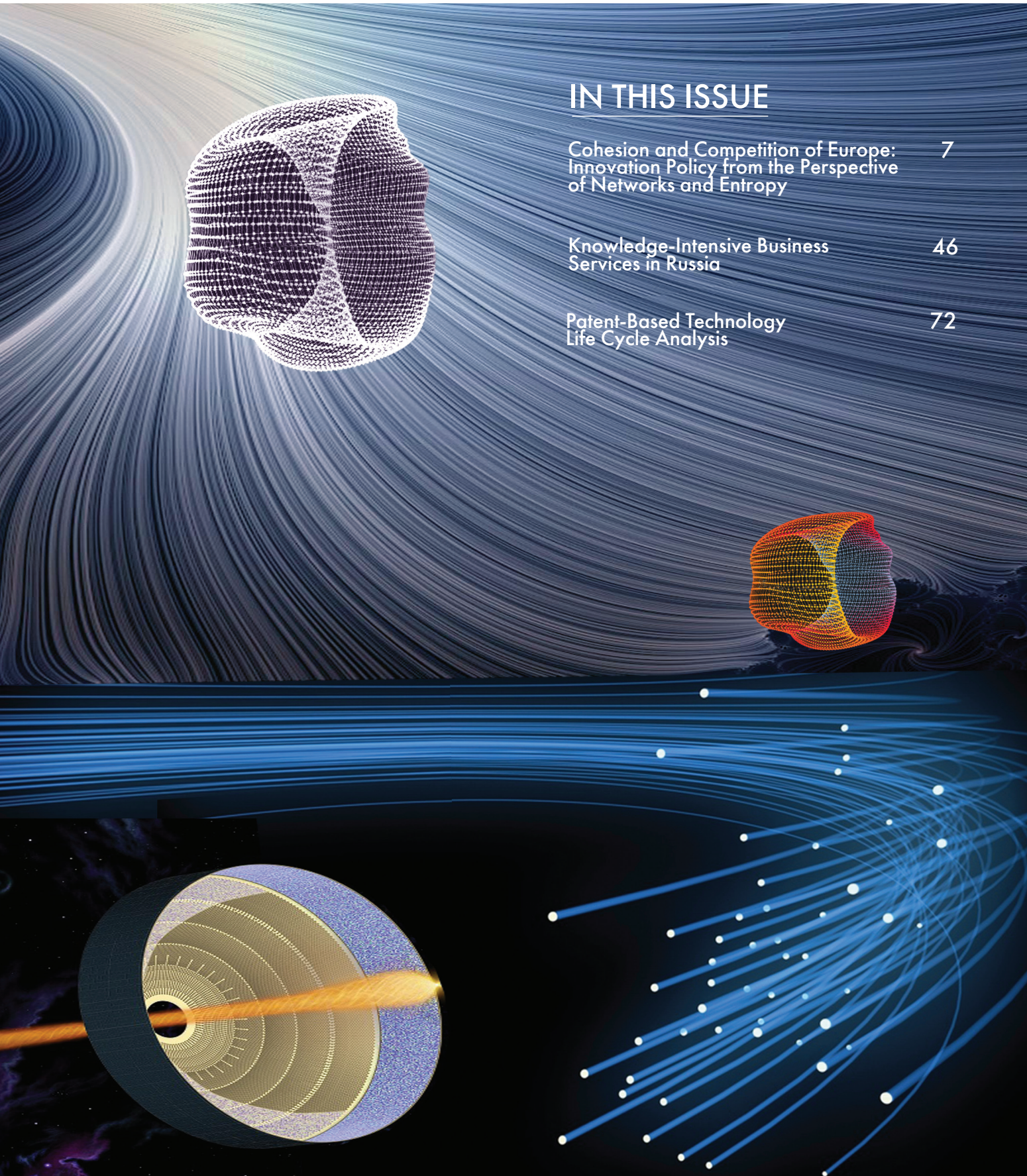
FORESIGHT AND STI GOVERNANCE

JOURNAL OF THE NATIONAL RESEARCH UNIVERSITY HIGHER SCHOOL OF ECONOMICS

ISSN 1995-459X
eISSN 2312-9972

2016
Vol.10 No 4



IN THIS ISSUE

FORESIGHT AND STI GOVERNANCE

National Research University
Higher School of Economics

Institute for Statistical Studies
and Economics of Knowledge

Address:
National Research University Higher School of Economics
20, Myasnitskaya str., Moscow, 101000, Russia
Tel: +7 (495) 621-40-38
E-mail: foresight-journal@hse.ru

http://foresight-journal.hse.ru/en/

Periodicity — quarterly

ISSN 1995-459X
eISSN 2312-9972

Publisher:
National Research University
Higher School of Economics

ABOUT THE JOURNAL

Foresight and STI Governance (formerly Foresight-Russia) — a research journal established by the National Research University Higher School of Economics (HSE) and administered by the HSE Institute for Statistical Studies and Economics of Knowledge (ISSEK), located in Moscow, Russia. The mission of the journal is to support the creation of Foresight culture through dissemination of the best national and international practices of future-oriented innovation development. It also provides a framework for discussing S&T trends and policies.

TOPICAL COVERAGE:

- Foresight methodologies
- Results of Foresight studies
- Long-term priorities for social, economic and S&T development
- S&T and innovation trends and indicators
- S&T and innovation policies
- Strategic programmes of innovation development at national, regional, sectoral and corporate levels
- State-of-the-art methods and best practices of S&T analysis and Foresight.

TARGET AUDIENCE:

Research scholars, university professors, policy-makers, businessmen, expert community, post-graduates, undergraduates and others who are interested in S&T and innovation analyses, Foresight and policy issues.

The topical coverage of the journal makes it a unique Russian language title in its field. Foresight and STI Governance is published quarterly and distributed in Russia and abroad.

INDEXING AND ABSTRACTING

SCOPUS™

EBSCO

RUSSIAN SCIENCE CITATION INDEX
WEB OF SCIENCE

eLIBRARY.RU

RePEc

ВИНИТИ

ULRICHSWEB™
GLOBAL SERIALS DIRECTORY

SSRN
tomorrow's research today

NEW JOUR
Electronic Journals & Newsletters

Journal's rankings in
E-Library.RU Citation Index
(impact factor for 2015)

1st — Studies of Science
1st — Management

NOTES FOR AUTHORS

Before submitting your article, please prepare your manuscript using the following guidelines:

Articles should be topical and original, should outline tasks (issues), describe the key results of the author's research and his/her conclusions;

Manuscripts are to be submitted via e-mail: foresight-journal@hse.ru

Format

All files should be submitted as a Word document.
The text should be in Times New Roman 14 pt, 1.5 spaced and fit to the width, all margins should be 20 mm.

Article Length

Articles should be between 20000 and 60000 characters (incl. spaces). Optimal size is 40 000 characters.

Article Title

To be submitted in native language and English. A title of not more than eight words should be provided.

Author Details (in English and native language)

Details should be supplied on the Article Title Page, including:

- Full name of each author
- Position, rank, academic degree
- Affiliation of each author, at the time the research was completed
- Full postal address of the affiliation
- E-mail address of each author

Abstract

An abstract should be: informative (no general words), original, relevant (reflects your paper's key content and research findings); structured (follows the logics of the results presented in the paper), concise (between 250 and 300 words).

- Purpose (mandatory)
- Design/methodology/approach (mandatory)
- Findings (mandatory)
- Research limitations/implications (if applicable)
- Practical implications (if applicable)
- Social implications (if applicable)
- Originality/value (mandatory)

It is appropriate to describe the research methods/methodology if they are original or of interest for this particular research. For papers concerned with experimental work describe your data sources and data processing techniques.

Describe your results as precisely and informatively as possible. Include your key theoretical and experimental results, factual information, and any interconnections and patterns shown. Give special priority in your abstract to new results and data with long-term impact, important discoveries and verified findings that contradict previous theories as well as data that you think have practical value.

Conclusions could be associated with recommendations, estimates, suggestions, and hypotheses described in the paper.

Information contained in the title should not be dublicated in the abstract . Try to avoid unnecessary introductory phrases (e.g. 'the author of the paper considers…').

Use language typical of research and technical documents to compile your abstract and avoid complex grammatical constructions.

The text of the abstract should include the key words of the paper.

Keywords

Please provide up to 10 keywords on the Article Title Page, which encapsulate the principal topics of the paper.

Headings

Headings must be concise, with a clear indication of the distinction between the hierarchy of headings.

Figures

All figures should be of high quality, legible, and numbered consecutively with arabic numerals. All figures (charts, diagrams, line drawings, web pages/screenshots, and photographic images) should be submitted in electronic form preferably in color as separate files, that match the following parameters:

Photo images – JPEG or TIFF format. Minimum resolution 300 dpi, image size not less than 1000x1000 pix

Charts, diagrams, line drawings- EXCEL or EPS format

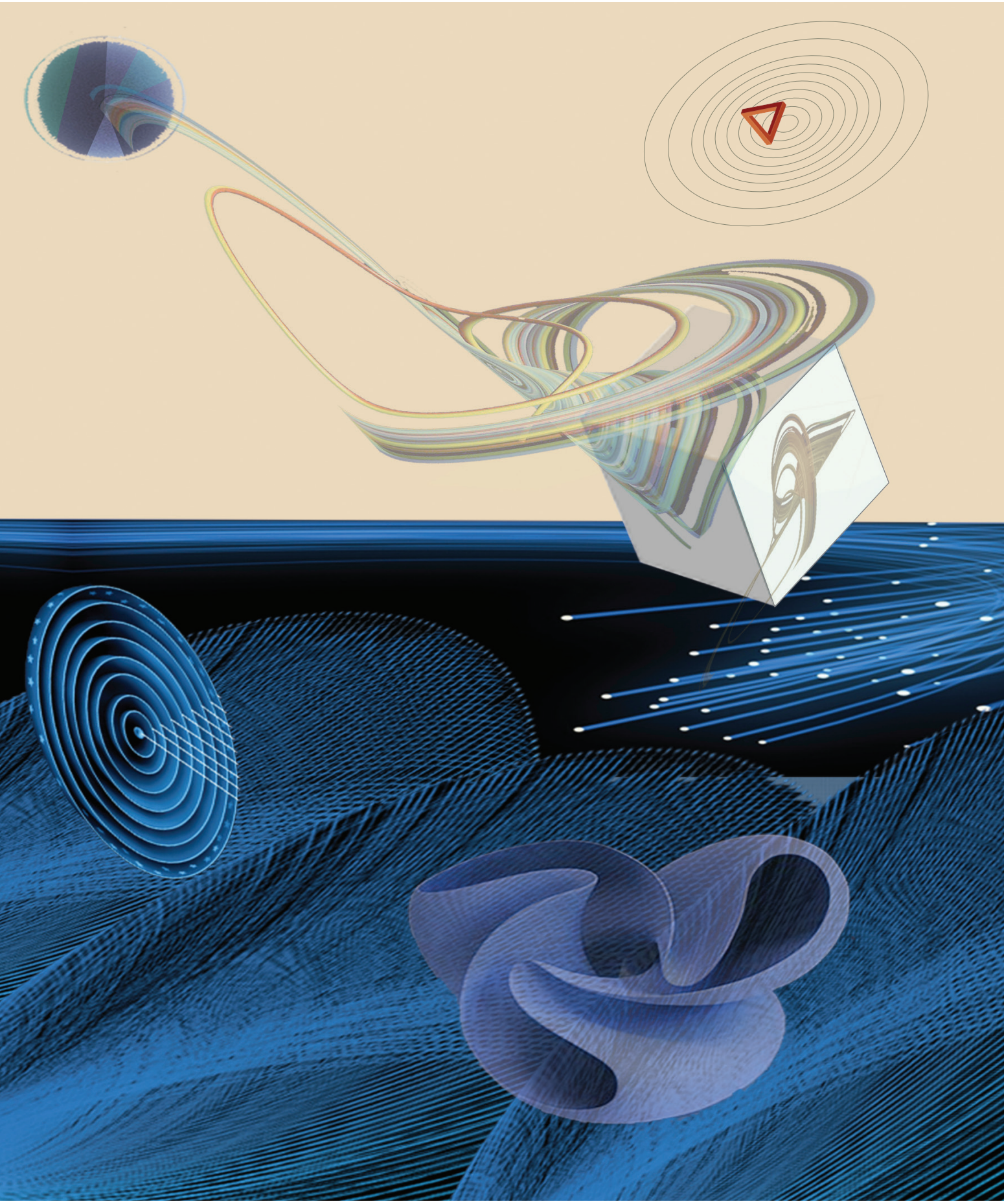
References

References to other publications must be in Harvard style and carefully checked for completeness, accuracy and consistency.

CONTENTS

Vol. 10 No 4 2016

STRATEGIES



Cohesion and Competition of Europe: Innovation Policy from the Perspective of Networks and Entropy

Umut Yılmaz Çetinkaya [a]
Expert, uycetinkaya@gmail.com.

Erkan Erdil [b]
Professor, erdil@metu.edu.tr.

[a] YNR Consulting, Ugur Mumcu Cad. 55, 3 06700 G.O.P., Cankaya, Ankara, Turkey.

[b] Department of Economics, Middle East Technical University (Universiteler Mahallesi), 1 Dumlupinar Bulvari, 06800 Cankaya-Ankara, Turkey.

Abstract

This study analyzes the innovation performance of the European Union in the context of the European Research Area (ERA). Literature related to the Systems of Innovation, network studies, Framework Programs and the European Research Area will be used to establish a theoretical framework for policy analysis. It forms a database from three different resources to establish a European Research and Innovation Network, which appears as a result of policy and program implementation at the European level. The evaluation of the European Union's innovation performance is discussed for developing policy recommendations, which are derived from theoretical arguments as well as analytical studies, based on network analysis and the notion of entropy. The implementation of a relatively simple rule by the European Commission, in addition to policies focusing on the development of countries' diversity and absorptive capacity, which are structural holes, may make an important contribution to improving cohesion and competition within the European Research Area, as well innovation in the European Union.

Keywords: systems of innovation; networks; Innovation Union; entropy; STI Policy.

DOI: 10.17323/1995-459X.2016.4.7.24.

Citation: Çetinkaya U.Y., Erdil E. (2016) Cohesion and Competition of Europe: Innovation Policy from the Perspective of Networks and Entropy. *Foresight and STI Governance*, vol. 10, no 4, pp. 7–24. DOI: 10.17323/1995-459X.2016.4.7.24.

With regards to innovation performance, Europe is falling behind its main competitors, the fact that its innovation performance is not at the desired level is a topic that has been extensively discussed and studied in the relevant literature [European Commission, 1995; 1997; *Caracostas, Muldur,* 1998; *Fagerberg et al.,* 1999; *Malerba,* 2004; *Asheim et al.,* 2011; *Camagni, Capello,* 2013; etc.]. Targets set to increase the innovation performance of Europe or improve its competitiveness are expressed more often than not in the implementation of programs, such as framework programs (FP). The goal of these programs is to increase the potential and opportunities of EU members deemed innovative and competitive, as well as rapidly develop these characteristics in less innovative and competitive members. Many academic studies, some of which are mentioned above, were carried out on the measures implemented to fulfill this task, and it seems that there are many more studies to come. Accordingly, rather than repetitive research, studies on specific topics with an interdisciplinary approach in the area could make important contributions to increasing innovation in Europe.

