario is based on the bigger effect of the policy portfolio effective as of October 26, 2011 and corresponds mainly with the projections of the experts.

Several groups of assumptions, or key assumptions for OPT scenario, are of great importance for the correct estimation by the model, so they are described below.

Population

Population dynamics follows dynamics that is forecasted in the General Plan of Moscow. This forecast contains saving the current level of the number of births, reduction of the number of deaths and stabilization of the net migration at the level of 50–75 thousand people per year. Thus, total population of Moscow by the end of 2025 will exceed 12 million people. This is possible due to the realization of the improvement of health, life capacity, fertility growth and migration mobility of population.

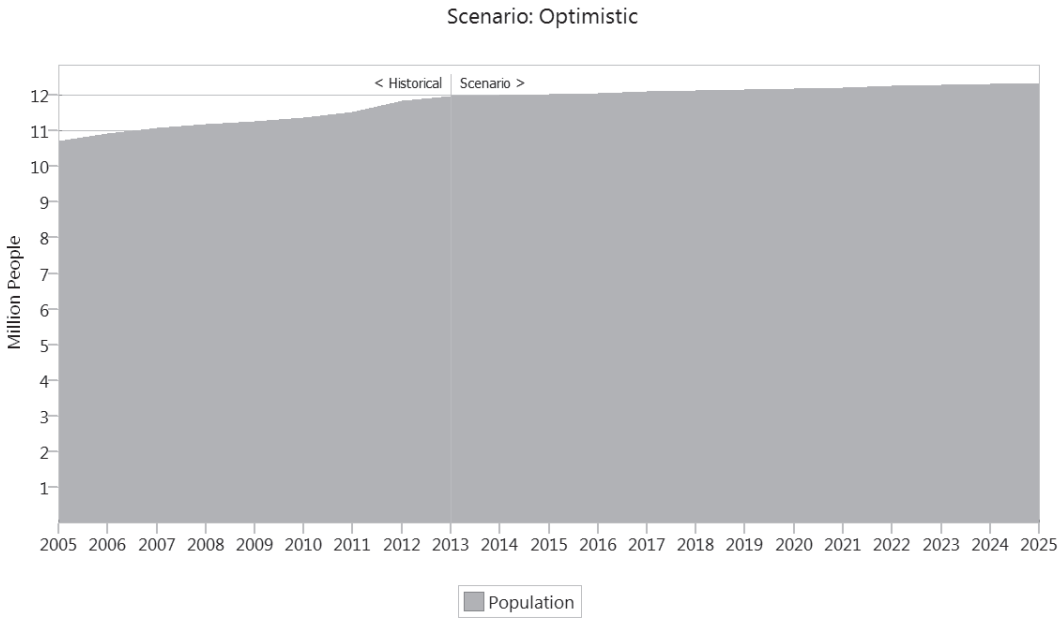

Figure 14. Demographics: population. OPT scenario.

Climate

Climate forecasts are based on the Roshydromet weather forecast reports and are results of a simple regression of the data gained analysis.

Economy

Real GRP as an indicator of economic activity is the key factor for forecasting GHG emission in the OPT scenario as well. In Moscow, this interplay is even higher, moderated by low energy efficiency and significant role of energy sector in the economy. Real GRP dynamics, with energy-efficiency dynamics and structural change in the economy are, thus, key factors of energy demand and, accordingly — GHG emissions.

If the goals of the current policies would be reached, experts forecast that GRP growth rate would be 2.5% on average and, thus, would reach around 333 billion euro by 2025.

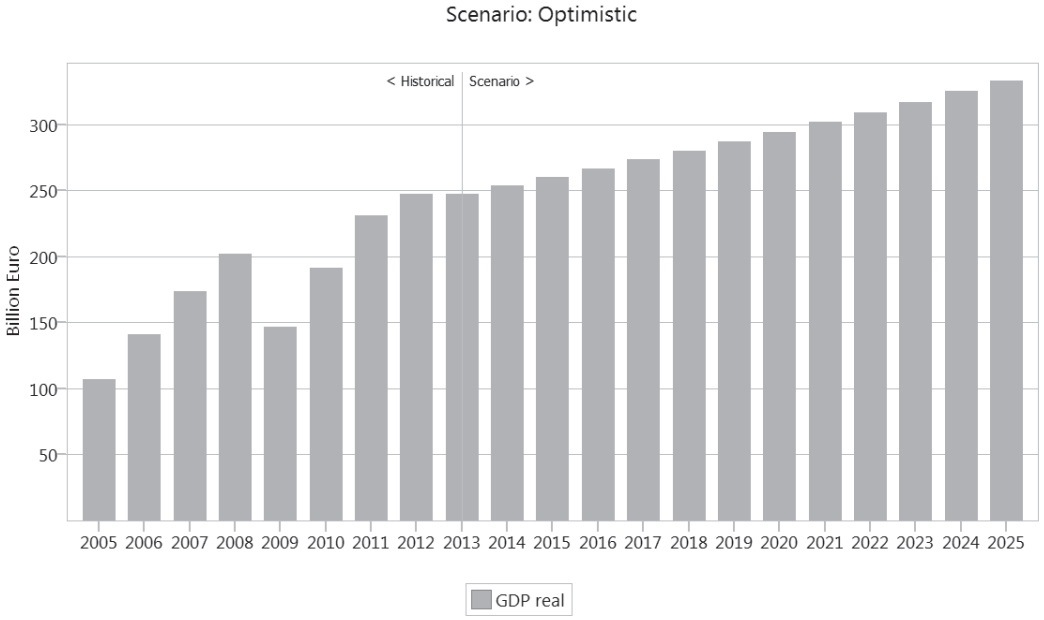

Figure 15. Economy: GRP real. OPT scenario.

Sectoral distribution of GRP will also follow the dynamics of total real GRP. However, the structure of GRP in 2025 differs from the one in 2013 as the share of services increases even more than in BAU scenario.

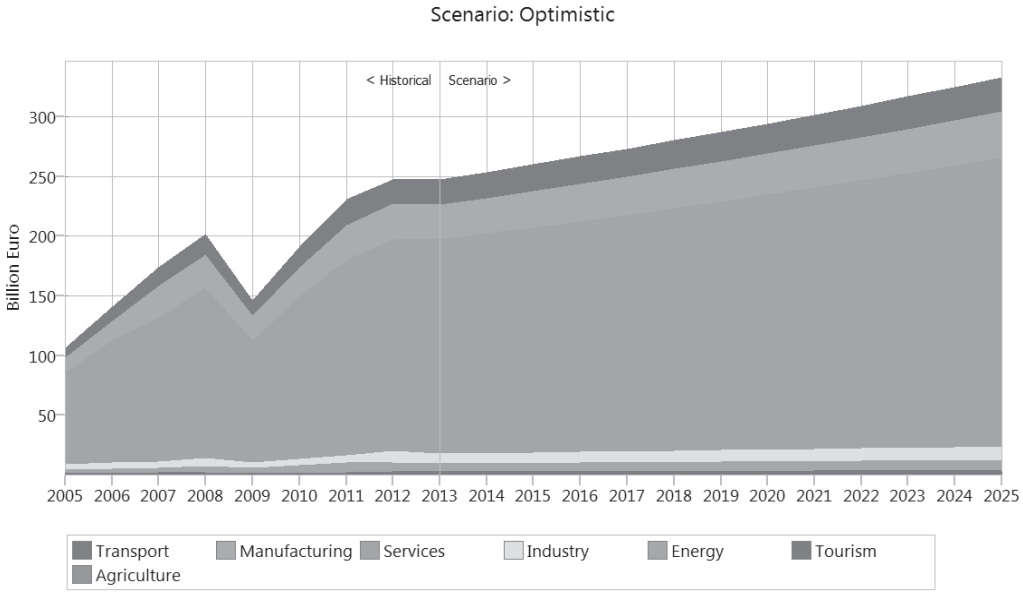

Figure 16. GRP distribution per sector. OPT scenario.

Energy Demand

In the OPT scenario the final energy demand in households sector will be decreasing as the result of energy saving policy of the Moscow government[6] and the global trend of consuming less energy and being closer to nature, which should allow to consume less heat and oil in this sector. Household sector, being the main consumer of total energy produced in Moscow, is thus of high importance in terms of GHG emission.

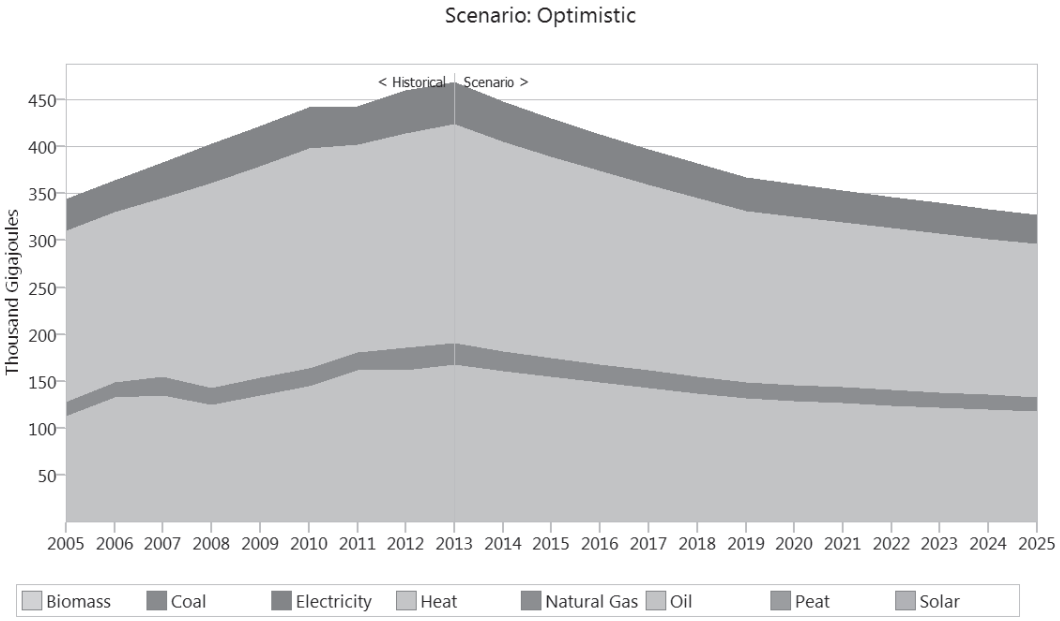

Figure 17. Final energy demand in Household sector. OPT scenario.

Agriculture has a significant contribution to the national economy, but a small share in the final consumption of commercial energies. The assumption for the growth rate of energy demand in the OPT scenario is that it follows its respective growth rate as described earlier in the GRP distribution per sector and in the BAU scenario as well. Fuel shares are considered to be almost the same across the years since no influencing policy instrument is applied.

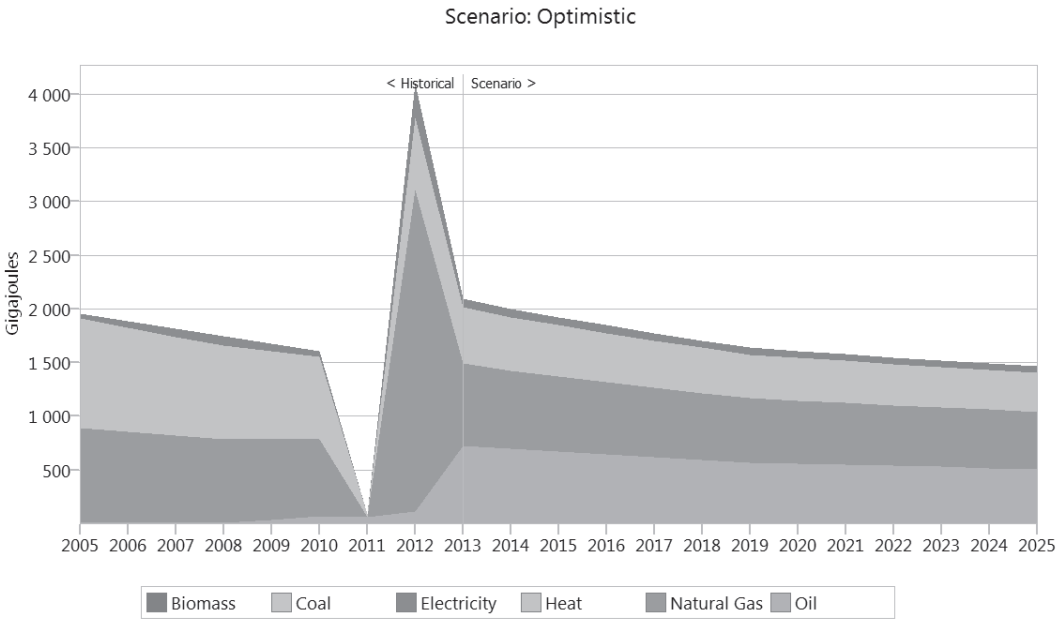

Figure 18. Final energy demand in agriculture sector. OPT scenario.

[6] Government Decree of the City of Moscow № 1075-ПП of 02.12.2008 «On the Moscow Energy Strategy until 2025».

Due to lack of data for the activity level, the industrial energy demand structure (industry sector) was formed mainly by experts' evaluations and partly by GRP structure. The growth rate of activity level and the growth rate of energy demand are equal to its respective growth rate described earlier in the GRP distribution per sector section. Fuel shares are considered steadily since no policy instruments are applied.

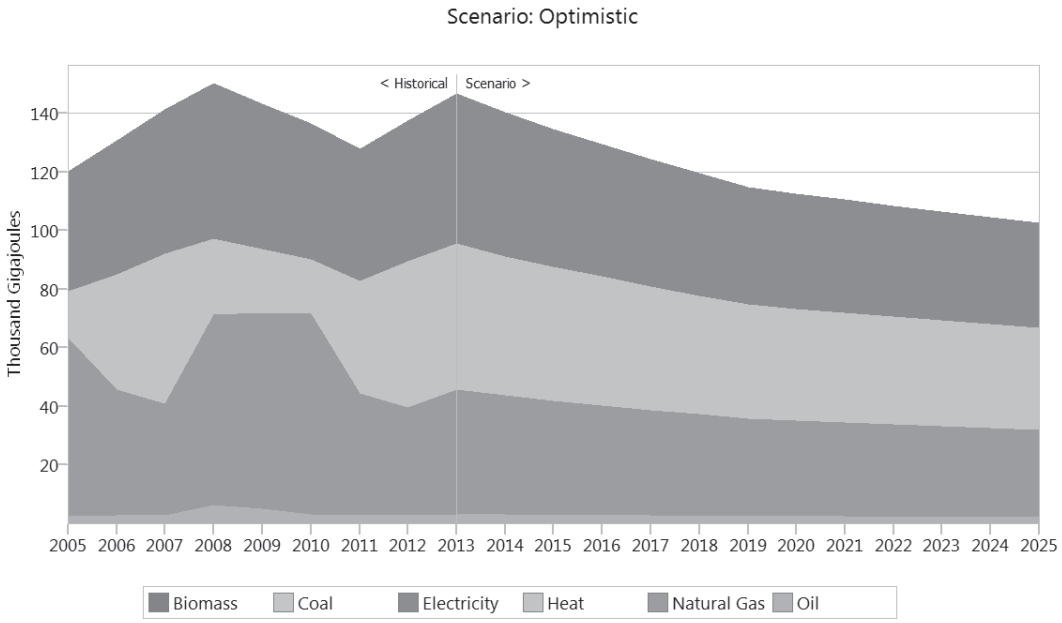

Figure 19. Final energy demand in Industry sector. OPT scenario.

Based on the experts' expectations on the successful transport strategy realization, final energy demand in transport sector is estimated.

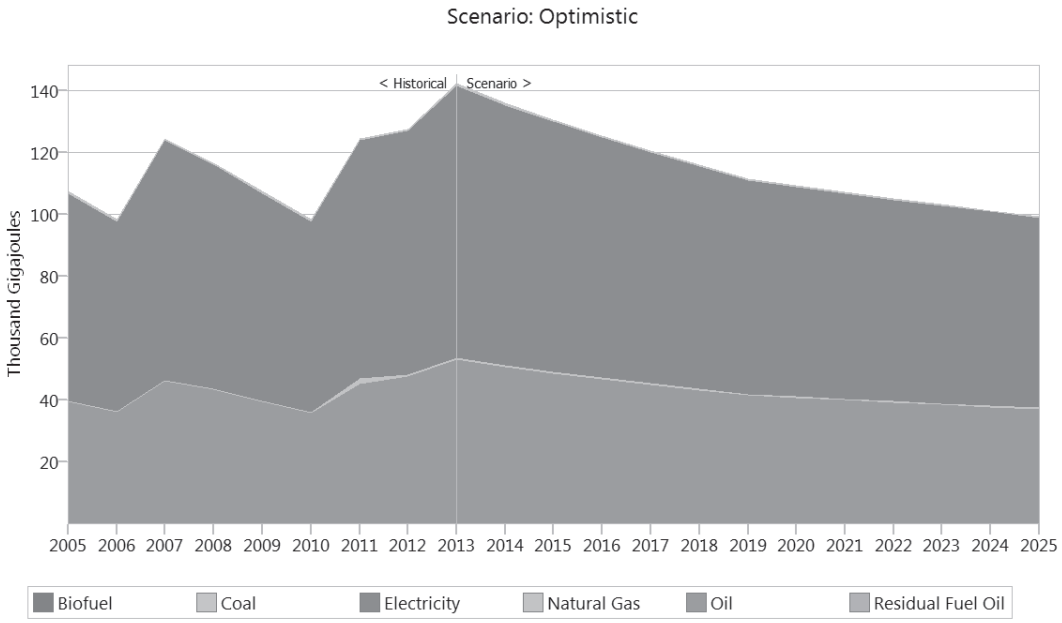

Figure 20. Final energy demand in transport sector. OPT scenario.

Transformation

Total transformation energy losses are over 28%, but by 2025 they will be reduced by almost 5 percentage points. Most of the losses are connected with electricity and heat and each of them loses about 8% during transmission and distribution. Assuming that little modernization is planned that could influence this situation and that the equipment is slowly aging, the growth rate of transformation efficiency is no more than 1–2%.

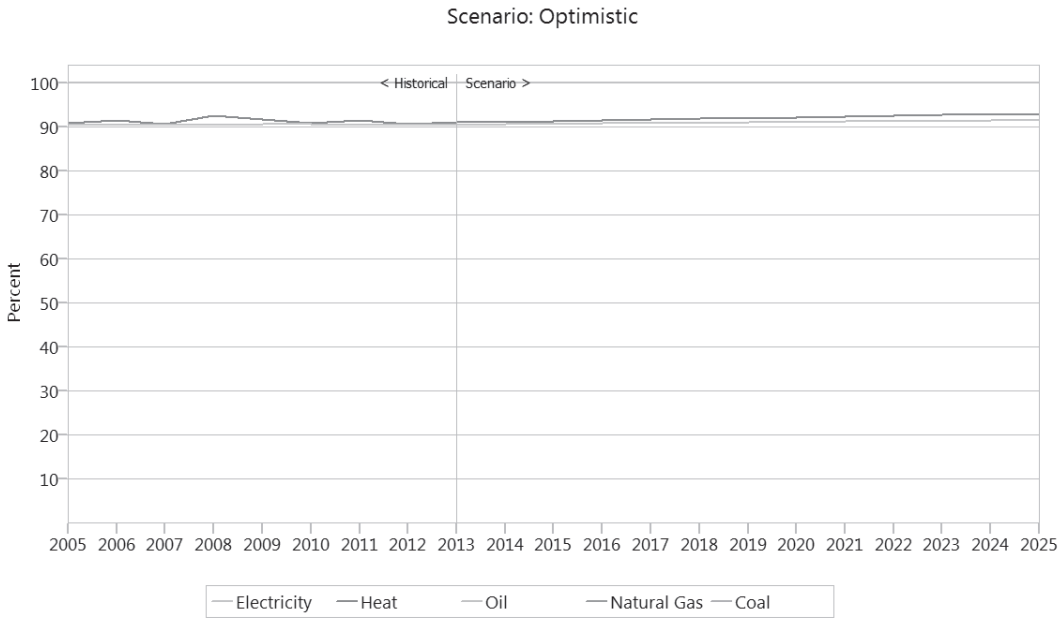

Figure 21. Transformation efficiency – transmission and distribution. OPT scenario.

Own use losses are less than that in transmission and distribution and equal to about 10% (2% — heat and 8% — electricity). Assuming that no innovations would be implemented, own use losses are considered to remain steady.

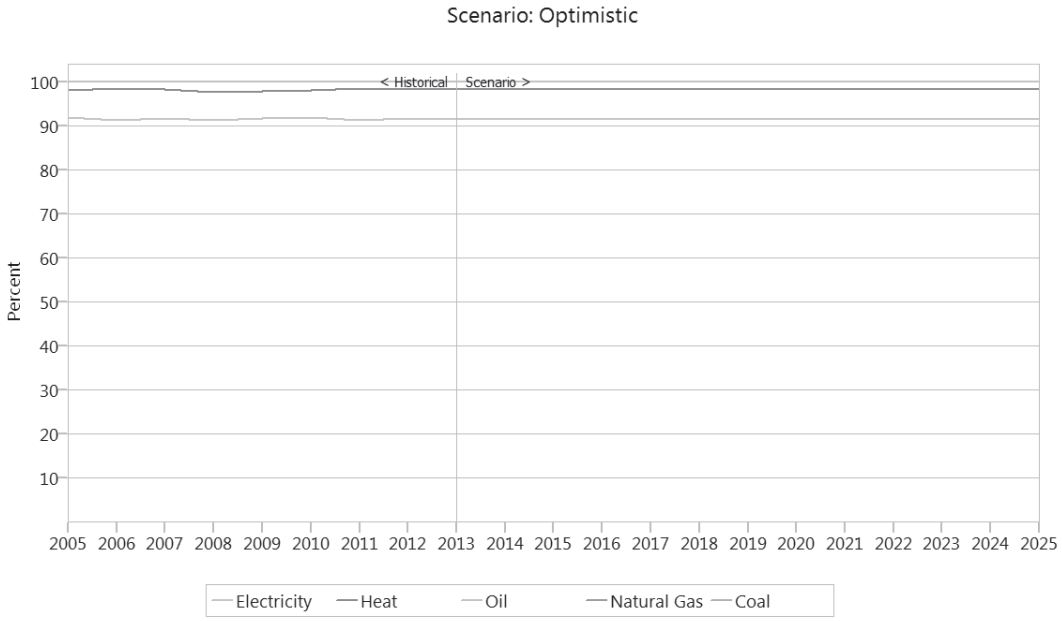

Figure 22. Transformation efficiency — own use. OPT scenario.

Global Warming Potential (GHG Emissions)

The OPT scenario shows us that comparing to 2013 the GHG emission will be reduced steadily and in 2015 will reach the reduction by 9%, in 2025 it will achieve the total reduction equal to 30%.

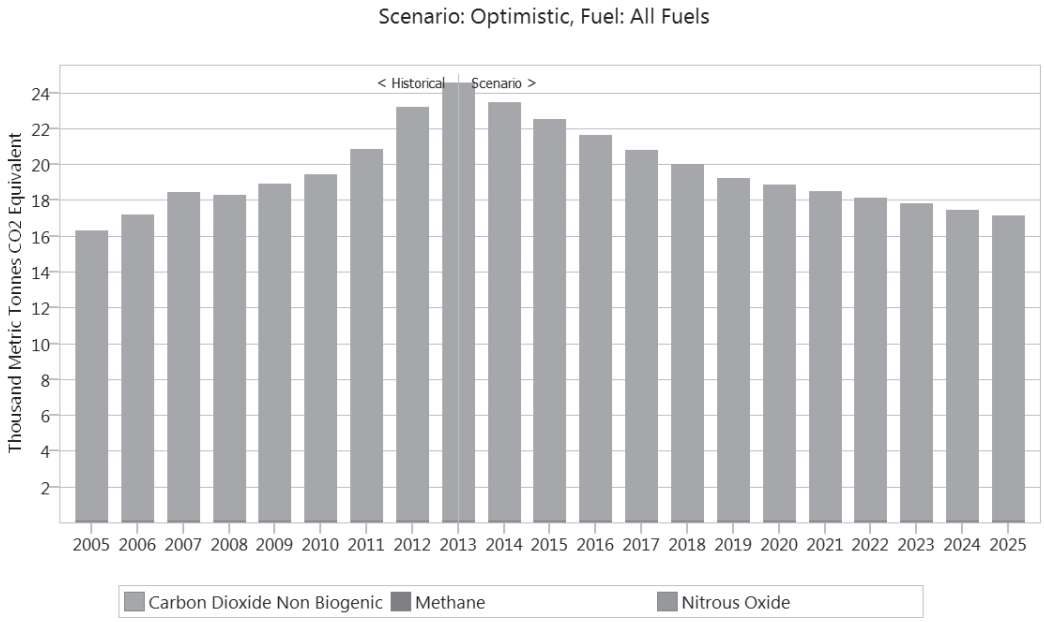

Figure 23. Global warming potential by GHGs. OPT scenario.

PESSIMISTIC SCENARIO

Pessimistic (PES) scenario is based on the bigger effect of the policy portfolio effective as of October 26, 2011 and corresponds mainly with the projections of the experts.

Several groups of assumptions, or key assumptions for PES scenario, are of great importance for the correct estimation by the model, so they are described below.

Population

Population dynamics follows dynamics that is forecasted in the General Plan of Moscow. This forecast contains saving the current level of the number of births and stabilization of the net migration at the level of 50–75 thousand people per year, however, the number of deaths will show an insignificant growth. Thus, total population of Moscow by the end of 2025 will not exceed 12 million people and will show a decrease comparing to 2013. This is a possible scenario due to the partial realization of the improvement of health, life capacity, fertility growth and migration mobility of population.

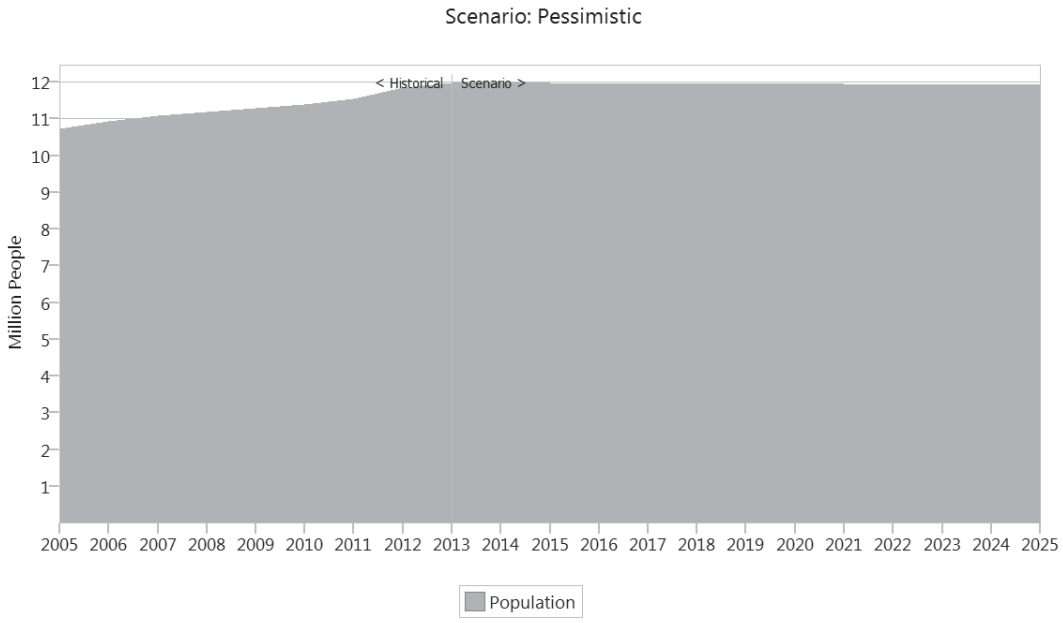

Figure 24. Demographics: population. PES scenario.

Climate

Climate forecasts are based on the Roshydromet weather forecast reports and are results of a simple regression of the data gained analysis with the only assumption that the situation with the greenhouse effect would become worse.

Economy

Real GRP as a key indicator of economic activity for forecasting GHG emission in the PES scenario too. In Moscow this interplay is moderated by low energy efficiency and significant role of energy sector in the economy. If the goals of the current policies would be reached, experts forecast that GRP growth rate would be 0.1% on average and, thus, would reach not more than 251 billion euro by 2025.

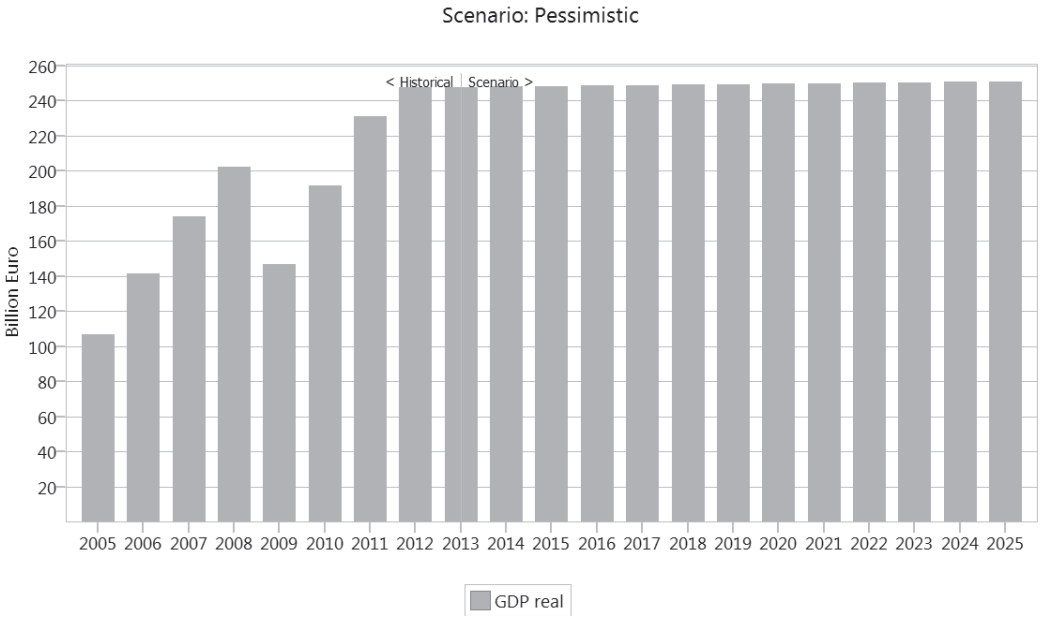

Figure 25. Economy: GRP real. PES scenario.

Sectoral distribution of GRP will also follow the dynamics of total real GRP. The structure of GRP in 2025 is almost the same as the one in 2013.

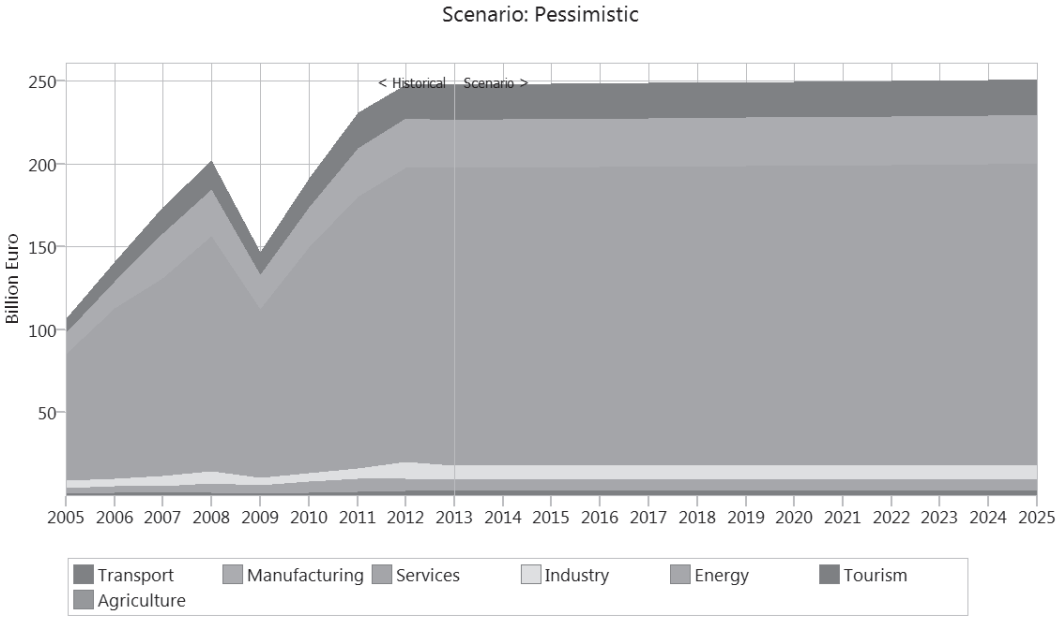

Figure 26. GRP distribution per sector. PES scenario.

Energy Demand

In the PES scenario the final energy demand in households sector will be decreasing as the result of energy saving policy of the Moscow government, which should allow consuming less heat and oil in this sector. Household sector, being the main consumer of total energy produced in Moscow, is thus of high importance in terms of GHG emission.

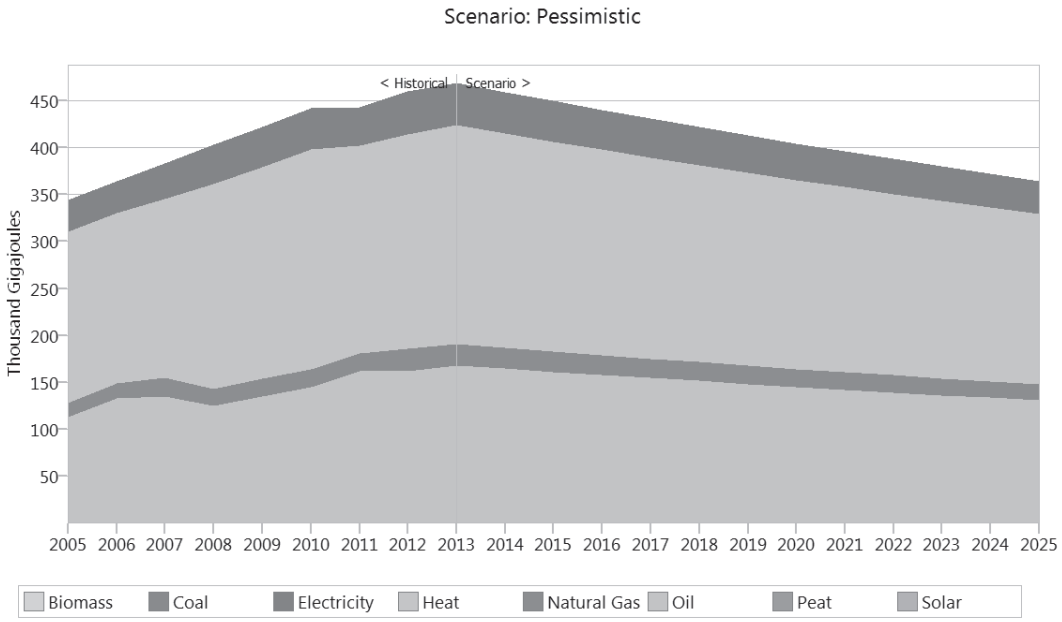

Figure 27. Final energy demand in household sector. PES scenario.

Agriculture has a significant contribution to the national economy, but a small share in the final consumption of commercial energies. The assumption for the growth rate of energy demand in the OPT scenario is that it follows its respective growth rate as described earlier in the GRP distribution per sector and in the BAU and OPT scenarios as well. Fuel shares are considered to be almost the same across the years since no influencing policy instrument is applied.

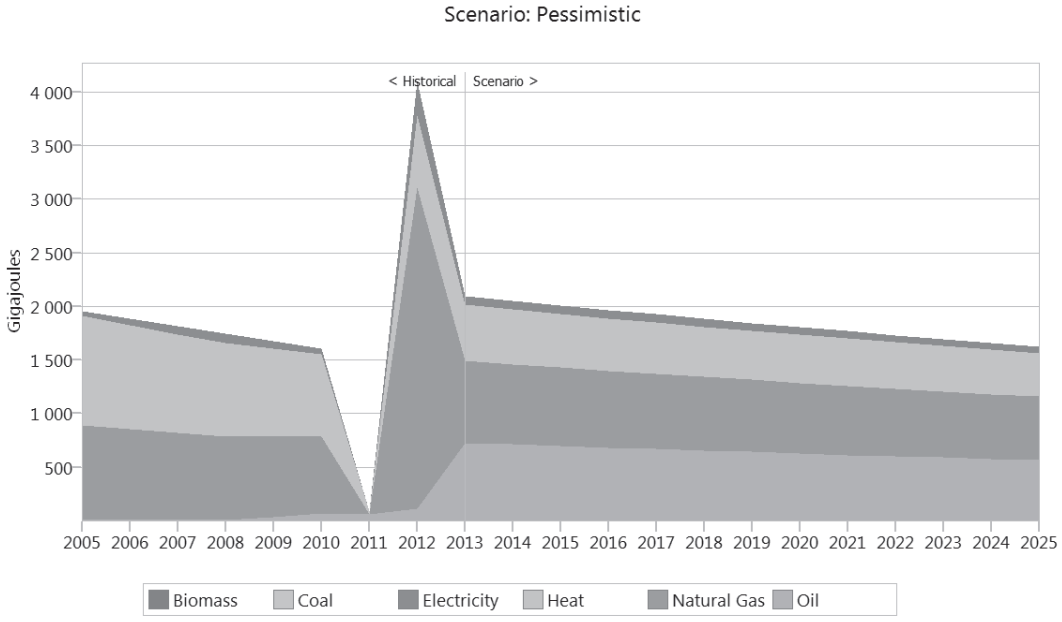

Figure 28. Final energy demand in agriculture sector. PES scenario.

Due to lack of data for the activity level, the industrial energy demand structure (industry sector) was formed mainly by experts' evaluations and partly on GRP structure. The growth rate of activity level

and the growth rate of energy demand are equal to its respective growth rate described earlier in the GRP distribution per sector section. Fuel shares are considered steadily since no policy instruments are applied.

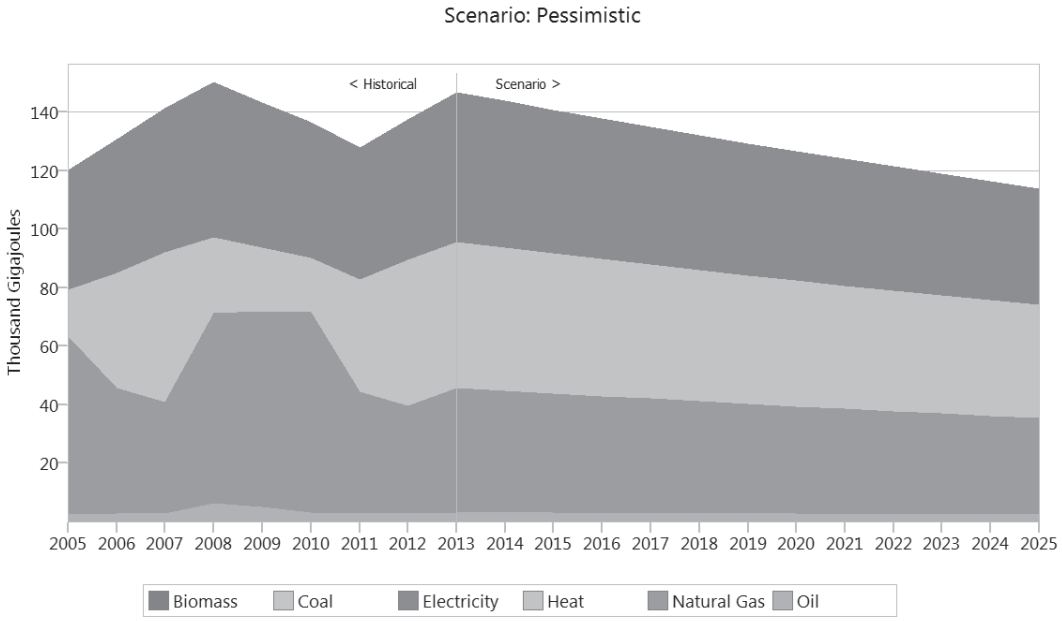

Figure 29. Final energy demand in industry sector. PES scenario.

Based on the experts' expectations on the successful transport strategy realization, final energy demand in transport sector is estimated.

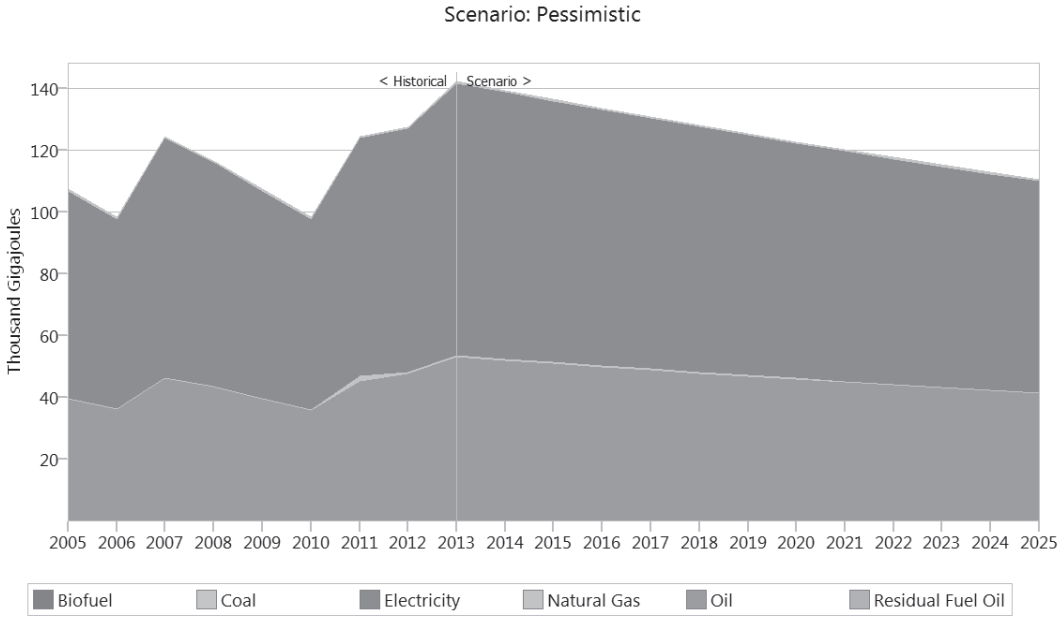

Figure 30. Final energy demand in transport sector. PES scenario.

Transformation

Total transformation energy losses are over 28%. Most of the losses are connected with electricity and heat and each of them loses about 8% during transmission and distribution. Assuming that no modernization is planned that could influence this situation and that the equipment is slowly aging, the growth rate of transformation efficiency is close to zero or even negative.

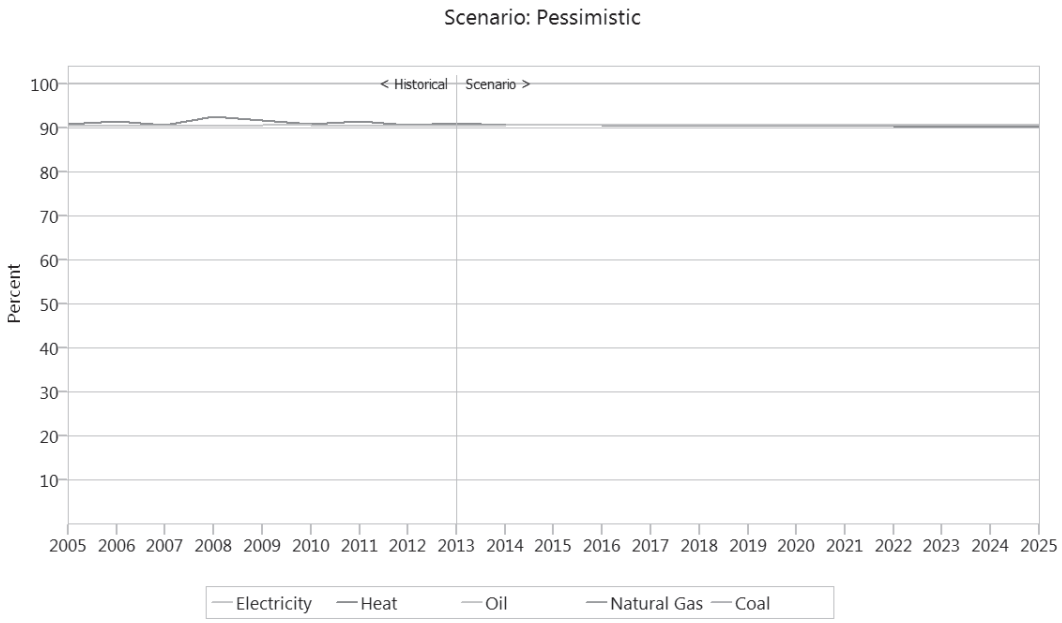

Figure 31. Transformation efficiency — transmission and distribution. PES scenario.

Own use losses are less than that in transmission and distribution and equal about 10% (2% — heat and 8% — electricity). Assuming that no innovations would be implemented, own use losses are considered to remain steady.

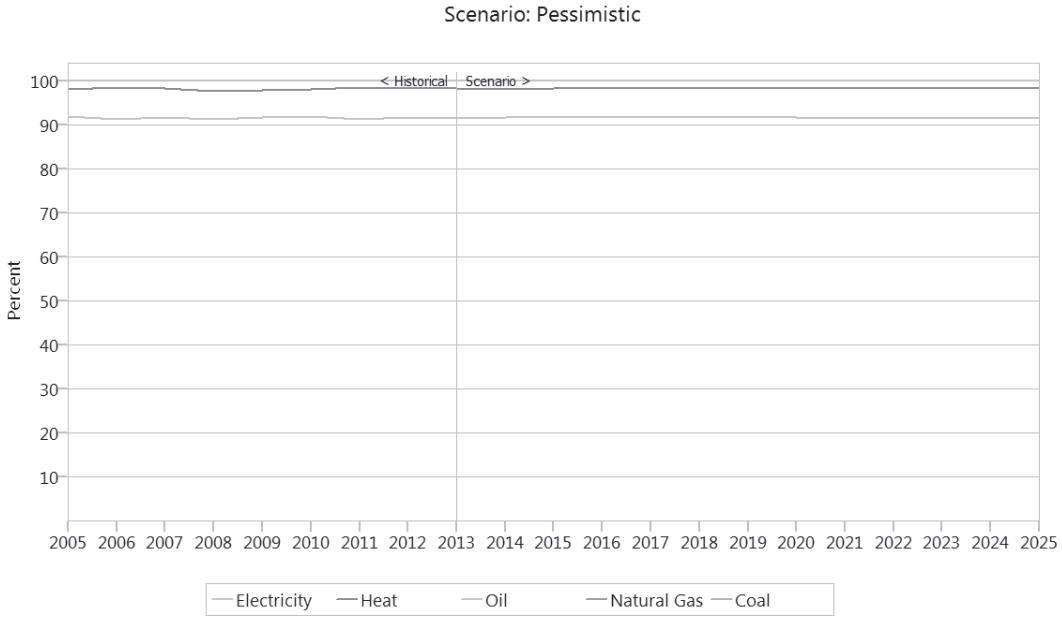

Figure 32. Transformation efficiency — own use. PES scenario.

Global Warming Potential (GHG Emissions)

The PES scenario shows us that comparing to 2013 the GHG emission will be reduced steadily and in 2015 will reach the reduction by 4%, in 2025 it will achieve the total reduction equal to 22%.

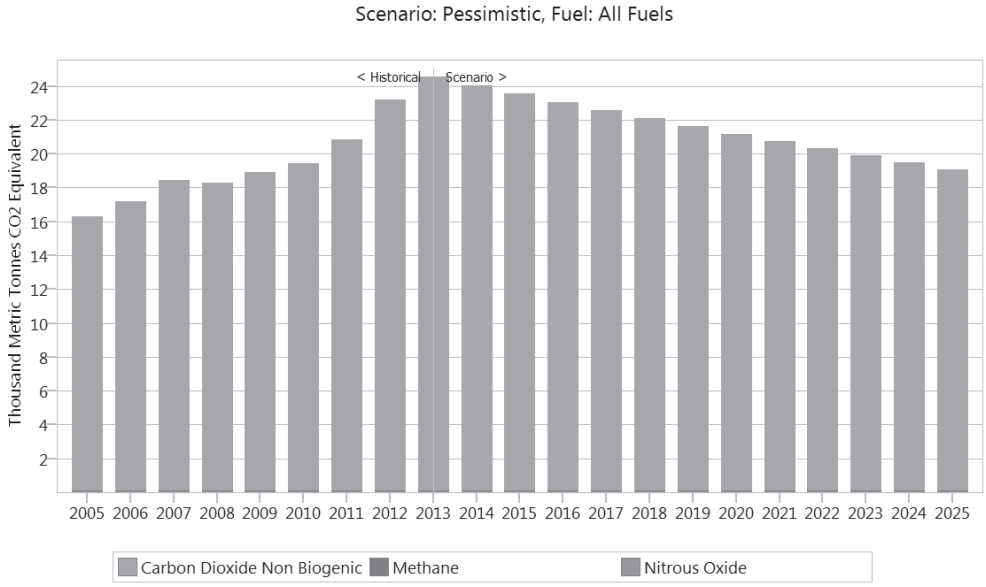

Figure 33. Global warming potential by GHGs. PES scenario.

RESULTS OF LONG-RANGE ENERGY ALTERNATIVES PLANNING SYSTEM (LEAP)

Based on the analysis of official documents and governmental programs, three scenarios of economic development of Moscow until 2025 were developed. Mentioned scenarios accounted for greenhouse gas emissions from various sectors of Moscow economy.

As part of the research, an econometric model in LEAP environment was built, encompassing fuel and energy balances data, as well as historical and forecasted GRP, industry and energy structure, sectoral and total energy efficiency, and the demand for energy from sectors of economy forecasted for up to 2025.

According to the BAU scenario, GHG emissions will be reduced by 7% by 2015 and decrease by 22% by 2025. OPT scenario will achieve reductions in GHG emissions by 9% and 30% in 2015 and 2025, respectively. However, in the PES scenario the decrease in GHG emission is only 4% and 22% in 2015 and in 2025 correspondingly. Analysis of GHG emissions by sectors shows a non-monotonic behavior of the service sector in terms of GHG emissions in all scenarios, an increase in GHG emissions in 2020 from 2% to 12% in OPT and PES scenarios respectively. Calculations showed a decrease in energy intensity of GRP in 2020 to 7% for BAU and OPT, and by 4% for the PES scenarios. Modeling showed anticipatory reduction of GHG emissions by households, which reaches in 2025 24%, 30% and 22% for the BAU, OPT and PES respectively.

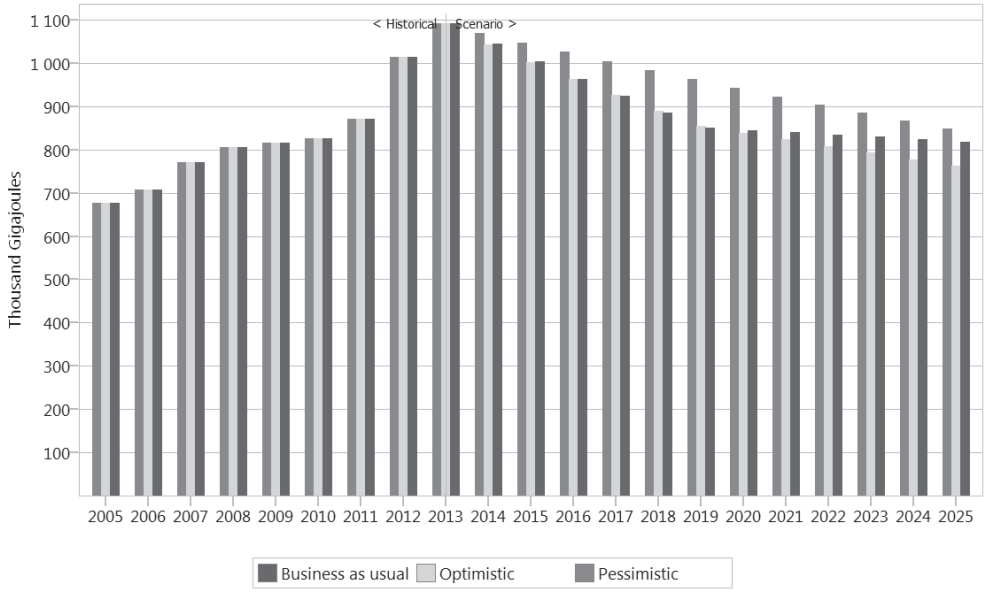

Figure 34. The final energy demand for all three scenarios.

The main outcome of the analysis is that the Pessimistic scenario shows the highest demand for energy. However, the Optimistic one shows the lowest demand on energy as it assumes the successful realization of energy saving programs.

As we can see on the chart below, the Optimistic scenario is the most environmentally friendly, the Pessimistic one is easier to implement, and Business-as-Usual balances interests of all stakeholders in charge. This might be interpreted as an evidence of lack of governmental regulation and motivation to intervene in energy sector to make it greener and more sustainable.

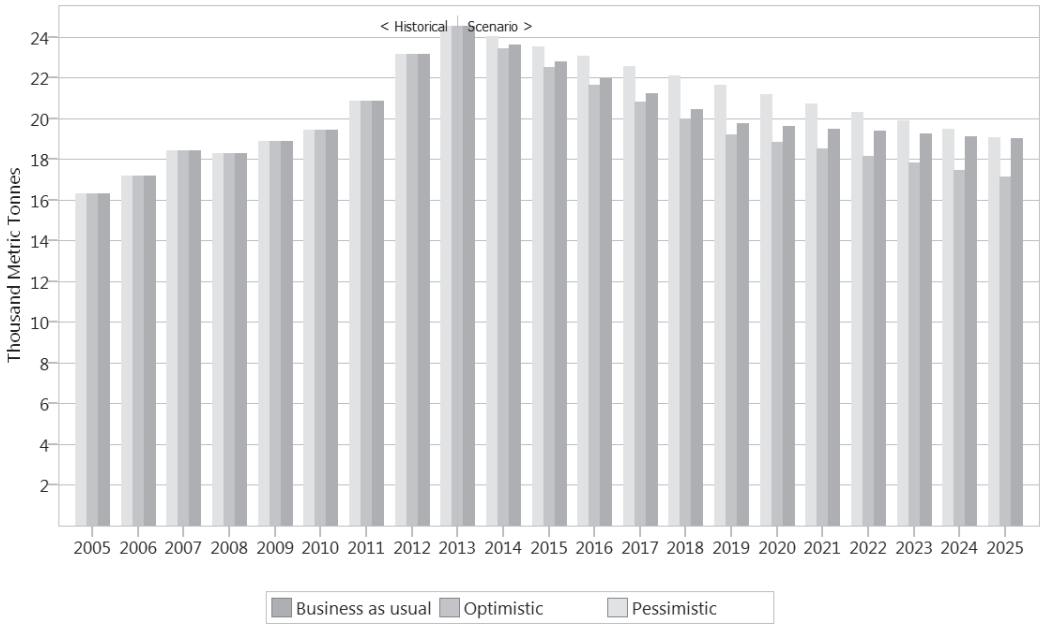

Figure 35. The evolution of the global warming potential for three analyzed scenarios.

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ANNEX

Table 2. Dynamics of energy capacity of GRP in Moscow and in the industries of Moscow for the period 2010–2012.

	Consumption, thousand tons of fuel equivalent			GRP, mln. RUR			Energy capacity of GRP, tons of fuel equivalent / mln. RUR		
	2010	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
Full energy consumption	42944	43258	44008	8375864	8610388	8739544	5,13	5,02	5,04
Final energy consumption	28932	30224	31712	8375864	8610388	8739544	3,45	3,51	3,63
Agriculture	55	3	140	n/a	1499	1522	n/a	2,00	92,01
Manufacturing	5038	4751	5006	1072111	1111779	1127344	4,70	4,27	4,44
Production and delivery of electricity, gas and water	645	423	633	293155	292276	296615	2,20	1,45	2,13
Construction	730	742	760	217772	218644	223891	3,35	3,39	3,39
Transport and telecom	3355	4253	4357	862714	862714	875522	3,89	4,93	4,98
Services and others	5024	5955	6079	5930112	6123477	6214651	0,85	0,97	0,98
Wholesale and retail trade			1626			3233991			0,50
Hotels and restaurants			100			79179			1,26
Education			738			205433			3,59
Health and social services			373			263167			1,42
Other community, social and personal services			1485			232098			6,40
Other industries			936			2200782			0,43

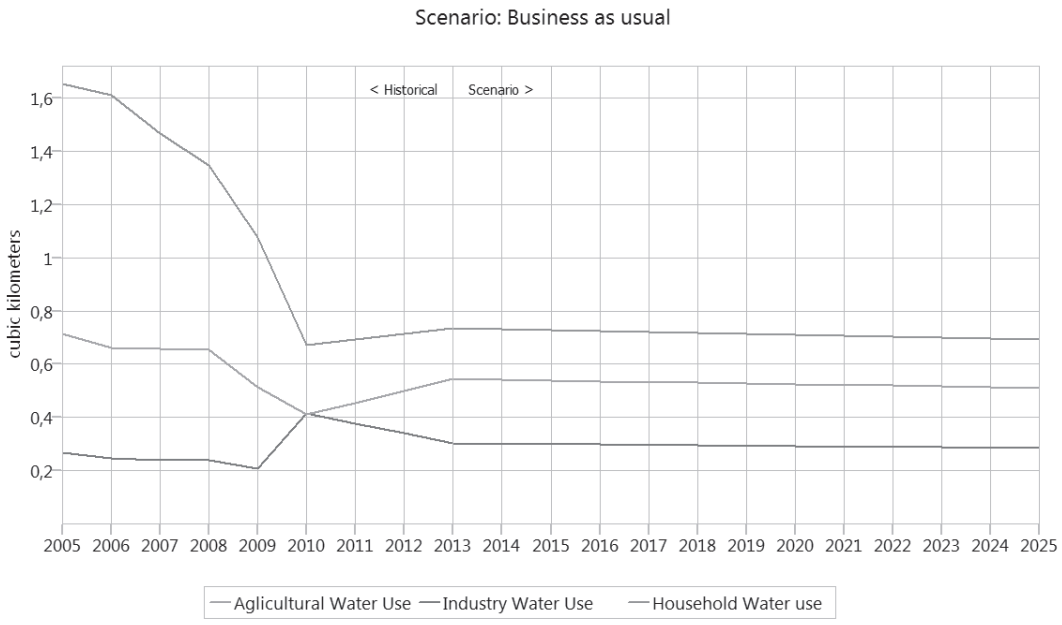

Figure 36. Water use — BAU scenario.

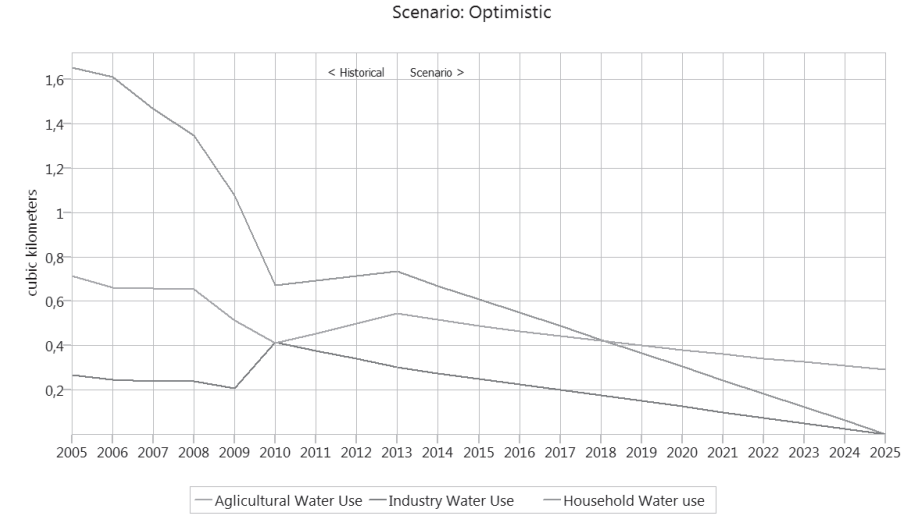

Figure 37. Water use – OPT scenario.

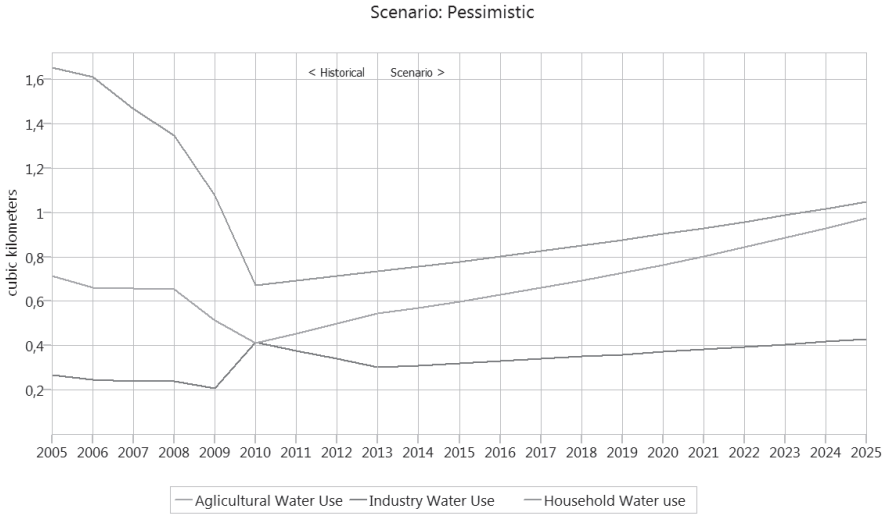

Figure 38. Water use – PES scenario.

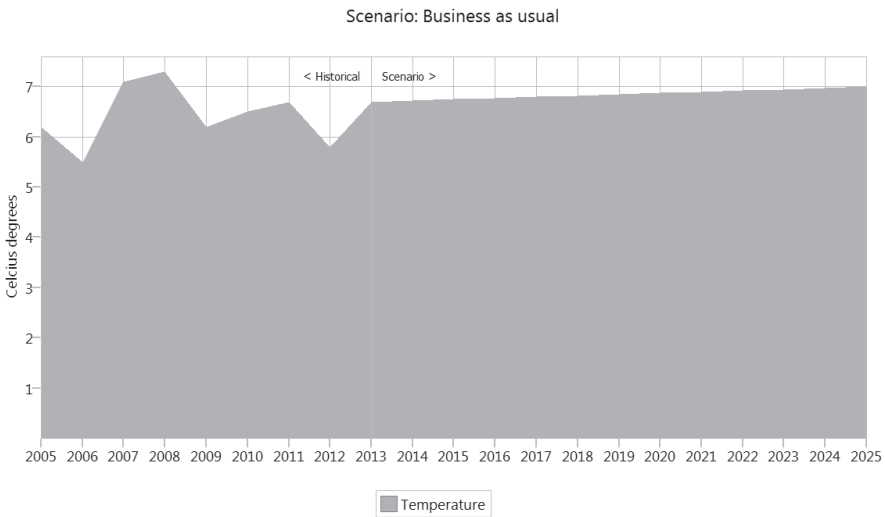

Figure 39. Average year temperature prognosis – BAU scenario.

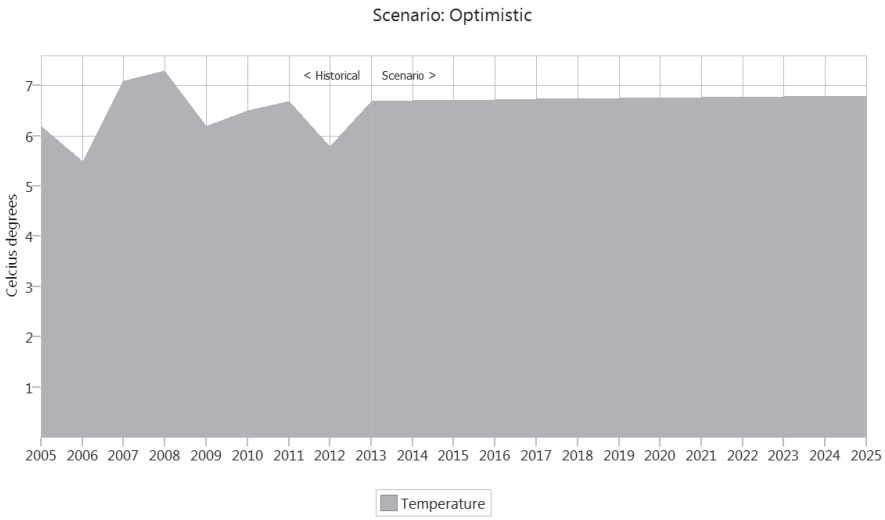

Figure 40. Average year temperature prognosis – OPT scenario.