This study focuses innovation performance of the European Union (EU). In order to evaluate and provide policy recommendations for improving the EU's innovation performance, various well-founded academic arguments and EU projects are evaluated. The basic academic framework of this study is based on the Systems of Innovation (SIs) approach. Not only innovation indicators, but also the network, which the authors designate as the European Research and Innovation Network in this study, is obtained from the practical projects implemented by the European Commission (EC). The database for innovative performance and network analysis is constructed using the data from the Innovation Union Scoreboard (IUS), Regional Innovation Scoreboard (RIS), and CORDIS. The study of innovation and network relations is also supported by the European Research Area (ERA), another EC major policy. The results of this analysis became the inputs for policy recommendations, which are based on an academic discussion of the systems of innovation (SI) for increasing innovation performance of the European Union.

The following two sections will determine the paper's theoretical framework. We will discuss the relationships between SIs, networks and the Innovation Union. Then we will introduce how the concept of entropy, specifically Boltzmann's and Prigogine's views, will be used in this article. After that, data and methodological foundation for the establishing and analyzing the European Research and Innovation Network will be explained. In short, the followings will be analyzed: the network containing the nodes formed by countries and regions (NUTS-2); the relationship between the innovation performance of countries and regions with a network structure will be discussed; the ERA will be examined in order to observe whether it has been on the intended track or not; network analysis and entropy calculations will be used to analyze the innovation performance of the EU; finally policy recommendations to increase innovation performance of the European Union will be presented.

The aforementioned discussions will yield two policy recommendations and tools to improve the innovation performance of the European Union. A key recommendation is that a simple rule be established, stating that requirements be set by the European Commission in the project application process for the inclusion of a node with a low eigenvector value in the project consortium may help increase the cohesion and innovation performance of Europe. In terms of the EU's competitiveness, in light of the ability of important gatekeepers to connect with global networks but the system's low absorptive capacity in terms of benefiting from those competitors, it will be proposed that policymakers of the EU focus more on the development of diversity and absorptive capacity of nodes, structural holes, in order to benefit more from the European Research and Innovation Network in increasing the innovation performance of the EU.

Systems of Innovation, Networks and the Innovation Union

Scholars in the field of innovation studies focus on the impact of network structures on the production of information and knowledge, as well as their transformation into new products and services and processes [*Powell, Grodal,* 2005]. Andersen [*Andersen,* 1996; 1997] focuses on graph theory and simulation models within the SIs framework. Some researchers examined the geographical distribution of the innovation network and the relationship of geography within the network [*Becattini,* 1990; *Camagni,* 1991; *Cooke,* 1996; *Marshall,* 1961; *Piore, Sabel,* 1986; *Storper,* 1997; *Asheim, Gertler,* 2005]; while others studied the structural characteristics of the network [*Das, Teng,* 2002]; or the governance of the network structure [*Pietrobelli, Rabellotti,* 2009; *Gereffi et al.,* 2005; *Sturgeon et al.,* 2008]; and others were concerned with cognitive distance between the participants in a network [*Gereffi et al.,* 2005]; and the strength of the ties between said participants [*Granovetter,* 1973], the production and transfer of knowledge and information and their impact on the creation and development of innovations [*Nooteboom,* 2004]. Many authors analyzed the impact of inter-organizational networks on innovation [*DeBresson, Amesse,* 1991; *Freeman,* 1991; *Hagedoorn,* 1990, 1993; *Nooteboom,* 2004; *Powell et al.,* 1996; *Soh, Roberts,* 2003].

As evident from the abundance of the studies in the field over the course of the last decade, the role of networks in science, technology and innovation (STI) policies have been increasingly discussed. The key idea behind this discussion is the focus on interactions among various actors as the most important factor for developments in STI. In other words, instead of focusing on a single actor and its behaviors, policymakers have started to focus on the importance of cooperation, collaboration and communication among numerous actors. In fact, the expectations of policymakers concerning network analysis were already articulated in notable works [*Freeman,* 1991; *Lundvall,* 1992; *Metcalfe,* 1995; *Foray, Lundvall,* 1996], which are considered the building blocks for the SIs approach.

Innovation processes involve the generation and application of knowledge, where the success or failure of any SIs depends mainly on how the knowledge of actors is integrated via networks [*Foray,* 2006] and on the structure of the SIs. With these networks, actors not only achieve dispersed specific and diversified knowledge, but also obtain more opportunities to increase their internal knowledge [*Kogut, Zander*, 1992; *Powell et al.,* 1996]. The reason for this, Allen [*Allen,* 2001] said is that diversity among actors in a system increases the effectiveness of the system. It is diversity that enables actors in SIs to evaluate and respond to the demands not only of the market, but also the system itself. If new knowledge is introduced into the system, regardless of whether it is produced within the system or not, the actors of the system's 'cognitive distance' [*Nooteboom,* 1992, 2005] start to become similar and the system encounters inertia or lock-in.

The impact and structure of networks on the production and diffusion, dissemination and distribution of knowledge resulting from actors and their interactions, began to gain recognition in the literature in the 2000s [*Malerba et al.,* 2007]. For instance, Latora & Marchiori [*Latora, Marchiori,* 2004] state that "the network structure can be as important as the nonlinear interactions between elements, and… structural properties of the network can be of fundamental importance for understanding the dynamics of the system". Networks have an important role to play in maximizing the advantages obtained from the creation and diversification of knowledge and the intensification of cooperation in the SIs approach.

Regarding the negative factors, most intervention policies of governing bodies are not developed within the framework of the network approach [*Hyötyläinen,* 2000]. At the same time, research has shown little interest in policy questions related with networks, though these policies have potential to be important components in the development of appropriate policies. Among others, two reasons may be stated as to why the relationship between network analysis and policy are overlooked by researchers. First is the lack of appropriate data and the second is, as stated by Carlsson [*Carlsson,* 2000] and Flap et al. [*Flap et al.,* 1998]: the network approach is subject to the explanatory power.

On a positive note, network analysis has started to become an important component for policy development and implementation as an increasing number of actors, blurred boundaries and roles among actors, dispersed (especially tacit) knowledge, deepening interdependencies, etc., make network analysis techniques a good option for a policy development and implementation. That is, networks "are an important component of national systems of innovation. An important function of science and technology policy is to strengthen existing innovation-related networks and to help build networks in areas where they are lacking" [OECD, 1992]. Therefore, policy analysis "is finding out what governments do, why they do it, and what differences it makes" [*Dye,* 2012]; network analysis enables policymakers to study the structure and corresponding configurations. For instance, Peterson [*Peterson,* 2003] states that "policy network analysis is never more powerful as an analytical tool than when it is deployed at the EU level' and 'few … would deny that governance by networks is an essential feature of the EU". In this sense, the reduction of the failures stemming from the network, or use of a network to increase competitiveness and innovation performance as much as possible, necessitates the development and implementation of appropriate policies.

In short, following the termination of the first framework program (FP1) in 1987, the second (1987–1991) and third (1990–1994) framework programs (FPs) were implemented, demonstrating the characteristics of a technology push model. At around the same time, the systems of innovation view started to pervade policy advisory circles [*Soete, Arundel,* 1993]. Indeed, this approach was reflected in FP4 (1994–1998), where particular support was provided for such areas as the diffusion of technology, the integration of SMEs, training, and mobility. Employing a user-oriented approach, FP5 (1998–2002) was shaped specifically for solving societal problems and socioeconomic challenges, as well as increasing research opportunities and the potential for cutting-edge technologies. In the last two decades, the role of innovation in the context of European development has grown in importance [European Commission, 2000, 2006, etc.]. FP6 (2002–2006) may be regarded as an important break with the previous FPs. It focused on science and technological advancements and, a technology push in a similar way to FP2 and FP3. However FP6 introduced new instruments (integrated projects and networks of excellence) and encouraged a rise in the number of partners in the projects to obtain critical mass. Moreover, it also endeavored to facilitate the ERA in overcoming underinvestment in R&D, fragmentation of research, and coordination problems at different levels.

FP7 was aimed at strengthening the scientific and technological base of European industry as well as at encouraging its international competitiveness, while promoting research that supports EU policies. Therefore, starting from FP6, and particularly in FP7, not only the number of participants in FP projects' network increased; but also, especially, after the articulation of the European Research Area (ERA) in 2000, framework programs became one of the major tools for European research and innovation policymaking. By leveraging sufficient additional funding for research, development and innovation, it is expected that FP8 (Horizon 2020) will tangibly contribute to building and developing an economy based on knowledge and innovation across the entire EU. In this way, it will not only support the Europe 2020 strategy and other policies to be implemented, but it will also contribute to the targets of the ERA, which were enumerated as follows: "[t]he Innovation Union must involve all regions. The financial crisis is having a disproportionate impact on some less performing regions and hence risks undermining recent convergence. Europe must avoid an 'innovation divide' between the strongest innovating regions [countries] and the others" [European Commission, 2010a].

When the explanations up to this point are analyzed at the country level, it is not difficult to say that although several rankings place EU member states such as Sweden, Finland, Germany, Denmark, and UK among the world leaders in terms of innovation performance, the rest of the EU member states remain mid-range, and the aggregate performance of the EU27 lags behind that of US and Japan, despite their significant prevalence over BRICS countries. In addition, China and India are quickly catching up with the former, displaying a particularly rapid rate of relative improvement; where, if China maintains its rate of improvement over the last five years, the performance gap with the EU27 will diminish in the short term [*Archibugi et al.,* 2009]. Moreover, other Asian countries, such as South Korea and Singapore, which recently came to be considered the new innovation hot-spots, are also on their way forward. The Innovation Union Scoreboard 2013 depicts South Korea as being beside the US and Japan and having a performance lead over the EU27.

Therefore, Europe began to lose its relative headway in the production of knowledge, not necessarily because Europe does less, but rather because the others do more. A distribution pattern similar to these countries can also be observed among regions (as shown in RIS 2012) for which, due to intensified global competition, it is necessary to implement 'smart specialization' approaches to strengthen the existing 'hot spots' of innovation, which would give regions the edge needed to determine niche development strategies that would allow them to meet local needs and survive this evolutionary phase of knowledge-based societies [*Foray, van Ark,* 2007; European Commission, 2010b]. By and large, Europe's underachievement, as demonstrated in the RIS 2012 and IUS 2013 data, indicates not only the low performance in growth and jobs, but also the impediments hindering the completion of the ERA.

Entropy

As stated by Boltzmann [*Boltzmann,* 1974], the macrostate of a gas is determined by temperature, inner energy, pressure and volume, while the microstate of a system is portrayed by momentum (*px*, *py, pz*) and spatial coordinates (*x,y,z*) of each point comprising the macrostate. There are many microstates, and entropy measures the number of macrostates (or conditions) that can be fulfilled. Put differently, when entropy is 0 (zero), there is only one microstate, implying full predictability, which means there is no possibility of another microstate. On the other hand, when the entropy is higher, there are more possibilities for microstates, bringing a lower degree of predictability. From the point of view of SIs, this situation can be characterized as the existence of more possibilities for microstates, indicating higher entropy, which means that entities are capable of innovating. This can also be depicted in Boltzmann's entropy formula, a probability equation relating the entropy S of an ideal gas to the quantity W, which is the number of microstates corresponding to a given macrostate. Provided below, Boltzmann's formula shows the relationship between entropy and the number of ways atoms or molecules of a thermodynamic system can be arranged:

$$S = k \log W \text{ or } S = -\Sigma_i w_i \ln(w_i) \quad (1)$$

For instance, we assume that there are events i (i = 1, 2, 3, …, n) occurring with probabilities w_i, $\Sigma_i w_i = 1$ and $0 \leq w_i \leq 1$.

If an event is realized with absolute certainty $w_i=1$, we obtain $S=0$ (ln1=0). Accordingly, probabilities of w_i can signify the capability of genes to change or adapt a system; or the emergence of an innovation within a system. Therefore, entropy is lower when probability is less distributed; or entropy is higher when probability is distributed equally. As a result, the lowest entropy means either maximum order (all microstates in one macrostate) or maximum certainty of a single outcome. The highest entropy (equal distributions of microstates and all macrostates) means either maximum uncertainty regarding the outcome or the greatest opportunity for innovation.

In the concept of entropy, it is argued that we cannot see any exchanges in a closed system through the boundaries of the system due to the lack of gradients, and consequently, the system reaches equilibrium (maximum entropy), a process which is irreversible [*Prigogine, Stengers,* 1984]. That is, the ability of a system to perform work is restricted; as such, the entropy of an isolated system never decreases due to the second law of thermodynamics, resulting in a lock-in or entropic death [*Saviotti,* 1988]. On the other hand, Prigogine explained that sum of entropy is made up of imported entropy and entropy produced in open systems. In 'dissipative structures', developed by Prigogine [*Prigogine,* 1976] and other members of the Brussels school as open systems, entropy disappears from the system, which increases the organization of the system at the expense of increased disorder in its environment. Therefore, dissipative structures, demonstrating the ability to self-organize by exporting entropy via fluctuations and working under conditions far from equilibrium, denote a system which is highly organized but always in transition and dependent on the flux of inputs.

Data and Methodology

Obviously, the precision of any analytical study is determined by the accuracy of the presented data. For this purpose, data from Innovation Union Scoreboard (IUS), Regional Innovation Scoreboard (RIS), and CORDIS are prepared for analysis. The database constructed using these three resources permitted an analysis to be used for the development of policy recommendations in the following sections. Furthermore, the two main approaches to entropy, by Boltzmann and Prigogine, are used for analyzing the relationships between network structure and innovation performance.

Data

CORDIS "is the European Commission's primary public repository and portal for disseminating information on all EU-funded research projects and their results in the broadest sense"[1]. IUS and RIS databases will be used to set up a relationship between the network established by CORDIS participants and the notion of innovation. The IUS provides the innovative values for many Europe countries, as well as relative innovative values for some important partner countries outside the EU. The RIS, on the other hand, provides the innovative values of many European regions (NUTS-2). Combining these three resources, a database was created for the article, allowing us to focus on and develop policy recommendations for increasing the innovation performance of the European Union from the perspective of network analysis.

Inconsistencies in the raw CORDIS data obtained from the European Commission were removed from the database in order to use it in network analysis. As such, not all information concerning the projects and participants could be acquired from the raw database; some projects lacked budget information, while the names of the participants, or project timeframes were missing in others, and so on. For example, while the raw database contained 40,097 participants and 12,386 projects in FP4, a cross-check of the start and end dates of projects in FP4 yielded 41,988 participants and 12,815 projects in FP4. When data was further specified based on two criteria (program name and timeframe), 36,320 participants and 11,108 projects remained as the inputs for the FP4 network.

Method

A network, modeled on three stages, called the European Research and Innovation Network, was formed using the database established for this article in order to analyze and discuss the innovation performance of Europe and the ERA. The first stage, which will be called an 'open network', is modeled at the country level, and includes all nodes, which are participants of the FPs (both European and non-European). The second stage is a network, called a 'closed network' comprised of the countries, which are mentioned in the IUS 2013 document as nodes. Finally, a network called the 'regional network' is formed for NUTS-2 level regions.

After modeling the European Research and Innovation Network at three stages, standard measurement techniques were applied to inspect network characteristics such as path length, clustering coefficients, and so on. They will then be employed to explore this network in terms of innovation performance and in order to analyze the ERA in terms of the cohesion and competitiveness of Europe. For an exploration of the relationships between characteristics of network and innovativeness of countries and regions (NUTS-2), which are also nodes in the European Research and Innovation Network, innovation performance of countries and regions obtained from IUS 2013 and RIS 2012 respectively, are correlated with network values of the past six years.

Finally, the study uses from the notion of entropy in analyzing the innovation performance of Europe with an approach that greatly diverges from the general usage and interpretation of the concept. Many studies focus on network entropy from the point of distribution of links between nodes. For instance, Mowshowitz [*Mowshowitz,* 1968] developed an approach based on graph invariants such as vertex degrees, distances, etc., and on an equivalence criterion for information-theoretic measures. Nishikawa et al. [*Nishikawa et al.,* 2003] quantified the heterogeneity of complex networks using the standard deviation of degree. Solé & Valverde [*Solé, Valverde,* 2004] proposed using entropy of remaining degree distribution for heterogeneity, which is also discussed by Bar-Yam [*Bar-Yam,* 2003]. Wang et al. [*Wang et al.,* 2006] suggested using entropy of degree distribution to measure the heterogeneity of complex networks. Wu et al. [*Wu et al.,* 2010] proposed that entropy of degree sequence be used a measure of the heterogeneity of complex networks.

Basically, if a network is comprised of telephones and lines, or web pages and links, where there are stable links among nodes, it may be useful to consider the role of links in terms of entropy analyses. As observed in these network examples, if there are concrete nodes and links among constituents of networks, it is important to make probability calculations in line with Shannon's formula [*Shannon*, 1948] to find out the entropy of a network. On the other hand, when we talk about innovation, we cannot see concrete nodes and links among the components of a network. In this sense, one of the unique contributions of this article is that the characteristics of European Research and Innovation Network will be linked with the innovation performance of the countries from Boltzmann's and Prigogine's views on entropy. In short, a simple rule is set forth based on Boltzman's view, and based on Prigogine's view, the innovation performance of Europe vis-à-vis its competitors will be discussed in order to produce policy recommendations for increasing the innovation performance of Europe and the improvement of the ERA's performance.

Analysis and Results

Network Structure

Since FP1, the European Union has been promoting and supporting research and development collaborations by bringing together organizations in related fields to turn ideas into new products,

[1] Cited from: http://cordis.europa.eu/guidance/home_en.html, accessed 19.02.2016.

services, and solutions in order to improve competitiveness. This support is based on the basic reason that knowledge is not solely the most valuable resource and the source of competitive advantage [*Kogut, Zander,* 1992], but also is produced by combining previously unconnected knowledge, generating new knowledge and by exchanging knowledge among actors. In short, knowledge production is a social process and it can be produced through the interactions of actors rather than as a creative act of a single individual or organization [*Hakansson,* 1989; *von Hippel,* 1988]. Such assumptions led the researchers to analyze networks in order to understand the role of network structure in facilitating exchanges, combinations, and the creation of knowledge [*Kogut, Zander,* 1992; *Tsai,* 2002; *Tsai, Ghoshal,* 1998).

A number of studies analyzed the networks established under the FPs. Roediger-Schluga & Barber [*Roediger-Schluga, Barber,* 2006] focused on the structure of R&D collaboration networks in the first five FPs, and found characteristics of complex networks. Breschi & Cusmano [*Breschi, Cusmano,* 2002] dwell on the R&D network established during FP3 and the first part of FP4. Investigating the network with the help of social network analysis and graph theory, they found the existence of small-world and scale-free characteristics. Protogerou et al. [*Protogerou et al.,* 2010] concentrated on R&D collaboration networks in the field of Information Society Technologies (IST) during FP4, FP5 and FP6. They found the existence of small-world structure as well as preferential attachment. All these studies focus on the projects and participants as nodes to determine the network structure. However, in this study, countries and regions (NUTS-2) will be considered the nodes upon which the network will be established, the links will be the R&D projects.

Based on the reviewed literature, relationships between the number of participants, average timeframes, cost and funding of projects are also investigated. Correlation coefficients calculated among those that are shown in Table 1. As per the results, the rise in the number of participants have higher positive effects on the number of projects, as well as average duration, cost and funding. Furthermore, the increase in the number of partners in a project is in line with the recommendations made by evaluation studies of the FPs, highlighting the importance of simplifying administrative procedures.

The results obtained at the regional (NUTS-2) and country level (open network) networks are depicted in Table 2 and Table 3, respectively. An analysis of the data shows that starting from FP1, most regions or countries entered the network by connecting to central regions or countries. In both types of networks we see an increase in average betweenness centrality and a fall in average closeness centrality values, which can be accepted as an indication of increasing social capital [*Borgatti et al.,* 1998]. The notion of path dependency can help explain this situation: successful project management capabilities and experience acquired in the past allow those actors to become coordinators or participants in future projects and helps them reduce the marginal cost of each additional project. Furthermore, the acquired visibility or reputation makes them attractive partners for newcomers demonstrating preferential attachment. Finally, experience in past projects may also decrease the transaction cost among partners in subsequent partnerships, which has the potential to augment mutual trust and understanding and therefore improve collaboration.

As a result, the shared characteristics of both networks such as scale-free degree distributions, relatively low average path length, high clustering, low assortativity values, etc., throughout the FPs in both networks, may be accepted as unchanging characteristics of network formation mechanisms, despite changes in FP rules. All networks show small-world characteristics, have relatively high clustering coefficients and short path lengths, meaning the structure of the network supports knowledge creation and knowledge diffusion [*Cowan,* 2004]. An analysis of participants in FPs reveals that same organizations participate repeatedly in FPs and continue to cooperate with each other after the conclusion of the project. Furthermore, increasing clustering coefficients in FPs in both networks demonstrates that the creation and integration of the ERA has been in line with the intended purpose.

Network Structure and Innovativeness

As discussed above, the stimulation of innovation is one key concern of policymakers at all levels. Correspondingly, the development and implementation of network policies may be regarded as a tool to overcome network failures [*Nooteboom, Stam,* 2008]. In other words, connecting actors through links to provide an exchange of information, knowledge, etc. can be seen as an appropriate policy within the framework of the systems of innovation approach [*Carlsson, Jacobsson,* 1997]. Therefore, in addition to

Table 1. **Correlation Coefficient among Number of Participants, Average Duration, Cost, and Funding**

	Number of Participants	Number of Projects	Average Duration of Projects	Average Cost of Projects	Average Funding of Projects
Number of Participants	1.00				
Number of Projects	0.74	1.00			
Average Duration of Projects	0.79	0.45	1.00		
Average Cost of Projects	0.82	0.36	0.55	1.00	
Average Funding of Projects	0.78	0.33	0.55	0.97	1.00

Source: calculated by the authors.

Table 2. **Network Characteristics (Regional Level)**

Graph Metric	FP1	FP2	FP3	FP4	FP5	FP6	FP7
Graph Type	Undirected						
Vertices	189	223	271	281	298	309	322
Unique Edges	1195	2166	3137	4230	5187	5359	5421
Edges With Duplicates	2487	11751	14472	33291	41352	44510	60877
Total Edges	3682	13917	17609	37521	46539	49869	66298
Self-Loops	218	878	833	1987	3746	2337	3572
Average Geodesic Distance	2.14	1.92	1.94	1.83	1.79	1.82	1.80
Graph Density	0.10	0.17	0.16	0.24	0.26	0.25	0.25
Assortativity (wh)	–0.011	–0.017	0.003	0.015	0.035	0.018	0.004
Average Degree	19.429	38.278	44.266	67.480	77.054	77.974	81.814
Average Clustering Coefficient	0.4690	0.6323	0.6322	0.6888	0.6850	0.6761	0.6801
Power Law	3.12	2.60	2.58	2.20	2.40	2.28	2.37
Average Betweenness Centrality	108.45	102.71	127.66	117.53	117.98	127.62	130.01
Average Closeness Centrality	0.0025	0.0024	0.0019	0.0020	0.0019	0.0018	0.0018

Source: calculated by the authors.

the networks explained in the previous section, a third type of the European Research and Innovation Network, a closed network was established with the countries listed in IUS 2013 and participated in the FPs. To assess the effect of project participation on innovation performance, the correlation values obtained between the number of projects and innovation performance values both at the country and NUTS-2 regional levels were calculated. According to correlation results, about half of the innovation performance of nodes (country and region) can be linked by the number of projects in which they participated.

Innovation performance and clustering values of countries in these three types of networks are correlated in order to analyze the relationships between innovation and clustering values of nodes (country or region). A negative correlation is found between innovation performance and clustering values at the regional and country levels (for instance, correlation coefficients between innovativeness values and clustering values in 2011 are -0.4266 with 00183 (*p* value); -0.6226 with 0.00008 (*p* value); and -0.43965 with 4.268 (*p* value) for closed, open and regional scale networks, respectively). Important gatekeepers at the country level in FP7 (Germany, France, Italy, and United Kingdom) are interested in identifying the countries filling structural holes and playing critical roles in bringing closed and open networks together. Then, the innovation performance value of countries and number of FP7 projects of countries are correlated with the important actors enumerated in IUS 2013 (Brazil, Canada, China, India, Japan, South Korea, Russia, the United States, and South Africa). According to the results, the average correlation coefficient is 0.4431 (for each year, *p* values are found lower than 0.01137). Based on above findings, it may be said that collaboration with important rivals is significant for increasing the innovation performance of Europe. Furthermore, with regards to the role of the most important gatekeepers (Germany, France, Italy and United Kingdom), it seems they are the main actors not only in terms of knowledge production, but also for knowledge exchange between closed and open networks.

Table 3. **Network Characteristics (Open Network)**

Graph Metric	FP1	FP2	FP3	FP4	FP5	FP6	FP7
Graph Type	Undirected						
Vertices	21	67	111	139	144	152	168
Unique Edges	21	96	177	339	316	416	437
Edges With Duplicates	3490	12830	20700	45013	51952	57237	74439
Total Edges	3511	12926	20877	45352	52268	57653	74876
Self-Loops	796	2297	3694	6899	7247	8158	11281
Average Geodesic Distance	1.56	2.22	2.17	1.99	2.01	1.98	2.00
Graph Density	0.44	0.10	0.07	0.10	0.10	0.12	0.11
Assortativity (wh)	–0.011	–0.037	–0.009	–0.049	–0.023	–0.022	–0.016
Average Degree	10.000	7.164	8.234	13.525	14.667	17.842	18.619
Average Clustering Coefficient	0.7862	0.6008	0.5987	0.7744	0.7755	0.7466	0.7616
Power Law	0.94	2.39	2.97	2.93	2.77	2.84	3.02
Average Betweenness Centrality	6.38	41.46	65.50	69.30	73.37	74.61	84.87
Average Closeness Centrality	0.0320	0.0069	0.0042	0.0037	0.0035	0.0034	0.0030

Source: calculated by the authors.

As stated above, starting from FP1, the average degree value of nodes increases; indicating that the capacity of countries is increasing in terms of maintaining links with others. The increase in average degree of nodes not only provides links between previously unconnected nodes, but may also bring about difficulties when finding appropriate links or ways to reach partners, information, knowledge, etc. For instance, studies in the field of supply networks [*Choi et al.,* 2001], and in the biotechnology sector [*Rycroft,* 2007], found out that increased connectivity was not linearly related with an increase in efficiency, which is measured by delivery time and product development time, respectively. However, it has been found that there is a positive correlation between innovation and the degree values of nodes in the three types of network (for instance, correlation coefficients between innovativeness values and degree values in 2011 are 0.4483 with 0.01 (p value); 0.5690 with 0.0005 (p value); and 0.6801 with 0.01 (p value) for closed, open and regional level networks, respectively).

As stated earlier, the rise in the number of project partners may be in line with recommendations from evaluation studies [Expert Group, 2010] that emphasize the significance of curtailing administrative procedures. On the other hand, this may potentially have a negative effect on project performance, as the increase in the number of partners in a project will probably decrease the probability of interactions among the partners and building trust becomes more difficult. For instance, Lundvall et al. [*Lundvall et al.,* 2002] argued that successful innovation is an outcome of interactive learning processes based upon close relationships between actors. Ruef [*Ruef,* 2002] and Powell et al. [*Powell et al.,* 1996] discussed the importance of the number of actors in enabling the combination of different information, knowledge, resources, etc. On the other hand, Tatikonda and Rosenthal [*Tatikonda, Rosenthal,* 2000] assert that there are negative effects stemming from project size on innovation, though they could not provide strong empirical evidence for their argument. Furthermore, the role of different actors in innovation is widely discussed [*Nooteboom,* 2000; *Ruef,* 2002, etc.]. In general, it is presumed that diverse partners bring the latest information, knowledge, and resources into the project, increasing the success of innovative activity. Therefore, correlations between average project size (number of participants) and innovative value between the years 2006–2012 were made in order to assess their relationships. As per the result (-0.6494), there is an inverse relationship between the project size and innovative value.

Moreover, the role of different types of actors in collaborative projects was also analyzed. Accordingly, between the years 2006–2012, the amount of cooperation by each country with others was calculated in order to analyze the notion of participant diversity in projects. Contrary to the inverse relationship between the project size and innovation performance value, a positive correlation was found between innovation performance and the diversity of partners, with an average correlation coefficient of 0.4105 (for each year, except for 2006, p values are found lower than 0.0572).

In order to visualize the analysis of the aforementioned network relationships, heat maps at the country and regional (NUTS-2) levels were generated and analyzed. The heat map of each country or region was determined according to the total number projects, in which the country or region in question participated throughout all FPs (Figure 1 and Figure 2). These two tools of analysis reveal some interesting findings. Accordingly, if two nodes, countries, or regions, previously participated in a project, they show an inclination to participate in new projects together. Moreover, there is also a tendency to participate in a new project with the previous coordinator.