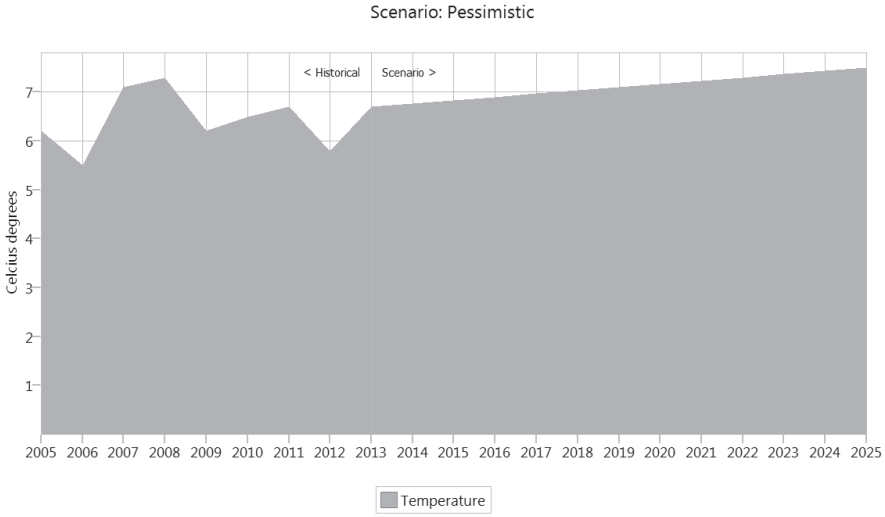

Figure 41. Average year temperature prognosis – PES scenario.

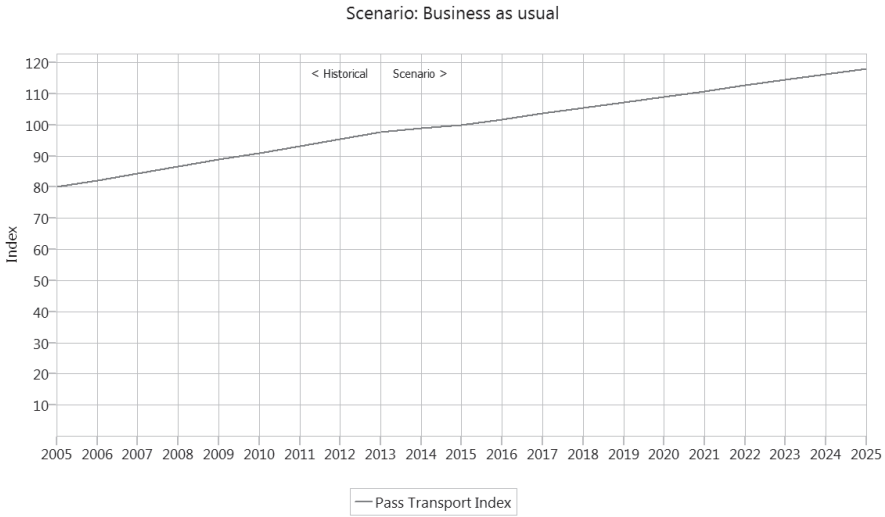

Figure 42. Passenger transport index – BAU scenario.

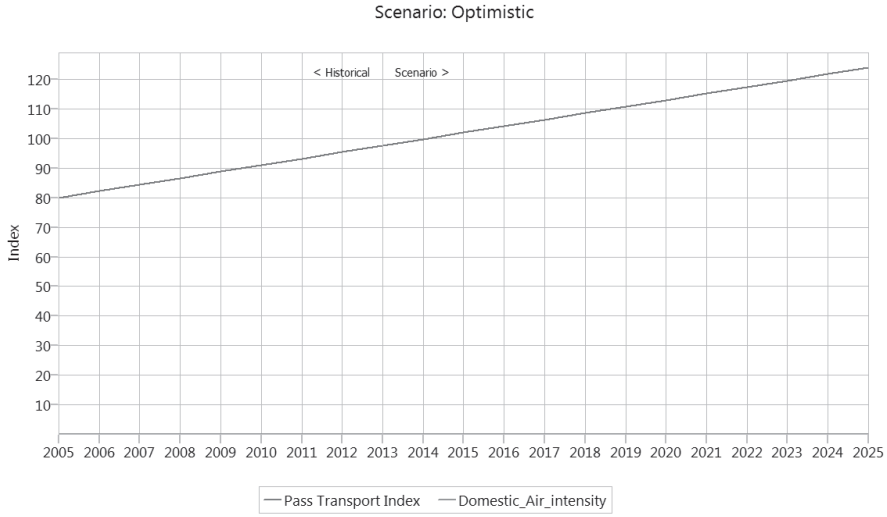

Figure 43. Passenger transport index – OPT scenario.

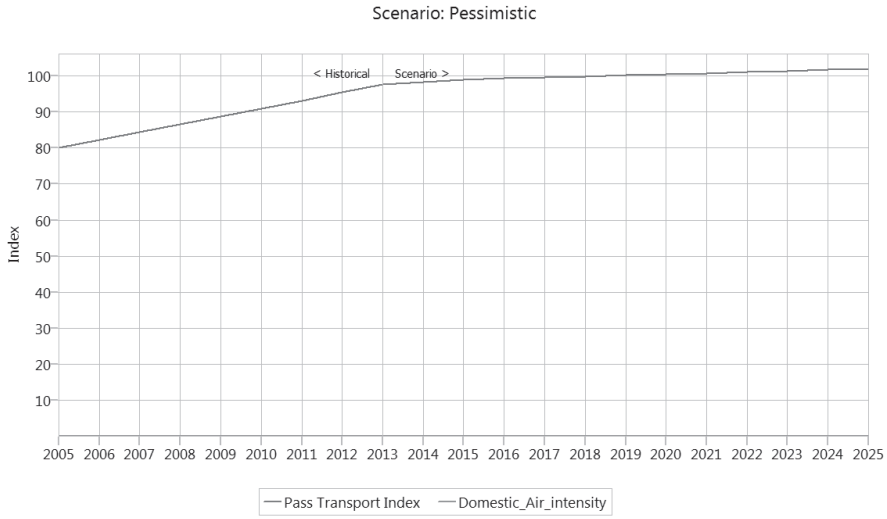

Figure 44. Passenger transport index – PES scenario.

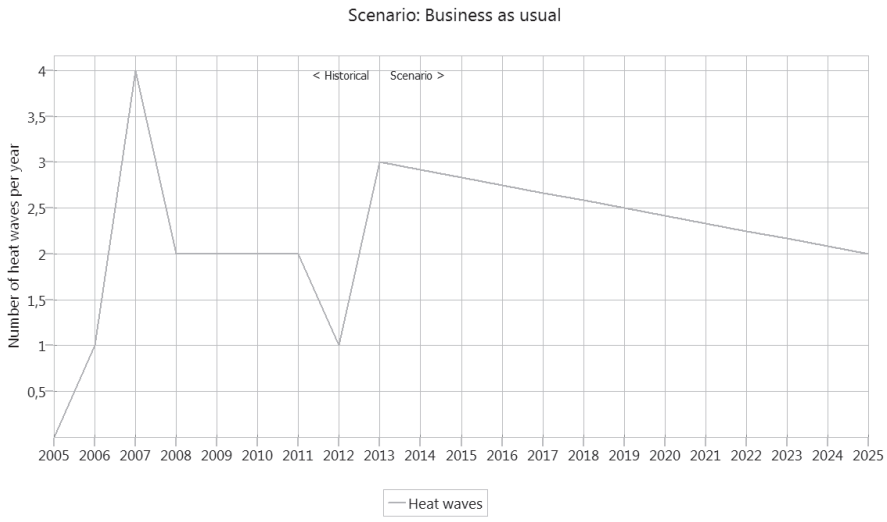

Figure 45. Extreme heat waves – BAU scenario**.**

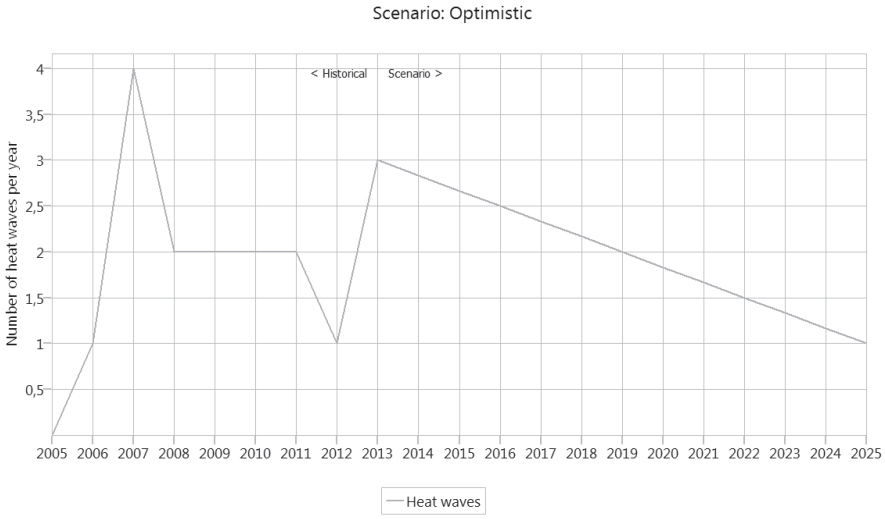

Figure 46. Extreme heat waves – OPT scenario.

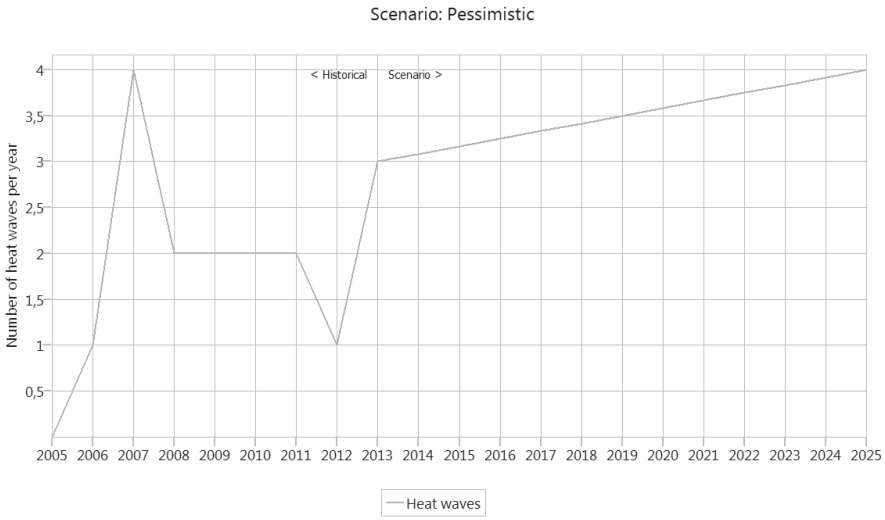

Figure 47. Extreme heat waves – PES scenario.

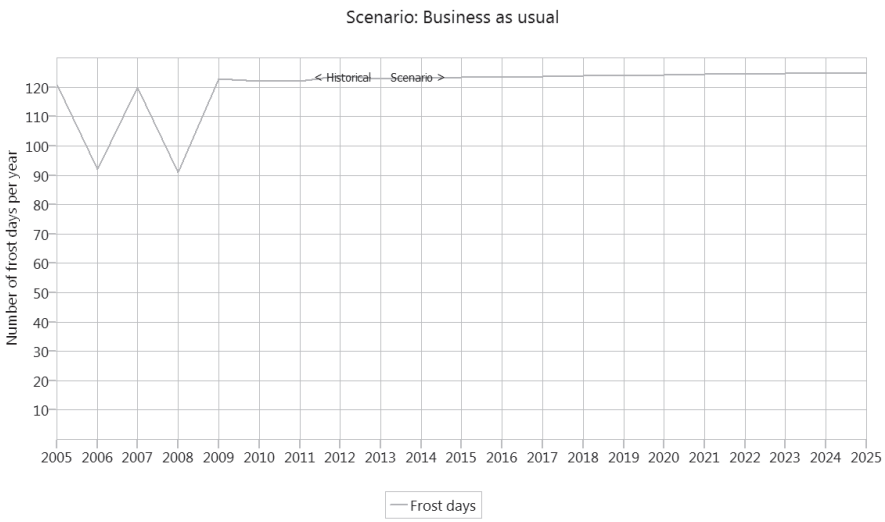

Figure 48. Extreme frost days – BAU scenario.

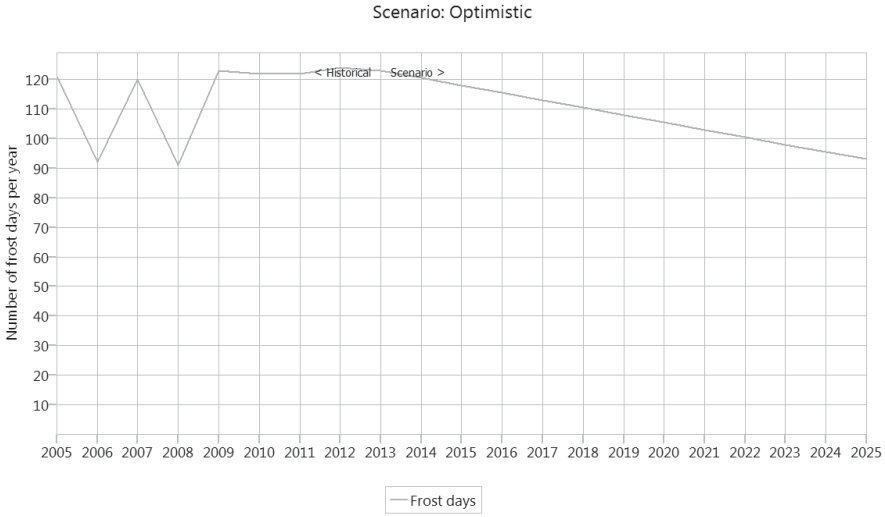

Figure 49. Extreme frost days – OPT scenario.

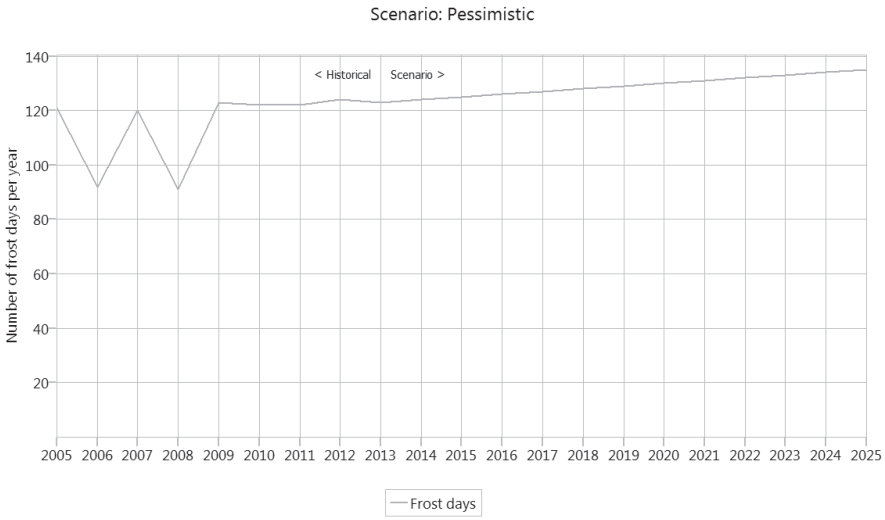

Figure 50. Extreme frost days – PES scenario.

Investing in War: Empirical Evidence of Investors' Unsustainable Behavior in Times of Armed Conflict*

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Abstract. We investigate the impact of the armed conflicts, economic sanctions, and other threats on the equity risk premium estimated dynamically using generalized autoregressive conditional heteroskedasticity (GARCH) approach. We find that the ERP fall to negative values during period of conflict. The results could be explained by unethical behavior, selfish motivation and "myopic risk-seeking" of equity investors. This behavior is robust across all countries, periods and selected national stock indices covered in research.

Аннотация. В работе исследуется влияние вооруженных конфликтов, экономических санкций и других угроз на премию за риск для обыкновенных акций, моделируемую динамически как GARCH-процесс. ERP падает до отрицательных значений в период конфликта. Результаты можно объяснить неэтичным поведением, эгоистичной мотивацией и близоруким восприятием риска инвесторами. Феномен устойчив по странам, срокам и национальным фондовым индексам, охваченным в исследовании.

Key words: War, economics of armed conflict, sustainability, market behavior, risk premium, GARCH.

ESTIMATION OF RISK PREMIUM USING ARCH/GARCH MODELS

There are three main approaches that are used to estimate the ERP. The first is to survey subsets of investors and managers, financial directors, academics in order to obtain information about their expert expectations about returns on equity in the future (survey-based ERP). The second, historical premium approach, is to analyze the returns obtained in the past on equities relative to risk-free investments and use this historical equity premium as the expectation. The third approach is to attempt to analyze a forward-looking equity premium based on the current trading prices or some market rates; it is also called implied premiums approach.

ARCH (AutoRegressive Conditional Heteroscedasticity) is well-known econometric model used for the analysis of time series (especially financial). Based on ARCH, the conditional variance is equal to:[1]

$$\sigma_t^2 = V(u_t \mid u_{t-1,\dots,} u_{t-p}) = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2,$$

where α is basic volatility; u_t — time series.

ARCH models were first proposed by Engle in 1982. Already in 1986[2], Bollerslev proposed a generalization of these models (GARCH). ARCH-model assumes the dependence of the conditional variance only on the squares of past values of the series. One can generalize this model by assuming that the conditional variance also depends on past values of the conditional variance:[3]

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-1}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2.$$

GARCH-in-mean (GARCH-M) was proposed by Engle *et al.* in 1987. In this case, it is not a special model for the conditional variance. It is about using

[1] Determinants of the time varying risk premia, Pornpinun Chantapacdepong University of Bristol March 13, 2007, Department of Economics, University of Bristol

[2] Engle, R. F., Lilien, D. M., and Robins, R. P., 1987, Estimating Time-Varying Risk Premia in the Term Structure: the ARCH-M model, Econometrica, Vol. 55, No 2 (March 1987), p.391–407.

[3] Determinants of the time varying risk premia, Pornpinun Chantapacdepong University of Bristol, March 13, 2007, Department of Economics, University of Bristol

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the conditional variance as a factor of the regression model for the risk premium. If we denote the excess return y_t, then the GARCH-M model means that:[4]

$$y_t = a + f(\sigma_t^2) - E[f(\sigma_t^2)] + u_t.$$

Returning to GARCH, it combines mean and variance processes estimations and establishes risk-return connection at market level.

In practice scholars failed to confirm steady relationship. The probable cause of it is the evolution of market processes. Returns were supposed to be driven only by their mean and variance until Ball and Torous (1983) refuted the thoughts of continuous sample path of stocks by presenting the evidence that stocks have log normally distributed jumps. The GARCH model is able to capture smooth returns fluctuations and variation while it fails to predict occasional significant movements. Taking these "jumps" into consideration allows to model risk properly. It implies that jumps are the third variable which along with mean and variance explains stock returns. The introduction of jumps allows for non-normality of returns' distribution which has been observed during the recent financial crisis.

Chan and Maheu (2002) introduced the autoregressive jump intensity model (ARJI) which is the extension of the jump diffusion model. Their novelty is the integration of GARCH model into the jump diffusion model. This combination yields the capture of both the smooth and persistent volatility changes over time and sudden jumps of returns together with clustering of these jumps and time-variation of its size. Returns are modeled in accordance with the simple diffusion model and the Poisson jump model of stock returns for the additional source of volatility. The number of jumps per period is defined by the Poisson process.

The paper of Arshanapalli, Fabozzi, and Nelson (2011)[5] proposes an approach that combines GARCH-M model with the autoregressive jump intensity (ARJI) model in order to test the equity risk-return relationship. The dataset consists of monthly market risk premiums which are calculated as the difference between the value-weighted returns on NYSE, AMEX, and NASDAQ stocks and one-month T-Bill rate for the period of 1926–2010. The findings support the significance of strong risk-return relationship after 1950. The expected returns are greatly affected by jumps when they occur through the conditional variance. The jump size depends on the sign of the equity premium for the previous period: if it is negative the size will increase, if it is positive the size will decrease.

Following the main purpose of the study Arshanapalli *et al.* find the empirical evidence of existence of persistent relationship between risk and return and suggest that the jump should be considered as element of risk and taken into account by investors.

This model requires determination of the risk-free rate, which is rather difficult for developing countries. The choice of Arshanapalli *et al.* to take U.S. one-month T-Bill rate as risk-free is stipulated by monthly data. Developing countries hardly have liquid or issue one-month debt securities. Also the complexity of the approach makes it difficult to apply in day-to-day practice. Moreover it doesn't assume of modeling the term structure of equity premium.

ARMED CONFLICTS AND WAR: CONCEPT AND CONSEQUENCES

According to the Nobel Laureate Richard E. Smalley war is among the ten biggest problems facing the society of mankind for the next fifty years, it takes the 6th place[6] in his rating. In the 1832, the military general of the Prussian army Carl von Clausewitz in his treatise *On War* defined the war as follows: "War is … an act of force to compel our enemy to do our will."[7]

Leading research centers headed by Uppsala University (Sweden) and the Center for International Development and Conflict Management (CIDCM) at the University of Maryland (USA) define armed conflict as contradiction concerning the power or territory, that is disputed by the application of armed force by the political communities of at least two opposing sides, and in which at least 25 people die[8]. If the confrontation involves government armed forces, it is considered to be a "state-based conflict". If the state is neither one of the warring parties, the conflict is considered to be "non-state". The "war" can be considered only as a relatively large and intense conflict — the armed confrontation, which directly led to the deaths of at least 1,000 people per year (direct combatants and civilians killed as a result of military action).

Main cause of wars is the desire of the political

[4] Ibid.

[5] Arshanapalli, B., Fabozzi, F. J., and Nelson, W., 2011, Modeling the Time-Varying Risk Premium Using a Mixed GARCH and Jump Diffusion Model, Working paper series, SSRN No 1893038.

[6] Smalley, Richard E. (2008). Smalley Institute Grand Challenges. Rice University. Retrieved 24 April 2011.

[7] Clausewitz, Carl von (1984) [1832]. In Howard, Michael; Paret, Peter. On War [Vom Krieg] (Indexed ed.). New Jersey: Princeton University Press. p. 75.

[8] Uppasala University, Department of Peace and Conflict Research, definitions on www.pcr.uu.se/research/ucdp/definitions/

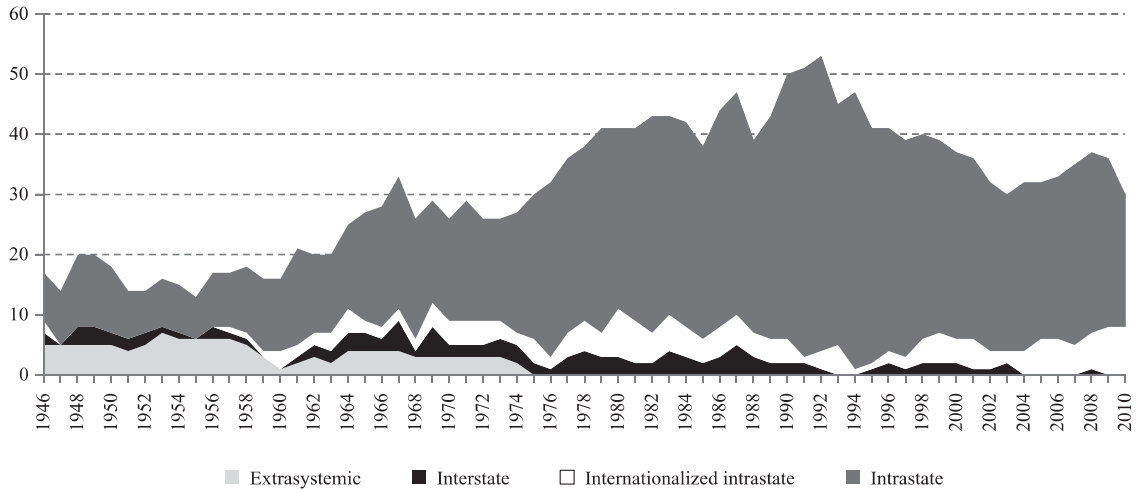

Fig. 1. **Number of armed conflicts by type, 1946–2010.**

forces to use armed struggle to achieve a variety of foreign and domestic political purposes. Main means of achieving the objectives of war is an organized armed struggle, as well as economic, diplomatic, ideological, informational and other means of struggle. In this sense, the war is an organized armed violence, the aim of which is to achieve political goals.

The direct object of war is to impose one's will on the enemy. One political entity is trying to change the behavior of another, to make him give up its freedom, ideology, rights to something, to give away the required national wealth, the territory, water area, etc. Implementation of these aspirations by non-military means, for example, in the process of negotiations, accompanied by the threat of force, may lead to so-called "voluntary accession" of one state to another, without the use of armed force.

According to Linebarger, the war is a kind of conviction, expensive, dangerous, bloody and unpleasant, but very effective, if other measures do not provide the desired results[9]. Often the initiators of the war pursue indirect goals, such as strengthening of their internal political position, destabilization of the region as a whole, diversion of enemy's forces.

In real life there is often no clear distinction between the attacking and the defending sides, because both sides are on the verge of open aggression, and which of them will attack first is a matter of luck and adopted tactics.

For 2010, since the end of World War II 246 armed conflicts in 151 countries were registered. General statistics from 1946 to 2010 can be seen in Figure 1[10].

It should be noted that since the end of 2010 to the end of 2012 there was a sharp increase in the number of armed conflicts, especially civil wars. At the same time wars are often waged without heavy involvement of aggressor's human resources. Social networks, mass media and funded opposition are becoming the main instruments of war.

The growth of armed activity and the apparent desire of some states to contribute to conflict forced to think about the objectives of these states, what they want to achieve by means of direct or indirect entry into the armed conflict.

Armed conflicts and wars are the factors that have greatest and usually negative impact on the economy. Besides the fact that war is inherently extremely costly, the country may lose its key industries, which are the main source of replenishment of the budget. Thus, both sides of the conflict face the losses, financial and of course human.

This study is based on the desire to understand what motivates countries to join the armed conflict or inflame it. In other words, what is the potential profit from participation in hostilities?

A country can join the armed conflict of geopolitical or economic reasons. Geopolitical reasons may be associated with desire to gain control over the territory of the country, change the unwanted political regime, etc.

Economic reasons are most often associated with natural resources. For example, the cause of the war may be a desire to cancel the current contracts for extraction of energy resources with a subsequent transfer to the energy corporations of the aggressor or their allies. Also, armed conflicts may be initiated for other reasons: national, ethnic, religious, ideological, etc.

[9] Paul M.A. Linebarger. Psychological Warfare. International Propaganda and Communications. ISBN 0–405–04755-X (1948). Revised second edition, Duell, Sloan and Pearce (1954).

[10] Themner L., Wallensteen P., 2011, Armed conflict, 1946–2010, J PEACE RES 48 (4):525–536, Uppsala Conflict Data Program, Department of Peace and Conflict Research, Sweden.

Within this broad topic of research, this paper analyzes the changes in equity risk premium in the countries involved in the armed conflicts and the war. And in this case conflicts are considered in conjunction with economic sanctions and threats.

DATABASE AND TOOLS USED

The Correlates of War Project (COW) was founded in 1963 by J. David Singer from University of Michigan (USA) with the main goal of systematic accumulation of scientific knowledge and information about the armed conflicts and war. All COW data is available free for public.

For the analysis it is necessary to choose those armed conflicts, where the participants had their national stock index. That's why we choose the second half of 20-th century and early 21-st century. We excluded participants, which hadn't developed stock market at the moment of involvement in the conflict. The third criterion is the period of conflict. It may be too short and also too long.

In case of short wars or conflicts, it is hard enough to measure the dynamics of stock indexes; often short wars and conflicts are part of a long full-scale confrontation. Thus the results can be distorted, and therefore data cannot be used in the study. As an example, there are numerous military operations between Israel and Palestine. To consider each conflict separately does not make sense, because in reality the conflict between these two countries is not terminated at the time of the ceasefire.

On the other hand, long-term wars are not always suitable for the analysis of the equity risk premium, as this indicator is influenced by many factors and the war is just one of them. For example, the second Chechen war, in which Russia participated, lasted about 10 years (1999–2009), a period of rapid growth of the Russian economy, and the country's participation in the conflict was not so significant, in order to really have a strong impact on stock performance. Therefore, changes in the equity risk premium in this period are unlikely to depend on the participation of Russia in the second Chechen war.

The last stage of preparation of the base is selection of equity indexes.

We analyzed 12 countries, including Australia, Canada, France, Germany, India, Italy, Netherlands, Pakistan, Peru, Turkey, United Kingdom and USA which were involved in eleven conflicts: Cenepa Valley; Communist Coalition; Gulf War; Invasion of Afghanistan; Invasion of Iraq; Kargil War; Libyan civil war; Second Laotian, Phase 2; Vietnam War, Phase 2; and War in Kosovo.

For the analysis of the available database we used R-Project[11] and historical prices of national stock indices from Bloomberg.[12]

The next step was to obtain the results of the equity risk premium. In our case, we do not need to obtain specific daily performance of the risk premium. We need to analyze the changes in ERP before the conflict (1 year), during and after conflict (1 year). This data was obtained with help of R-Project function and *rugarch* and *quantmod* libraries.

EMPIRICAL FINDINGS

In the course of the study we obtained very unusual and even unpredictable results. Almost always, regardless of the country, period and selected national stock index, the equity risk premiums reduced during involvement in armed conflicts.

Equity risk premium is the compensation to the investor for adoption of additional risk. Thus, the higher the risk, the higher the premium for it.

If the equity risk premium of the asset is reduced, this means investors perceive less risk associated with the purchase of an asset and, therefore, two things happen. First, investors who own this asset have benefit from the one-time capital gain, because future corporate profits now are discounted at a lower rate. This is similar to the effect of lower interest rates on the price of bonds. Second, assumptions about future revenues are changing. Since the size of the risk premium reflects the expected return, the decline in risk premiums means lower future returns.

If the equity risk premium for this asset class is rising as investors perceive more risk associated with their possession, things come back. The first consequence of the growth of risk premiums will the falling of the prices, because the future profits now are discounted at a higher rate. But, at the same time, investors can expect higher returns on their investments. Thus, in practice, the exact opposite happens to the fact that investors expect when they extrapolate future results of previous periods.

The very fact that during the conflicts investors perceive less risk is against to elementary logic, because armed conflicts in essence can be destructive to the economy.

Possible cause of this trend may be related to the hypothesis that the war is a business, a way of making a profit.

[11] www.r-project.org.
[12] www.bloomberg.com.

Fig.2. Dynamics of the S&P500 index during Gulf war.

Fig. 3. Dynamics of the S&P500 index during the war in Kosovo.

Fig.4. Dynamics of the S&P500 index during invasion in Iraq.

It should be noted that most countries in our database of conflicts acted as aggressors, the wars were not carried out on their territory, and the main goal of the conflict was the resources of the country and political influence in the region. War as a whole was carried out against potentially weak states, and hence the positive outcome was expected.

First analyst comments after the first strikes on Afghanistan by U.S. and British armed forces, stated that the military campaign launched by the United States against Afghanistan could benefit the U.S.

Fig.5. Dynamics of the DAX 30 during the war in Kosovo.

Fig.6. Dynamics of CAC 40 during the Gulf war.

economy in recession. At the same time, U.S. analysts cited the example of the Gulf War. For example, *The Wall Street Journal* expected an increase of interest in the stocks of the arms industry. Since the September 11 attacks the investors have been expecting retaliation from U.S., therefore the stock quotes of defense contractors steadily raised. Analysts noted that prior to the "sting operation" interest of investors was towards the shares of producers of electronic equipment for military purposes, and after it started, the demand for the shares of all arms producers increased.

In addition to government orders armed conflict is an additional justification to cover government debt through emission. Partly this can be done through the mechanisms of freezing the assets of the country, i.e. imposing sanctions. For example, in accordance with paragraphs 17, 19, 20 and 21 of UN Security Council Resolution 1970 (2011) and paragraphs 19, 20 and 21 of UN Security Council Resolution 1973 (2011), the U.S. authorities have frozen the assets of Muammar Gaddafi and members of his family worth about $ 30 billion. The fall in the risk premium should occur simultaneously with the growth of the national stock indices. The growth of the stock indexes indicates positive expectations of investors regarding the available assets. Positive expectations, in turn, lead to reduction of the level of risk and the level of equity risk premiums respectively. Figures 2, 3 and 4 show the dynamics of S&P500 during Gulf war, war in Kosovo and invasion in Iraq.

According to the data, the period of U.S. entry into armed conflict is characterized by an increase in national stock exchange. The situation is similar in other countries.

Figure 5 shows the dynamics of the German index DAX 30 during the war in Kosovo.

The next index is French CAC 40. Figure 6 shows the dynamics of CAC 40 during the Gulf war.