The European Research Area

The ERA can be understood as integrated countries or regions collaborating within networks while competing for markets. In line with the above discussion, the ERA should be designed, developed and implemented in order to create synergy, competition, and cohesion, instead of creating conflicts, among actors. As such, to what extent the ERA is complete and how it supports the European Research and Innovation Network was analyzed. A negative correlation was assumed between the geographical distances of the project partners and the intensity of the interaction among project partners, as it is assumed that an increase in the distance between two partners will decrease the probability of those becoming partners in a project [*Hoekman et al.,* 2007]. In brief, the findings reveal that:

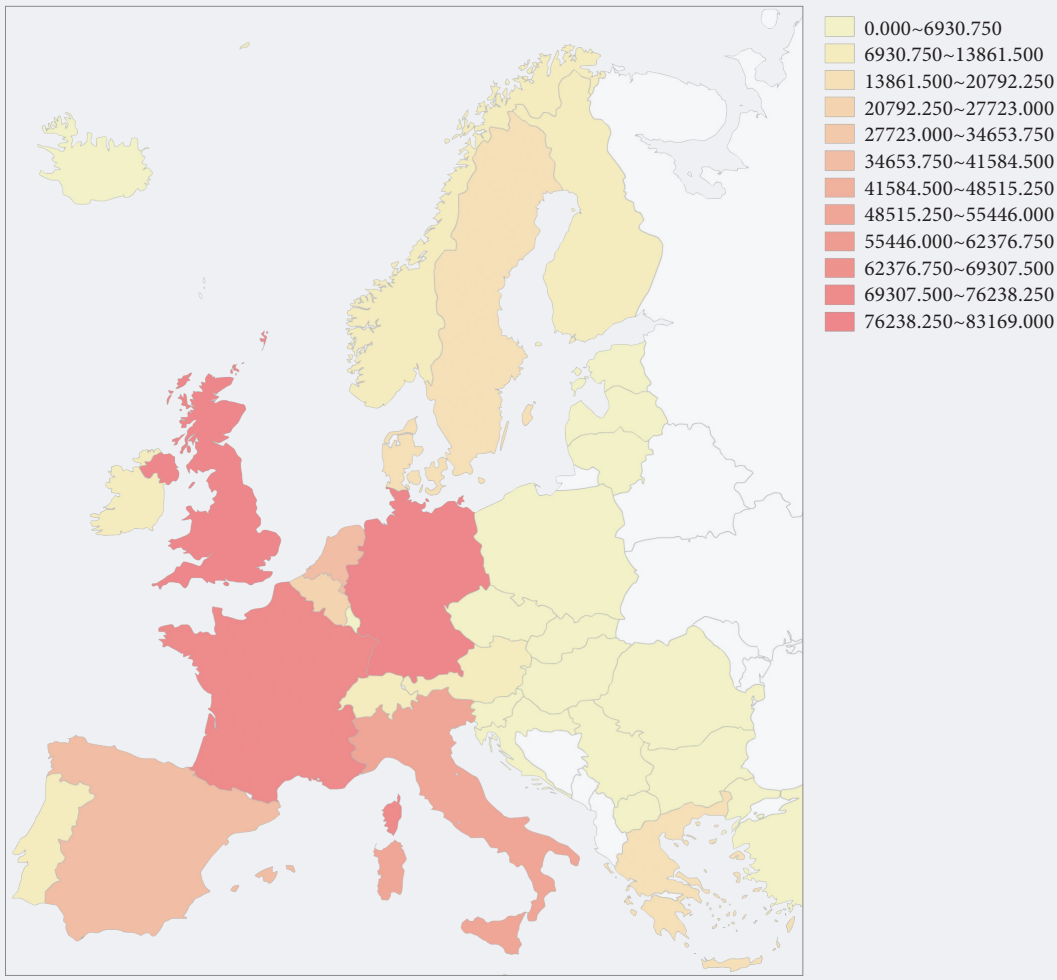
1. Regions (NUTS-2) and countries prefer collaborating with those nearby, implying that geographical distance is still an important factor in the selection of partners for research activities.

2. Scale-free structure of network indicates that nodes prefer to collaborate with nodes that have more links, instead of periphery nodes or lagging nodes. On the other hand, this situation suggests that periphery nodes or lagging nodes could not enter the 'network of excellence', and disparities between these two will only increase [*Clarysse, Muldur*, 2001].

3. Regions (NUTS-2) prefer to collaborate with domestic partner(s) rather than 'foreign' ones, entailing that institutional infrastructure (norms, values, etc.) and national policies such as taxes, labor, funding, etc., are still important factors in selecting partner(s) for research activities.

As shown in Figure 3 and Figure 4, the importance of distance increases from the east of Europe to the west in both networks. Western Europe, as well as some parts of Northern Europe give much more importance to the notion of distance. These nodes are also important actors for the competitiveness and innovation performance of Europe. As a result, the ERA is not complete because proximity is still an important factor for nodes in their selection of partners. Moreover, with regards to the aforementioned finding, it is assumed that if an increase in the number of nodes is higher than the increase in the self-loops value, which demonstrates the existence of a project participant in the same regions more than

Figure 1. **Number of Projects (National)**



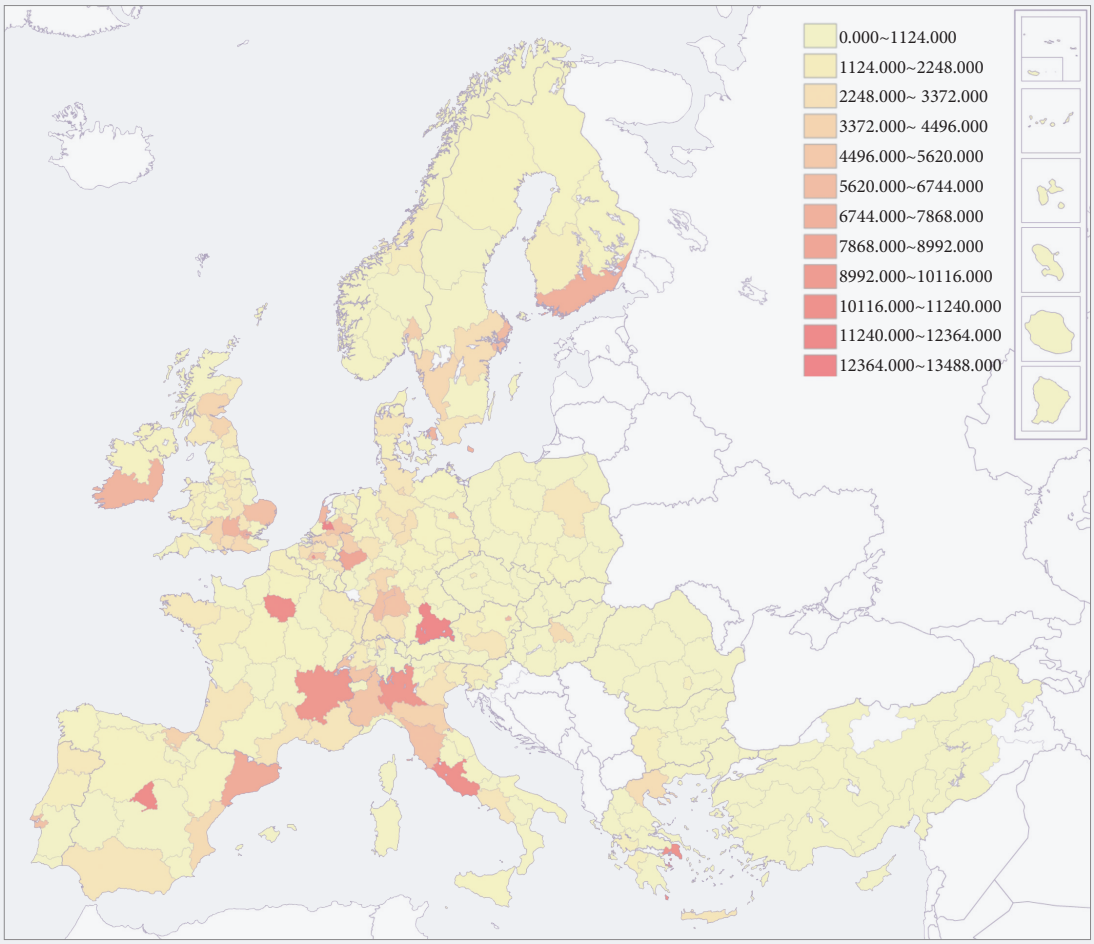
Source: compiled by the authors.

once, regions can be said to prefer collaborating with domestic partner(s) instead of 'foreign' ones. The results show that while the number of partners increases 0.70-fold from FP1 to FP7, the increase in self-loops is 15.38-fold from FP1 to FP7.

The ERA can be considered a useful tool for removing artificial barriers related to geography and borders. Moreover, it helps establish networks among organizations, advanced regions and countries, which are important components for increasing the competitiveness and innovation performance of Europe on a global scale. However, they can also deepen discrepancies among organizations, regions and countries, which undermine the social sustainability of the system due to the unintended negative consequences of innovation policies. Thus, this dual structure, which increases both competitiveness and discrepancies, should be accepted as the result of unavoidable outcomes of the programs and policies related to the ERA.

A positive correlation between the number of projects and innovation performance value of nodes can be regarded as indicators for the existence and/or development of the ERA. The research area is based upon European integration at the regional, national and continental levels in accordance with the Lisbon Agenda, which aims to improve European competitiveness by developing collective innovation and research capabilities of Europe as a whole. The European Commission is proceeding based on the assumption that this dual structure will be eradicated over time, given that those lagging regions will increase their knowledge base, innovation performance, and competitiveness over time with the help of funding. However, findings show the clear trend of preferential attachment. That is, nodes prefer to collaborate with nodes having more links instead of periphery or lagging nodes. Therefore, as one of the contributions of this article, it can be said that improving the knowledge base, innovation performance, competitiveness, and so on is necessary but not sufficient; the periphery or lagging regions and countries still must pass a threshold to become attractive partners for FP projects or the European research network.

Figure 2. **Number of Projects (Regional)**

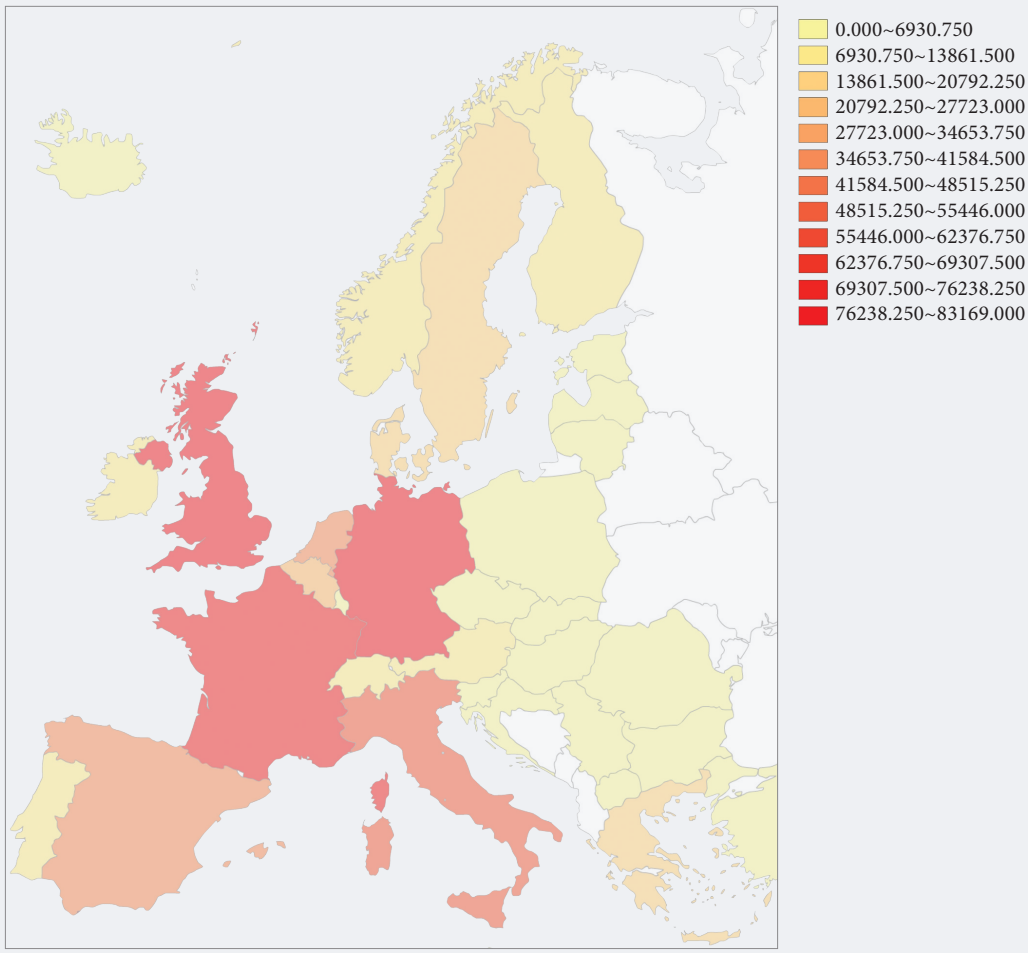


Source: compiled by the authors.

Accordingly, the related literature also underlines the difficulty of entering a scale-free network due to preferential attachment, and entering small-world type of networks due to the difficulty of attaining access to closed networks or cliques. As explained in [*Uzzi, Spiro,* 2005; *Fleming et al.,* 2007; *Schilling, Phelps,* 2007], cliques have strong ties with each other, making it difficult to introduce new information and knowledge or persuade members of cliques to implement new mechanisms. Furthermore, as mentioned above, it is found that as the value of average degree rises, implying that the capacity of regions (NUTS-2) and countries increases in terms of maintaining links with others. When the increase in the number of unique and duplicated links among the nodes are analyzed, the increase in the ratio of duplicate values is observed to be much higher than that of unique values, demonstrating that vertices (regions and countries) primarily prefer to establish links with the existing nodes, instead of new ones.

This situation has positive and negative sides, depending on the vantage point. While it may be regarded as the establishment of a main structure of FP networks or declining transaction costs among the partners with the contribution of the EU, This may also be seen as a situation, in which, the same actors, doing the same thing with different tools receive support with only a few transforming into well-known reference companies in the world as an outcome in the processes. Put differently, while this process increases the sustainability of the structure, at the same time, it potentially can simultaneously reduce the opportunities for newcomers. As such, it may be speculated that this relatively semi-locked network (or the notion of path dependency), teaming up with previous partners, may not only lead to redundancy, but also trigger risks of lock-in [*Leonard-Barton,* 1992]. That is to say, it is difficult for latecomers, which may be an organization, region or a country, to form a hub because of the network structure, which may hamper the re-orientation of relations in the network towards more productive research areas.

Figure 3. **Distance vs. Intensity (Country)**



Source: compiled by the authors.

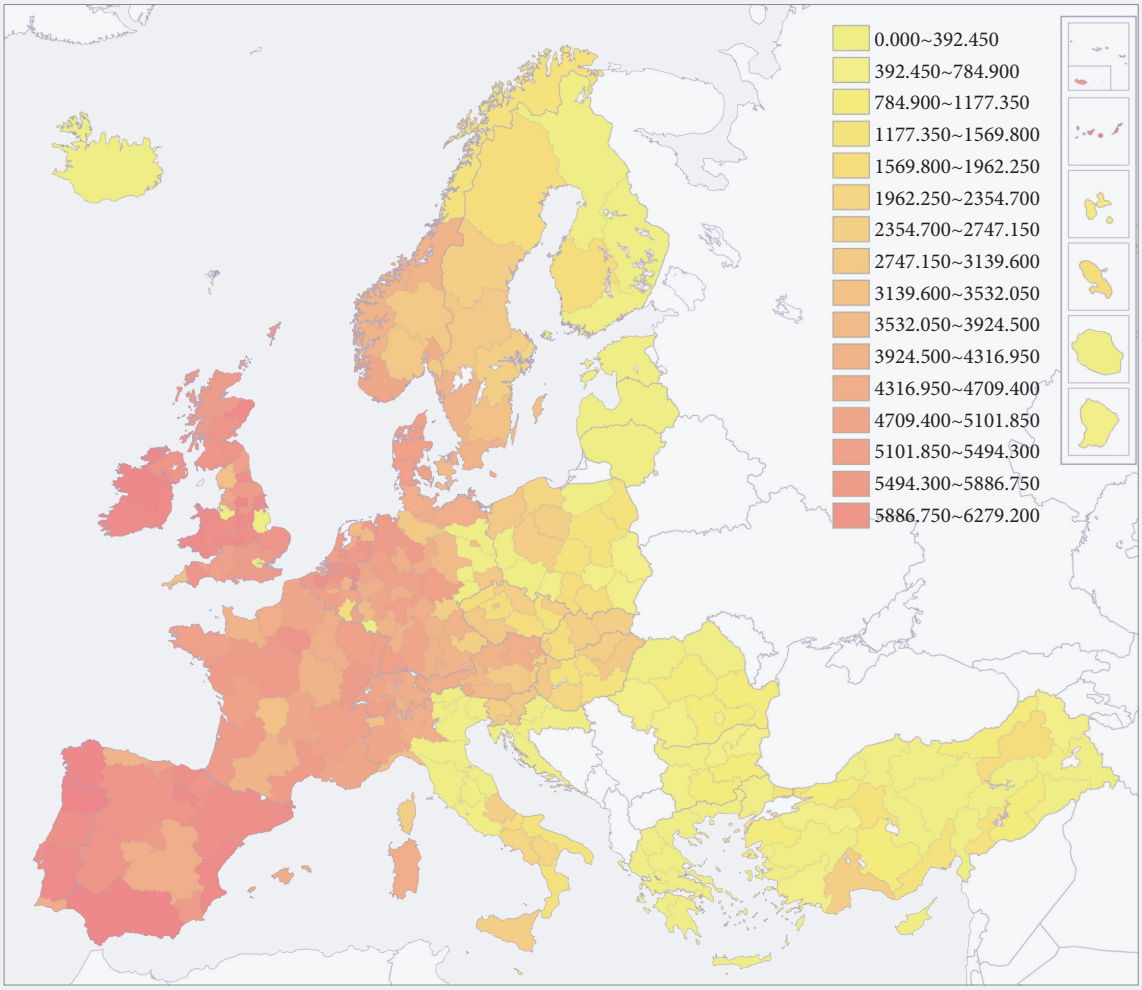
Network Structure, Entropy, and Innovation Performance

In line with the discussion on Boltzmann's entropy, the possibility of achieving innovation is lower when inputs of innovation are concentrated in a single country, organization, or region, while it is higher if they are distributed among various entities. Inputs such as human resources, research systems, firm investments, etc., which have different values are distributed differently among countries in IUS 2013. For instance, the value of 'firm investments' (composed of business R&D expenditure and non-R&D expenditures on innovation) for the year 2012 is 0.287 in Italy and 0.417 in Belgium, indicating the probability of finding a firm investing in R&D and non-R&D for innovation is higher in Belgium than Italy. As explained above, the distribution cannot be changed; in accordance with the even distribution of probabilities among nodes. On the other hand, the existence of competition among countries does not permit a concentration of probabilities. This leaves only one alternative, upon which policies can be developed.

Several researchers argued that links in networks are important means for exchanging information, knowledge, resources, etc. [*Ahuja,* 2000; *Powell et al.,* 1996; *Leoncini et al.,* 1996; *Ter Wal, Boschma,* 2011], which are important components for new combinations [*Nelson, Winter,* 1982] and innovations. In this framework, the position of an actor is an important factor in determining its innovation performance [*Schilling, Phelps,* 2007]. As discussed by Singh [*Singh,* 2005], by influencing the structure of network, policymakers may increase not only the information, knowledge and capabilities of the actors, but also the ability of actors to innovate.

When the relationship between the structure of the network established by FPs and innovation performance values are analyzed, the correlation results given in Table 4 are obtained for the three types networks. In Table 4, innovation performance value shows the highest correlation with the eigenvector

Figure 4. **Distance vs. Intensity (Region)**



Source: compiled by the authors.

value denoting a node's importance in a network based upon the node's connections, and next, with the degree values in country networks, either open or closed, in a regional network. As per the discussions above, it does not make sense to expect a redistribution of links among the countries for obtaining high degree values in order to make positive contributions to the innovation performance of the countries. On the other hand, the eigenvector value may be taken into consideration as a tool for policy intervention. That is, the inclusion of a node with a low eigenvector value in a project consortium not only enables the establishment of a consortium with the preferred partners, but also supports the existing degree distribution, which contributes to the competitiveness of Europe.

The last statement is also supported by Demetrius & Manke, who suggest "[w]hile robustness is defined as the resilience of the network against changes in the underlying network parameters, network entropy characterizes its pathway diversity" [*Demetrius, Manke,* 2005]. As such, in an unweighted and undirected network (like the networks established in this article), topological entropy can be calculated using the Kolmogorov-Sinai formula for entropy, according to which, topological entropy is positively correlated with the largest eigenvector value of the network. In this framework, the largest entropy value among all nodes in FPs is found and correlated with the innovation performance value of Europe. The correlation coefficient between them is -0.052, meaning that they are almost uncorrelated.

Next, the most relevant eigenvector value according to the argument of Demetrius & Manke [*Demetrius, Manke,* 2005] was investigated and it was found that average eigenvector centrality is most correlated with innovation performance, which is -0.8379. This indicates an inverse relationship between average eigenvector centrality and innovation performance: a decreased average eigenvector centrality yields a higher innovation performance value. The network structure results is characterized not only by the configuration of nodes and sectors, but also by the interactions between the components of the institutional infrastructure, as discussed by Kogut [*Kogut,* 2000]. In this sense, the position and links of

Table 4. **Correlation Coefficients of Average Network Characteristics and Innovativeness**

Closed Network	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Degree	0.4729	0.3248	0.3429	0.4069	0.4483	0.4392
Betweenness Centrality	0.2499	0.0213	0.2240	0.2593	0.3916	0.4507
Closeness Centrality	0.4668	0.3365	0.3482	0.4296	0.4609	0.4497
Eigenvector Centrality	0.4763	0.3238	0.3348	0.3912	0.4336	0.4167
Clustering Coefficient	–0.0307	–0.2151	–0.2730	–0.3759	–0.4265	–0.4755
Open Network	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Degree	0.5967	0.5873	0.5807	0.5638	0.5690	0.5455
Betweenness Centrality	0.4371	0.4054	0.4138	0.3793	0.3896	0.3739
Closeness Centrality	0.5694	0.5519	0.5476	0.5383	0.5453	0.5246
Eigenvector Centrality	0.5810	0.6078	0.6143	0.6047	0.6037	0.5694
Clustering Coefficient	–0.6782	–0.6573	–0.6328	–0.6154	–0.6226	–0.5905
Regional Network	**2007**		**2009**		**2011**	
Degree	0.5916		0.6445		0.6801	
Betweenness Centrality	0.4131		0.4043		0.4262	
Closeness Centrality	0.6474		0.6409		0.6734	
Eigenvector Centrality	0.6135		0.6637		0.6949	
Clustering Coefficient	–0.0617		–0.2423		–0.4396	

Source: calculated by the authors.

the node determine its eigenvector value. Therefore, it is not possible to demand that nodes (countries or regions) change the links they have, to integrate the nodes with low eigenvector values into the networks. Instead, a policy developed upon eigenvector in his study may be implemented in a manner that allows the nodes with low eigenvector values to be taken into the networks. In the case of such a situation, the eigenvector value pertaining to both the countries with previously low and high eigenvector values will change accordingly.

The choice of strategy is determined by the eigenvector distribution of each node in the network. It was found that eigenvector values of nodes are in accordance with the power law value of the network (correlation coefficient is 0.7888 with p=0.03). Furthermore, there is an inverse relationship between the innovation performance and power law value, indicated with a correlation coefficient value of -0.5247. As an emergent structure, we cannot trade the innovation performance of Europe for the characteristics of a network, implying that instead of deciding who will establish a network, a simple rule may be added to the application process, which may bring about a more democratic distribution (or lower power law value) and more innovation.

Another interesting finding is the relationship between the European Research and Innovation Network and the entropy of the system. Based on discussions by Prigogine & Stengers [*Prigogine, Stengers,* 1984], it can be stated that entropy of an isolated system never decreases due to the second law of thermodynamics and thus, we observe a lock-in or entropic death [*Saviotti,* 1988]. In this sense, the average degree value of countries consisting of non-members, candidates and EFTA members is 969.71 between the years 2006–2012, meaning that the European Research and Innovation Network clearly maintains its links with outside entities. However, this statement is no more than stating the obvious in terms of the relationship between entropy and the European Research and Innovation Network. The critical point here is the analysis of the relationships between the European Research and Innovation Network and degree values of important rivals, as stated in the Innovation Union Scoreboard 2013 (IUS) report. Essentially, the changes in the innovation performance value of Europe, stated in IUS 2013, and in degree values of each important rival from successive years (2006–2007, 2007–2008, etc.) are calculated. In this framework, it is assumed that a positive correlation value will be obtained if the relationships between the European Research and Innovation Network and its important rivals have a positive effect on innovation performance of Europe, or vice versa. Correlation results obtained between the innovation performance value of Europe and the degree values of important rivals are given in Table 5.

According to IUS 2013, the United States, South Korea, and Japan have a performance lead over Europe; while Brazil, Canada, China, and Russia lag behind. The obtained results given in Table 6 are consistent with IUS 2013 statements, demonstrating a positive correlation between Europe and Brazil, Canada, China, and Russia; and a negative correlation between Europe and the United States, South Korea, and Japan. Put differently, when its relations with three of its rivals are considered, the existing policy and implementations in Europe have not proved as beneficial as expected.

Table 5. **Correlation Coefficients between Changes in Average Innovation Performance Value of Europe and changes in Degree Values of Important Rivals**

Countries	Innovation Performance
Brazil	0.87
Canada	0.78
China	0.02
India	—
Japan	–0.99
South Korea	–0.99
Russia	0.06
United States	–0.89

Source: calculated by the authors.

Policy Recommendations

The dual structure (competition and cohesion), resulting from the implementation of projects related to the ERA, should be considered when ERA policy is developed, so that all of the EU rather than only the most successful participants benefit. However, the discussion on the ERA based on the obtained results proved that the ERA has not yet been completely established [European Commission, 2012]. The European Commission states that the "ERA is at the heart of the Europe 2020 strategy and its Innovation Union (IU) policy flagship and why the European Council has called for ERA to be completed by 2014" [European Commission, 2012]. Since, it is thought that one way or another, the fulfillment of the ERA will provide harmony among the policymakers in terms of not only their perception and implementation of SIs policies, but also eliminate or at the very least minimize concerns and disagreements stated above.

When the relationship between network structure established by FPs and innovation performance values were analyzed, it was found that innovation performance shows the highest correlation with the eigenvector value and then with the degree values in either open or closed country or regional networks. Based on the explanations above one should not count on a redistribution of links among the countries in order to improve the innovation performance of countries. As such, the European Commission may decide on the duration of support, the amount of a project's budget, the amount of project funding, and the types of participants. However, as a network is an emergent structure, even if the high clustering or low path length have positive effects on the dissemination and production of information and knowledge, the Commission should not decide who will work on the project. Therefore, in terms of cohesion, the eigenvector value may be considered a tool for policy intervention.

Given the emergent structure of the European Research and Innovation Network and the importance of current nodes, which can be either a country or a region, for the innovation performance and competitiveness of Europe, the European Commission may introduce a simple rule. For the project application process, it may stipulate the inclusion of a node with a low eigenvector value in the project consortium. This would both allow for the free establishment of said project consortium, and facilitate the participation of nodes with low innovation performance in the network. That is, when the sustainability of EU innovativeness is considered, managing the increase in diversity without leading to a decrease in the system performance, is a question to be answered by EU policymakers. This study suggests using an eigenvector calculation as a simple but effective tool for increasing the cohesion of a region or country in order to build the Innovation Union, including the ERA. Participation in FP projects will gradually increase the knowledge base of periphery and lagging regions or countries. One may ask whether there is a negative side to the inclusion of periphery and lagging regions or countries in a project in terms of the overall innovation performance of the EU, or leader regions or countries. As stated earlier, this rule does not prevent any partners from establishing a project consortium with others. In other words, at least one node, which has a lower eigenvector value, will be included in a project consortium, and the rest of project partners will be selected according to the free will of the applicants (project leader or coordinator) of the project.

The problem of cooperation is tied to the issue of the EU's competitiveness. As mentioned, there are enough links among the nodes (regions and countries) to prove that nodes are able to collaborate with others. Concerning the competitiveness of EU, with regards to the role of the most important gatekeepers (i.e. actors filling structural holes), it is found that they are the main actors not only in terms of knowledge production and diversity, but also for knowledge exchanges between closed and open networks, or between the EU and other regions. However, when relations with the three most important competitors are considered, the existing policy and project implementations have not proven as beneficial as expected by the architects of the European Research and Innovation Network. Put differently, based on the finding that indicates a negative correlation between the clustering coefficient and innovation performance, and a partially positive correlation between the number of projects with important rivals and innovation performance, it may be stated that collaboration with important competitors is a significant factor in boosting innovation performance in Europe. Instead of focusing on obtaining high clustering, which may also indicate the existence of redundant links among nodes, a decrease in differences, etc., focusing

on structural holes may be considered an alternative for increasing innovation performance in the EU. Therefore, regarding the ability of important gatekeepers to connect with global networks but the low absorptive capacity of the system in terms of benefiting from those rivals, it is logical to propose that policy makers of the EU focus more on the development of diversity and absorptive capacity of nodes in order to benefit more from the European Research and Innovation Network to increase the EU's innovation performance .