The obtained results do not contradict the results obtained on the risk premium. Stock indexes during periods of conflict are really growing. It is worth noting that before the war, there is a short-term drop in the market, but most of the future growth is ahead of

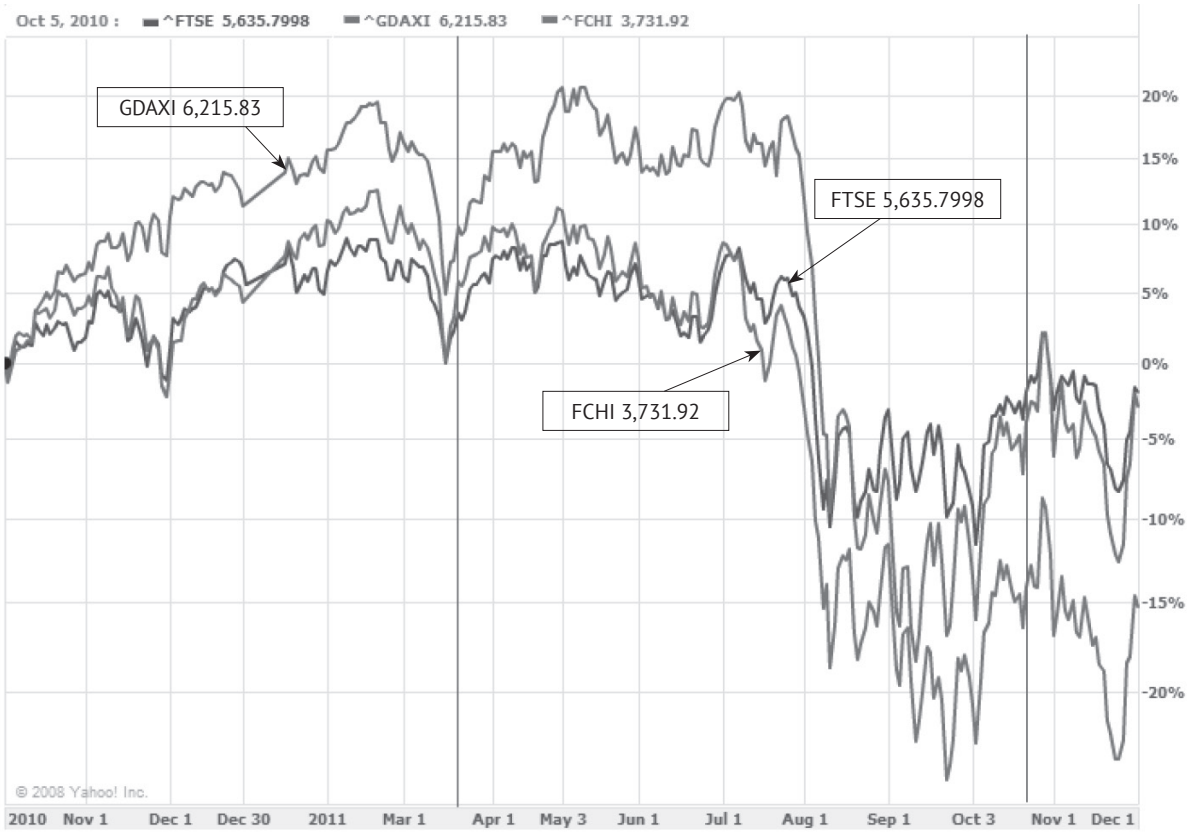

Fig 7. Dynamics of the European stock market during the conflict in Libya (2011).

Fig. 8. Dynamics of the American stock market during the conflict in Libya (2011).

the previous period and this growth continues even after the official end of the armed conflict.

Speaking about the possible inaccuracy of data, it should be taken into account that the equity risk premium falls regardless of country or index type. The selected period also does not affect the result.

The only example of a departure from established patterns is the armed conflict in Libya in 2011. In this case, the risk premiums in France and the United States have increased at the time of their entry into the active phase of hostilities. However, this may due to the deep economic and political problems within countries: the public disapproval of austerity measures, the debt crisis in the U.S., the Eurozone crisis and political scandal surrounding the election campaign of the former French president Nicolas Sarkozy. All these facts could have an impact on the dynamics of the risk premium. The dynamics of the European and American stock market is described in Figures 7 and 8.

Summarizing, we can state the hypothesis that in the past few decades, the equity risk premium has fallen in response to the country's entrance into armed conflict. This contributes to the growth of the national stock indices and the expectations of a successful outcome of the war for the country.

CONCLUSION AND INTRODUCTION TO FUTURE STUDIES

In the course of this study we have found very unusual results. Almost always, regardless of the country, period and chosen national stock index, the equity risk premiums have reduced in the period of involvement in armed conflicts. In such cases it is necessary to pay extra attention to double-check results and to study the problem in depth.

It is possible to highlight the following points for improvement of this research:

- selection of different methods of calculating the equity risk premium;
- use of different time periods;
- more in-depth analysis of the economic situation in the country during the conflict;
- grouping of conflicts and countries by categories;
- analysis of changes in the income in particular economic sectors
- social consequences.

Despite the fact that in the current study only minor deviations from the general hypothesis were identified, changing the method of calculation of the equity risk premium parameter may show slightly different results.

Short and excessively long conflicts were excluded in our research. For a more in-depth study it might be worthwhile to analyze how the market behaves in situations of short or long conflicts. Much also depends on the type of conflict and its intensity. It would be interesting to see how various forms of conflict, or conflict intensity, or sanctions affect the asset pricing. The role of countries is also worth mentioning in research, as they also can be divided into aggressors, defenders, the winners and losers, developed economies and undeveloped ones. Thus it is possible to obtain more specific information about the pricing of assets.

Various sectors of the economy in different ways may experience periods of conflict or crisis. For defense industries, manufacturers of military equipment and weapons, or information technology used for military purposes, war is profitable, because businesses get government contracts, the demand for their products increases, profits grow. However, there are other sectors of the economy — light industry, health, education, insurance, etc — which may experience an armed conflict differently.

Economics is inextricably linked to the social sphere, and conflicts affect human expectations and attitudes, unemployment, living standard and demographics. Therefore, the social aspect also needs analysis. And it is especially important to pay attention to social consequences of military conflicts and wars in those countries for which such conflicts were the most destructive.

Particular attention should be given to the analysis of the economies of countries which participated in the military conflicts, because conflicts are not the only factor influencing the equity risk premium. In assessing the economy one can analyze which phase (cycle) is the economy in, and identify cyclical pattern between the economy and the consequences of the armed conflict.

Recently, many researchers have been involved in the analysis of the issue of armed conflicts. It is one of the most popular topics of research and this is connected primarily with the scale of the possible consequences for the country and for humanity as a whole. However, in previous years the study of the issue has not been given special attention, because there are many aspects to the study of armed conflict, and many issues are still open.

Our result was confirmed by the positive dynamics of the national stock indices during the country's entry into the conflict. The growth of the stock indexes indicates positive expectations of investors regarding the available assets. Positive expectations, in turn, results in reduction of the level of risk and the level of equity risk premiums respectively. If the eq-

uity risk premium of the asset is reduced, this means that investors perceive less risk associated with the purchase of an asset, which is not typical for the period of war.

These results raise the question about what kind of benefit country can get from participation in the armed conflicts and war. Thus, results confirm the need for further, more thorough and in-depth study of the topic.

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Productivity Spillovers in the Russian Federation: The Case of the Chemical Market*

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Abstract. Over the last decades, much attention has been drawn to the question of productivity variation across countries. The differences in cross-country productivity could be explained by both foreign and domestic innovation. In order to estimate the influence of the former, the international transfer of technology should be considered. Foreign direct investment (FDI) and international trade are suggested to be major conduits of international technology transfer. The present paper aims to extend the current empirical literature by determining the effect and the source of productivity spillover in Russia in case of chemical industry. In order to find out the existence of FDI and international trade productivity spillover we applied the methodology developed by Ericson and Pakes (1995) and Olley and Pakes (1996). The econometric model was tested on the companies from chemical industry for the period 2007–2012. The empirical results show that FDI and international trade productivity spillovers are present in Russian chemical industry. The size of FDI spillovers is economically more important than imports-related spillovers. Based on the empirical results, we may predict that Russia's accession to the World Trade Organization in 2012 should result in productivity growth. However, further research on this topic will be possible when the statistical data becomes available for several years after accession.

Аннотация. На протяжении последних десятилетий большое внимание уделяется вопросу колебаний производительности в межстрановом аспекте. Различия в уровне производительности можно объяснить внешними и внутренними инновациями. Чтобы оценить влияние внешних инноваций, необходимо рассмотреть вопрос международной передачи технологий. Предполагается, что прямые иностранные инвестиции (ПИИ) и международная торговля в наибольшей степени способствуют международной передаче технологий. Настоящая работа призвана расширить эмпирические знания путем определения эффекта и источников переливов капитала в России на примере химического рынка. Мы применили методологии, разработанные Эриксоном и Пейксом (1995), а также Олли и Пейксом (1996), чтобы выявить присутствие переливов капитала, вызванных как ПИИ, так и международной торговлей. Эконометрическая модель была протестирована на данных компаний химической отрасли за 2007–2012 гг. Эмпирические результаты демонстрируют, что в российской химической промышленности присутствуют переливы капитала, вызванные как ПИИ, так и международной торговлей. Эффект от переливов капитала, вызванных ПИИ, имеет большее экономическое значение. Основываясь на результатах эмпирического исследования, можно предположить, что вступление России в ВТО в 2012 г., вероятно, приведет к росту производительности. Однако дальнейшее изучение данного вопроса будет возможно, как только станут доступны статистические данные за последующие годы после присоединения.

Key words: Productivity spillover, FDI, trade liberalisation, Russia.

* Влияние прямых иностранных инвестиций на рост производительности на примере российского рынка химического сырья.

INTRODUCTION

Over the last decades, much attention has been drawn to the question of productivity variation across countries. The differences in cross-country productivity could be explained by both foreign and domestic innovation (Eaton and Kortum, 1999; Keller, 2002). In order to estimate the influence of the former, the international transfer of technology should be considered. Grossman and Helpman (1991) suggested that foreign direct investment (FDI) and international trade are major conduits of international technology transfer.

FDI is believed to provide recipient countries with knowledge transfer as well as capital. The argument is that multinational corporations (MNCs) establish subsidiaries overseas and transfer knowledge to their subsidiaries. The transferred knowledge has a certain public good quality and may spread through non-market mechanisms over the entire economy leading to productivity spillovers in domestic firms (Blomstrom, 1989).

Expectation of productivity spillovers from knowledge transfers has been a major impetus to policy makers in many countries to provide FDI-friendly regime. In developing countries, policies in favor of FDI have been introduced since the early 1980s. Since then, net inflows of FDI have increased dramatically and FDI has been the most significant part of private capital inflows to developing countries.

Now an important question is whether these huge FDI inflows indeed bring about productivity spillovers for recipient countries, particularly for developing economies. The evidence is fairly mixed so far. Some empirical studies confirm positive productivity spillovers from FDI (for example, Caves, 1974; Chakraborty and Nunnenkamp, 2008; Görg and Strobl, 2005; Javorcik, 2004; Schiff and Wang, 2008), but others find negative or no spillovers (e.g., Aitken and Harrison, 1999; Barry *et al.,* 2005; Djankov and Hoekman, 2000; Haddad and Harrison, 1993). The mixed evidence intuitively implies that there is no universal relationship between FDI and domestic firms' productivity. Some studies, however, argue that the mixed findings may be attributed to domestic firms' characteristics or host countries' ability to absorb productivity spillovers (Görg and Greenaway, 2004; Smeets, 2008). Nevertheless, differences in findings depend significantly on research design, methodological approach, types of data used, estimation strategy, and even on the construction of the spillover variable.

On the other hand, recently many developing countries have experienced dismantling of barriers to trade that has left domestic industry exposed to greater competition while at the same time allowing the most productive firms the opportunity to trade with a larger and more diverse world market. Trade liberalization episodes in the developing world have attracted the interest of much academic research aimed at understanding the extent to which exposure to foreign competition impacts on industry and firm productivity.

A large and growing empirical literature has linked trade to productivity using firm-level evidence, particularly for developing country contexts, and has attempted to disentangle these mechanisms. Tybout *et al.* (1991) find evidence of productivity enhancing effects from increased trade exposure using the case of trade liberalization in Chile in the 1970s. Pavcnik (2002) also finds for Chile that sectors facing new import competition saw faster productivity growth and attributes these effects to both within-firm productivity improvements and reallocations of resources away from the least productive firms. Similarly, Eslava *et al.* (2004) and Fernandes (2007) show that trade, labor and financial reforms in Columbia in the 1990s were associated with aggregate productivity improvements due to a more efficient allocation of resources. Fernandes also links productivity gains under trade liberalization to increases in imported intermediates, skills and machinery investments. Evidence for imported inputs as a channel for productivity growth is also provided by Kasahara and Rodrigue (2008) and Halpern *et al.* (2005) for Chile and Hungary, respectively. Amiti and Konings (2007) estimate the productivity gains associated with tariff reductions in intermediate inputs in Indonesia and find that the productivity gains from tariff reductions are at least as high as the gains associated with lower output tariffs. Moreover, they also show that these gains are achieved through learning, variety and quality effects. Blalock and Veloso (2007) also investigate the impact of imports on productivity growth of firms in Indonesia focusing on supply chain linkages. They find evidence that importing is a source of technology transfer for upstream firms supplying import-intensive downstream sectors. The overall evidence, however, is not conclusive. Van Biesebroeck (2003), for example, finds no evidence that productivity improvements in Columbia are due the use of foreign inputs. Similarly, Muendler (2004) finds limited effects of foreign inputs on productivity in Brazil.

The study proposed could provide a greater depth of knowledge about modern developments in the field of research of productivity spillovers. The results of the study may support the continuing fiscal and investment incentives provided by the Russian government for FDI, as well as stable trade liberalization policy. Moreover, the research topic is of current interest taking into consideration accession of the Russian Federation to World Trade Organization (WTO).

The present paper aims to extend the current empirical literature by determining the effect and the source of productivity spillover in Russia in case of chemical

industry. In order to achieve the stated aim and answer research questions, the paper is organized as follows. Section 1 presents the conceptual framework for exploring the mechanisms through which FDI as well as international trade might impact the productivity of firms. Section 2 describes the role of chemical manufacturing sector in Russia. In Section 3 empirical approach and research design are discussed. Section 4 presents the results. Finally, conclusions are made.

1. CONCEPTUAL FRAMEWORK FOR PRODUCTIVITY SPILLOVERS

The concept of productivity spillovers embodies the fact that foreign enterprises own intangible assets such as technological know-how, marketing and managerial skills, international experience or reputation, which can be transmitted to domestic firms, raising their productivity level. Productivity spillovers diffusion is thus a matter of externalities from established foreign producers to domestic ones. As mentioned previously, there are two main sources of productivity spillovers, namely FDI and international trade. In the following sections, the mechanisms of such sources will be considered.

1.1. PRODUCTIVITY SPILLOVERS: GENERAL OVERVIEW

Foreign firms are presumed to have inherent advantages, particularly in scale and technological knowledge and in access to international markets that allow them to overcome the cost of setting up in a different country and to produce more efficiently (Blomstroem & Kokko, 1997; Hymer, 1976). Often, these advantages take the form of proprietary assets, technology or management and marketing practices (what Markusen (2002) terms as "knowledge capital"). These imply higher productivity of foreign-owned firms themselves. Moreover, productivity spillovers may have positive effects on local firms. Productivity spillovers generally take place when the entry or presence of multinational firms leads to efficiency or productivity benefits for local firms that are not fully internalized by the foreign firm (Blomstroem & Kokko, 1998).

There are several mechanisms through which these spillover effects occur. These can be split into competition and demonstration effects (Girma, Greenaway, & Wakelin, 2001). The presence of more efficient foreign firms in an industry may increase competition in domestic industries as foreign firms tend to populate industries where the initial cost of entry is high (Caves, 1974). They may also break up domestic monopolies by lowering excess profits and generally improving allocative efficiency. Local firms can also improve their productivity by copying technology from multinational firms in their industry. Foreign firms may not be able to internalize all the gains of their technology and domestic firms may benefit through their contact with foreign firms, either as suppliers, consumers or competitors. On the other hand, entry of foreign firms may crowd out domestic firms, reducing their scale and thus their productivity. The extent to which spillovers occur helps determine the productivity effect for local firms from the presence of foreign firms in the same or related industries.

In a seminal study of Venezuela, Aitken and Harrison (1999) find that positive productivity effects are confined to plants with foreign equity participation, and then only small ones, but that domestic plants are negatively affected, with a very small overall positive effect. In a study of Lithuania, Smarzynska & Javorcik (2004) find evidence consistent with spillovers from foreign affiliates to their local suppliers in upstream industries, although only for projects with shared domestic and foreign ownership, not for wholly owned foreign subsidiaries. Liu (2008) distinguishes between a level and a growth effect of foreign presence on total factor productivity (TFP). Learning advanced foreign technology is costly and requires that scarce resources be devoted to the effort, which is why a short-term negative effect on the level of TFP is expected, and a long-term positive effect on the growth rate of TFP. Panel data on Chinese manufacturing firms confirms the theoretical expectations.

This paper joins the literature exploring the effect of trade liberalization on productivity, for example, Bernard and Jensen (2009) for the US, and Trefler (2004) for Canada. Except for these studies testing data on developed countries, more evidence has been found in developing countries, such as Bustos (2009) for Argentina, Schor (2004) for Brazil, Tybout *et al.* (1991) and Pavcnik (2002) for Chile, Fernandes (2007) for Columbia, Krishna and Mitra (1998) and Topalova & Khandelwal (2010) for India, Amiti and Konings (2007) for Indonesia, Iscan (1998) for Mexico and Levinsohn (2003) for Turkey. These studies find that lower output tariffs have boosted productivity due to "import competition" effects, whereas cheaper imported inputs can raise productivity via learning, variety, and quality effects. Moreover, these studies were extended by Haichao Fan (2012) by introducing endogenous quality and endogenous number of imported varieties.

1.2. PRODUCTIVITY SPILLOVERS FROM FDI

In the recent years, the attraction of FDI has been an important topic on the agenda of many governments. Policy mechanisms such as tax reductions for foreign firms tempt to stimulate inward FDI. The main reason for this growing interest stem from the positive externalities the presence of foreign multinational affiliates

may generate in the host country. Accordingly, the entrance of foreign MNCs is often seen as a conduit for transfer of technology and knowledge within and across sectors. The linkages between foreign MNCs and local host-country firms can be distinguished between horizontal and vertical spillovers. On the one hand, technology from foreign MNCs may spill over to local competitors within the same industry (horizontal spillovers). On the other hand, productivity enhancing knowledge may be absorbed by local client firms or supplier firms across industries due to vertical linkages (vertical spillovers).

The results of studies analyzing spillover effects due to inward FDI are rather inconclusive, ranging from negative to positive depending on the data and method used. Mainly focusing on horizontal spillovers, the earliest empirical industry-level analyses found positive evidence of FDI externalities in Australia (Caves, 1974) and Canada (Globerman, 1975). Both analyses concerned sectoral (rather than firm-level) production functions and found a positive correlation between the local firms' productivity growth on industry-level and FDI inflows. Other studies discussed the effects of FDI using well-elaborated case studies (Rhee and Belot, 1989; Larrain *et al.,* 2000), but the results of these studies lack the potential to be generalized into clear-cut policy implications. More recently, some cross-sectional studies at the firm level have confirmed the existence of intra-industry spillovers using data from UK and Greece respectively (Driffield, 2001; Dimelis and Louri, 2002). As highlighted by Görg and Strobl (2001), technology diffusion is a dynamic phenomenon making panel data analysis the most appropriate method to estimate improvements in host-country firms' productivity. Recent econometric studies using panel data find positive effects on of FDI spillovers on productivity performance for host country firms (Keller and Yeaple, 2003; Haskel *et al.*, 2002). Based on a micro-level study of US manufacturing firms, Keller and Yeaple estimated that the share of productivity growth during the sample period 1987–1996 accounted by FDI spillovers at 14%. Similarly, Haskel *et al.* found that the foreign-affiliate presence in an industry, measured by the industry share of employment accounted by foreign firms, is positively correlated with the domestic firms' total factor productivity (TFP) in that industry. Their estimations indicate that spillovers from inward FDI explain about five percent of the ten percent rise of TFP in local UK manufacturing firms during the period 1973–1992. On the other hand, other studies have reported inconclusive or even negative effects of FDI on host country firm productivity (Girma and Wakelin, 2001; Barrios and Strobl, 2002).

Most empirical studies have mainly focused on the intra-industry spillover effects on domestic firms' productivity, while little attention was given to inter-industry spillovers through customer and supplier linkages with foreign multinationals. The first studies analyzing the effect of backward and forward spillovers on host-country firms' productivity dynamics have focused on developing countries (Blalock, 2001; Javorcik, 2004; Kugler, 2006). These studies could not find any evidence for the existence of forward spillover effects, but report significant productivity-enhancing backward spillovers to local upstream firms. Positive horizontal spillover effects due to the presence of foreign-owned affiliates within the sector were found, but these results were not robust across all different specifications of the models. The failure to find evidence for horizontal spillovers may not be surprising, as foreign multinationals will have strong incentives to protect their superior technology by patenting mechanisms or secrecy in order to prevent leakages to local competitors (Veugelers and Cassiman, 2004). Moreover, at least in the short run, the entrance of foreign multinationals may also be harmful to local firms through increased competition effects. Foreign MNCs may reduce growth opportunities and the potential to reap scale economies by domestic firms, and they may attract the most qualified employees (De Backer and Sleuwaegen, 2003), which may have negative productivity consequences for domestic firms. Eventually, this may drive less cost-efficient host-country firms out of the market.

The presence of foreign MNCs is not likely to affect the productivity performance of domestic firms equally. A number of studies have suggested that the gains from spillovers due to FDI are conditional on the absorptive capacity and catching-up capabilities of local firms and on the geographical proximity to foreign affiliates (Görg and Greenaway, 2004). According to the absorptive capacity argument of Cohen and Levinthal (1989) domestic firms need to possess a certain level of human capital and technological knowledge in order to understand, assimilate and use incoming spillovers from foreign affiliates. Domestic firms are better able to catch-up with superior technologies of foreign firms when the technology gap between both parties is not too large (Findlay, 1978). Following this reasoning, different empirical studies have analyzed the correlation between the domestic firms' technological capabilities and their ability to benefit from FDI spillovers. In a panel data study on 4000 UK manufacturing firms covering the period 1991–1996, Girma *et al.* (2001) analyses the conditional effects of intra-industry FDI spillovers on labor productivity according to the skill intensity and competitiveness in the sector and the technology gap between firms and the productivity frontier. The results show that FDI spillovers benefit domestic firms with a relatively small technology gap relative to the technol-

ogy leader in a positive way, irrespective of the competition and skill level in the sector.

1.3. PRODUCTIVITY SPILLOVERS FROM INTERNATIONAL TRADE

International trade is one of the primary avenues for the diffusion and adoption of new technologies worldwide. This is particularly true and important for developing nations where it is believed that importing new technologies is a significant source of productivity and economic growth. Trade liberalization is considered to be one of the ways of promoting international trade and, therefore, increasing productivity.

Trade liberalization may affect productivity through several mechanisms. Firstly, the competitive pressure arising from increased imports may result in plants eliminating slack and using inputs more efficiently (Holmes and Schmitz, 2001). In contrast, infant-industry arguments sustain that protection may lead to productivity gains when learning-by-doing is important. Secondly, liberalization may boost within-plant productivity by allowing for international technology diffusion as predicted by the endogenous growth models of Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991). When technological knowledge is embodied in goods, an increase in the access to imported intermediate inputs of higher quality and broader variety, and to more efficient capital goods improves plant productivity. The exposure to export markets may also bring technological spillovers. Thirdly, liberalization may alter plant's incentives to invest in productivity-enhancing technology. Goh (2000) finds that liberalization increases these incentives by reducing the opportunity cost of technological effort (the foregone profits from the ensuing delay in output commercialization). In contrast, Rodrik (1992) shows that liberalization decreases these incentives when it reduces the plant's market share. Finally, when productivity is heterogeneous across plants, liberalization may increase industry productivity even with unchanged within-plant productivity. Melitz (2003) shows that increasing an industry's exposure to trade leads to the exit of less productive plants and the reallocation of output to more productive plants, contributing to industry productivity growth. In sum, most theoretical models predict that trade liberalization results in productivity gains.

However, the empirical evidence of the impact of trade is fairly mixed. For example, Pack (1988) has concluded that there are no systematic differences in cross-country TFP growth rates for countries that have different trade orientations. Young (1994), in his study for large number of countries, also finds no positive relationship between open policy regime and TFP growth rate.

At the industry level, Gokcekus (1995) finds that the technical efficiency of the Turkish rubber industry improved significantly during a period of substantial trade liberalization in the early 1980s. Cornwell *et al.* (1990), in their study of the US airlines industry, find an improvement in the productivity of firms after the industry was deregulated. In the case of India, studies looking into the impact of liberalization on productivity have yielded contradictory results. It needs to be mentioned that the period considered for liberalization in most of these studies is after the mid-1980s, when Indian industry was gradually opening up. Pushpangadan and Babu (1997) in their review of various studies conclude that there is no systematic relationship between liberalization and productivity growth. Srivastava's (1996) estimates based on a production function find significantly higher TFP growth after the mid-1980s than in the pre-reform period. The results match the widely held belief that liberalization increases efficiency as demonstrated by Ahluwalia (1991). Srivastava's analysis, however, finds that there exists virtually no price competition during the post-reform period as the price-cost margin shows a higher value for most sectors.

Balakrishnan and Pushpangadan (1994) adopt a double-deflation procedure instead of a single deflation methodology as employed by Ahluwalia and other researchers and find results opposite to these studies. They find that the TFP growth is slower after 1980s liberalization than in the previous decade. A study conducted by Krishna and Mitra (1998), using a methodology similar to Srivastava's, examines mark-ups and productivity growth after 1991 reforms for four industry groups: electrical machinery, non-electrical machinery, electronics and transport equipment. The study finds evidence of increased productivity except for the transport equipment sector.

Summarizing this section it is possible to conclude that there is some evidence confirming the impact of FDI and international trade on the host-country productivity. However, the study of the Russian economy is limited. So in order to fill such a gap, in the next section we will introduce the model that would allow estimating the effects of foreign presence in Russia.

2. OVERVIEW OF THE RUSSIAN CHEMICAL INDUSTRY

Before starting construction our econometric model and discussion of the results, it is important to make an overview of the chemical industry because the understanding of the background allows us to interpret the model outcomes better. Chemicals are an integral part of daily life in today's world. There is hardly any industry where chemicals are not used and there is no

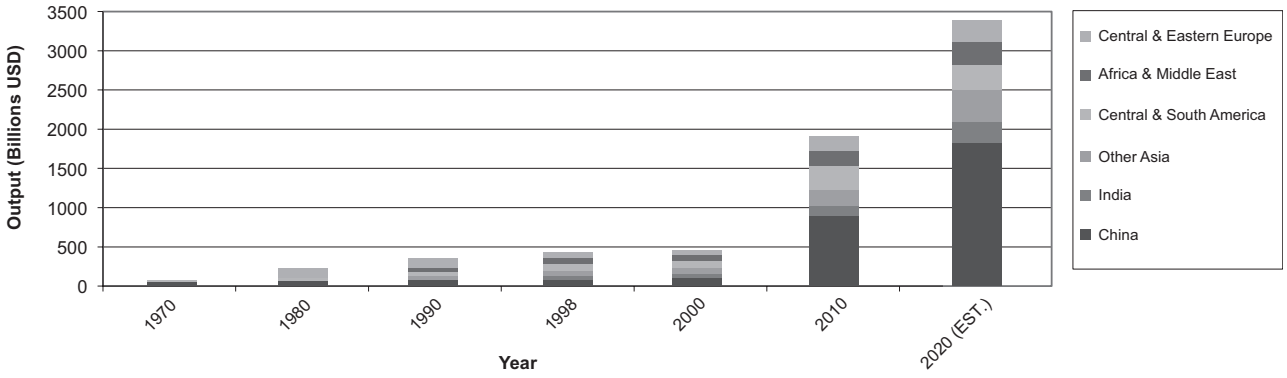

Figure 1. Chemical industry output: developing regions & countries with economies in transition.
Source: UNEP, 2012. Global Chemicals Outlook: Towards Sound Management of Chemicals. GPS Publishing, p. 10.

single economic sector where chemicals do not play an important role.

Industries, which produce and use chemicals, have a significant impact on employment, trade and economic growth worldwide, but chemicals can have adverse effects on human health and the environment. A variety of global economic and regulatory forces influence changes in chemical production, transport, import and export, use and disposal over time. In response to the growing demand for chemical-based products and processes, the international chemical industry has grown dramatically since the 1970s. Global chemical output (produced and shipped) was valued at US$171 billion in 1970. By 2010, it had grown to $4.12 trillion (UNEP, 2012). Figure 1 illustrates the chemical industry output trend from 1970s, and shows estimated numbers for 2020.

2.1 CHEMICAL MARKET PERFORMANCE

According to the Ministry of Industry and Energy of Russian Federation, the chemical complex comprises 1.8% of the Russian GDP, 6.8% of the industrial production, and about 10.4% by the volume of products shipped to all enterprises in the structure of the manufacturing sector. By 2020, it is planned to increase the share of the chemical industry in the GDP by 1.5 times. This increase will particularly result from growth in the overall chemical production (more than 50% growth is expected compared with 2011, while by 2030 this figure is expected to increase by 2.4 times). The main factors hindering the development of the industry include technological backwardness in several sectors of the chemical industry, high depreciation of fixed assets due to a lack of investment activity and restriction of access of Russian chemical products to the markets of certain countries, and the deterioration of the world market under increased competition. Russia's accession to the WTO in 2012 has made it possible to remove access limitations for Russian chemical companies to a number of foreign markets. However, the WTO membership, the planned subsequent accession to the Organization for Economic Cooperation and Development (OECD), and the adoption of a series of Russian long-term strategies for the development of domestic industry will require fundamental changes in most industries.

Generally, the evolving Russian economy, new technologies and global market fluctuations have resulted in the following sector trends:

- growth of Russian industrial output;
- rapid increase of end-users;
- sharp competition among chemical suppliers;
- increased investment;
- new project development;
- high demand for new/updated equipment.

Nearly 8000 companies (not more than 10% are large or medium-sized) owning almost 7% of all of the country's industrial capital assets work in the chemical and petrochemical industries in Russia (Enterprise Europe Network, 2012). Table 1 contains the list of major chemical producers in Russia.

Moreover, chemical industry is an integral part of Russian export. Its share in total exports equaled to 6% in 2012.

2.2 OVERVIEW OF THE CHEMICAL MARKET STRUCTURE

As the Russian market stands right now, the strength of buyers is reaffirmed by the ability of customers to procure similar materials from more than one producer. As a consequence, end users have become very price-conscious. There are only a few isolated cases where a certain chemical product can be purchased from only one manufacturer. The producer's control over the entire supply chain is common on the Russian market. The market segment of commodity chemicals in particular exhibits pronounced vertical integration. Enterprises engaged in natural resources extraction add value to the raw materials they acquire through the process of chemical production.

Table 1. Major chemical producers.

Name	Focus
Sibur Holding (Moscow)	Petrochemical
Gazprom Neftekhim Salavat (Salavat, Republic of Bashkortostan)	Petrochemical
Nizhnekamskneftehim (Republic of Tatarstan)	Petrochemical
EuroChem (Moscow)	Fertilizer Production
Uralkali (Berezniki, Permsky region)	Potassium Fertilizer
Akron (Veliky Novgorod)	Mineral fertilizer

Source: Enterprise Europe Network. 2012. Chemical Industry in Russian Regions, p. 2.

The process of entering the Russian chemicals market is capital intensive. Trying to enter the Russian market on a small scale will not lead to good results in the long term. Companies should be prepared to invest in large-capacity processing facilities.

Competition is intense, because companies are mostly selling unbranded products. Product substitution is unlikely to occur, as consumers need to purchase products of particular chemical composition, available only from local producers. The main product categories on the Russian market are base chemicals, including both inorganic and organic solutions, specialty chemicals, pharmaceutical products, and chemicals for use in the agricultural industry.

Key buyers in the Russian chemicals market include manufacturers of plastic products, pharmaceuticals, consumer chemical manufacturers, as well as utility companies. Oil and gas companies are considered to be key suppliers for the sector. The buyers are large-scale to medium businesses that have good negotiating positions with respect to key producers.

Chemical products are traditionally divided into two groups: base chemicals and specialty chemicals.

Traditionally, bulk base chemicals are not differentiated and are referred to only on the basis of their composition. At the same time, in view of the myriad of different applications of base chemicals, the number of potential clients for these products is high. It is not uncommon for base chemical manufacturers to operate in several regional submarkets. Regional variety and diversity of product application, in turn, can work to curtail buyer power. Base chemicals are usually essential supply materials for the buyers. Chemical production is very often contracted for on a long-term basis.