Evidently, the preferred tools in the implementation of the aforementioned recommendations are a critical issue. The selection of policy tools forms a part of the policy formulation and they are actually part of the policy implementation itself. Notwithstanding which policies and tools related with innovation are selected, their framework and impact are mainly determined by the ultimate political objectives, which might be related to various topics ranging from economic issues such as growth, employment, and inflation, to social, environmental and defense concerns. Furthermore, selection and implementation of appropriate innovation policy tools depend on the causes behind the problems identified by the researchers, governing authorities, etc. The analysis in this study reveals two important causes, giving rise to the two main policy recommendations (Table 6), stated above. One of the causes is the imbalance among nodes (regions and countries in Europe) in terms of knowledge accumulation, capacities, and capabilities, which prevent the cohesion and development of the ERA and increase the innovation performance of the EU. The second is the low level of diversity and absorptive capacity of nodes, especially gatekeepers, preventing the rise of competitiveness in the ERA and adding to the innovation performance gap with the important rivals stated in IUS 2013, specifically the US, Japan and South Korea.

The regulatory, economic and soft tools [*Borrás, Edquist,* 2013] used for innovation policies, can be considered important means used by governing bodies for policy intervention. Within the scope of systems of innovation and network studies cited in this article, two instruments were selected in order to implement the suggested policy recommendations. One is in the framework of regulatory instrument in accordance with the classification by Borrás & Edquist [*Borrás, Edquist,* 2013]. It stipulates that the inclusion of a node with a low eigenvector value in projects may be used for balancing nodes (regions and countries in Europe) in terms of knowledge accumulation, capacities, and resources for stimulating the cohesion and development of the ERA and innovation performance of the EU. The second tool falls into the category of economic or soft instruments. In order to increase the diversity and absorptive capacities of actors, specifically gatekeepers, vis-a-vis Europe's important competitors, which are listed in IUS 2013, this study considers the use of public procurements or public-private partnerships (PPP) for increasing the competitiveness of the ERA and decreasing the innovation performance gap with important rivals, specifically the US, Japan and South Korea. Given that the specific and complex projects, which are being implemented as part of a contract or in partnership with state agencies, facilitate the growth of specific knowledge and capabilities of actors, which furthermore increases the diversity as well as absorptive capacity of actors in line with the announced strategic targets.

As a result, Barca's report underlined the importance of a combined exogenous and endogenous push for institutional changes in nodes (country and/or region). While innovation policy, which supports advancements, deepens inequalities among the nodes, the cohesion policy facilitates measures to eliminate inequalities among the nodes [*Barca,* 2009]. In this sense, the recommendations developed in this study related to the cohesion and competitiveness of the ERA as well as the innovation performance of the EU could be seen as an appropriate input for developing institutional infrastructures in the nodes (country or region). In accordance with Prigogine's argument, while the European Research and Innovation Network, in a sense, draws resources for its development from the outside by improving its ability to manage links with non-EU countries, especially important rivals. At the same time, the eigenvector approach enables the EU's cooperation by increasing the absorption and diffusion of knowledge between nodes, especially lagging or periphery nodes. In this way, not only political concerns related to the effect of the 'hollowing out' of globalization on the innovation systems in Europe or with network failures [*Varblane et al.,* 2007] can be diminished, but also global networks can be used for increasing the performance of systems of innovations at all levels.

Contributions and Future Directions of Study

As discussed by some of the authors [*Arnold*, 2011; *Weber,* 2010; *Richardson,* 2000; etc.], the bridge between network analysis and policy development should be established and this link should be used

Table 6. **Aims, Instruments, and Policy**

		Aim	
		Cohesion	*Competitiveness*
Instrument	*Regulatory Instrument*	Decrease in diversity among the actors	
	Soft Instrument		Increase in the diversity and absorptive capacity of actors, which fill structural holes
		Eigenvector Value of Node	*Public Procurement and/or PPP*

Source: calculated by the authors.

for developing and implementing policy. That is, network analysis techniques should say more than the obvious results that can be obtained using mathematical operations, such as the changes in network sizes, the determination of the importance of actors by adding the number of projects they participated in, etc. The methodology developed in this study, which aimed to use network analysis in order to produce policy recommendations, will contribute to answering valid criticisms in the literature.

It is believed that this study might provide a base for two different types of studies for integrating network studies and policy development and implementation. The first type is an investigation into the relationship between the growth, collaboration and innovations in the European Union. The existing study already deals with the relationship between innovation and collaboration and a discussion on this relationship, combined with social capital and growth, will be able to contribute to the development of academic studies on trust, social capital, and innovation.

Another field of study is the analysis of network structure, the position of actors in it and the performance of nodes, either national or regional. Particularly in an environment where network formation is encouraged, the examination of network structure and the impact of performance in a network will contribute to programs such as FPs, which support network formations.

Conclusion

The European Research and Innovation Network, formed at three stages in this study, emerged as a result of policies implemented at the European level, was analyzed with the help of standard network analysis techniques to evaluate RTD (research, technology and development) policies, implemented by the European Commission. At the same time, discussions on entropy were combined with the results obtained from the analysis of the European Research and Innovation Network, and discussions on SIs, within the framework of the EC's projects related to the ERA and innovation performance of the EU. In this way, network analysis can be used not only as a component of policy recommendation, but as one of the unique contributions of the study. The innovation performance of Europe was discussed and policy recommendations were made using discussions and analyses of systems of innovation and network studies.

This approach yielded with two main policy recommendations. Firstly, the implementation of a simple rule — the inclusion of a node with a low eigenvector value in a project consortium by the EC will not only increase the cohesion process of the ERA but also the innovation performance of EU. Secondly, without forgetting the emergent structure of the European Research and Innovation Network and the importance of current nodes for innovation in Europe, it can be said that when relations with three of the most important rivals (the United States, South Korea, and Japan) are considered, the existing strategies and their implementation have not proven as beneficial as expected by the European authorities. In this sense, policymakers of EU should focus more on the development of diversity and absorptive capacity of nodes that form structural holes, in order to benefit more from the European Research and Innovation Network and increase the innovation performance of Europe.

We would like to thank M.T. Pamukcu, S. Akcomak and Y. Ustuner for their invaluable contributions in establishing a basis for the study and the members of the Science and Technology Policy Studies department at METU.

References

Ahuja G. (2000) Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. *Administrative Science Quarterly*, vol. 45, no 3, pp. 425–455.

Allen P.M. (2001) A complex systems approach to learning in adaptive networks. *International Journal of Innovation Management*, vol. 5, no 2, pp. 149–180. DOI: 10.1142/s136391960100035x

Andersen E.S. (1996) From static structures to dynamics: Specialisation and innovative linkages. *Economic Interdependence and Innovative Activity: An Input-Output Analysis* (ed. C. de Bresson), Cheltenham, UK; Brookfield, US: Edward Elgar, pp. 331–353.

Andersen E.S. (1997) Innovation Systems: Evolutionary Perspectives. *Systems of Innovation: Technologies, Institutions, and Organizations* (ed. C. Edquist), London; Washington: Pinter, pp. 174–179.

Archibugi D., Denni M., Filippetti A. (2009) *The Global Innovation Scoreboard 2008: The Dynamics of the Innovative Performances of Countries*, Rochester, NY: Social Science Research Network.

Arnold E. (2011) *Understanding the long-term impacts of the EU framework programme of research and technological development*, Twente: University of Twente.

Asheim B.T., Gertler M.S. (2005) The geography of innovation: Regional innovation systems. *The Oxford Handbook of Innovation* (eds. J. Fagerberg, D.C. Mowery, R.R. Nelson), Oxford; New York: Oxford University Press, pp. 291–317.

Asheim B.T., Moodysson J., Tödtling F. (2011) Constructing Regional Advantage: Towards State-of-the-Art Regional Innovation System Policies in Europe? *European Planning Studies*, vol. 19, no 7, pp. 1133–1139.

Barca F. (2009) *An Agenda for a Reformed Cohesion Policy: A Place-based Approach to Meeting European Union Challenges and Expectations*, Brussels: Economics and Econometrics Research Institute (EERI).

Bar-Yam Y. (2003) *Dynamics of Complex Systems*, Boulder, CO: Westview Press.

Becattini G. (1990) The Marshallian industrial district as a socio-economic notion. *Industrial Districts and Inter-firm Cooperation in Italy* (eds. F. Pyke, G. Becattini, W. Sengenberger), Geneva: International Institute for Labour Studies, pp. 37–51.

Borgatti S.P., Jones C., Everett M.G. (1998) Network measures of social capital. *Connections*, vol. 21, no 2, pp. 27–36.

Borrás S., Edquist C. (2013) *The Choice of Innovation Policy Instruments*, Lund: Lund University, CIRCLE.

Boltzmann L. (1974) *The second law of thermodynamics* (Populare Schriften, Essay 3, address to a formal meeting of the Imperial Academy of Science, 29 May 1886). Reprinted in Ludwig Boltzmann, Theoretical physics and philosophical problem (translated by S.G. Brush). Boston: Reidel (Original work published in 1886).
Breschi S., Cusmano L. (2002) *Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes*, Milano: Universita' Bocconi.
Camagni R. (1991) Local 'milieu', uncertainty and innovation networks: towards a new dynamic theory of economic space. *Innovation Networks: Spatial Perspectives* (ed. R. Camagni), London: Belhaven Press, pp. 121–142.
Camagni R., Capello R. (2013) Regional Innovation Patterns and the EU Regional Policy Reform: Toward Smart Innovation Policies. *Growth and Change*, vol. 44, no 2, pp. 355–389.
Caracostas P., Muldur U. (1998) *Society, the endless frontier: A European vision of research and innovation policies for the 21st century*, Luxembourg: Office for Official Publications of the European Communities.
Carlsson B., Jacobsson S. (1997) Diversity creation and technological systems: A technology policy perspective. *Systems of Innovation: Technologies, Institutions, and Organizations* (ed. C. Edquist), London; Washington: Pinter.
Carlsson L. (2000) Policy Networks as Collective Action. *Policy Studies Journal*, vol. 28, no 3, pp. 502–520.
Choi T.Y., Dooley K.J., Rungtusanatham M. (2001) Supply networks and complex adaptive systems: Control versus emergence. *Journal of Operations Management*, vol. 19, no 3, pp. 351–366.
Clarysse B., Muldur U. (2001) Regional cohesion in Europe? An analysis of how EU public RTD support influences the techno-economic regional landscape. *Research Policy*, vol. 30, no 2, pp. 275–296.
Cooke P. (1996) The new wave of regional innovation networks: Analysis, characteristics and strategy. *Small Business Economics*, vol. 8,no 2, pp. 159–171.
Cowan R. (2004) *Network models of innovation and knowledge diffusion*, Maastricht: Maastricht Economic Research Institute on Innovation and Technology.
Das T.K., Teng B.-S. (2002) Alliance Constellations: A Social Exchange Perspective. *The Academy of Management Review*, vol. 27, no 3,pp. 445–456.
DeBresson C., Amesse F. (1991) Networks of innovators: A review and introduction to the issue. *Research Policy*, vol. 20, no 5, pp. 363–379.
Demetrius L., Manke T. (2005) Robustness and network evolution — An entropic principle. *Physica A: Statistical Mechanics and Its Applications*, vol. 346, no 3–4, pp. 682–696.
Dye T.R. (2012) *Understanding Public Policy* (14th edition), Boston: Pearson.
European Commission (1995) *Green Paper on Innovation* (COM (95) 688 final, 20 December 1995), Brussels: European Commission.
European Commission (1997) *The first action plan for innovation in Europe. Innovation for growth and employment* (COM (96) 589 final,20 November 1996), Brussels: European Commission.
European Commission (2000) *Towards a European Research Area: Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions* (COM (2000)6), Luxembourg: Office for Official Publications of the European Communities.
European Commission (2006) *An Innovation-friendly, Modern Europe: Communication from the Commission to the European Council* (COM(2006)589, 20 October 2006), Luxembourg: Office for Official Publications of the European Communities.
European Commission (2010a) *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Europe 2020 Flagship Initiative Innovation Union* (COM(2010)546), Luxembourg: Office for Official Publications of the European Communities.
European Commission (2010b) *The role of community research policy in the knowledge-based economy: Post-2010 strategies for research policies*, Luxemburg: Publication Office of the European Union.
European Commission (2012) *A Reinforced European Research Area Partnership for Excellence and Growth* (COM(2012)392), Brussels: European Commission.
Expert Group (2010) *Interim Evaluation of the Seventh Framework Programme*, Brussels: European Commission.
Fagerberg J., Guerrieri P., Verspagen B. (eds.) (1999) *The Economic Challenge for Europe: Adapting to Innovation Based Growth*, Cheltenham; Northampton: Edward Elgar.
Flap H., Bulder B., Beate V. (1998) Intra-organizational Networks and Performance: A Review. *Computational & Mathematical Organization Theory*, vol. 4, no 2, pp. 109–147.
Fleming L., King C., Juda A.I. (2007) Small Worlds and Regional Innovation. *Organization Science*, vol. 18, no 6, pp. 938–954.
Foray D. (2006) *Economics of knowledge*, Cambridge, MA; London: MIT.
Foray D., Lundvall B.-A. (1996) The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy. *Employment and Growth in the Knowledge-Based Economy,* Paris: OECD, pp. 11–32.
Foray D., van Ark B. (2007) *Smart specialisation in a truly integrated research area is the key to attracting more R&D to Europe* (Expert Group "Knowledge for Growth", Policy Brief no 1), Brussels: European Commission.
Freeman C. (1991) Networks of innovators: A synthesis of research issues. *Research Policy*, vol. 20, no 5, pp. 499–514.
Gereffi G., Humphrey J., Sturgeon T. (2005) The governance of global value chains. *Review of International Political Economy*, vol. 12, no 1, pp. 78–104.
Granovetter M. (1973) The Strength of Weak Ties. *American Journal of Sociology*, vol. 78, no 6, pp. 1360–1380.
Hagedoorn J. (1990) Organizational modes of inter-firm co-operation and technology transfer. *Technovation*, vol. 10, no 1, pp. 17–30.
Hagedoorn J. (1993) Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal*, vol. 14, no 5, pp. 371–385.
Hakansson H. (1989) *Corporate Technological Behaviour: Cooperation Networks*, London; New York: Cengage Learning EMEA.
Hoekman J., Frenken K., van Oort F. (2007) *Towards a European Research Area*, Rotterdam: NAi Publishers.
Hyötyläinen R. (2000) *Development mechanisms of strategic enterprise networks: Learning and innovation in networks*, Espoo: Technical Research Centre of Finland.
Kogut B. (2000) The network as knowledge: Generative rules and the emergence of structure. *Strategic Management Journal*, vol. 21, no 3, pp. 405–425.
Kogut B., Zander U. (1992) Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. *Organization Science*, vol. 3, no 3, pp. 383–397.
Latora V., Marchiori M. (2004) *The Architecture of Complex Systems*, Santa Fe: Santa Fe Institute. Available at: http://www.w3.org/People/Massimo/papers/2002/architecture_book_02.pdf, accessed 15.09.2015.
Leonard-Barton D. (1992) Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, vol. 13 (special issue), pp. 111–125.
Leoncini R., Maggioni M.A., Montresor S. (1996) Intersectoral innovation flows and national technological systems: Network analysis for comparing Italy and Germany. *Research Policy*, vol. 25, no 3, pp. 415–430.
Lundvall B.-Å. (ed.) (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.
Lundvall B.-Å., Johnson B., Andersen E.S., Dalu B. (2002) National systems of production, innovation and competence building. *Research Policy,* vol. 31, no 2, pp. 213–231.

Malerba F. (2004) *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*, Cambridge, UK: Cambridge University Press.
Malerba F., Vonortas N., Cassi L., Corrocher N., Wagner C. (2007) *Networks of Innovation in Information Society: Development and Deployment in Europe*, Luxembourg: Office for Official Publications of the European Communities.
Marshall A. (1961) *Principles of Economics* (9th ed.), London, New York: Macmillan for the Royal Economic Society.
Metcalfe S. (1995) The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives. *Handbook of the Economics of Innovation and Technological Change* (ed. P. Stoneman), Oxford, UK; Cambridge, MA: Blackwell, pp. 409–512.
Mowshowitz A. (1968) Entropy and the complexity of graphs: I. An index of the relative complexity of a graph. *The Bulletin of Mathematical Biophysics*, vol. 30, no 1, pp. 175–204.
Nelson R.R., Winter S.G. (1982) *An evolutionary theory of economic change*, Cambridge, MA: Belknap Press of Harvard University Press.
Nishikawa T., Adilson E. Motter A.E., Ying-Cheng Lai Y.-C., Hoppensteadt F.C. (2003) Heterogeneity in oscillator networks: Are smaller worlds easier to synchronize? *Physical Review Letters*, vol. 91, no 1 (online publication). Available at: https://www.researchgate.net/publication/10622587_Heterogeneity_in_Oscillator_Networks_Are_Smaller_Worlds_Easier_to_Synchronize, accessed 15.10.2015.
Nooteboom B. (1992) *Towards a dynamic theory of transactions*, Tilburg: Tilburg University.
Nooteboom B. (2000) Learning by Interaction: Absorptive Capacity, Cognitive Distance and Governance. *Journal of Management and Governance*, vol. 4, no 1–2, pp. 69–92.
Nooteboom B. (2004) *Inter-Firm Collaboration, Learning and Networks: An Integrated Approach*, London; New York: Routledge.
Nooteboom B. (2005) *Innovation, Learning and Cluster Dynamics*, Tilburg: Tilburg University, Center for Economic Research.
Nooteboom B., Stam E. (2008) *Micro-Foundations for Innovation Policy*, Amsterdam: Amsterdam University Press.
OECD (1992) *Technology and the economy: The key relationships*, Paris: OECD.
Peterson J. (2003) *Policy Networks* (IHS Political Science Series: 2003, no 90), Vienna: Institute for Advanced Studies.
Pietrobelli C., Rabellotti R. (2009) *Innovation Systems and Global Value Chains*, Bologna: Universita' di Bologna.
Piore M., Sabel C. (1986) *The Second Industrial Divide: Possibilities for Prosperity* (reprint edition), New York: Basic Books.
Powell W.W., Grodal S. (2005) Networks of Innovators. *The Oxford Handbook of Innovation* (eds. J. Fagerberg, D.C. Mowery, R.R. Nelson), Oxford; New York: Oxford University Press, pp. 56–85.
Powell W.W., Koput K.W., Smith-Doerr L. (1996) Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*, vol. 41, no 1, pp. 116–145.
Prigogine I. (1976) Order Through Fluctuation: Self-Organization and Social System. *Evolution and Consciousness: Human Systems in Transition* (ed. E. Jantsch), Reading, MA: Addison-Wesley, pp. 93–130.
Prigogine I., Stengers I. (1984) *Order out of chaos: Man's new dialogue with nature*, Toronto; New York: Bantam Books.
Protogerou A., Caloghirou Y., Siokas E. (2010) *Policy-driven EU Research Networks: Impact on the Greek S&T System*, Copenhagen; Aalborg: Copenhagen Business School; Aalborg University.
Richardson J. (2000) Government, Interest Groups and Policy Change. *Political Studies*, vol. 48, no 5, pp. 1006–1025.
Roediger-Schluga T., Barber M.J. (2006) *The structure of R&D collaboration networks in the European Framework Programmes*, Maastricht: UNU-MERIT.
Ruef M. (2002) Strong ties, weak ties and islands: Structural and cultural predictors of organizational innovation. *Industrial and Corporate Change*, vol. 11, no 3, pp. 427–449.
Rycroft R.W. (2007) Does cooperation absorb complexity? Innovation networks and the speed and spread of complex technological innovation. *Technological Forecasting and Social Change*, vol. 74, no 5, pp. 565–578.
Saviotti P.P. (1988) Information, variety and entropy in technoeconomic development. *Research Policy*, vol. 17, no 2, pp. 89–103.
Schilling M.A., Phelps C.C. (2007) Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation. *Management Science*, vol. 53, no 7, pp. 1113–1126.
Shannon C.E. (1948) A Mathematical Theory of Communication. *Bell System Technical Journal*, vol. 27, no 3, pp. 379–423. DOI: 10.1002/j.1538-7305.1948.tb01338.x.
Singh J. (2005) Collaborative Networks as Determinants of Knowledge Diffusion Patterns. *Management Science*, vol. 51, no 5, pp. 756–770.
Soete L., Arundel A. (1993) *An integrated approach to European innovation and technology diffusion policy: A Maastricht memorandum*, Brussels; Luxembourg: Commission of the European Communities.
Soh P.-H., Roberts E.B. (2003) Networks of innovators: A longitudinal perspective. *Research Policy*, vol. 32, no 9, pp. 1569–1588.
Solé R.V., Valverde S. (2004) Information theory of complex networks: On evolution and architectural constraints. *Complex Networks* (eds. E. Ben-Naim, H. Frauenfelder, Z. Toroczkai), Heidelberg: Springer-Verlag, pp. 189–210.
Storper M. (1997) *The Regional World: Territorial Development in a Global Economy*, New York: Guilford Press.
Sturgeon T., Biesebroeck J.V., Gereffi G. (2008) Value chains, networks and clusters: Reframing the global automotive industry. *Journal of Economic Geography*, vol. 8, no 3, pp. 297–321.
Tatikonda M.V., Rosenthal S.R. (2000) Technology novelty, project complexity, and product development project execution success:A deeper look at task uncertainty in product innovation. *IEEE Transactions on Engineering Management*, vol. 47, no 1, pp. 74–87.
Ter Wal A.L.J., Boschma R. (2011) Co-evolution of Firms, Industries and Networks in Space. *Regional Studies*, vol. 45, no 7, pp. 919–933.
Tsai W. (2002) Social Structure of "Coopetition" within a Multiunit Organization: Coordination, Competition, and Intraorganizational Knowledge Sharing. *Organization Science*, vol. 13, no 2, pp. 179–190.
Tsai W., Ghoshal S. (1998) Social Capital and Value Creation: The Role of Intrafirm Networks. *Academy of Management Journal*, vol. 41, no 4, pp. 464–476.
Uzzi B., Spiro J. (2005) Collaboration and Creativity: The Small World Problem. *American Journal of Sociology*, vol. 111, no 2, pp. 447–504.
Varblane U., Dyker D., Tamm D., von Tunzelmann N. (2007) Can the National Innovation Systems of the New EU Member States Be Improved? *Post-Communist Economies*, vol. 19, no 4, pp. 399–416.
von Hippel E. (1988) *The Sources of Innovation*, New York; Oxford: Oxford University Press.
Wang B., Tang H., Guo C., Xiu Z. (2006) Entropy Optimization of Scale-Free Networks Robustness to Random Failures. *Physica A: Statistical Mechanics and Its Applications*, vol. 363, no 2, pp. 591–596.
Weber M., Paier M., Heller-Schuh B., Scherngell T., Barber M. (2009) *Evaluating R&D collaboration networks — Lessons from a comprehensive interdisciplinary modelling approach* (Project number NEST-2006-028875 Network Models, Governance and R&D Collaboration Networks (NEMO), Deliverable D5.1), Vienna: AIT Austrian Institute of Technology GmbH.
Wu J., Tan Y.-J., Deng H.-Z., Zhu D.-Z. (2010 A new measure of heterogeneity of complex networks based on degree sequence. *Unifying Themes in Complex Systems* (eds. A. Minai, D. Braha, Y. Bar-Yam), Berlin; Heidelberg: Springer, pp. 66–73.

Import Dependence and Import Substitution in Russian Manufacturing: A Business Viewpoint

Yury Simachev [a]
Chief Researcher, ysimachev@yandex.ru.

Mikhail Kuzyk [b, c]
Head of Division, and Senior Researcher, kuzyk@iacenter.ru.

Nikolay Zudin [b, d]
Expert, n.zudin@csr.ru.

[a] Institute for Statistical Studies and Economics of Knowledge, National Research University Higher School of Economics, 20 Myasnitskaya str., 101000 Moscow, Russian Federation.

[b] Interdepartmental Analytical Center, P.O. Box 35, 31/29 Povarskaya str., 121069 Moscow, Russian Federation.

[c] Institute of Applied Economic Research, Russian Presidential Academy of National Economy and Public Administration, 82 / 1 Vernadsky prospekt, Moscow 119571, Russian Federation.

[d] Center for Strategic Research, 10 Vozdvizhenka str., 125009 Moscow, Russian Federation.

Abstract

This study evaluates the import dependence of Russian industrial firms and analyzes the 'switch' to using Russian products and technologies in the context of their availability and firms' interest in them. The main information source for the study was a survey of company executives conducted in September-October 2015. The obtained results suggest that in quantitative terms the import consumption levels for manufacturing industries in Russia are relatively small, especially compared with the corresponding levels of Western European countries. At the same time, about two thirds of the surveyed companies are significantly dependent on imports, primarily imports of machinery and equipment. The main reason for the use of imports is the absence of Russian analogues. If they are present, there are problems with the low quality of those Russian analogues and the fact that they are not in line with the client's technological requirements. In general, a higher level of import dependence is typical of high-tech and successful companies, which means that these companies are the most vulnerable to any import restrictions.

The current import dependency level does not satisfy many companies which forces them to try to reduce this dependency: mostly it takes the form of switching to national suppliers, slightly less often — import diversification. The Russian import substitution policy is associated with an attempt to revive, modernize or create the missing production elements in the national economy, i.e., it is essentially vertical. However, in the absence of close work with the horizontal measures, such as the development of certain critical technologies, the formation of new areas of knowledge and filling previously missing science competences, such a policy is characterized by a 'limited shelf life', constant lag, with a focus primarily on the price competitiveness. All this generates an expansion of an economy that is highly sensitive to currency fluctuations. A proactive import substitution policy linked to new emerging markets is needed.

Keywords: import of products, technologies, and services; import dependence; import substitution; Russian industry; technological level of production; firms' behavior.

DOI: 10.17323/1995-459X.2016.4.25.45.

Citation: Simachev Y., Kuzyk M., Zudin N. (2016) Import Dependence and Import Substitution in Russian Manufacturing: A Business Viewpoint. *Foresight and STI Governance*, vol. 10, no 4, pp. 25–45. DOI: 10.17323/1995-459X.2016.4.25.45.

The focus of the import substitution strategy currently being implemented in Russia is the manufacturing sector. There are two main reasons for prioritizing these government policy objectives: the deteriorating international situation and the related risks (some of which have already materialised) of discontinued imports of products, technologies, and services Russian companies need, combined with the officially recognised high import dependence of a whole range of Russian industries.

Theoretical approaches to import substitution evolved in the scope of the structuralist and neo-Keynesian schools of thought[1]. The structuralist approach is based on a division of the global economy into a centre and periphery. The import substitution policies of 'peripheral' countries were seen as a means of overcoming their lagging behind, and reducing their economic dependence on the industrially developed 'centre' [*Prebisch*, 1950; *Cristobal*, 1990; *Franko*, 2007]. Meanwhile neo-Keynesians consider substituting imported manufactured products with locally produced ones the key driver of economic growth [*Chenery, Syrquin*, 1975]. Criticism of import substitution policies in most cases is aimed at their structuralist versions — when trying to overcome dependence on industrially developed countries, governments of 'peripheral' ones fell into the extreme of autarkic industrial development, and in their desire to make the economy self-sufficient, they ignored the advantages offered by international division of labour [*Baer*, 1972; *Bruton*, 1998].

A rich practical experience of implementing import substitution policies has been accumulated by now, not just in developing, but also in industrially developed, countries as well. For the former, such policies commonly serve "catch-up" industrial development purposes, striving to reduce the economic and technological dependence on the leading nations of the world — which brings them into the domain of structuralist approaches. Some of the developed countries pursuing import substitution policies are trying to step up socioeconomic development on the regional and local levels; one of the best examples is the US (see, e.g., [*Kwon*, 2010; *Kurre*, 2011]). The re-industrialisation initiated by the US and the EU is directly related to this issue; the so-called reshoring became its major component after the 2008–2009 recession. This is the practice of bringing major corporations' production facilities back to their home countries. This trend became the strongest in the US, where it was actively supported by the government, which believes it contributes to job creation and gives an extra impulse to economic growth [*Irisova*, 2013; *Panicz*, 2015; *Pobyvaev, Tolkachev*, 2015]. On the whole, industrial nations' approach to import substitution is leaning towards the neo-Keynesian theory.

The implementation of large-scale import substitution policies in Latin American countries is commonly seen as a classic example of the (initially) predominantly structuralist approach[2]. Argentina was the pioneer here, having started to pursue relevant policies in the mid-1940s, followed by several other countries in the region. Initially import substitution was mainly promoted in consumer industries which did not require major investments or advanced (in global terms) competencies, such as textile, light manufacturing, and food industries. Subsequently import substitution support was extended to more capital- and knowledge-intensive industries and sectors too. In addition to implementing various preferential and protectionist measures, the governments of certain countries, in particular of Brazil, made a lot of effort to bring in foreign investments. Major international companies and transnational corporations were actively drawn into large-scale long-term investment projects which implied the localisation of production and technology transfer [*Baer*, 1972; *Debowicz, Segal*, 2014; *Kravchenko*, 2015; *Vatolkina, Gorbunova*, 2015; *Kozyreva, Novikova*, 2015].

Though certain measures had a negative impact on industries and sectors not considered high priority, the results of the first stage of import substitution policy implementation in Latin American countries were favourable. The previous signs of stagnation were replaced by noticeable growth; the share of manufacturing industries in these nations' economies increased; and the quality of life improved. The success of Latin American countries prompted China, India, and certain Sub-Saharan African countries to adopt similar policies in the 1960s [*Bruton*, 1998; *Kwon*, 2010; *Vatolkina, Gorbunova*, 2015; *Kozyreva, Novikova*, 2015].