Specialty chemicals constitute one more set of chemicals industry products that have a diverse application across several industries and that are highly priced. Specialty chemicals are generally derived through innovative processes, and are sold on the basis of their specially designated purpose. It only matters what a particular compound can do, not what chemicals it contains. The versatility of application of specialty chemicals means that these products are easy to sell, or to transform for other uses. The cost of remaking one specialty chemical product into another may include expenses associated with the loss of time from waiting until a previous unprofitable contract expires. The power of buyers in this market segment is well-balanced by the leverage that the producers enjoy.

2.3 SUPPLIER OF CHEMICAL PRODUCTS AND MARKET ENTRANCE CONDITIONS

The chemicals industry is heavily reliant on the oil and natural gas sector for basic materials that are combined to produce both carbon-based chemicals and inorganic substances. Suppliers are strong and few in number, as the Russian oil and gas industry is very centralized.

The positions of suppliers are even stronger, as the price of hydrocarbons continues to rise. Chemical producers have formed strong relationships with the suppliers of their raw materials in a struggle for profitability. Additionally, a number of key suppliers in the oil and gas industry have chemical and petrochemical manufactures. Thus, the influence of suppliers over downstream chemical producers that do not have their own natural resources is strong.

The power of suppliers, on the other hand, is constrained due to the lack of differentiation in raw materials supplies. The materials a particular chemical manufacturer would buy from one hydrocarbons producer would be the same that it would get from another oil or gas producer.

Still, as the raw materials are bought and sold on an open market, manufacturers are not able to control the price. Strategies for hedging risk and reducing the instability of prices are necessary.

There also are chemicals that are not dependent on oil, but rather require certain minerals or water. Sodium chloride, for instance, can be formed by evaporating sea water or extracted in mining operations. The chemical is then used to create other sodium compounds. Another element from the periodic table, sulfur, is also critical to the production of many base chemicals.

Existing economic conditions have forced many chemical producers to reduce output volumes. These

reductions negatively affected the suppliers of raw materials.

While chemicals do have inherent value and may have immediate uses and applications (i.e. cleaning chemicals), more frequently, chemicals are used as a starting point in a production chain that ends with the manufacture of valuable goods. Therefore, chemicals are produced in bulk quantities in order to enable manufacturers to profit from the sale of large volumes.

Accessing the Russian chemicals market therefore entails significant commitments. Large scale production facilities would be required for a foreign player to rise to the challenges of the Russian market. Therefore, the intensity of investment and the size of most chemical operations in Russia narrow the class of companies that would be capable of entering the country.

A number of factors, however, make the Russian market attractive. The products of the chemical industry are sold as unbranded commodities. As a result, marketing strategies are greatly simplified. Absent contractual commitments, a consumer would be just as likely to buy from a new player on the market as from an established producer. The processes and formulas used to manufacture chemicals used by the Russian industry have been around for decades, in many cases without intellectual property restrictions.

Many large and middle-size companies are present on the Russian chemicals market. Because producers of chemicals sell commodities, it is not easy for market participants to offer tangible incentives not to seek a better deal from a different manufacturer. Overall, the market requires high capital outlays and infrastructural investment. The dominant players on the Russian market are local producers, such as Nizhnekamskneftekhim, Togliattiazot Chemical Company, and Uralkali.

The combination of all the factors outlined above naturally breeds competition. Competition is generally tolerable at times of market growth, but can be very aggressive during periods of economic slowdown.

3. MODEL AND ESTIMATION FRAMEWORK

In academic world, the problem of FDI and international trade spillovers is examined with the help of different econometric models that allow analyzing huge amount of data and eliminating the influence of possible bias. We generally employ Olley-Pakes model with some modifications due to lack of information. Model specification and data description will be presented in the next section.

3.1 MODEL SPECIFICATION

Since there is no consensus on the existence of strong spillovers, we take a broad view on how FDI and imports might affect the productivity of domestic firms. Instead of modeling a particular mechanism, our approach is to ask whether there is evidence for higher productivity of domestic firms when there is more foreign activity in terms of FDI and imports. Based on the previous research we might conclude that this is the question that has been asked so far, with the answer being non-affirmative.

Our analysis relies on correctly measuring firm productivity. To this end we employ the methodology developed by Ericson and Pakes (1995) and Olley and Pakes (1996).[1] These authors develop a framework for dynamic industry equilibrium analysis where firms optimally choose sales and investment, as well as entry and exit. For our purposes, two aspects of the Olley and Pakes approach are most important: firstly, it allows for firm-specific productivity differences that exhibit idiosyncratic changes over time, and secondly, the model endogenizes the firm's liquidation decision by generating an exit rule. These features address two major concerns that have afflicted productivity calculations for a long time: simultaneity and selection biases. To see this, consider the following equation:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + u_{it} \quad (1)$$

where y_{it} is the logarithm of output of firm i at time t, and correspondingly, l_{it}, m_{it}, and k_{it} are the firm's (log of) labor, materials, and capital inputs. The last term, u_{it}, is an error representing all disturbances that prevent (1) from holding exactly. Let this term be composed of two parts,

$$u_{it} = \omega_{it} + \eta_{it} \quad (2)$$

Consider the case when neither ω_{it} and η_{it} are observed by the econometrician, whereas the firm cannot observe η_{it}, but it does know ω_{it}. The term η_{it} could be capturing unpredictable demand shocks while ω_{it} could be firm productivity, for instance. If ω_{it} is known to the firm, the optimal labor input choice will be a function of ω_{it}, and simple ordinary least squares (OLS) estimation will suffer from a simultaneity bias because $E\left[u_{it} \middle| l_{it}\right] \neq 0$.[2] If the term ω_{it} is constant over time,

[1] The following introduces only the most salient features of their approach. See also Griliches and Mairesse (1995) for more discussion of the relative strengths and weaknesses of the Olley-Pakes approach.

[2] The existence of this bias depends on the possibility that input choice can be varied; this explains why we use the example of labor as an input, which is generally considered to be not subject to large adjustment costs. In the multivariate case, the OLS bias can usually not be unambiguously signed. However, if labor and capital are positively correlated, and labor is more strongly correlated with ω_{it} than capital, then OLS will tend to overestimate β_l and underestimate β_k.

$\omega_{it} = \omega_i$, all t, taking time- or within-firm differences of (1) and proceeding with OLS on the transformed data can lead to consistent parameter estimates. But in our framework, ω_{it} is firm productivity, and how this changes in relation to imports and FDI is exactly the question we are asking. This strategy is therefore removed from consideration. As shown below, we will identify ω_{it} from the firms' investment choices. Knowing ω_{it} allows us to control for the simultaneity of input choices, and thus to avoid this bias.

We now turn to the selection problem. The firm maximizes the expected discounted value of its future net cash flows. At the beginning of the period, the firm learns its productivity ω_{it}, which is assumed to evolve according to an exogenous Markov process. Then, the firm makes three choices. It decides whether to exit or not, it chooses variable factors (labor and materials), and how much to invest in capital. For a sufficiently low value of ω_{it}, a firm's value of continuing in operation will be less than some (exogenous) liquidation value, and it will exit; call the threshold level at which a firm is indifferent between exiting and staying ω_t.

One can show that if the firm's per-period profit function is increasing in k, the value function must be increasing in k as well, while ω_t is decreasing in k. The reason is that a firm with a larger capital stock can expect larger future returns for any given level of current productivity, so that it will remain in operation at lower realizations of ω_{it}. Relatively small firms exit at productivity draws for which relatively large firms would have continued to operate, so that the relatively small firms that stay in the market tend to be those that received unusually favorable productivity draws. The correlation between ω_{it} and k_{it} is negative, and failing to account for the self-selection induced by exit behavior will lead to a negative bias in the capital coefficient. The Olley and Pakes approach generates an exit rule, so that we can account for this self-selection and avoid the associated bias.

In terms of estimation, we take the following steps. In equations (1), (2), we assume that labor and materials are variable inputs so that their choice is affected by ω_{it}, whereas capital k_{it} is only determined by past values of ω, not the current one. Dropping the firm subscript for ease of notation, let it be the firm's optimal investment choice at time t. Provided that $i_t > 0$, it is possible to show that investment is strictly increasing in ω_t for any k_t.[3] This means that the investment function can be inverted to yield

$$\omega_t = h_t(i_t, k_t) \tag{3}$$

Substituting (3) and (2) into (1) gives

$$y_t = \beta_l l_t + \beta_m m_t + \varphi_t\left(i_t, k_t\right) + \eta_t, \tag{4}$$

with $\varphi_t\left(i_t, k_t\right) = \beta_0 + \beta_k k_t + h_t(i_t, k_t)$. Because $\varphi_t(.)$ contains the productivity term $\omega_t = h_t(.)$ that is the source of the simultaneity bias, equation (4) can be estimated to obtain consistent estimates β_l and β_m on the variable inputs, labor and materials. Equation (4) is a partially linear regression model of the type analyzed by Robinson (1988), and we use a fourth-order polynomial in investment and capital to capture the unknown function $\varphi_t(.)$.

With consistent estimates of β_l and β_m in hand, we proceed to estimating the effect of capital on output, β_k, which is not identified in (4) because it is combined with capital's effect on investment. We assume for simplicity that k_t is uncorrelated with the innovation in ω_t, $\xi_t = \omega_t - \omega_{t-1}$ or, ω_t is a random walk[4]. Substituting this into (4) gives

$$y_t - \hat{\beta}_l l_t - \hat{\beta}_m m_t = \beta_k k_t + \hat{\varphi}_{t-1} - \beta_k k_{t-1} + \xi_t + \eta_t, \tag{5}$$

where $\hat{\varphi}_{t-1}$ comes from estimating (4), and $\hat{\varphi}_{t-1} - \beta_k k_{t-1}$ is an estimate of ω_{t-1}.

The probability of survival to period t depends on ω_{t-1} and ω_{t-1}, the unobserved level of productivity that would make a firm shut down its operations, which can be shown to depend only on capital and investment at time t-1. We generate an estimate of the survival probability by running a probit regression[5] on a fourth-order polynomial

[3] The requirement that investment must be positive may be limiting for some applications. Levinsohn and Petrin (2001) propose therefore a variant of Olley and Pakes' approach in which productivity is identified from materials inputs (which is usually greater than zero). In our sample, the zero-investment problem is negligible.

[4] A random walk is a mathematical formalization of a path that consists of a succession of random steps.

[5] In statistics, a probit model is a type of regression where the dependent variable can only take two values.

in capital and investment (lagged by one period); the estimated survival probability is denoted by $\hat{P}_t$. The final step is to estimate β_k from the resulting equation:

$$y_t - \hat{\beta}_l l_t - \hat{\beta}_m m_t = \beta_k k_t + g(\hat{\varphi}_{t-1} - \beta_k k_{t-1}, \hat{P}_t) + \xi_t + \eta_t. \quad (6)$$

Here we approximate the unknown function g (.) by a fourth-order polynomial in $\hat{\varphi}_{t-1} - \beta_k k_{t-1}$ and $\hat{P}_t$; β_k is then estimated non-linearly across all terms that contain it.

Using the estimates of coefficients of labor, materials, and capital, we estimate log total factor productivity as $tfp_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it}$. Our empirical analysis relates firms' TFP, it is tfp_{it}, to the degree of foreign activity through imports (it IM_{it}) and FDI (it FI_{it}):

$$tfp_{it} = \beta X'_{it} + \gamma_1 IM_{it} + \gamma_2 FI_{it} + e_{it}, \quad (7)$$

where X'_{it} is a vector of control variables, and e_{it} is an error term; the exact definitions of IM_{it}, it FI_{it}, and X'_{it} are discussed in the following data section.

3.2 DATA DESCRIPTION

This study is based on data sample of chemical manufacturing firms in Russia from Standard & Poor's Capital IQ database. Capital IQ database includes only publicly traded companies and publishes data from the companies' balance sheets according to legal reporting requirements. Unlike census data, the Capital IQ database has the advantage of being publicly available. However, our sampling is rather small as Russian companies do not usually provide statistical agencies with required financial and non-financial data.

Our sample consists of a total of 18 Russian-owned firms that were active between the years 2007 and 2012, which represent the Russian chemical industry. From Capital IQ database, we obtain data on the firms' (log) output y, as well as (log) labor, materials, and capital inputs (l, m, and k), where our output measure is net sales. In some cases we have had to fill in small amounts of missing data, typically for the firms' number of employees. These data were hand-collected from firms' annual reports.

Our primary interest is whether productivity is related to the importance of imports and foreign-owned affiliates in the firm's relevant economic environment. We measure the importance of imports for a given firm by the amount of imports; this variable is denoted by it IM. This information was collected from Russian customs database. Correspondingly, the importance of FDI is measured by the number of foreign affiliate employment in total employment of the firm (denoted by it FI). Data on foreign employment comes from Rosstat annual surveys. However, the number of foreign employees is estimated as the report provides only average rate of foreign employees by industry.

These measures of imports and FDI broadly capture the prevalence of foreign economic activity in a particular chemical industry. If specialized imports are important in triggering technology spillovers, or if foreign affi liates of MNEs generate positive externalities for Russian firms by building up more efficient supplier chains or a pool of highly skilled technicians, it is plausible that this is correlated with our measures of foreign presence in that industry.

Additional variable will be employed to better isolate spillover effects (see Table 2 for variable construction). Previously, we have noted that it is important to control for changes in the degree of market competition that might be associated with changes in foreign activity. We follow Nickell (1996) and others and use the firm's mark-up to capture these effects (denoted by FM). To the extent that a higher firm mark-up indicates less competitive pressures, we expect that a firm's productivity growth slows down.

Finally, we employ the following linear panel regression to estimate the spillover effects:

$$Y_{it} = \beta_0 + \beta_1 L_{it} + \beta_2 K_{it} + \beta_3 M_{it} + \beta_4 FM_{it} + \beta_5 IM_{it} + \beta_6 FI_{it} + \beta_7 Inv_{it} + u_{it}, \quad (8)$$

where i denotes firm, t implies year and u_{it} is the disturbance term.

First of all, we need to provide by some descriptive statistics to define the characteristics of our data. Particularly, for panel data it is important to know whether variability is mostly across individual (entity) or across time. If we focus on the three main variables of interest which are sales, measured by net sales, import share and FDI share, the main observations are the following.

Table 2. Variable definitions.

Variable	Measurement
Sales (Y)	Net sales
Labor (L)	Number of employees
Capital (K)	Value of property, plant and equipment, net of depreciation
Materials (M)	Firm-level year-end materials inventory stocks
Firm mark-up (FM)	Firm's sales over sales minus profits; profits is measured by net income
Import share (IM)	Value of imported goods
FDI share (FI)	Number of foreign affiliate employment
Investment (Inv)	Capital expenditures

Table 3. Descriptive statistics of the data.

Variable	Mean	Std. Dev.	Min	Max	Observations
ynetsa~s overall	16282.94	37104.5	40.9	141452	N = 108
between		37227.03	380.1	117998.7	n = 18
within		7460.019	-20632.73	39736.27	T = 6
imimpo~e overall	3.01	2.734568	.01	11.4	N = 108
between		2.731948	.5	9.75	n = 18
within		.6025656	1.463333	4.66	T = 6
fifdis~e overall	1300.214	5655.03	59.52	41871	N = 108
between		2321.141	62.22667	7286.343	n = 18
within		5181.064	-5914.75	35884.87	T = 6

The averaged mean of the net sales is USD 16282,94 mln., import amount — USD 3,01 mln., number of foreign affiliate employment — 1300 persons. Concerning the variability around these means we can say that for sales and import share mostly of it is attributed to between individual variations compared to a weak variability across time, and vice versa for FDI share. Indeed we see that the total variability of netsales is 44687,059 (44687,059 represents the standard error).This variability decomposes itself as an individual variability of 37227,030 and only a variability across time of 7460,019. We can do the same conclusions concerning the amount of import since almost 82% of its total variation is attributed to a cross section variation. As for FDI share, the situation is opposite. Here only 31% of its total variation is attributed to a cross section variation. We can finally notice that the variability is much higher for the net sales than amount of import and number of foreign-affiliated employees.

The analysis methodology as well as the results of the estimation will be discussed in the next section.

4. ANALYSIS METHODOLOGY AND RESULTS

The analysis of panel data allows the model builder to learn about economic processes while accounting for both heterogeneity across individuals, firms, countries, and so on, and for dynamic effects which are not visible in cross sections. Modeling in this context often calls for complex stochastic specifications. In order to analyze the panel data, several econometric models were employed, namely OLS regression, regression model with fixed effects and random effects. Then the most appropriate model was chosen to estimate the panel data.

4.1. MODELS CONSTRUCTION

Often the distribution of econometric value has an asymmetry. Going to the logarithm allows reducing it. Furthermore, the transition to the logarithm in some cases allows bringing the distribution of residuals to normal. Therefore, for our estimation we used logarithmic values of all the variables. All econometric models were constructed with the help of STATA 11.2 software package.

Several possibilities are offered to estimate these panel data. We can choose to use a restrictive pooled OLS model without taking into account the special features of the data. On one hand, the graphics below show that the distribution of the net sales according to amount of import and number of foreign employees is not dispersed and that the OLS seem to be appropriate.

However, it is just a first approach. If we want to be more precise and take into account the unobserved individual heterogeneity we can estimate a fixed effects model or a random effects one, provided that this unobserved heterogeneity is time invariant.

Firstly, the OLS regression model was built. It is a generalized linear modelling technique that may be used to model a single response variable which has been recorded on at least an interval scale. The technique may be applied to single or multiple explanatory variables and also categorical explanatory variables that have been appropriately coded. The results are presented below:

Table 4. OLS regression model.

Source	SS	df	MS	Number of obs = 104
				F(7, 96) = 641.69
Model	302.192893	7	43.1704132	Prob > F = 0.0000
Residual	6.45854026	96	.067276461	R-squared = 0.9791
				Adj R-squared = 0.9775
Total	308.651433	103	2.99661585	Root MSE = .25938

lynetsales	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lllabour	-.1087084	.0935847	-1.16	0.248	-.2944726	.0770558
lkcapital	.4583853	.057005	8.04	0.000	.3452313	.5715392
lmmaterials	.4237243	.076147	5.56	0.000	.2725737	.5748749
lfmfirmmar~p	.3868898	.2095575	1.85	0.068	-.0290785	.802858
limimports~e	.086404	.090191	0.96	0.340	-.0926236	.2654317
lfifdishare	.3805763	.0792214	4.80	0.000	.2233232	.5378295
linvestment	.0327922	.0142688	2.30	0.024	.0044689	.0611156
_cons	.4223255	.6080333	0.69	0.489	-.7846112	1.629262

R^2 is high (97,90%). It means that varies in X explain 97,9% of varies in Y. Prob > F is less than 0,05, therefore R^2 is not random and quality of specification of econometric model is high. However, one of the most important variables is not significant (0,340 > 0,050), namely amount of import.

Secondly, regression model with fixed-effects (FE) was constructed. It is used when it is needed to analyze the impact of variables that vary over time. FE explores the relationship between predictor and outcome variables within an entity (country, person, company, etc.). Each entity has its own individual characteristics that may or may not influence the predictor variables (for example, the business practices of a company may influence its net sales).

When using FE we assume that something within the entity may impact or bias the predictor or outcome variables and we need to control for this. This is the rationale behind the assumption of the correlation between entity's error term and predictor variables. FE removes the effect of those time-invariant characteristics from the predictor variables so we can assess the predictors' net effect.

Another important assumption of the FE model is that those time-invariant characteristics are unique to the entity and should not be correlated with other individual characteristics. Each entity is different, therefore the entity's error term and the constant (which captures individual characteristics) should not be correlated with the others. If the error terms are correlated then FE is no suitable, since inferences may not be correct and it is needed to model that relationship (probably using random-effects); this is the main rationale for the Hausman test, which will be discussed further.

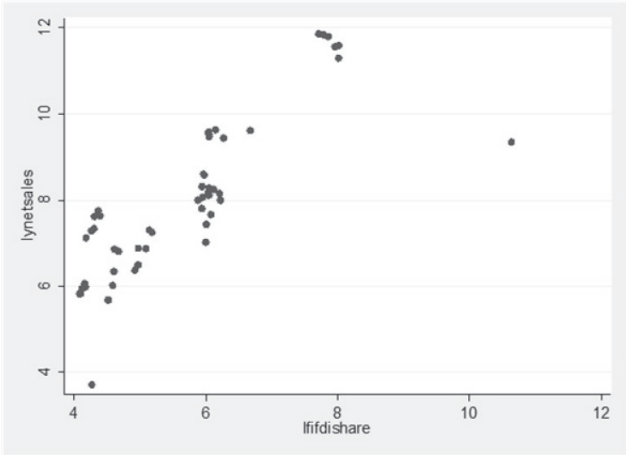

Figure 2. Scatter diagram: net sales and FDI share.

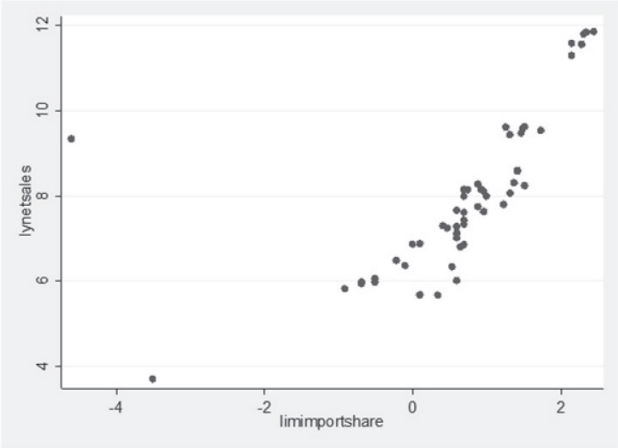

Figure 3. Scatter diagram: net sales and import share.

The equation for the FE model becomes:

$$Y_{it} = \beta_1 L_{it} + \beta_2 K_{it} + \beta_3 M_{it} + \beta_4 FM_{it} + \beta_5 IM_{it} + \beta_6 FI_{it} + \beta_7 Inv_{it} + \alpha_i + u_{it}, \quad (9)$$

where α_i is the unknown intercept for each entity (n entity-specific intercepts). Table 5 shows the results of the FE model.

Table 5. Regression model with fixed effects.

```
Fixed-effects (within) regression               Number of obs      =       104
Group variable: company                         Number of groups   =        18

R-sq:  within  = 0.7698                         Obs per group: min =         5
       between = 0.9620                                        avg =       5.8
       overall = 0.9543                                        max =         6

                                                F(7,79)            =     37.75
corr(u_i, Xb)  = -0.6427                        Prob > F           =    0.0000
```

lynetsales	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lllabour	-.0654411	.1897335	-0.34	0.731	-.4430962	.312214
lkcapital	.1492522	.1201148	1.24	0.218	-.0898305	.3883348
lmmaterials	.3996918	.1140372	3.50	0.001	.1727065	.6266771
lfmfirmmar~p	.778163	.2081864	3.74	0.000	.3637782	1.192548
limimports~e	.5103775	.1592608	3.20	0.002	.1933768	.8273782
lfifdishare	.7677402	.1285814	5.97	0.000	.5118053	1.023675
linvestment	.0109556	.0125719	0.87	0.386	-.0140681	.0359794
_cons	.2298174	1.915348	0.12	0.905	-3.582587	4.042222
sigma_u	.43975151					
sigma_e	.18265759					
rho	.85285775	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(17, 79) =     6.74                 Prob > F = 0.0000
```

The overall R^2 is also high and constitutes 95,43%. It means that the quality of the model is good. Moreover, the test (F) to see whether all the coefficients in the model are different than zero has been passed. Unlike the previous model, the variable which demonstrates the influence of imports on sales is significant (0,002 < 0,05). Rho is known as the intraclass correlation. 85,29% of the variance is due to differences across panels.

It should be also mentioned that FE model controls for all time-invariant differences between the individuals, so the estimated coefficients of the fixed-effects models cannot be biased because of omitted time-invariant characteristics. One side effect of the features of FE models is that they cannot be used to investigate time-invariant causes of the dependent variables. Technically, time-invariant characteristics of the individuals are perfectly collinear with the entity dummies. Substantively, FE models are designed to study the causes of changes within an entity. A time-invariant characteristic cannot cause such a change, because it is constant for each person.

Finally, regression model with random effects (RE) was constructed (results are presented in Table 5). The rationale behind random effects model is that, unlike the FE model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model. Green (2008) argued that the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not.

If there is reason to believe that differences across entities have some influence on the dependent variable, then RE model should be used. An advantage of RE is that time invariant variables can be included. In the FE model these variables are absorbed by the intercept. The RE model is:

$$Y_{it} = \beta_1 L_{it} + \beta_2 K_{it} + \beta_3 M_{it} + \beta_4 FM_{it} + \beta_5 IM_{it} + \beta_6 FI_{it} + \beta_7 Inv_{it} + \alpha_i + u_{it} + \varepsilon_{it}, \quad (10)$$

where u_{it} – between-entity error, ε_{it} – within-entity error.

RE assumes that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables. In RE it is important to specify those individual characteristics that may or may not influence the predictor variables. The problem with this is that some variables may not be available, therefore leading to omitted variable bias in the model. RE allows generalizing the inferences beyond the sample used in the model.

Table 6. Regression model with random effects.

```
Random-effects GLS regression                   Number of obs      =       104
Group variable: company                         Number of groups   =        18

R-sq:  within  = 0.7304                         Obs per group: min =         5
       between = 0.9837                                        avg =       5.8
       overall = 0.9744                                        max =         6

                                                Wald chi2(7)       =   1492.84
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

lynetsales	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lllabour	-.1169475	.1233432	-0.95	0.343	-.3586958	.1248008
lkcapital	.3232325	.0797434	4.05	0.000	.1669384	.4795267
lmmaterials	.408037	.0943266	4.33	0.000	.2231603	.5929137
lfmfirmmar~p	.6573192	.2083416	3.16	0.002	.2489771	1.065661
limimports~e	.2679408	.1194744	2.24	0.025	.0337753	.5021063
lfifdishare	.490643	.0951408	5.16	0.000	.3041704	.6771156
linvestment	.0162339	.0128974	1.26	0.208	-.0090445	.0415123
_cons	.9876227	.8314596	1.19	0.235	-.6420082	2.617254
sigma_u	.15851608					
sigma_e	.18265759					
rho	.42959236	(fraction of variance due to u_i)				

The overall R^2 is higher than in FE model and constitutes 97,44%. It means that the quality of the model is good. Moreover, the test (F) to see whether all the coefficients in the model are different than zero has been passed. In the model both variables that reflect FDI and international trade spillovers are significant (0,000 and 0,025 respectively). However, Rho is lower than in the previous model and demonstrates that only 42,96% of the variance is due to differences across panels.

In the next section we will perform several tests to determine the most appropriate model for the analysis of FDI and international trade spillovers on Russian chemical market.

4.2. SELECTION OF THE MOST APPROPRIATE MODEL

Three main regression models, namely OLS regression, RE and FE regression models, have been estimated. In this section all these models will be tested to choose the most adequate for our panel data.

Firstly, a simple OLS regression was compared with FE regression. The Wald test is used to determine which of the two models is more appropriate for the presented data. STATA run this test automatically while generating the results for FE model (see Table 4). The following line shows the results:

```
F test that all u_i=0: F (17, 79) = 6.74 Prob > F = 0.0000
```

As Prob > F is less than the 0,05, FE model is considered to better describe the obtained data.

Breusch-Pagan Lagrange multiplier (LM) is used to decide between simple OLS regression and RE regression. The null hypothesis in the LM test is that variances across entities are zero. This means no significant difference across units (i.e. no panel effect). Table 7 represents the results of the test in STATA.

Table 7. Breusch-Pagan Lagrange multiplier (LM) test.

```
lynetsales[company,t] = Xb + u[company] + e[company,t]

Estimated results:
                         Var     sd = sqrt(Var)
-------------------------------------------------
       lynetsa~s    2.996616       1.731074
               e    .0333638       .1826576
               u    .0251273       .1585161
-------------------------------------------------
Test:   Var(u) = 0
                     chibar2(01) =    13.85
                  Prob > chibar2 =   0.0001
```

As Prob > chibar2 is less than 0,05, we reject the null and conclude that random effects are appropriate. It means that there is evidence of significant differences across entities, therefore we can run RE regression.

From theoretical point of view, to determine whether we should use a FE model or a RE model we have to question ourselves about a potential problem of endogeneity and more precisely about a correlation between unobserved individual heterogeneity α_i and observed regressors. If we suspect such a relation we have to use a FE model since it is the only one to be consistent. There are a lot of variables that could explain the productivity of the enterprise and be included in the term of unobserved individual heterogeneity α_i. We could think that some of these characteristics are correlated with observed regressors. For example the management quality of a firm, which is unobservable, can influence productivity and affect training. We could also think of the intellectual capacity of an employee which is linked to the performance of a firm and which can explain the number of training hours affected to him. These findings lead to think that there may be correlation between the individual specific effects and the regressors and so we can be tempted to use a fixed effects model. To be absolutely sure we can perform some tests.

From econometrical point of view, to choose between a FE and a RE model we can perform a Hausman test which tests the null hypothesis of an absence of correlation between the individual specific effects and the regressors. $E(\alpha_i + \varepsilon_{it} \left| X_{it} \right.) = 0$, where α_i is the time invariant unobservable effect and ε_{it} the error term. Under this hypothesis the RE model is valid but if it is not fully respected, the estimators of the RE model are inconsistent and we have to use the FE model.

The standard Hausman test implemented on Stata verifies that there are no systematic differences between the estimators of the RE model and the FE one. A test statistic can be built on these differences, looking at the variance-covariance matrix of the vector of difference $[b - \hat{\beta}]$, where b is the within estimator and $\hat{\beta}$ is the RE GLS estimator.

$$Var\left[b - \hat{\beta}\right] = Var\left[b\right] + Var\left[\hat{\beta}\right] - Cov\left[b, \hat{\beta}\right] - Cov[b, \hat{\beta}], \tag{11}$$

The covariance between an efficient estimator and its difference with an inefficient estimator equals to zero: $Cov\left[b, \hat{\beta}\right] - Var\left[\hat{\beta}\right] = 0$.

By inserting this result in the previous equation, we obtain:

$$Var\left[b - \hat{\beta}\right] = Var\left[b\right] - Var\left[\hat{\beta}\right] = \Psi \tag{12}$$

This results in a test, following a χ^2 (K-1), based on the Wald criterion:

$$W = [b - \hat{\beta}]' \hat{\Psi}^{-1} [b - \hat{\beta}] \tag{13}$$

The results of this test are presented below:

Table 8. Hausman test.

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lllabour	-.0654411	-.1169475	.0515064	.1441709
lkcapital	.1492522	.3232325	-.1739804	.0898252
lmmaterials	.3996918	.408037	-.0083452	.0640857
lfmfirmmar~p	.778163	.6573192	.1208438	.
limimports~e	.5103775	.2679408	.2424367	.1053085
lfifdishare	.7677402	.490643	.2770972	.0864951
linvestment	.0109556	.0162339	-.0052783	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 22.28
Prob>chi2 = 0.0023
(V_b-V_B is not positive definite)

As Prob>chi2 is less than 0,05, the null hypothesis is rejected and we need to use FE model. This is consistent with our panel data, because the entities are the same across the sampled 6-year period.

Based on the results of the test, it may be concluded that the FE regression model is the most adequate for estimating the panel data obtained to assess the influence of FDI and international trade spillovers on Russian chemical market.

4.2. TESTING THE QUALITY OF FIXED EFFECTS MODEL AND INTERPRETING RESULTS

Before making any conclusions based on FE regression model, it is important to conduct several tests to check whether the model shows adequate results.

In order to test for cross-sectional dependence/contemporaneous correlation, Pesaran CD test will be introduced. Cross-sectional dependence is a problem in macro panels with long time series (over 20–30 years). This is not much

of a problem in micro panels (few years and large number of cases), like in our case. Therefore, we assume that our model will pass this test without any difficulties.

Table 9. Perasan CD test.

```
Pesaran's test of cross sectional independence = 0.170, Pr = 0.8652
Average absolute value of the off-diagonal elements = 0.580
```

As Pr = 0,8652 is more than 0,05, there is no cross-sectional dependence in the model.

To detect whether a phenomenon of heteroscedasticity is present in our data we can perform a test of Wald which tests the presence of heteroscedasticity between individuals. It tests the null hypothesis that the variance of the error is the same for all individuals.

Table 10. Test for heteroscedasticity.

```
Modified Wald test for groupwise heteroscedasticity
in fixed effect regression model
H0: sigma (i) ^2 = sigma^2 for all i
chi2 (18) = 110.44
Prob>chi2 = 0.0000
```

The P value is inferior to 5%, which leads us to reject the null hypothesis of homoscedasticity between individuals. A phenomenon of heteroscedasticity is present.

Serial correlation causes the standard errors of the coefficients to be smaller than they actually are. A Lagram-Multiplier test for serial correlation is employed. It tests the null hypothesis of the absence of first order autocorrelation in the errors.

Table 11. Test for autocorrelation.

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      17) =     54.794
           Prob > F =      0.0000
```

The null value of the P value leads us to reject the null hypothesis and to validate the presence of autocorrelation of first order. At that point of the study we have seen that a phenomenon of autocorrelation and heteroscedasticity are present in our data. To take this phenomenon into account, we use the method of bootstrap to obtain panel robust standard errors. For more efficiency we have performed 500 replications from the original sample. The final model is presented in Table 12.

Table 12. FE model with robust standard errors.

```
Fixed-effects (within) regression               Number of obs      =       104
Group variable: company                         Number of groups   =        18

R-sq:  within  = 0.7698                         Obs per group: min =         5
       between = 0.9620                                        avg =       5.8
       overall = 0.9543                                        max =         6

                                                Wald chi2(7)       =         .
corr(u_i, Xb)  = -0.6427                        Prob > chi2        =         .

                                (Replications based on 18 clusters in company)
```

Table 12. FE model with robust standard errors. *(Continued from previous page)*

lynetsales	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
lllabour	-.0654411	.2324586	-0.28	0.778	-.5210515	.3901694
lkcapital	.1492522	.1509844	0.99	0.323	-.1466719	.4451762
lmmaterials	.3996918	.1139047	3.51	0.000	.1764426	.622941
lfmfirmmar~p	.778163	.2733327	2.85	0.004	.2424407	1.313885
limimports~e	.5103775	.2011871	2.54	0.011	.1160581	.904697
lfifdishare	.7677402	.1759583	4.36	0.000	.4228683	1.112612
linvestment	.0109556	.0102039	1.07	0.283	-.0090437	.030955
_cons	.2298174	2.944158	0.08	0.938	-5.540626	6.000261
sigma_u	.43975151					
sigma_e	.18265759					
rho	.85285775	(fraction of variance due to u_i)				

We see, with the R^2 between, that the part of the variability across individuals which is explained by the explicative variables is about 96%. The R^2 within gives an idea of the contribution of the random effects to the model, which is of 77% in this case. Finally we can note that more than 85% of the variance is due to differences across panel.

Concerning the variables, they are all significant except for labour, capital and investment. However, the constant is not significant. From the estimated econometric model we can interpret the coefficients:

- If materials increase by 10%, the sales will decrease by 4,00%;
- If firm mark-up increases by 10%, the sales will decrease by 7,78%;
- If import share increases by 10%, the sales will decrease by 5,10%;
- If FDI share increases by 10%, the sales will decrease by 7,67%;

The results of the above FE regression model confirms our theoretical hypothesis that foreign activity of the entities on Russian chemical market in the form of FDI and international trade leads to increase of productivity within the whole industry.

These results have important implications for policymakers in Russia. As chemical industry represents a significant part of the economy, productivity growth in this particular sector may lead to a high increase in GDP. In the light of the above-mentioned results, we could conclude that accession to the WTO will benefit Russia.

However, the study findings may be limited by two constraints. Firstly, it will be severely bounded in the time period of data to be collected, as the firm product-level trade data of each transaction from Russian customs agency is available only from 2005. Secondly, quantitative research always has its limits, although methodology itself implies minimum noise from input data, probably it's not able to capture the dynamics of certain parameters.

CONCLUSION

Governments all over the world spend large amounts of resources in order to attract multinational companies to their region or country, often based on the assumption that such companies generate various types of positive externalities, or spillovers, to domestic firms. This stands in sharp contrast to the influential recent literature that has used microlevel data to provide econometric evidence for such FDI spillovers — without finding much. In this paper, we estimate international technology spillovers to Russian-owned manufacturing firms via imports and FDI between the years of 2007 and 2012. Our results suggest that FDI leads to significant productivity gains for domestic firms. The size of FDI spillovers is economically important. There is also some evidence for imports-related spillovers, but it is weaker than for FDI.

The results emphasize the importance of internationalization for productivity and welfare growth, both through the internationalization of domestic firms and through foreign direct investments by multinational firms. The results imply that export promotion policies and FDI promoting policies should be designed in a balanced manner, as they may potentially be substitutes in reaching productivity growth. Policies aiming to facilitate internationalization of domestic firms should furthermore not focus solely on developing export markets but also on the facilitation of import activities for high quality inputs.

However, despite the presence of positive spillovers from FDI, the policy implications of these findings are not straightforward. These results may support the continuing fiscal and investment incentives provided by the Russian government for FDI. However, more general policies should be pursued, which not only attract FDI but also benefit domestic firms, for example, building modern infrastructure, increasing and strengthening the institutions for accelerating and sustaining economic growth.

Based on the empirical results, we may predict that Russian accession to the WTO in 2012 should result in productivity growth. However, further research on this topic will be possible when the statistical data is available for several years after accession.

Our research suggests a number of future research directions. For one, the heterogeneity of FDI spillover strength across industries partly reflects the heterogeneity in the motivation for FDI. Not all FDI is equally likely to transfer technology internationally, which suggests a promising avenue of future research focusing on specific industries and mechanisms. Another issue is whether the literature so far has taken a sufficiently broad view of the effects that MNEs' entry might have, including inter-industry effects, the longer-run effects (e.g. of worker training programs), and signaling effects to other potential foreign investors.

For the time being, the results in this paper provide the strongest evidence supporting the provision of subsidies to attract FDI from a viewpoint of social welfare. Another important question, of course, is whether a socially optimal policy is indeed implemented, given the political-economic realities of local electoral competition.

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Innovations as Factor of Absorptive Capacity of FDI Spillovers across Regions of Russian Federation*

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Abstract. We study how innovations affect increase of regional total factor productivity (TFP) as a result of productivity spillovers from foreign direct investment (FDI), and confirm the presence of phenomenon in Russian data. TFP is modeled using data envelopment analysis (DEA) with the human capital, energy and capital as inputs, and the gross regional product as output. We develop innovations index for the regions of the RF, proxying for regional absorptive capacity, based on 17 variables, characterising economic, social and infrastructural aspects of regional development. FDI variable accounts for spatial distribution of FDI flows.

Аннотация. Мы исследуем, как инновации влияют на повышение совокупной производительности факторов (СПФ) в регионах в результате прямых иностранных инвестиций, и подтверждаем наличие феномена в российских данных. СПФ моделируется методом оболочечного анализа с человеческим капиталом, потреблением энергии и капитальными инвестициями в качестве входов и валовым региональным продуктом в качестве выходов. Влияние инноваций отражается при помощи специально разработанного индекса, основанного на 17 переменных, характеризующих экономические, инфраструктурные и социальные аспекты регионального развития.

Keywords: FDI spillovers, Data Envelopment Analysis, innovation indexes, regional development, international trade.

1. INTRODUCTION

The issue of foreign direct investments and their effects on the host countries, especially in respect of productivity spillovers, has been widely discussed in recent years. Naturally, the largest attention was paid to the emerging markets and developing economies. Although large body of research was accumulated, the evidence from Russia is rather scarce. Even though there are several studies that focus on Russia as a whole, no attempt has been made to investigate the regions of the Russian Federation. However, such research can provide important evidence from both science and policy perspectives. The present paper proposes research of the effects FDI have on regional productivity, the existence of spillover effects and the role, which the regional absorptive capacity plays in these processes. Most researches nowadays agree that foreign direct investments boost local productivity in the form of spillovers; however, the extent to which the productivity can be increased is determined by the absorptive capacity of the given region. Therefore, modeling the absorptive capacity and implementing the results in researching FDI spillovers is essential for obtaining consistent results. The present paper discusses these issues in more detail and provides investigation of FDI spillovers over the regions of Russia.

Given the two megatrends taking place in Russia today, namely, the recent joining to the WTO and the official government's position regarding fostering innovation in the country, the present research seems to be rather relevant. First, the findings are

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likely to provide valuable policy implications regarding fostering innovations and managing FDI in the region. Moreover, the research will help in identifying the best and the worst regions-outliers. The following hypothesis will be tested in the course of the present paper: the innovations absorptive capacity of the region affects its ability to absorb FDI productivity spillovers.

The rest of the paper is structured in the following way: section 2 provides an overview of the phenomenon of FDI spillovers followed by the literature review and evidence on the FDI spillovers from emerging markets; section 3 introduces the Index of Innovations Absorptive Capacity for regions of the Russian Federation. Section 4 provides the description of the model, the specification of the regression and the obtained results. Section 5 concludes.

2. DETERMINANTS OF FDI ABSORPTIVE CAPACITY ACROSS THE WORLD: META-ANALYSIS OF EVIDENCES FROM EMERGING MARKETS

FDI is a transfer of capital across borders, which allows the receiving economy to increase investment beyond its savings rate. Traditionally, development economics have focused on this addition to the capital stock as core contribution of foreign investment to economic development (e.g. Lall and Streeten, 1977). FDI is a particularly appreciated source of capital because it has a more long-term character than portfolio investment, and direct investors make a stronger commitment to the host economy. It cannot be withdrawn quickly if the volatile environment goes through an economic downturn, such as the exchange rate crises in Mexico 1995, East Asia 1997 or Russia 1998. However, foreign investor's commitment comes at a price as investors expect high returns on high-risk investments, in the longer term this leads to capital outflows in terms of profit remittance or interest payments, which are reflected in other positions of the balance of payments. In recent years, scholarly attention has moved to the impact of international trade and FDI on economic growth in the host economy through productivity effects.

FDI spillover is an increase of total factor productivity of firms, regions or industries that are exposed to foreign direct investment to larger extent than the others. However, productivity rises even in the firms not obtaining FDI themselves. The reasons for this observation are knowledge and training obtained by employees of firms exposed to FDI, changes in staff and other communication arising between FDI and non-FDI firms in the region. The key factor determining the associated positive FDI external effect is the absorptive capacity of a firm, region or industry. It is worth mentioning that researches in recent years have paid much attention to the effect, which FDI has on the productivity of domestic firms in emerging economies. Notably, most studies agree that usually foreign firms from developed countries are technologically more advanced and possess stronger management skills, and both features can be transferred to or repeated by domestic firms in emerging economies. These effects referred to as spillovers are treated as positive externalities that provide benefits to domestic firms due to the presence of FDI, leading to increase in productivity of domestic firms.

In recent years a lot of research was undertaken on the issue of spillover effects in innovation or knowledge production, especially in emerging economies. Generally, the findings of studies on FDI spillovers in emerging economies are mixed. There are many studies confirming existence of positive FDI spillover effects, for example, such evidence was found in the researches undertaken by Blomström, 1986; Buckley, Clegg, and Wang, 2007; Tian, 2007; Wei and Liu, 2006. Yet there are as well many works suggesting that FDI either leads to no spillover effect or even negatively affects productivity of domestic firms in emerging markets.

This section reviews existing studies on FDI spillovers in emerging markets, discusses models and approaches and summarizes the results. The review is organized in the following way: first, the general studies of spillovers will be discussed, followed by the review of the researches examining FDI spillovers in emerging economies, structured according to the region.

2.1. OVERVIEW OF GENERAL STUDIES ON FDI SPILLOVERS

One of the first studies undertaken by Findlay (1978) suggests that FDI can lead to productivity increases in the host country due to the knowledge and management techniques diffusion to local firms. Worth mentioning is the research conducted by Lipsey (2002), which highlights that it is not sufficient to evaluate overall FDI contribution to home country productivity without undertaking any detailed analysis, examining factors determining productivity spillovers.

Several important studies were contributed to investigating mechanisms of FDI spillovers occurrence. The first mechanism refers to the demonstration effect, in this case domestic firms have an

opportunity to observe foreign firms' technologies and management practices and increase their productivity by imitating those practices (Blomstrom and Kokko, 1998). The second mechanism deals with building domestic linkages. First the knowledge from the FDI-firm subsidiary diffuses to domestic suppliers and distributors, and afterwards it can be adopted by domestic firms dealing with the same suppliers and distributors (Spencer, 2008). Thirdly, spillovers can result from employee turnover. When former employees of FDI-firms start working for domestic firms, the knowledge they obtained in foreign firms can be transferred to domestic ones. The fourth option is associated with increases in competition in the market after FDI-firms entrance. These increases force domestic firms to increase productivity, for example, by improving management standards or obtaining more technologies, in order to stay competitive in new circumstances (Blomstrom and Kokko, 1998). However, the research undertaken by Aitken and Harrison in 1999 suggests that the fourth mechanism, on contrary, may lead to decreases in domestic firms' productivity in case of demand shifts from them towards foreign firms or if the entrance of FDI-firms leads to increases in costs of production factors, such as labor.

The studies undertaken by North (1991) and Ghemawat (2003) suggest that there is a positive association with the divergence of FDI host countries and the spillover effects as domestic firms are able to absorb wider range of technologies and business practices. This fact is confirmed by researches made by North (1991) and Wan and Hoskisson (2003), suggesting that technological and strategic activities of firms differ among countries. Empirical study undertaken by Van Wijk, Van den Bosch, and Volberda (2001) confirms that the wider the spectrum of available knowledge, the higher is the propensity of local firms to absorb it. Moreover, due to different technological and management practices brought by international firms from various countries, the total "bank" of industry knowledge leads to economies of scope and scale, thus increasing the abilities of local firms to combine the knowledge elements for their benefit (Zhang and Li, 2010). Another important factor, noticed by Cohen and Levinthal (1990) is the absorptive capacity of the firm, or, to put it more simply, its ability to recognize the value of new technologies, management practice and knowledge and implement it to extract benefits.

In 2006 M. Kugler published the research on the likelihood of intra-industry and inter-industry spillovers. He argues that inter-industry spillovers are more likely to occur than the intra-industry ones, as the international firms tend to prevent technology leakages to competitors. Thus, the productivity spillovers between non-competing or complementary industries are more likely. The data from Colombian Manufacturing Census was merged with FDI information from Central Bank transaction records to perform econometric analysis. The research results confirm existence of limited intra-industry spillovers and widespread inter-industry spillovers, associated with diffusion of technology, knowledge etc. to the firms, holding downstream and upstream positions relative to MNC subsidiary.

2.2. STUDIES OF FDI SPILLOVERS IN INDIA

Another research, conducted by M. Ghosh and S.S. Roy (2013), was analyzing FDI spillovers in India for the period 1991–2010. Their sample included more than 8000 firms in the following industries: textiles and garments, chemicals, metals and metal product, machinery and transport equipments. The results of the study suggest that FDI spillovers significantly affect technological strategies of Indian manufacturers as well as dependency on foreign technologies.

2.3. FDI SPILLOVERS IN AFRICAN COUNTRIES

Worth mentioning is the study undertaken by Thiam Hee Ng (2007) that focused on the FDI spillover effects in fourteen Sub-Sahara countries, namely, Benin, Botswana, Congo, Cote d'Ivoire, Gambia, Ghana, Malawi, Mauritius, Nigeria, Senegal, Seychelles, Togo, Tanzania and Zambia. Total factor productivity estimates from UNIDO on the country level and the FDI as a share of GDP were used to perform Granger causality test on the whole sample and the Toda-Yamamoto version of the Granger causality test on the sample of 8 countries characterized by non-stationary FDI inflows. The research results suggest only weak evidence of increases in TFP associated with FDI in two countries, namely, Botswana and Congo. Another important finding is the fact that FDI contributes more to the transfer of "soft" knowledge, like managerial or organizational skills, than to "hard" knowledge that forces technological changes. In addition, the study results suggest that FDI *per se* do not increase productivity, and other factors are important and should be considered.

Another research, undertaken by S. Ghali and S. Rezgui (2011) focused on FDI productivity spillovers in Tunisia. The DEA method was used to assess the sample of 674 manufacturing firms for the period 1997–2001, which can be treated as a representative one. The findings suggest the presence of

technology spillovers at the firm level, but provide no evidence of horizontal spillovers.

2.4 EVIDENCE FROM LATIN AMERICA

The study undertaken by M. Blomström in 1989 was focused on 145 Mexican industries, in which both domestic and FDI firms are presented. Blomström analyzes and compares performance of domestic and foreign firms of similar size, the study focuses on labor productivity, capital-labor ratio, wage level, wage share of value-added and profitability. The industries are grouped according to specialization into: light consumer goods, intermediates, consumer durables and capital goods. The findings suggest that labor of international firms posses some intangible assets, which lead to their significantly higher productivity. The studies also confirmed the existence of spillover efficiency by means of regression analysis. In addition, the research identifies competitive pressure as the spillover transmission mechanism; however, their results did not support the hypothesis that FDI accelerates technology transfer.

Another interesting research was undertaken by Rajneesh Narula and Anabel Marin in 2005 and dealt with investigating the relationship between direct and indirect FDI spillovers in Argentina, based on the surveys for two periods 1992–1996 and 1998–2001. The authors examine limited spillover effects observed in Argentina despite the findings of multiple studies in other economies. The study suggests that there exist direct spillover effects in the form of human capital employment and development, however, no significant evidence of indirect spillovers was found. The results of this study also show that FDI *per se* do not contribute to higher economic growth, and spillover effects arise only in case domestic industry has sufficient capacity to absorb the externalities associated with FDI.

2.5. FDI SPILLOVERS IN EUROPEAN DEVELOPING COUNTRIES

An interesting research was conducted by Priit Vahter (2011) regarding FDI spillovers in Estonia. He used the data on the whole population of Estonian manufacturing firms for the period 1995–2004 along with panel data set from two CIS surveys on innovation-related variables. The goal of the study was to examine the relationship between FDI entry and FDI share and total factor productivity of domestic firms. The findings suggest that there is no short-term association between FDI and increase in productivity of domestic firms; nevertheless there is a positive relationship between FDI and the following innovation activities of domestic firms. Moreover, FDI inflow intensifies derivation of knowledge in the home country. In general, the research proves the existence of knowledge spillovers associated with FDI; however, these flows do affect the short-term productivity.

2.6. EVIDENCE FROM CHINA

In general, there are numerous studies on FDI spillovers in China due to multiple factors. First, China has experienced large inflow of foreign direct investments during recent years. Second filing company data with the Chinese National Bureau of Statistics (CNBS) is obligatory for all Chinese firms, therefore large and consistent data sets are available for Chinese enterprises. In addition, it is worth highlighting the recent success in development and growth exhibited by China, therefore, this country definitely attracts the attention of researches.

At first this section briefly presents the main conclusions of several studies and then focuses on some more recent researches in greater detail. The examination of Chinese provincial-level panel data for the period 1999–2008 carried out by Sang and Yue (2011) revealed the important role of FDI spillovers in encouraging independent innovation development by Chinese companies. These results confirmed similar findings obtained in studies undertaken by He and Xu (1999) and Yao and Zhang (2001). Another valuable research was undertaken by Zhang and Sun (2011) to evaluate the effect of four factors namely the level of human capital, the domestic R&D input, the perfection level of institutions, and the level of economic development on import trade and FDI spillovers. The obtained results prove the importance of those factors in fostering FDI spillovers in East China only. The influence of difference in FDI levels among regions was investigated by Xuan and Li (2010) using the data on thirty provinces for the period 1990–2007. The results suggest that FDI spillover effects depend on local absorptive capacity and the degree of FDI involvement in the regional economy.

The study undertaken by Yan Zhang, Haiyang Li, Yu Li and Li-An Zhou in 2008 is the first attempt to examine the effect of heterogeneous FDI arising from different countries on productivity of domestic firms in emerging economies. The authors complemented the data from the Annual Industrial Survey Database (1998–2003) of the Chinese National Bureau of Statistics (CNBS) with the information from the Foreign Direct Investment Enterprise Database. In the course of research, 3 hypotheses were tested and supported by the data: the diversity of FDI

country origins positively influences the productivity of industry domestic firms; this relationship is stronger for large domestic firms than for small ones; moreover, the strongest association is found for intermediate technology gap between international and domestic firms.

Another study, undertaken by Sizhong Sun in 2010 focused on export FDI spillovers in Chinese manufacturing industry for the period from 2000 to 2003. The firm-level data was analyzed using a Heckman sample selection model. The FDI lead to both export spillovers in participation and in export intensity decisions. The spillover effects are affected by firms' absorptive capacity and learning efforts and therefore are heterogeneous across firms.

Worth mentioning is the research conducted by Xiaowen Tian, Vai Io Lo, Shuanglin Lin and Shunfeng Song in 2011 examining the panel data set on 11 324 Chinese manufacturers. The study results suggest that intra-region FDI spillovers are generally positive; however, inter-industry ones can be both negative and positive. In general, negative spillovers affect the firms in backward periphery, but not the advanced growth pole firms. Moreover, the domestic firms in the growth pole are typically able to acquire benefits from FDI-firms in the periphery via products they sell. In general, the research supports evidence that FDI lead to spatial spillover effects, which are contributing to regional inequalities in emerging economies.

One of the most recent studies was undertaken by Hao Xu, Difang Wan, and Ying Sun in 2014. The authors used panel data on the coastal provinces of East China for the period 2001–2010, and arrived at the conclusion that the effects of FDI technology spillovers were insignificant, but their effects crucially depend on regional absorptive capacity.

2.7 FDI SPILLOVERS IN SOUTHEAST ASIA

The research performed by Takii (2004) suggests that the productivity of foreign firms in Indonesia is higher than that of local firms, the differences are attributed to the degree of foreign ownership. Another work by Takii and Ramstetter (2000) investigating productivity differences between international and domestic firms in Thailand, Malaysia and other Asian countries did not provide evidence of existence of significant differences. However, cross-sectional studies on Taiwan (Chuang and Lin, 1999), Indonesia (Sjoholm, 1999, Takii 2005), and Thailand (Kohpaiboon, 2005), report positive spillovers from foreign presence. Blalock and Gertler (2004) carried out a research on Indonesian data and found evidence of vertical, mainly upstream, spillovers, but not horizontal ones. Noor Aini Khalifah and Radziah Adam Malaysia in 2009 researched the data derived from *Annual Survey of Manufacturing Industries of Malaysian* for the period 2000–2004, and concluded that there is no influence of FDI on local labor productivity. Yasuyuki Todo and Koji Miyamoto studies Indonesian manufacturing firms for the period 1994–1997; their findings suggest existence of intra-industry knowledge spillovers from R&D international firms to local firms, but no evidence of similar spillovers from non-R&D firms.

2.8 EVIDENCE FROM RUSSIA

The existing research on FDI spillovers in Russia is rather limited, in large extent due to lack of reliable and comparable data. Nonetheless, there are some studies worth mentioning. One was carried out in 2000 by Yudaeva, Kozlov, Melentieva and Ponomareva, and focused on investigating the effect of foreign direct investment on productivity. The authors used the data derived from the Registry of Foreign Owned Firms, and the Russian Enterprise Registry Longitudinal Database (RERLD) combined with GNOZIS database information for missing values. The results of the study suggest that the productivity of foreign firms is higher than that of the local ones. In addition, the research shows that the FDI effect on domestic firms' productivity depends on both location and size of domestic firm: small enterprises located in the same region are forced by foreign firms' entrance to decrease outputs; however, middle-size enterprises tend to increase outputs. These findings constitute an indirect evidence of FDI spillover effects existence. In addition, the research suggests that regions with higher level of education are more exposed to FDI spillover benefits. Another research made by Yudaeva *et al.* (2003) provides rather detailed study of FDI in Russia. The analysis of the data for 1994–1998 provides evidence that foreign firms in Russia are more than twice as efficient as the local ones. Moreover, the study suggests the existence of positive and significant spillovers from international to local firms. Worth mentioning is a relatively recent research carried out by Irina Tytell and Ksenia Yudaeva in 2005, focused on four developing economies, namely, Russia, Ukraine, Poland, and Romania. The research finding suggests the existence of foreign firms' productivity superiority only in less corrupt regions, while no significant advantage is present in highly corrupt regions. Particularly in Russia negative spillover effects are observable in less corrupt regions. In addition, worth highlighting are the positive spillovers that export-oriented international firms generate on local ones.

3. THE INDEX OF INNOVATIONS ABSORPTIVE CAPACITY OF REGIONS OF RUSSIAN FEDERATION

The total of 17 indicators are used to measure innovations absorptive capacity of Russian regions, each value being ranked from the lowest to the highest, and the corresponding score from 1 for the lowest value to 83 for the highest was assigned. Consequently, the assigned values, which can be treated as scores of a region for each indicator, were used to construct the Sub-Indexes and the main index. The Index of Innovations Absorptive Capacity of regions of Russian Federation is composed of four Sub-Indexes: the Business Activity Sub-Index, the Innovation Activity Sub-Index, the Regional Industrialization Sub-Index and the Social Welfare Sub-Index. All four sub-indexes are discussed further in more detail.

3.1. THE BUSINESS ACTIVITY SUB-INDEX

The Business Activity Sub-Index reflects the entrepreneurship environment and consists of 5 equally weighted indicators:

- Business activity: The business activity level measured as the number of enterprises per 1000 citizens;
- Small business turnover: The turnover of small and medium businesses scaled to the region's GRP;
- Small business investments: The volume of investments into small businesses scaled to the region's GRP;
- Capital investments: The volume of capital investments scaled to the region's GRP;
- FDI: The volume of foreign direct investments scaled to the region's GRP.

The business environment plays an important role in determining innovation capacity. If the level of entrepreneurship activity is low, then there is practically no one to implement the innovation output. Therefore, the higher is the value of the Business Activity Sub-Index, the higher is the total innovation capacity of the region. The Business Activity Sub-Index is embodied in the total Index with the weight of 30%, chosen empirically.

3.2. THE INNOVATION ACTIVITY SUB-INDEX

The Innovation Activity Sub-Index is designed to measure efforts put into the process of innovation. The indicators include:

- Innovation activity of organizations: Innovation activity of enterprises measured as the percentage of firms undertaking technological, marketing and organizational innovations;
- Patents: The number of patents scaled to the population;
- Technology production: The number of technological advances developed in the region scaled to the population;
- Technology usage: The number of technological advances put into practice in the region scaled to the population;
- Science: The number of enterprises undertaking scientific research and development activities scaled to the population.

All the indicators are equally weighted under the framework of the Innovation Activity Sub-Index. The ability to adopt and implement innovations is of crucial importance for the innovation capacity, as recognized by most researches. Therefore, the Innovation Activity Sub-Index is introduced to the total Index with the weight equal to 40%.

3.3. REGIONAL INDUSTRIALIZATION SUB-INDEX

The Regional Industrialization Sub-Index is formed by four equally weighted indicators:

- Electricity production: the amount of electricity produced in the region in millions kW per hour, scaled to GRP;
- Electricity consumption: the amount of electricity consumed in the region in millions kW per hour, scaled to GRP;
- Automobile roads density: the density of paved roads for public use per 1000 square kilometers, in case the data for a particular region is unavailable, the figure for the Federal District is used;
- Railway roads density: the density of railway roads for public use per 1000 square kilometers, in case the data for a particular region is unavailable, the figure for the Federal District is used.

The industrialization of the region plays an important role in determining the innovation capacity. Electricity consumption is traditionally used as an indirect measure of economic activity. The density of roads plays a crucial role particularly in Russia, where there are numerous territories that are difficult to access. The Regional Industrialization Sub-Index is embedded into the total Index with the weight of 15%.

3.4. THE SOCIAL WELFARE SUB-INDEX

The Social Welfare Sub-Index is presented by the half difference of the scores for the average salary level and the level of corruption, and embedded into the total Index with the weight of 15%. The following argument justifies the inclusion of both factors into the Social Welfare Sub-Index.

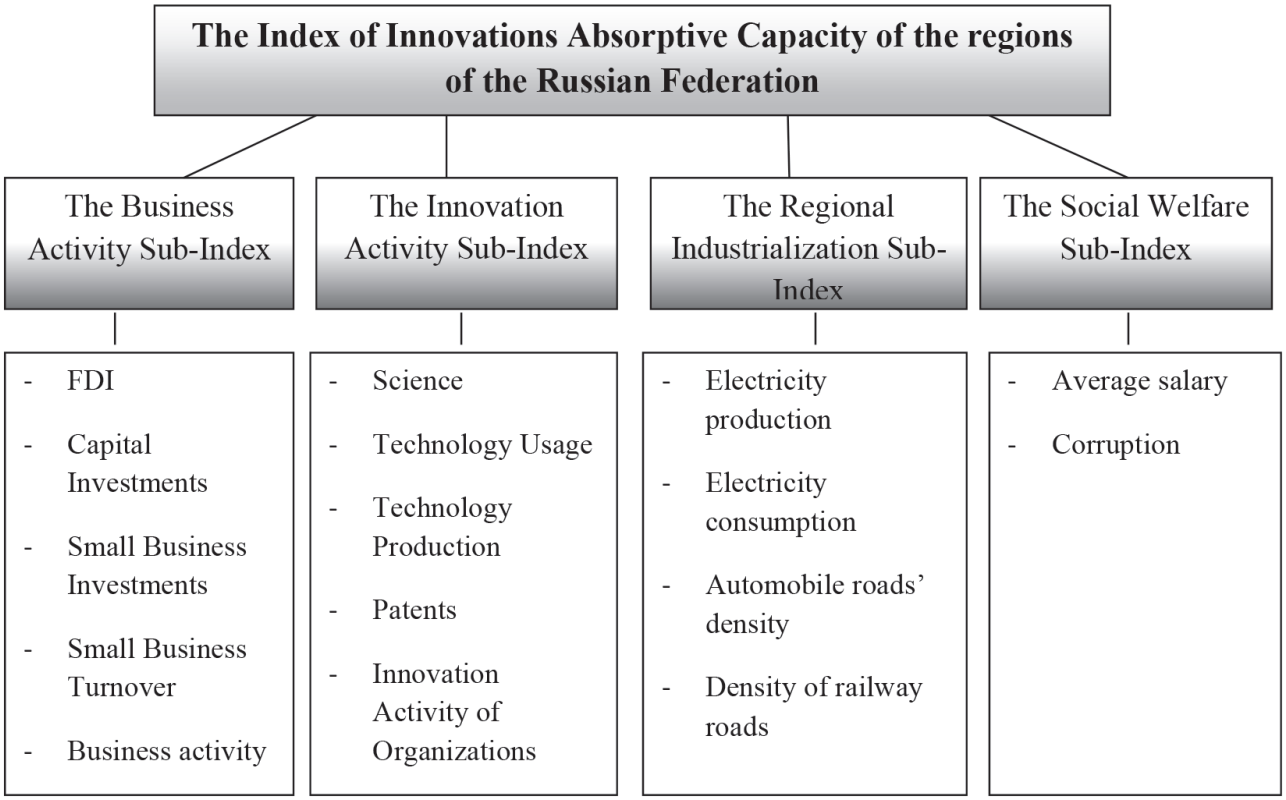

Figure 1. The structure of IACI for RF.

The higher salary in a particular region is the result of higher level of economic and business activity. Consequently, corruption also arises in those regions. First of all, this notion implies the existence of business at the given territory that corrupt officials are able to get bribes from. Secondly, the existence of so-called "kickback" that entails the return of certain amount of money in order to obtain a contract or state funding implies the allocation of state funding for some business activities, therefore there should exist some substantial number of enterprises. The third type of corruption arises inside firms when managers of middle-level making purchase decisions are able to collude with suppliers and make decisions maximizing their own return instead of firm's profits. This fact implies that the business if of substantial size so that it is run by hired managers whose actions are not transparent and cannot be fully controlled by the owners.

Although the list of aforementioned factors is definitely not exclusive their assessment allows to construct a meaningful index and to make comparisons. Most likely the Index of Innovations Absorptive Capacity of regions of Russian Federation would benefit from introduction of additional meaningful indicators chosen with care and properly scaled.

The structure of the Index of Innovations Absorptive Capacity of regions of Russian Federation is shown at the Figure 1.

3.5. DATA SOURCES

All the data, except for the corruption, was derived from the official Rosstat statistics. The data for each indicator was available for the period 2007–2011; consequently the Index was calculated for each year of the given period. The main advantage is therefore the implementation of "hard" data; the whole 100% of all indicators are represented by actual figures and therefore not subject to perception bias. The official statistical data is, unfortunately, characterized by two main limitations: very narrow scope of available relevant indicators and far from ideal representation of underlying phenomena due to various reasons, one of the most important being the substantial share of shadow economy not reflected by the figures. Nevertheless, we can assume that the data limitations are evenly distributed among the regions and therefore do not significantly affect the ability of the Index to allow meaningful comparisons. The data on corruption is derived from the ranking made by the organization "Bezopasnoe otechestvo" on the corruption in the area of state purchases in 2013. Although there is no data for the corruption in each year under consideration, the data for 2013 is a good

Table 1. The IACI for RF results.

Region	Ranking 2007	Ranking 2008	Ranking 2009	Ranking 2010	Ranking 2011
Sverdlovskaya Oblast	2	1	2	2	1
Nizhegorodskaya Oblast	1	2	1	1	2
Magadanskaya Oblast	4	14	15	4	3
Novosibirskaya Oblast	8	4	8	8	4
Tomskaya Oblast	7	6	4	7	5
Tatarstan Republic	3	7	5	3	6
Chelyabinskaya Oblast	13	5	12	13	7
Moskovskaya Oblast	11	9	6	11	8
Karelia Republic	27	38	34	27	9

proxy due to the following argument. The example of Singapore, where the economy is highly democratic, while the state politics can be described as the dictatorship, shows that the level of corruption can be significantly decreased during a short period of time such as 10 years. However, the case of Russia does not seem to be similar to Singapore. It is more likely that Russia's case is closer to that of Europe, namely gradual step-by-step changes. From this point of view the Europe's current state of corruption is the result of developments over the course of 300 years. Therefore, any changes, which took place during 7 years, will account to approximately 2% of changes, which can definitely be neglected taking into account the overall level of data preciseness. The corruption ranking was constructed to measure the level of corruption in the area of government purchases among the regions of Russian Federation. The data was derived from the official statistics presented on the government website and includes 6 indicators:

- The existence of justified claims;
- The existence of tenders with a single application;
- The existence of procedures due to which only one applicant was accepted;
- The existence of auctions with decreasing bid of less than 5%;
- The existence of auctions in which the principal rejected to sign a contract with the winner;
- The existence of quotes requests for purchases of the same product for the amount exceeding 500 thousand rubles (breaking up the order), which violates the order of the Ministry of Economic Development #273 of 07 June 2011.

Table 1 shows the top-10 regions according to their rank in 2011 as well as the respective results for the years 2007–2010.

As can be inferred from the Innovations Absorptive Capacity Index of regions of Russia the regions on the top of the ranking, namely Sverdlovskaya and Nizhegorodskaya oblasts, remain the same over the last 5 years. This result is determined largely by the high score in the Innovation Activity Sub-Index, reflecting the fact that many patents were registered in those regions as well as the high level of technology production and implementation. Moreover, both regions enjoy central geographical location and consequently well-designed infrastructure, which is reflected by the high score in the Regional Industrialization Sub-Index. In addition, worth highlighting is the progress made by the Magadanskaya Oblast over the time period under consideration. This result can be attributed to the dramatic increase in both the Business Activity Sub-Index and the Innovation Activity Sub-Index score made from 2009 to 2010, which reflects the rapid development of the region.

The bottom part of the ranking is unfortunately also very stable with the last 5 positions constantly filled by the regions of Russian South, namely Dagestan, Chechen Republic, Ingushetia, Karachay–Cherkess Republic and North Osetia-Alania. All 5 regions scored very poorly in all 4 sub-rankings, although it is worth mentioning that the scores obtained by Dagestan are 3–5 times higher than those obtained by Chechnya. The obtained results are actually not surprising as those regions are poorly developed, obtained highest scores in the corruption ranking, allow limited access of women to participation in the economic and business activities due to religious reasons, moreover, the regions suffered (and still suffer) from high-level of emigration to other regions of Russia and abroad.

On the whole the Innovation Absorptive Capacity Index of regions of Russia provides a rather clear picture of Innovation Absorptive Capacity and its distribution over the territory of Russia.

4. FDI SPILLOVERS IN RUSSIA

The local TFP was modeled using the DEA (Data Envelopment Analysis) in the following way: the region is treated like a "black box" transforming the inputs it can use into the outputs that is the gross regional product. Thus the region can be viewed as a function transforming the human capital (the economically active population was taken as a proxy), electricity consumption and capital investment into the GRP. Consequently the GRP is a function of human capital, electricity and capital investments.

The FDI spillovers were modeled by undertaking the following procedures. First, the ratio of the volume of sales of FDI firms to the total industry sales in the region was calculated. Then the average value for all industries was taken. The sum of regional FDI variables with the FDI variables of the neighboring regions was taken and multiplied by the squared distance. The regions were treated as neighboring only if they posses common borders. The innovations absorptive capacity was introduced in the second section of the current paper.

The panel data regression of the following form was used:

$$TFP_{it} = \alpha + \beta_{it}^{T} INNOV_{it} + \beta_{it}^{T} HFDI_{it} + u_{it},$$

where TFP stands for total factor productivity, INNOV is the Innovation Absorptive Capacity Index and HFDI is the FDI spillover, where subscript **i** denotes the region and subscript **t** denotes the period, $u_{it,}$ is the disturbance term with 0 mean. The one-way (individual) Random Effect Model was estimated. The effects are considered to be random as the variation across regions is assumed to be random and not correlated with any other variables presented in the model.

Coefficients :

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	0.4250613	0.0832936	5.1032	5.189e−07 ***
INNOV	−0.0078176	0.0011148	−7.0126	1.013e−11 ***
HFDI	0.7747339	0.1632257	4.7464	2.895e−06 ***

All the coefficients are shown to be significant; moreover the R-Squared, the coefficient of determination representing how close the regression is to its fitted line, is equal to 0.16, which is a good value for this type of models. In addition, it is worth highlighting the very small p-value, therefore one can definitely conclude the hypothesis of neutrality of FDI and Innovations Absorptive Capacity towards the TFP. The obtained results provide support for the null hypothesis that is the existence of FDI spillover effects. The coefficient for the innovations absorptive capacity is negative, although, this result seems highly counterintuitive; the following reasoning provides an explanation. The effect of foreign direct investment on the TFP of the regions with low innovations activity is the highest exactly because of low innovations that is because of the high but not yet realized potential. Therefore FDI in this case act as the trigger for this potential. The following argument is also important: although Russia possesses highly developed human capital in terms of education and general approach to citizens' development, which is largely the heritage of Soviet period, as well as rather developed infrastructure also remaining from Soviet times, there is very limited knowledge regarding the management policies and the practical implementation of those assets in the present reality. Consequently, the FDI presence forces the development and transformation processes.

The obtained results suggest the following implications for the policymakers. Firstly, the policy should be aimed at attracting foreign direct investments, especially to the regions of highest potential, namely, those in which the innovations level is low. Therefore, encouraging foreign presence in such regions will be beneficial for the regional growth and respectively for the total country's economic growth. The policymakers' actions may include decreasing barriers of entry, beneficial fiscal policies, such as tax exemption and other incentives attractive for foreign investors. Moreover, it would be beneficial for the total economic development and growth to support and promote factors fostering innovations absorptive capacity.

5. CONCLUSIONS

In the course of the present paper the research on FDI spillover effects in the regions of the Russian Federation was undertaken. Previous studies provided limited evidence on this issue. The conducted research suggests the following:

FDI spillovers do occur in the regions of Russia; moreover, the corresponding regression coefficient is statistically significant. Therefore, we can conclude that higher volumes of foreign direct investments should lead to higher productivity and, consequently, boosted economic growth;

The Innovations Absorptive capacity does affect the total factor productivity. However, the corresponding regression coefficient is negative, although, statistically significant. This fact implies that the regions with lower innovation activity levels that consequently posses higher innovation potential are the ones that benefit more from FDI.

Aside from the findings, the paper introduces the Innovations Absorptive Capacity Index for regions of the Russian Federation. The Index allows ranking the regions according to their respective innovations absorptive capacity and making meaningful assessments and comparisons.

The future research would provide valuable insights in the following directions: supplementing the Innovations Absorptive Capacity Index by the additional data and modifying it respectively; undertaking regression analysis of the data not only for the neighboring regions, but also for the inter-region associations, as many economic and business links are based not only on geographical proximity, but also on business interests. Likely, interesting results may be obtained taking into account the large volume of economic links built from and to Moscow. In addition, valuable insights can be provided by testing the data on inter-regional investments and respective spillover effects.

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A Structural Model of Exchange Rate Dynamics*

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Abstract. The concept of formation of the equilibrium exchange rate on the conversion market was developed, taking into account foreign trade, capital flows and other components of the balance of payments. As the main determinants of theoretical-structural model of the dynamics of the exchange rate equal countries are used, in the terms of trade, capital mobility, cumulative releases, internal and external prices. The result is a new final structural dependence of the dynamics of the exchange rate on the key macroeconomic determinants. The results obtained are applied to the study of the concept of purchasing power parity that allowed to justify theoretically — from positions of macroeconomic approach — a fundamental mismatch between the value of the exchange rates and the theory of purchasing power parity.

Аннотация. Разработана концепция формирования равновесного валютного курса на конверсионном рынке, учитывающая внешнеторговые операции, движение капитала и иные составляющие платежного баланса. В качестве основных детерминант теоретико-структурной модели динамики валютного курса равноправных стран используются условия торговли, элиминирующиеся в процессе рассмотрения модели, факторы мобильности капитала, совокупные выпуски, внутренние и внешние цены. В результате получена новая итоговая структурная зависимость динамики валютного курса от ключевых макроэкономических детерминант. Полученные результаты применяются к исследованию концепции паритета покупательной способности, что позволило теоретически с позиций макроэкономического подхода обосновать фундаментальное несоответствие значений валютных курсов теории паритета покупательной способности.

Keywords: Exchange rate, modeling, balance of payments, trading conditions, purchasing power parity.

CONCEPTUAL APPROACH TO THE ESTIMATION OF THE EQUILIBRIUM EXCHANGE RATE

In economic literature there is a steady interest to the problems of forming the fundamental equilibrium value of the exchange rates. Here we support the point of view of Engel, Mark and West (2007, revised in 2011): "Standard models of exchange rates, based on macroeconomic variables such as prices, interest rates, output, etc., are thought by many researchers to have failed empirically. We present evidence to the contrary".

The need for a thorough analysis of the behavior of macroeconomic aggregates, their interdependence is complicated by the effects of devaluation on the global level consideration. Conducting internal macroeconomic policy often leads to improvement of the situation at the expense of the environment. The negative effects of devaluations lead to the issue of "fair" rates of exchange, which must be resolved solely with regard to fundamental economic factors that are aimed at removing growing in international trade voltage. And here perhaps the most important problem is the coordination between participants, their combined vision system, the degree of agreement on the activities, as well as mutual accountability. In this article we study significant trends observed in the world economy, based on the class of models of the exchange rate dynamics of two equal countries-suppliers developed by the author (Kuzmin, 1999, 2010, 2012).

Conceptually to study the dynamics of exchange rates with varying degrees of floating we determine the exchange rate e as the average weighted on volumes of foreign currency values N conducted market transactions $e_i, i \in (1, N)$ for a certain period of time:

$$e \equiv \sum_{i=1}^{N} \frac{D_i}{\sum_{j=1}^{N} D_j} \times e_i, \qquad (1)$$

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where, e_i, D_i, R_i are, respectively, the exchange rate, the amount in foreign currency, the amount in the domestic currency of the *i-th* transaction, i.e.

$e_i D_i = R_i \cdot$ or $e_i = R_i / D_i$.

Thus, from (1) can be obtained by summing over *i*:

$$e = \sum_{i=1}^{N} \frac{D_i}{\sum_{j=1}^{N} D_j} \times \frac{R_i}{D_i} = \sum_{i=1}^{N} R_i \Big/ \sum_{j=1}^{N} D_j .$$

Here in the formula we can take into account the funds that came to the currency market:

- on the supply side of the national currency for transactions of current account operations (hereinafter in formula (2) variables with top index CA) and capital movement (variables with top index K),
- on the supply side of foreign currency for the same purposes, including foreign exchange receipts from exports,
- in the interventionist actions of monetary authorities to regulate the exchange rate (variables with top index CB).

Thus, the main result of a conceptual level shows that the exchange rate is equal to the aggregate amount of funds in domestic currency, divided by the total amount of funds in foreign currencies traded in the currency market during this period. In the final formula, disaggregated flows on accounts of the balance of payments can be represented as:

$$e = \frac{\sum R^{CA} + \sum R^{K} + \sum R^{CB}}{\sum D^{CA} + \sum D^{K} + \sum D^{CB}} . \qquad (2)$$

THE BEHAVIOR OF INVESTORS AND TRADING CONDITIONS IN THE MODEL OF EXCHANGE RATE DYNAMICS

In this model, the world presents two countries that trade with each other, in accordance with their international competitive positions (trading conditions), expressed by the value of the real exchange rate. There are also equal bilateral relations of the two countries-contractors and joint actions of monetary authorities to maintain stability of the exchange rate at the desired level. The variant of "one small country and the rest of the world" is preferable to model according to the methodology set out in the articles by the author (Kuzmin, 2011, 2014).

Thus, the flow of funds in the formula (2) are presented symmetrically in relation to each other export-import flows of partners and capital flows: I*=E, E*=I, $K^{*-} = K^{+}, K^{*+} = K^{-}$.[1] In the framework of the introduced notations $\sum R_i^K = K^{-}, \sum D^K = K^{+}$ — accordingly, the amount of funds outflow (demand in national currency for foreign currency) and inflows of foreign currency supply on the capital account, and

$\sum R_i^{CA} = I \quad \sum D_i^{CA} = E$ — accordingly, the demand in national currency for foreign currency from imports and supply of foreign currency from exports.

In the result the exchange rate is represented in the form

$$e_t = (I_t + K^{-}) \Big/ (E_t + K^{+}) = (E_t^* + K^{*+}) \Big/ (E_t + K^{+}) = (E_t^* + K^{*+}) \Big/ (I^*_t + K^{*-}) = 1 \Big/ e_t^* ,$$

with perfect symmetry determination of exchange rates of these two countries-suppliers.

[1] Asterisk here and below marks the variables related to the opposite side.

An important place in the study of the factors movement of the exchange rate is the analysis of the impact of relative international competitive advantages in global trade flows and, indirectly through the creation of a favorable investment climate, on capital flows. Structural changes in the world, the presence of real imbalances have a significant impact on the mobility of the exchange rate, and their deviations from the equilibrium values and the emergence of these mega world trade factors are creating competitive advantages for residents of one country over the other. This is due to the mechanisms of change in real exchange rates, which are based on the decisions of the agents at the micro level, thus affecting global trade flows (and indirectly through the creation of a favorable investment climate on the capital flows). Relative prices and costs are important factors in the terms of trade and international benefits, by which the real exchange rate has a tendency to return to its equilibrium value.

Also, increasing demand for national currency, supplemented by a decrease in the supply of foreign currency, is caused by the following real and psychological factors:

- fears of investors about raising interest rates to curb the economy from overheating,
- improval of the investment climate by increasing economic growth and inflow of portfolio and direct investment,
- perceived and anticipated effects of import substitution.

All these factors are related to the capital account. We would accept the hypothesis that the magnitude of capital inflows is a function, increasing in real total product (international investors and speculators want to buy its part at their prices for aforementioned reasons) and in terms of trade, represented by the value of the real exchange rate $e^R_{t-1} = e_{t-1} P^*_{t-1} / P_{t-1}$. The last explanation lies in the fact that the fall of the national currency (respectively the increase in the exchange rate) improves the investment conditions for non-residents.

The following dependence is observed:

$$K_t^+ = k_{K^+} P_t^* \sqrt[3]{(Q_{t-1}{}^2 Q_t)^{\theta}} e^R_{t-1}, \tag{3}$$

where Q_t - cumulative real issue (for example, real GDP), P_t — total price levels and indexes *t, t-1* indicate, respectively, the beginning and the end of the period.

The function of the outflow of capital allocated for investment and speculative purposes is defined symmetrically:

$$K_t^- = k_{K^-} P_t \sqrt[3]{(Q^*_{t-1}{}^2 Q^*_t)^{\rho}} e^{*R}_{t-1}. \tag{4}$$

On construction θ and ρ can serve as a measure of international capital mobility — their value corresponds to a greater mobility of the relevant cross-country flows.

Also the volume of exchange, supplied to the domestic market, is determined by the volume of exports, which depends on the real terms of trade, and is determined by the decisions of producers-exporters in time *t-1*:

$$E_t = P^*_t k_E \sqrt[3]{(Q_{t-1}{}^2 Q_t)} e^R_{t-1} = P^*_t k_E \sqrt[3]{(Q_{t-1}{}^2 Q_t)} e_{t-1} P^*_{t-1} / P_{t-1}. \tag{5}$$

Part $k_E \sqrt[3]{(Q_{t-1}{}^2 Q_t)}$ reflects the fact that the export is a part of total output (for the reasons similarly expressed by Kuzmin (1999)).

Accordingly, the demand for the local currency is symmetrically determined by the decisions of producers and importers (recall that the importing country is exporting its contractor):

$$I_t = E^*_t = P_t k_I \sqrt[3]{(Q^*_{t-1}{}^2 Q^*_t)} e^{*R}_{t-1} = P_t k_I \sqrt[3]{(Q^*_{t-1}{}^2 Q^*_t)} e^*_{t-1} P_{t-1} / P^*_{t-1}. \tag{6}$$

Many authors in the analysis of the exchange rate distinguish the terms of trade, reflected in the effectiveness of foreign trade operations, as one of the determining factors. Structurally similar dependencies

were generally confirmed by Bahmani-Oskoee and Goswami (2004), who focused on research of export-import operations in the world trade.

The model of the exchange rate of the ruble (Kuzmin, 2011) is also substantiated and proved on the statistical series of exports and imports of Russia in 1997–1999 and 2007–2009 and the use of agents at the micro level as the main determinants of foreign trade transactions in terms of trade, expressed and adjusted for price levels of the nominal exchange rate.

Interesting research (Caramazza, 1993) showed that investors' expectations of changes in the parity DEM/FRF during 1987–91 can be explained largely by some fundamental macrovariables, including the relative inflation differential and the terms of trade. In (Bartolini, 1993) similarly a link is found between trade advantages and market expectations of devaluation in 1987–1993. Also a link was found between the expected devaluation and that CPI is an indicator of the international advantages.

In fact at this stage there is a conceptual difference in the assessment of threads on import operations and the subsequent results compared to the modeling methodology "one small country and the rest of the world", where the import is not dependent on the actual conditions of trade expressed by the value of the real exchange rate. Symmetry and equality are making adjustments, and the future will permit analysis of a number of important and interesting effects in the behavior of the real and nominal bilateral exchange rates, balance of the payment balance and formation of an international competitive advantage.

Substituting in (2) formulas (3), (4), (5), (6) and taking into account the symmetry of the real bilateral exchange rate $e^{R}_{t-1} = e_{t-1} P^{*}_{t-1} \big/ P_{t-1} = 1 \big/ e^{*R}_{t-1}$:

$$e_t = \frac{k_I P_t \sqrt[3]{Q^{*\,2}_{t-1} Q^{*}_{t}}\, e^{*R}_{t-1} + k_{K^-} P_t \sqrt[3]{(Q^{*\,2}_{t-1} Q^{*}_{t-1})^{\rho}}\, e^{*R}_{t-1}}{P^{*}_t k_E \sqrt[3]{Q^{2}_{t-1} Q_t}\, e^{R}_{t-1} + P^{*}_t k_{K^+} \sqrt[3]{(Q^{2}_{t-1} Q_t)^{\theta}}\, e^{R}_{t-1}} = \frac{P_t \sqrt[3]{(Q^{*\,2}_{t-1} Q^{*}_{t})^{\rho}}\,(k_I \sqrt[3]{(Q^{*\,2}_{t-1} Q^{*}_{t})^{1-\rho}} + k_{K^-})}{P^{*}_t e^{2}_{t-1} \left(P^{*}_{t-1} \big/ P_{t-1} \right)^2 \sqrt[3]{(Q^{2}_{t-1} Q_t)^{\theta}}\,(k_E \sqrt[3]{(Q^{2}_{t-1} Q_t)^{1-\theta}} + k_{K^+})}, \quad (7)$$

$\theta \geq 0, \rho \geq 0.$

Now, using the properties $\rho, \theta >> 0$ and assuming a constant due to the significantly greater stability dynamics of the average member of the species $\sqrt[3]{(Q^{2}_{t-1} Q_t)^{1-\theta}}$ in comparison with the mobility of external and internal prices,

$$\frac{(k_I \sqrt[3]{(Q^{*\,2}_{t-1} Q^{*}_{t})^{1-\rho}} + k_{K^-})}{(k_E \sqrt[3]{(Q^{2}_{t-1} Q_t)^{1-\theta}} + k_{K^+})} = (k^{/})^3 = const,$$

let's rewrite (7) in the form

$$e_t (e_{t-1})^2 = \frac{k^{/} P_t}{P^{*}_t} \frac{Q^{*\rho/3}_t}{Q^{\theta/3}_t} \left(\frac{k' P_{t-1}}{P^{*}_{t-1}} \frac{Q^{*\rho/3}_{t-1}}{Q^{\theta/3}_{t-1}} \right)^2. \quad (8)$$

Intertemporary separation of variables makes it in the final formula:

$$e(t, Q(t), P(t), P^{*}(t), Q^{*}(t)) = e_t = k^{/} \frac{P_t}{P^{*}_t} \frac{Q^{*\rho/3}_t}{Q^{\theta/3}_t}. \quad (9)$$

You can now specify the exogenous variables in the model. In (9) there are the price levels *P, P** and comprehensive products *Q, Q** in the countries of this bilateral exchange rate. Other important determinants of the behavior of the exchange rate are indicators of capital flows between countries, certain values ρ, θ.

In the model-building process other factors (variables import and export, as well as other components of the balance of payment, and terms of trade) were eliminated.

Generally speaking, the formula (9) is true if the assumption about the equality of the coefficient *k"* is constant. This problem can be circumvented by using the other functions of the linear form (as shown by the author (Kuzmin, 2010)). Under other equal $(P_t^* = const, Q_t = const, Q_t^* = const)$ exchange rate is directly linked to changes in domestic prices. That is, any actions of the authorities to increase the money supply will lead to an outflow of funds on the foreign exchange market and proportional increase of the rate. On the other hand, if the exchange rate is managed by the Central Bank it is appropriate to change it in direct accordance with the dynamics of domestic prices. Especially it comes to the regime of regulated (called "dirty") floating. You can also see that the currency rate rises with increasing foreign prices, reflecting the symmetry of the situation.

Here it is important to note that one of the most important factors that determine the medium and long term movement of the nominal exchange rate is the inflation differential between countries. This is confirmed by the work (Lane, 1999), dynamically $\frac{P_t}{P_t^*}$, or in logarithms $D_\pi = \pi - \pi^*$ in definitions of the author, who examined the econometric model on quite representative data of 1974–1992, including the OECD countries, taking into account the behavior of the real exchange rate, defined as $e^R = e\left(P^* \diagup P\right)$.

Checking of the dependency of type (9) within the scope of verification of monetary models was repeatedly carried out with success. On the basis of methods of assessment maximum likelihood approach for determining the co-integration vector time series of Johansen-Juselius (Chouldhry, Lawler, 1997), based on data on exchange rates of the Canadian dollar against the currencies of major contractors, and Moersch and Nautz, (2001), based on quarterly data at the rate of USD/DEM 1983–1996, confirmed the source of the dependence of the type (9).

In the model θ and ρ characterize the degree of physical supply of capital. These indices are responsible for huge changes in market exchange rates that occur due to explosive changes in the capital account, expressed in speculative attack on the currency. This is largely caused by the instability of the political situation, panic moods of investors, etc.— a situation typical for post-crisis Russia, when it devalued its national currency in 1998–99 more than four times, (that is comparable with the results of devaluations in Indonesia (73,8%) and South Korea (48%)), as well as serious and sufficiently rapid devaluation of September 2008 — February 2009.

PURCHASING POWER PARITY AND EQUILIBRIUM DYNAMICS OF THE EXCHANGE RATE

In the long term, however, it is changing in fundamental ways from the linear expressed by the formula (9). This is due to the change in the coefficient *k'*, which ceases to be a constant. It is easy to notice in $\sqrt[3]{\frac{(k_I \sqrt[3]{(Q_{t-1}^{*\,2} Q_t^*)^{1-\rho}} + k_{K^-})}{(k_E \sqrt[3]{(Q_{t-1}^2 Q_t)^{1-\theta}} + k_{K^+})}} = k'$, that uneven development of economies in the long run will result in changes to k', the greater the larger the difference in growth rates.

Stable high rates of growth, improving investment climate, inflow of capital into the country, credibility of national economic policy in the long term lead to appreciation of the nominal exchange rate (hence, the real exchange rate), which can be observed in the world economy on the example of the overvaluation of currencies of industrial countries against the developing. This effect is examined below.

Comparison of the results of the behavior of the exchange rate, expressed by the formula (9) and PPP-rate $e^{PPP} = P \diagup P^*$ leads to important conclusions: even in case of a zero trade balance and at the same time

zero balance capital — with a stable form of total releases $Q_t^{*1/3} \Big/ Q_t^{1/3} = const$ — equality of results will be achieved only if *k'=1* (that is, the equality of the coefficients associated with the coefficients of elasticity of exports and imports $k_{E^*} = k_E = k_I$ in total production), which generally speaking is not guaranteed. In the more general case when taking into account capital movement impossibility of *k'=1* due to non-uniformity of development (size and growth rate of total output), a mismatch behavior of the nominal exchange rate of the theory of PPP in the long term and in the medium term is guaranteed.

The above concerns not only the absolute, but relative version of PPP-rate. This concept, embodied in the works of G. Kassel, changes the form of dynamics $e^{PPP} = k P_t \Big/ P_t^*$, but with no conclusions. Also important here is the dynamic behavior of indicator $\sqrt[3]{\dfrac{(k_I \sqrt[3]{(Q_{t-1}^{*\,2} Q_t^*)^{1-\rho}} + k_{K^-})}{(k_E \sqrt[3]{(Q_{t-1}^{2} Q_t)^{1-\theta}} + k_{K^+})}} = k^{/}$, associated with the initial equilibrium, and the differential in rates of development $\dfrac{Q_t^{*\rho(t)/3}}{Q_t^{\theta(t)/3}}$.

Despite this, a significant number of economic models assume that the purchasing power parity must be performed at least in the long term for traded goods. But a considerable number of empirical studies tell about the controversial solution to the problem. On the one hand, a number of studies really confirm a close relationship of PPP and long-term changes in foreign exchange rates. The article (Hakkio, 1992) based on data for the period from 1900 identified a tendency for the return of the nominal exchange rate to its long-term values calculated by PPP in the long term of 3–12 years.

On the other hand, studies (Goodwin, Grennes, Wohlgenant, 1990) and (Frenkel, 1978) confirmed that the PPP-rate and the Law of One Price are very ill. Other studies, particularly comparison of developing and industrialized countries and in the short and in the long term, showed significant deviations of nominal exchange rates from the PPP. The results strongly depend on the calculation method of the real exchange rate — based on CPI or the GDP deflator.

Studying the ability of the PPP approach to predict future changes of the nominal exchange rate, the IMF experts (Cheung, Chinn, Pascual, 2004), based on data 1981–2002 from a number of developed countries (including the G-7) and developing countries, have come to a negative conclusion.

Model (Berka, Devereux, Engel, 2012) presents that nominal exchange rate movements give rise to persistent deviations from the Law of One Price even in traded goods.

According to the Russian statistics PPP-rate of ruble to its market rate at the end of the year varied considerably and amounted, respectively, to: in 1993–0,25, in 1997–0,7, in 1999–0,22, in 2006–0,48, in 2012–0,61 (author's calculations based on the data from Federal State Statistics Service of Russia, Central Bank of Russia and OECD).

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Prioritization of Russian Regions for Sustainable Investing Purposes Using Data Envelopment Analysis*

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Abstract. In the article we propose to use recently developed method, namely the robust shared-input Data Envelopment Analysis (DEA), to estimate the attractiveness of regions in the view of Sustainable Investing (SI). We apply DEA method over all regions of Russian Federation to identify a preferred alternative, to rank the alternatives in a decreasing order of preference and to classify the alternatives into a small number of categories for SI purposes using social-economic data for the latest available period (2013) and mathematical programming tools (Linear programming in RStudio). We argue that too little attention has been paid to the way regional sustainability and its determinants should be empirically analyzed. This article aims at presenting a methodology that provides a convenient and scientifically sound way of evaluation and monitoring of efficiency of SI in Russian regions. In order to determine possible practical application of obtained results, in our article we highlighted the role of hybrid financing in the frame of sustainable development and analyzed current gaps in the Russian legislation. It is hoped that this article will be useful for practitioners who are engaged in research and applications of operations research and performance measurement, including those who work in the field of economics.

Аннотация. В данной статье методология «Анализ среды функционирования» (АСФ) используется для определения приоритетных субъектов Российской Федерации в рамках проведения «ответственной» инвестиционной политики. АСФ проводится по всем субъектам Российской Федерации с целью категоризации альтернатив, определения наилучшей и ранжирования регионов для целей устойчивых инвестиций на основе социально-экономических данных за последний доступный период (2013 г.) с помощью инструментов математического программирования (линейного программирования в RStudio). Мы полагаем, что на текущий момент недостаточно внимания уделяется практическим аспектам анализа устойчивости регионов и решающих факторов их развития. В данной статье вашему вниманию предлагается удобная и научно-обусловленная методология оценки и мониторинга эффективности ответственного инвестирования в регионы России. Для определения возможного практического применения полученных результатов в статье подчеркивается роль гибридного финансирования в устойчивом развитии, а также проводится анализ необходимых изменений законодательной базы. Данная статья будет полезна для практиков, принимающих участие в работах по исследованию и внедрению исследований в операционную деятельность и оценке эффективности процессов (в том числе для тех, кто работает в области экономики).

Key words: Efficient Russian regions, long-term investing in Russia, DEA for sustainability, ranking regions, PPP, DEA.

INTRODUCTION

Regions are seen as having an increasingly important role in sustainable development (SD). First of all, this focus is justified by the important role of regions as intermediaries between the national and local levels and, secondly, by the growing consensus that SD is an essential criterion within future regional development.

Paul Erlich said: "We must acquire a life style which has as its goal maximum freedom and happiness for the individual, not a maximum Gross National Product." We agree that a financial indicator represented on the regional level in the form of Gross Regional Product (GRP) cannot discover potential for improvement within a region, as one input one output approach cannot give the whole picture of perfor-

* Анализ инвестиционной привлекательности российских регионов методом DEA.

mance efficiency. That is why crucial feature of SD lies in adaptation of an integrated vision and other factors are necessary for a holistic assessment of performance.

It is difficult to combine the entire set of ratios into a single numeric judgment, so we find the solution in application of Data Envelopment Analysis (DEA) technique. The main advantage of this method can be easily understood if you paraphrase the name "data envelopment analysis" — the efficient frontier envelopes (encloses) all the data we have. Mathematically the efficient frontier is the convex hull of the data that shows best possible performance that each constituent entity of Russian Federation could reasonably be expected to achieve.

DEA's empirical orientation and absence of *a priori* assumptions have resulted in its use in a number of studies involving efficient frontier estimation in the nonprofit sector, in the regulated sector, and in the private sector. In our study all of these sectors are combined in the form of public-private partnership (PPP).

The main objective of our research is to show performance, metrics, and pitfalls of this increasingly popular technique using as example one real life performance measurement problem: prioritization of regions in accordance with their attractiveness for sustainable investing (SI) purposes.

CONCEPT OF STRATEGIC SI APPROACH

"SI" is one of many terms used to describe strategies that aim to maximize social good and financial returns. Others include "social", "ethical", "mission-based" or "impact" investing. Whether the goal is to promote improved environmental, social, or governance practices, or to protect the value of one's assets, SI is moving from niche status to a broader-based acceptance.

The evolution of SI stretches over centuries. Religious investors from Jewish, Christian, and Islamic faiths and many indigenous cultures have long married morals and money, giving careful consideration to the way economic actions affected others around them and shunning investments that violated their traditions' core beliefs. In the American colonies, Quakers and Methodists often refused to make investments that might have benefited the slave trade, for example, and the earliest formalized ethical investment policies avoided so-called "sin" stocks — companies involved in alcohol, tobacco, or gambling. Indeed, the first fund to incorporate such sin-stock screening was the Pioneer Fund, opened in 1928 and screened since 1950 to meet the needs of Christian investors seeking to avoid involvement in such "vice" industries. The Fund continues to exclude tobacco, alcohol, and gambling industries from its portfolio to this day.

SI in its present-day form, however, arose in the aftermath of the social and cultural upheaval of the 1960s, an outgrowth of the civil-rights, feminist, consumer, and environmentalist movements and protests against the Vietnam War, which raised public awareness about a host of social, environmental, and economic problems and corporate responsibility for them. Religious organizations and institutional investors remained very much at the forefront of these concerns about corporate social responsibility and, in the 1970s, US institutions developed support to the emergent sustainable investing industry: the Investor Responsibility Research Center (IRRC) and the Interfaith Center on Corporate Responsibility (ICCR). The US Council on Economic Priorities began rating companies on social and environmental performance in 1969, and shareholder advocates turned to the proxy-resolution process to raise issues of concern at annual company meetings.

But in our research SD is outlined for the macroeconomic level, so the starting point for any measurement of the regional sustainability should be "Our Common Future", also known as the Brundtland Report, published in 1987 by the UN WCED, which coined SD as an integrative concept aiming to balance environmental and economic issues in a mutually beneficial way. Regarding its thematic breadth, issues other than strictly environmental were incorporated. While initially economic and social issues were addressed only as far as they were perceived to be relevant for environmental concerns, they evolved into equally important dimensions of SD.

The central thesis of the Brundtland Report is that "SD is not a fixed state of harmony, but rather a process of change, in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs."

THE ROLE OF HYBRID FINANCING STRATEGIES IN SD

Back in "Our Common Future" Gro Harlem Brundtland expressed the idea that "SD must rest on political will as the process is not straightforward and contemplates painful choices", which seems reasonable, but as budgets tighten and the public purse is pulled in many directions, it does not seem feasible. Thus the most eligible way of investing for the purposes of SD is cooperation of governments and development banks with the private sector. Public infrastructure deficits are compelling governments to bring in private sector

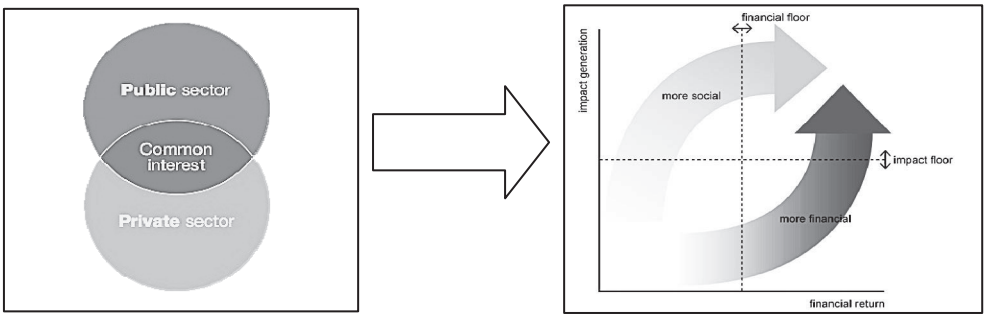

Figure 1. PPP: Combination of financial and social return.

capital and management efficiency through arrangements known as PPPs.

In today's economic environment, PPPs are defined as contractual agreements between a public agency or public-sector authority and a private-sector entity that allow greater private participation in the delivery of public services, or in developing an environment that improves the quality of life for the general public. PPPs can be used not only in the creation of physical assets and services, but also to meet wider environmental and social goals.

PPPs refer to arrangements where the private sector supplies infrastructure assets and services that traditionally have been provided by the government. They are mainly used to build and operate hospitals, schools, prisons, roads, bridges and tunnels, light rail networks, air traffic control systems, and water and sanitation plants.

This recently developed form of cooperation provides an agenda for action for purely financially motivated investors eager to mitigate risks and benefit from upside opportunities, as well as for governments seeking long-run economic development and civil society organizations aiming to achieve social and environmental progress (Figure 1).

There are advantages for both contract parties: for the government private financing can support increased infrastructure investment without immediately adding to government borrowing and debt, and can be a source of government revenue. At the same time better management in the private sector and its capacity to innovate can lead to increased efficiency; this in turn should translate into a combination of better quality and lower cost services. For the private sector PPPs present business opportunities in areas from which it was in many cases previously excluded.

In order to activate PPPs in the regions of our country the Ministry of Economic Development has carried out expertise assessments concerning law enforcement and concluded that in order to attract investment in infrastructure projects, certain amendments in federal budget, investment, land and tax legislation are needed. To that end the Ministry of Economic Development has developed two laws "On public-private partnerships" and "On amendments to legislation in connection with the 'On public-private partnerships' bill".

Introduction of the law regulations of PPPs at a federal level will allow to develop unified terminology, principles, tender procedures and even to create regulatory acts in the regions. The law sets out essential conditions and guarantees legal rights for PPP participants by maintaining the authority to control the activity of the private partner during project implementation regarding contractual commitments.

Moreover, the improvement of the law "On concessions" is taking place. In 2012 a number of amendments have been passed. New forms of concessions have been added, for example, the possibility to conclude the Life Cycle Contracts or so-called "DBFM (Design-Build-Finance-Maintain)" Model, when the private sector designs, builds and finances an asset and provides hard facility management or maintenance services under a long-term agreement.

Summing up all above-mentioned, we can say that for PPPs to be leveraged for environmental, social and economic sustainability, leadership and political will are the keys, both in terms of the overall policy framework for PPPs and from contracting parties at individual project level. This research, screening, and final ranking aim to provide a background, stimulate ideas and motivation to ease the process of making investment decisions and maximize the benefits of future long-term investments both for investor and the society.

DEA *vs* CUMULATIVE EXPERIENCE IN ANALYSIS OF PROJECT ALTERNATIVES

Any evaluation must have a starting point and purpose. Evaluation can be done in different phases of a project — *ex-ante, in medias res,* or *ex-post* (before, while or after a project is carried out). Regardless which phase of a project the same methods are applied, there are three basic forms or analysis:

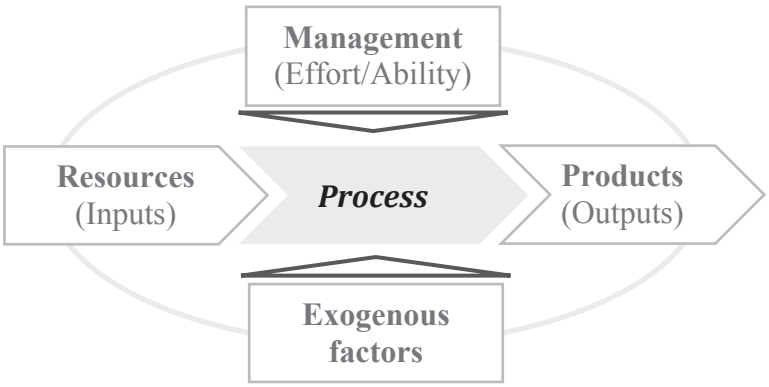

Figure 2. Visual explanation of DEA approach.

1. Cost-Benefit Analysis (CBA);
2. Cost-Effectiveness Analysis (CEA);
3. Multi-Criteria Analysis (MCA).

The CBA is an evaluation method that gives an overview of advantages and disadvantages of project alternatives or measures in terms of social welfare. These advantages and disadvantages are presented in the form of cost items and benefit items on a cost-benefit balance sheet. The items are expressed in terms of money ("monetized") as far as possible to enable the various project alternatives to be compared. CBA is a weighing-scale approach to making business decisions: all the pluses (the benefits) are put on one side of the balance and all the minuses (the costs) are put on the other. The main question in a CBA is "Do the benefits outweigh the costs?" The welfare effect is expressed in the balance of all costs and benefits. The costs and benefits of alternatives can also be compared to determine which alternative is preferable.

The aim of a CEA identifies the economically most efficient way to fulfill an objective. The analysis method can also be used to determine project alternative, given the maximum budget that will contribute most to the achievement of the objective (effect maximization). With a CEA, either the objective or the available amount of money is fixed.

A MCA, one of the most important branches of operations research, gives a decision-maker the opportunity to weigh a wide range of different effects against each other in the decision-making process. MCA aims to design mathematical and computational tools for selecting the best alternative among several choices, with respect to specific criteria, either by a single decision maker or by a group. MCA methods can be used to get large quantities of dissimilar information into a manageable form for decision-making. A MCA produces a "weighted sum" of the project's effects. For each project alternative, a number of criteria are used to give a weighing to each of the effects considered. The weightings determine how significant an effect is in the project alternative's overall score. The various alternatives are ranked in order of preference based on overall scores.

MCA includes DEA, which originates from production theory and implies that the performance of peer units, e.g. in this research we consider as regions, can be estimated by examination of the resources available to each unit and monitoring the "conversion" of these resources (inputs) into the desired returns (outputs) using mathematical programming techniques (Figure 2). The latter ones are frequently used as a planning aid to management to evaluate a collection of possible alternatives to select the best one.

HOW TO MEASURE THE PERFORMANCE OF REGIONAL AUTHORITIES WITH DEA

The first step of our research was to collect a very broad dataset of regional characteristics for the latest available period (2013). Our DEA study started with an exhaustive initial list of inputs and outputs: more than 70 variables were considered that were argued to be potentially related to differences in regional sustainability, but later it turned out that the more inputs and outputs are included in the analysis, the bigger is the percentage of regions that have an efficiency of 1, as they become too specialized to be evaluated with respect to other DMUs. In other words it is possible for DMUs to concentrate on a few inputs and/or outputs and score highest efficiency ratings, leading to large number of DMUs with the highest efficiency coefficient. Therefore, one ought to include only the inputs and outputs that are definitely relevant to all DMUs. Including too many inputs and outputs into the analysis will tend to make many regions efficient and the method loses its discriminatory power or its ability to distinguish the high performers from the rest. To put it differently, we are unable to estimate complex technologies of high dimensionality using a lot of data points.

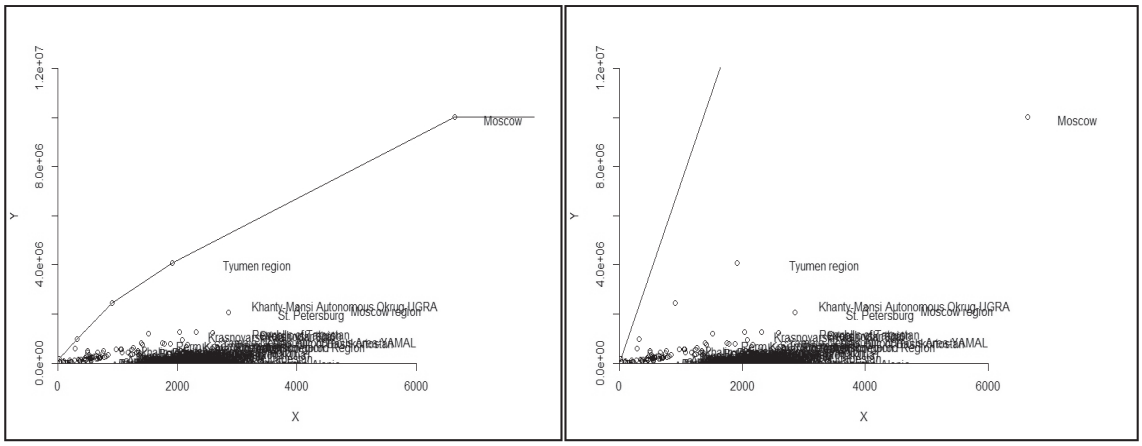

Chart 1. R-plot: VRS and CRS.

For these reasons, DEA researchers suggest using the rule of thumb for the relationship between the number of DMUs and the number of inputs and outputs, whereas the traditional rule says that the number of regions (or any other DMUs taken) must exceed 3 times the number of inputs plus the number of outputs, and the number of regions must exceed the product of the number of inputs and the number of outputs. These requirements are definitely at the low end and one can propose another rule. In order to make our esteems more precise we selected 30 most important variables and distributed them among 5 subject DEA models so that each model contained no more than 3 inputs and 3 outputs.

The main difficulty in any application of DEA lays in the selection of inputs and outputs. The criteria of selection of these inputs and outputs are quite subjective as there is no specific rule in determining the procedure for that. However, some guidelines may be suggested: one should pick up the most important quantitative (e.g., statistical) information and therefore to reduce the total number to a reasonable level.

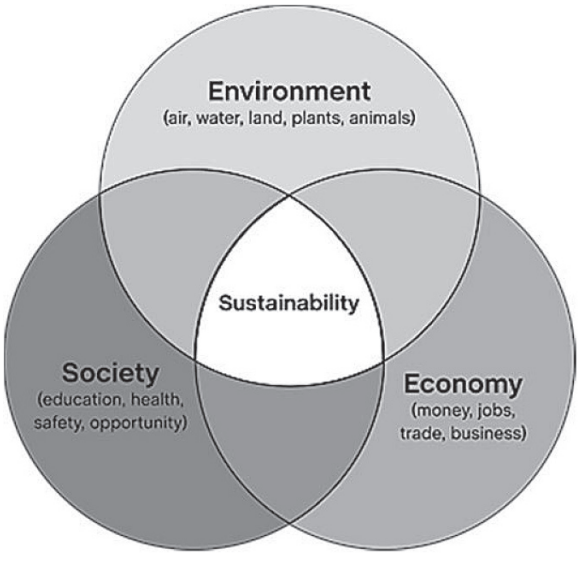

Figure 3. Three pillars of SD.

We were willing to prioritize regions not only in terms of their profitability (as usually is done by firms), so we considered inputs and outputs more generally than just costs and profits. We defined inputs as resources utilized by the DMUs or conditions affecting the performance of DMUs, while outputs were considered as benefits generated as a result of the operation of the DMUs.

In any study it is important to focus on specifying inputs and outputs correctly. In some cases it was difficult to classify a particular factor as input or output, as the factor could be interpreted in both ways. One of possible solutions implies the review on whether DMU, which performance is recorded as high in terms of that factor is considered more efficient or not. If yes, we classify the factor as an output. Otherwise, it is considered to be an input.

Traditional DEA models or so-called "base-oriented models" implicitly assume that factors (inputs and outputs) are discretionary, which means that they are controllable and can be set up by the decision-maker in order to achieve an optimal mix for production purposes. However, in many realistic situations, variables are exogenous and non-discretionary and depending on which variable is fixed we decide whether to use input- or output-oriented model. Input-oriented models are models where DMUs are deemed to produce a given amount of outputs with the smallest possible amount of inputs (inputs are controllable) and are frequently used in costs cutting. In the case of Russian regions, most inputs are non-discretionary. With output-oriented DEA, the LP is configured to determine entity's potential output given its inputs if it operated efficiently as entities along the best practice frontier. Output-oriented models are "…very much in the spirit of neo-classical production functions defined as the maximum achievable output given input quantities". For instance, the regional governments cannot directly and naturally change the amount of

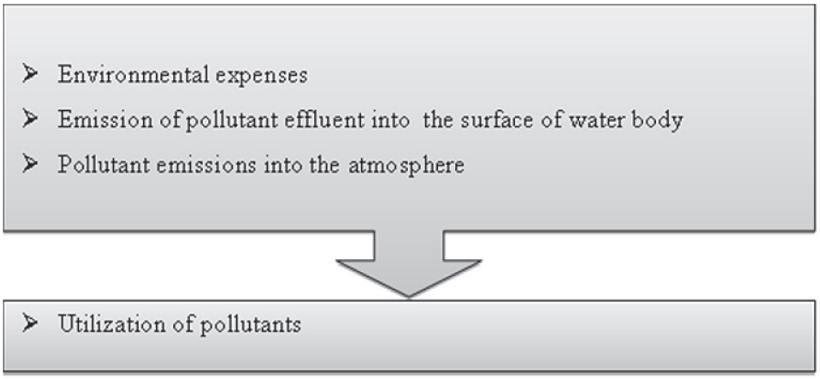

Figure 4. System of inputs and outputs that assess environmental issues.

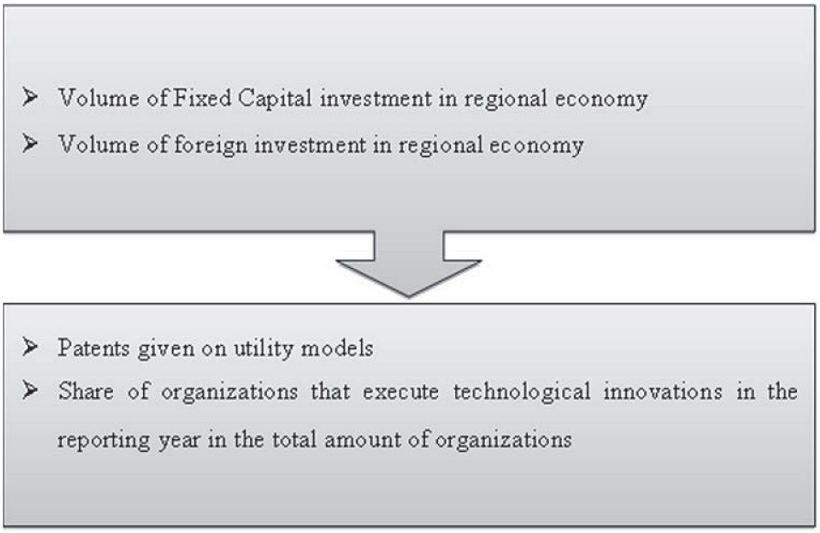

Figure 5. System of inputs and outputs that evaluate the development of infrastructure.

labor force, so we used the methodology that enabled to include non-discretionary variables in DEA. This is mainly done by maximizing/ minimizing only discretionary outputs/ inputs in the Linear Program (LP) model.

DEA can also integrate categorical variables (non-continuous variables) in the LP model such as discrete ordinal variables (dummy variables). Other authors have analyzed the issue using categorical variables by proposing alternate formulation of the LP model. Several authors have proposed different formulations that account for ordinal variables. Consequently, DEA embodies all different types of variables, whether they are discretionary or non-discretionary, categorical (ordinal) or continuous.

Throughout this paper, we use R Project to perform our calculations and applications. R is a powerful language and environment for statistical computing and graphics. It is a public domain (a so-called "GNU" project), which is similar to the commercial S language and environment, which was developed at Bell Laboratories (formerly AT&T, now Lucent Technologies) by John Chambers and colleagues. It is quite similar to other programming packages such as MatLab but more user-friendly than programming languages such as C++ or Fortran. In our research we used R in combination with the RStudio interface, where we downloaded package entitled "Benchmarking" in order to have an organized layout and several extra options.

One more common feature of DEA is that the envelopment surface differs depending on the scale assumptions that underpin the model. Two scale assumptions are generally employed: constant returns to scale (CRS), and variable returns to scale (VRS) (Chart 1).

The latter encompasses both increasing and decreasing returns to scale. CRS reflects the fact that output will change by the same proportion as inputs are changed (e.g. a doubling of all inputs will double output); VRS reflects the fact that production technology may exhibit increasing, constant and decreasing returns to scale. The CRS version is more restrictive than the VRS and as you will see further yields to a fewer number of efficient units and also lower efficiency scores among all DMUs. Input- and output-based capacity measures are only equivalent under the assumption of CRS.

Chart 2. Forecast for the share of SME in GNP.

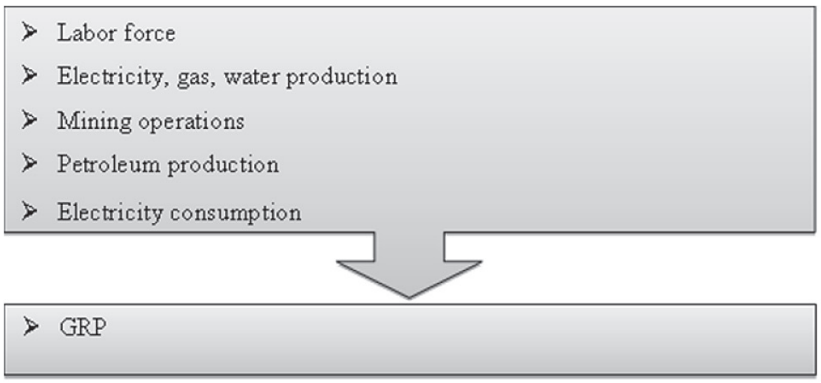

Figure 6. System of inputs and outputs to measure profitability.

In order to estimate the efficiency of regions we divided all the appropriate parameters into five categories (indices) which together form a complex picture of the region in terms of sustainability. First and foremost, sustainability can be achieved only in case all of three SD pillars are taken into consideration (Figure 3).

For all of them we set threshold values of efficiency that the regions must obtain in order to take part in the sustainability ranking. We conducted screening and if a region did not have the required efficiency coefficient in one of those indices, it meant that the strategy of development that was determined by regional authorities did not coincide with the strategy of sustainable growth so there was no use to invest in this region from that point of view.

The minimal values for each cluster were determined in accordance with the overall efficiency scores that DMUs obtained. In other words, to participate in the ranking DMU must obtain at least average efficiency for each of the SD pillars:

• Environment Index (Figure 4) with the minimal requirements to obtain 0,01 points out of 1 for environmental aspects: unfortunately, the average efficiency of green management are that low and to add to the trouble very often inverse correlation is observed between financial and environmental variables.

• Infrastructure Index (Figure 5) with a minimal requirement to obtain 0,45 points out of 1 as no projects can be realized in the location that are cut off from the outside world or controlled by local criminal authorities.

• Financial Index (Figure 6) with a minimal requirement to obtain 0,25 points out of 1 as sustainable investments as SI are neither synonymous with philanthropy nor an alternative; the profit is still the key issue of it.

Concept of Long-Term Socio-Economic Development of Russian Federation until 2020 determines key strategic aims that are diversification of regions through the increase of share of small and medium enterprises (SMEs).

By 2020 the share of SME in GNP will grow by 60–70% which means that in the following six years it is to be tripled in comparison with the current situation (Chart 2).

Table 1. Screening test results.

Constituent Entity of Russian Federation	Efficiency Coefficient (scale from 0 to 1)		
	Financial	**Environmental**	**Infrastructural**
Altai Krai	**1,000**	0,006	0,365
Altai Republic	1,000	1,000	0,488
Amur region	0,146	0,004	0,330
Arkhangelsk region	0,163	0,004	0,441
Astrakhan region	0,177	**0,013**	0,270
Belgorod region	0,180	0,009	0,442
Bryansk region	0,395	0,078	0,610
Chechen Republic	0,244	**1,000**	0,362
Chelyabinsk region	0,179	0,002	**0,506**
Chukotka Autonomous Area	**0,790**	0,000	**0,908**
Chuvash Republic	1,000	0,011	0,501
Irkutsk region	0,215	0,001	0,328
Ivanovo region	**0,543**	**0,054**	0,397
Jewish autonomous region	0,384	0,198	0,543
Kabardino-Balkar Republic	0,646	0,105	0,899
Kaliningrad region	0,260	0,032	0,466
Kaluga region	0,254	0,029	0,569
Kamchatka Krai	0,242	**0,092**	**0,594**
Karachay-Cherkess Republic	**0,626**	**0,116**	0,335
Kemerovo region	0,094	0,003	0,347
Khabarovsk Krai	0,137	0,001	**0,517**
Khanty-Mansi Autonomous Okrug — UGRA	0,016	0,000	**0,825**
Kirov region	**0,513**	0,004	0,430
Komi Republic	0,070	0,004	**0,499**
Kostroma region	0,814	0,063	0,562
Krasnodar Krai	**1,000**	0,009	**0,628**
Krasnoyarsk Krai	0,161	0,002	**0,501**
Kurgan region	**0,667**	**0,014**	0,410
Kursk region	**1,000**	**0,025**	0,276
Leningrad region	0,071	**0,012**	**0,728**
Lipetsk region	0,181	0,001	**0,614**
Magadan region	**0,982**	0,002	**0,490**
Moscow	**1,000**	0,005	**1,000**
Moscow region	**1,000**	0,003	**0,763**
Murmansk region	**0,441**	**0,011**	0,366
Nenets Autonomous Area	0,234	**0,024**	**1,000**
Nizhny Novgorod region	0,129	0,007	**0,679**
Novgorod region	0,496	0,015	0,593
Novosibirsk region	0,166	0,006	**0,482**
Omsk region	0,245	0,002	**0,561**
Orenburg region	0,226	0,009	0,322
Oryol region	**0,470**	**0,068**	0,255

Constituent Entity of Russian Federation	Efficiency Coefficient (scale from 0 to 1)		
	Financial	**Environmental**	**Infrastructural**
Penza region	0,233	**0,050**	**0,502**
Perm Krai	0,183	0,007	0,376
Primorsky Krai	0,207	0,001	**0,623**
Pskov region	1,000	0,111	0,544
Republic of Adygea	**0,572**	**0,435**	0,428
Republic of Bashkortostan	**1,000**	0,004	0,389
Republic of Buryatia	**0,426**	**0,010**	0,354
Republic of Crimea	–	–	–
Republic of Dagestan	**0,394**	0,001	**0,885**
Republic of Ingushetia	**0,935**	**1,000**	0,438
Republic of Kalmykia	1,000	0,319	0,521
Republic of Karelia	**0,661**	**0,022**	0,279
Republic of Khakassia	**0,333**	**0,012**	0,284
Republic of Mari El	**0,380**	**0,041**	0,449
Republic of Mordovia	0,219	**0,064**	**0,574**
Republic of North Ossetia-Alania	**0,378**	**0,105**	0,444
Republic of Sakha (Yakutia)	0,098	0,001	**0,576**
Republic of Tatarstan	0,243	0,001	0,398
Republic of Tyva	**1,000**	**0,121**	0,378
Rostov region	0,170	0,002	**0,464**
Ryazan region	0,284	0,023	0,497
Sakhalin region	0,052	0,001	**1,000**
Samara region	0,123	0,005	0,341
Saratov region	0,218	**0,018**	0,393
Sevastopol	–	–	–
Smolensk region	0,344	0,057	0,456
St. Petersburg	**1,000**	0,002	**1,000**
Stavropol Krai	**0,444**	**0,015**	0,415
Sverdlovsk region	0,065	0,001	**0,568**
Tambov region	0,618	0,034	1,000
Tomsk region	0,151	0,000	0,402
Tula region	0,152	0,008	**0,457**
Tver region	0,349	0,020	0,483
Tyumen region	0,019	0,002	**1,000**
Udmurt Republic	**0,349**	**0,013**	0,260
Ulyanovsk region	**0,264**	**0,034**	0,402
Vladimir region	0,316	0,032	0,452
Volgograd region	**0,250**	0,006	0,391
Vologda region	0,088	0,008	**0,995**
Voronezh region	0,134	0,004	**0,517**
Yamalo-Nenets Autonomous Area – YAMAL	0,018	0,001	**1,000**
Yaroslavl region	0,210	**0,013**	**0,574**
Zabaykalsky Krai	**0,881**	**1,000**	0,293

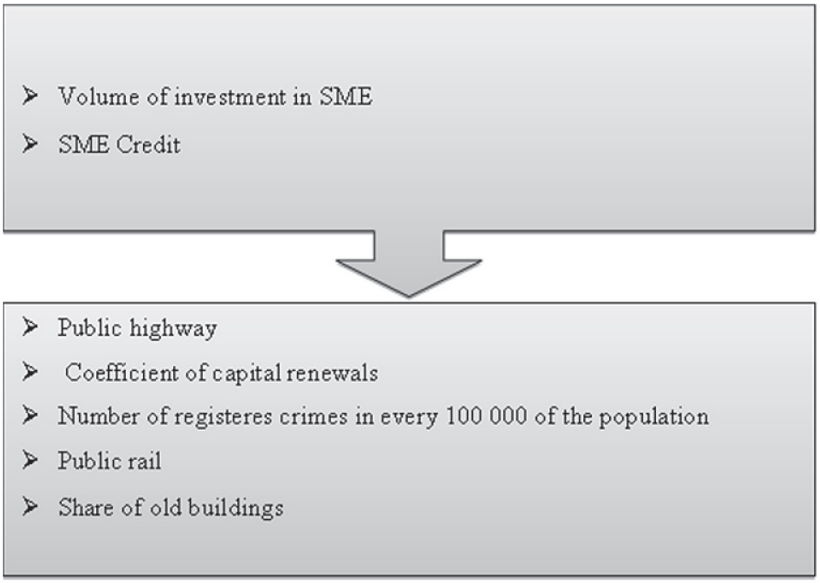

Figure 7. System of inputs and outputs that characterize entrepreneurial activity.

Being a roadmap for reforming Russia's social and economic spheres the Strategy 2020 should be the guideline for our Sustainable Development Investment Ranking, that is why we created SME index (Figure 7).

INNOVATIVE DEVELOPMENT OF RUSSIA

Russian authorities presented an exhaustive list of targeted key indicators within the context of Strategy for Innovative Development of the Russian Federation

Table 2. Innovative indicators tracking and targeting table.

Key Indicators targeted	Years		
Performance	**2010**	**2016**	**2020**
Education coverage in 5–14 y.o. group, %	94	98	100
Average teacher salary in% to country's average wage	65	80	100
Share of involved in lifetime learning process in 25–64 y.o. group, %	25	40	55
Number of patent applications per 10000 inhabitants	2	3	4
Number of innovative industrial technologies created	854	1500	2500
Innovation expenses share in GDP, %	1,4	2	2,5
Share of cutting edge hi-tech equipment not more than 8 y.o. in overall amount of R&D equipment, %	45	65	85
Share of innovative goods in services in overall goods exported, %	7	12	15
Amount of nanotechnology-related goods and services, bn euro	3	8,7	15
Share of companies employing technology innovations, %	8	15	25
Amount of innovative SMEs, formed as spin-offs from universities and public research organizations	600	2000	4000
Number of working in R&D per 10000 employed	111		
Average age of a researcher	49	45	40
Share of governmental expenses in R&D, %	65	50	35
Russia's share in overall world amount of scientific publications, % (acc. to Web of Science)	2,5	4	5
Place of Russia in information society development world ratings			18
Share of organizations and companies with broadband internet access, %	48	85	95

Key Indicators targeted	Years		
Share of companies and organizations with own websites, %	29	75	80
Share of households with internet access, %	26	75	90
Share of population utilizing internet to access governmental services, %	10	50	60
Financials, % of GDP	**2010**	**2012**	**2020**
Internal expenditures for R&D	1,3	1,5	2,4
Governmental expenditures for non-military R&D	0,88	0,9	1,1
Internal expenditures for education	4,8	5,6	7,0
State expenditures for education	4,0		6,0
Financials, bn euro	**2010**	**2012**	**2020**
Governmental university funding	0,4	0,4	0,6
Funding to attract international level scientists	0,08	0,1	0,25
State funding to applied research and IPR commercialization	0,7	1,8	3,6
State funding to basic research	0,5	2,9	3,9
State funding to innovation infrastructure development (incl. Skolkovo)	0,5	0,6	1,5

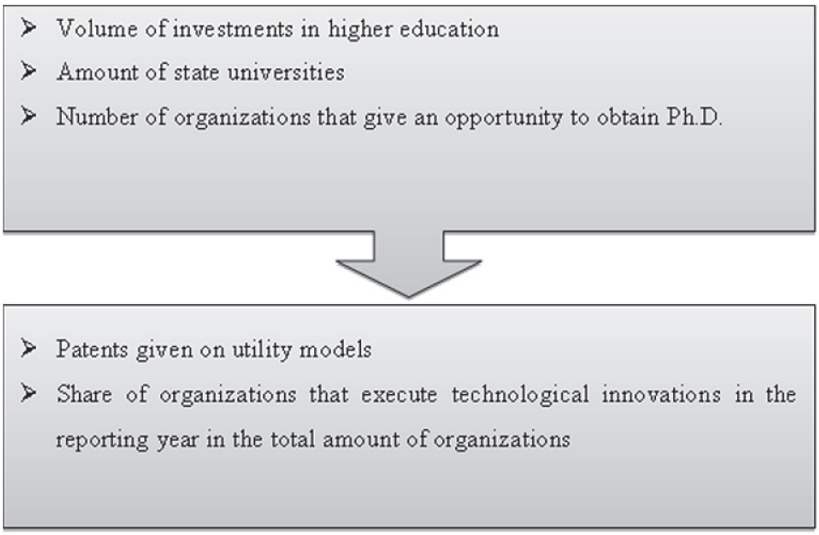

Figure 8. System of inputs and outputs that compute level of innovations.

2020, which provides long-term development milestones for the participants of the innovation process, gives guidelines on the investment policy within the basic and applied sciences and commercialization sectors (Table 2).

To follow the Innovative Strategy 2020 we designed model of innovative efficiency as well (Figure 8).

As a result we selected top 10 regions for each of two rankings that are created in accordance with country's strategic priorities (Figure 9), in which we recommend to invest for SD purposes: number of DMUs has resulted as efficient in DEA-CRS model. The initial data was taken for the year 2013, but for monitoring purposes it can be updated each year as the model is universal and does not require any script changes to be done, which is very convenient.

DISCUSSION AND CONCLUSIONS

In accordance with the conducted analysis Altai Republic received the highest efficiency score out of all regions for innovative activities, and this result coincides with the conclusions to which we arrive if we study publicly available information about this region: it is a member of innovation regions association, and some innovative clusters are already located there.

Jewish Autonomous Region shows the highest entrepreneurial efficiency but, despite that fact, according to the latest news the value of investments into the SME of the region has decreased significantly. If investors knew about DEA ranking for sustainable investing purposes, they could use that opportunity and get maximum return through proper investment allocation.

Figure 9. Top10 regions in terms of sustainability.

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