However, by the mid-1970s the positive results of import substitution policies, largely accomplished by saturating the domestic market and attracting foreign investments, were beginning to be increasingly eclipsed by negative effects later collectively referred to as the 'import substitution syndrome' [*Bruton*, 1998]. Excessively selective protectionism, and the irrational selection of sectors and industries that would receive priority support, frequently without considering their comparative advantages, resulted in 'greenhouse' conditions created for certain industries (and especially for specific companies), which turned into barriers hindering the flow of capital from inefficient production firms to efficient ones. Combined with an excessively strong focus on domestic demand, this resulted in locally made products' loosing global competitiveness. Also, due to import substitution policies' priorities skewed in favour of capital-intensive sectors, demand for financial resources significantly increased. Such resources primarily

[1] Certain authors, though, derive import substitution theory from early mercantilism [*Animitsa et al.,* 2015], with its insistence on limiting product imports.

[2] Note that one of the founders of the structuralist school, Raúl Prebisch, played a major role in shaping and implementing this policy as head of the UN Economic Commission for Latin America in the 1950s and early 1960s [*Franko,* 2007].

came from revenues generated by traditional sectors of the economy, in particular agriculture (mainly by exporting their products), and from foreign investments and loans. However, the regular expropriation of the traditional sectors' revenues, without paying due attention to their development, resulted in their gradual weakening, while the recession in developed countries had a negative impact on the availability of financial resources for developing countries [*Bruton*, 1998; *Rodrigues*, 2005; *Kwon*, 2010; *Zilberman, Strovskiy*, 2009; *Bodrunov, Rogova*, 2014; *Vatolkina, Gorbunova*, 2015; *Kravchenko*, 2015].

In the 1980s the 'import substitution syndrome' in various Latin American, Sub-Saharan African, and Asian countries (in particular India) became a major factor in the deterioration of the economic situation, a large-scale production slump, hyper-inflation, debt crisis, and social tension. All this prompted national governments to abandon 'heavy' import substitution policies and adopt a new, revised development model which provided for the liberalisation of foreign trade, promoting exports and direct foreign investments, and reducing the role of the state in the economy (including reduced direct public support and large-scale privatisation) [*Bruton*, 1998; *Narula*, 2002].

Many see the experience of a number of East Asian countries, first of all the so-called Asian Tigers (Taiwan, South Korea, Singapore, and Hong Kong), where import substitution in effect was only an element of comprehensive government policies to encourage and promote exports, as an alternative to the Latin American countries' import substitution policies (especially their second 'heavy' stage). The aforementioned Asian countries' governments concentrated on promoting high-tech industries, creating a favourable business environment, and investing in industrial infrastructure and education. It can be argued that at the core of this development model was the focus on external markets, and using national competitive advantages to the greatest extent possible. At the same time, various countries' specific policies were quite different. For example, South Korea and Taiwan significantly limited foreigners' opportunities to invest in priority sectors of their economies, and actively implemented protectionist policies. In Singapore and Hong Kong, on the contrary, there were practically no limitations on direct foreign investments, while these countries' governments concentrated on developing infrastructure. The steps they took helped to increase the competitiveness of the nations' industries on the global economy, significantly diversify the national economies, increase exports, and ultimately achieve sustainable economic growth [*Bruton*, 1998; *Narula*, 2002; *Amsden*, 2004; *Zhu*, 2006; *Ogujiuba et al.*, 2011; *Kondratiev*, 2014; *Demidenko*, 2015].

On the whole, the government promotion of import substitution in Latin American countries provides an example of a vertical industrial policy, while relevant national strategies implemented by the Asian Tigers can be seen as a horizontal industrial policies[3].

Approximately a year and a half after the relevant policy was announced in Russia, the authorities' declarations gradually became more clear and practically oriented. The most noticeable step along this way was the Russian Ministry of Industry and Trade's approval of import substitution action plans for 20 industries, mostly in the mechanical engineering sector (19 of them are civilian,[4] and the conventional weapons industry is an extra[5]). Contrary to the title, the bulk of the plans' content is not a description of specific actions but lists of, in total, about two thousand products and technologies which are supposed to be substituted with Russian analogues. Industry-specific plans are currently being reconsidered, i.e. a small number of top-priority projects is being selected to provide massive public support to, mostly using existing mechanisms and tools. However, there are examples of new support mechanisms being developed, focused (exclusively or mostly) towards import substitution, or of existing government policy tools being adapted to better suit relevant objectives. Such new mechanisms include[6] special investment contracts between the state and investors, aimed at setting up, upgrading, or launching the production of manufacturing products, in particular those currently unavailable in Russia[7]. Government funding is provided to cover the costs of participants in industrial clusters set up to implement joint import substitution projects[8]. An example of existing tools' adaptation is the restructuring of the Russian Foundation for Technological Development: import substitution in effect became the priority objective of the new Industrial Development Fund created on its basis. Note also a tendency to support import substitution-related projects which became apparent in activities of certain other development institutes such as the Foundation for Assistance to Small Innovative Enterprises and Vnesheconombank — which is at least reflected in their published reports.

The current attempt to implement an import substitution policy in Russia is certainly not the first one. In particular, since the late 1990s the government has tried to bring leading international companies to the Russian automobile industry, with a view toward gradually stepping up their localised production.

[3] For more on industrial policy types see, e.g., [*Kuznetsov, Simachev,* 2014; *Simachev et al.,* 2014b].

[4] Russian Ministry of Industry and Trade orders of 31 March 2015 Nos. 645, 647–663, of 20 January 2016 No. 197.

[5] Russian Ministry of Industry and Trade order No. 762 of 2 April 2015. However, unlike the plans for civilian industries (typically grand and lengthy), this document only mentions two product types: sporting rifles and ammunition for them.

[6] See, e.g., regulation of the Council of Federation of the RF Federal Assembly No. 512-SF of 9 December 2015.

[7] RF Government regulation No. 708 of 16 July 2015 "On special investment contracts in specific industries".

[8] RF Government regulation No. 41 of 28 January 2016 "On approval of Rules for Allocation of Federal Budget Subsidies to Participants of Industrial Clusters to Cover Part of the Costs of Joint Projects to Make Industrial Products for Import Substitution Purposes".

However, in terms of reducing the share of imported cars the results of these efforts were rather modest (see, e.g., [*Dranev et al.*, 2014]. On the other hand, the scale of measures currently being implemented or planned is unprecedented in recent Russian history, at least in terms of the number of industries covered by such initiatives.

It would be premature to try to assess the results of import substitution promotion, though one important aspect which can potentially undermine this policy is already apparent: its pronounced political undertones. Politics are pushing into the background the issue of how relevant the steps being taken or planned (and the import substitution strategy as such) are to the actual needs and interests of Russian companies — consumers of the imported products and technologies. Meanwhile this issue is critically important for the policy being implemented to achieve a positive impact, and not just for individual companies and industries but for the whole Russian economy.

Study goal, objectives, and data

The goal of the study is to empirically analyse Russian manufacturing companies' import dependence, and their potential (and willingness) to switch to Russian products and technologies. The main objectives of the study include the following:

- Assess the current level of Russian companies' dependence on imported products, technologies, and services used in their production processes;
- Analyse the reasons of Russian companies' choosing imported products, technologies, and services, and their potential to switch to Russian analogues;
- Analyse companies' efforts and plans to reduce their import dependence.

The data for the study was collected over the course of a survey of Russian manufacturing companies' managers conducted in September–October 2015. The objective of the survey (commissioned by the Interdepartmental Analytical Centre and implemented by the Information and Publishing Centre "Statistics of Russia") was to identify and measure the scale, trends, and sources of product, technology, and service imports by Russian manufacturers; to assess the current level of their import dependence; their import substitution needs; and the steps they were taking and planning in this field. The survey's sample was designed taking into account companies' size and industries they belong to, with priority attention given to the the industries for which the Russian Ministry of Industry and Trade approved import substitution promotion plans.

658 companies were included in the final sample (Table 1), about half of which belong to the engineering sector, and more than a quarter – to high-technology sectors. This structure was due to the aforementioned intention of primarily examining high-priority industries, in import substitution terms. Private companies prevail in the sample (as they do in the Russian manufacturing sector generally), though companies with public participation also have a sizeable representation. There are grounds to believe that the latter serve as conduits of government plans and ideas more frequently than others, including in the import substitution area.

An important feature of the sample is the approximately equal shares of small firms and relatively large companies. A sampling bias in relation to the entire population of industrial companies where small businesses dominate was provided during its initial design, since large companies are more frequently regulated by the state (and receive support from it) [*Fier, Heneric,* 2005; *Aschhoff,* 2010; *Simachev et al.,* 2014b], including probably in the scope of an import substitution policy. Financial circumstances of most of the surveyed companies were relatively favourable, but the sample also includes a significant portion of companies facing financial problems. A noticeable share of companies experience powerful pressure from the competition, primarily from foreign producers — which is important in terms of analysing the potential and conditions for import substitution. The sample includes a large representation of companies exporting their products to the former USSR republics and other countries, which, together with companies' financial situation and technological level, can be seen as a characteristic of their 'quality'.

Empirical analysis

Consumption of imports, and companies' dependence on them

A predominant portion of the sample (about 85% of the companies) use imported products, technologies, and services in their production. At the same time the share of imports in their production costs is usually not very high: for almost two thirds of the surveyed companies it does not exceed 20% (Figure 1). Industry-wise, the highest shares of imported products, technologies, and services in production costs were held by light and textile industry companies, car manufacturers, makers of pharmaceutical products, producers of electronic, radio, and computer equipment. The lowest shares were noted for companies producing railway rolling stock, shipbuilding and ship repair firms, producers of metallurgical and metal products, machinery and equipment manufacturers (except machine tools), and aircraft construction companies.

Data collected during the survey allows for the calculation of 'top' and 'bottom' averages for import shares, for the whole sample and specific industries (Table 2). Despite their notional nature, comparing these

Table 1. **Structure of the sample**

Sample design criteria		Company type	Share in the sample, %
Industry		Textiles, clothes, and footwear production	7.5
		Wood processing, production of timber, cellulose, paper and carton products	5.3
		Chemical production (except pharmaceuticals)	6.2
		Pharmaceutical production	4.7
		Metallurgy, production of metal products	9.7
		Production of machinery and equipment (except machine tools)	18.8
		Production of machine tools	4.0
		Production of electrical machinery and equipment	8.4
		Production of computers, data processing, radio, TV, and communication equipment	9.4
		Production of medical equipment	4.9
		Production of instruments	3.7
		Automobile industry	4.6
		Shipbuilding	4.1
		Rolling stock manufacturing	4.9
		Aircraft construction	4.0
Industry's technological level[I]		Low	22.5
		Medium	50.9
		High	26.6
Duration of operations		Less than 5 years	8.8
		5–10 years	16.3
		10–20 years	26.9
		More than 20 years	48.0
Number of employees		Less than 100	24.8
		101–200	23.0
		201–500	24.3
		More than 500	28.0
Public participation (including state corporations) in ownership			15.0
Member of an integrated business structure			29.2
Company's technological level[II]		Backward[III]	49.1
		Advanced[IV]	19.9
Financial situation		Poor	17.9
		Satisfactory	69.9
		Good	12.2
Key customers		Businesses*	84.2
		Population*	23.0
		State*	26.3
Competition on the domestic market	From Russian companies	None	8.2
		Moderate	55.9
		Strong	35.9
	From foreign companies	None	24.0
		Moderate	38.8
		Strong	37.2
Export	To the former USSR	None	45.3
		Up to 10% of output	46.1
		More than 10% of output	8.7
	To other countries	None	69.0
		Up to 10% of output	23.4
		More than 10% of output	7.6

[I] Here and below, high-technology industries include production of pharmaceuticals, computers, data processing, radio, TV, and communication equipment, medical equipment, instruments, and aircraft; medium-technology industries include chemical production (except pharmaceuticals), production of machinery and equipment, production of electrical machinery and equipment, automobiles, ships, and rolling stock; low-technology industries include production of textile, clothes, and footwear, wood processing, production of timber, cellulose, paper and carton products, metallurgy, and production of metal products (in accordance with the Federal State Statistics Service order No. 21 of 14.01.2014).

[II] Unlike industry's technological level, this indicator measures the level of specific companies compared with other Russian and international companies with an identical or similar profile.

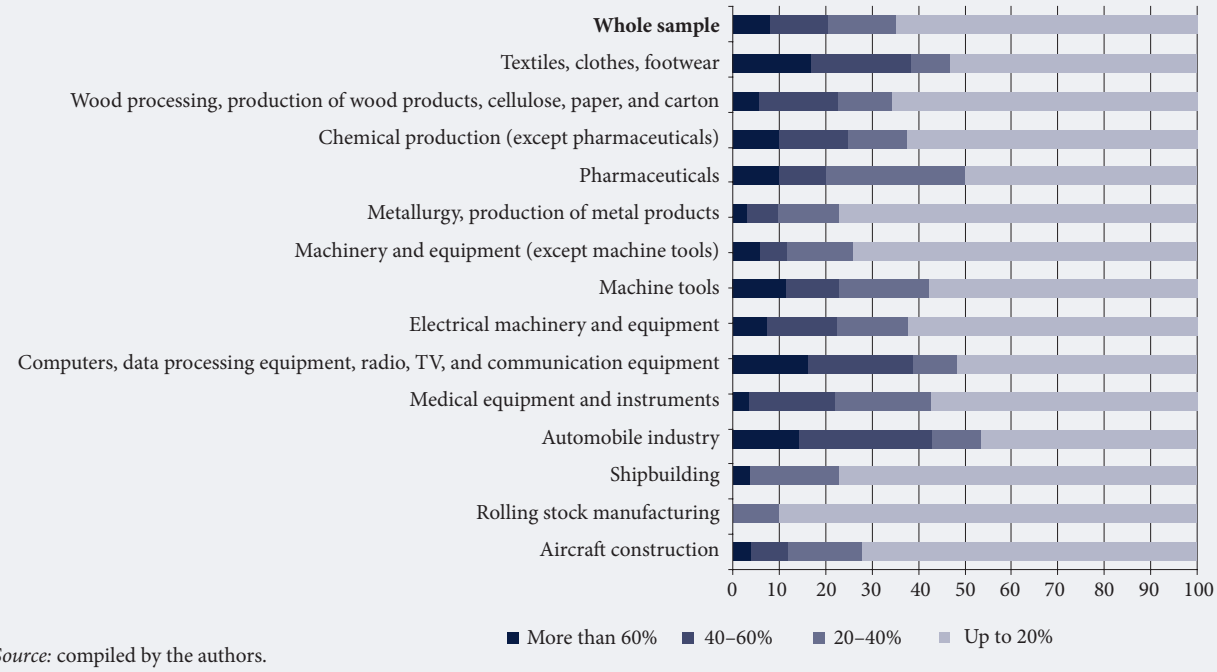
[III] Companies whose technological level is lower than that of international producers', and not higher than Russian ones'.

[IV] Companies whose technological level is higher than that of Russian producers', and not lower than international ones'.

* Not mutually exclusive groups.

Source: composed by the authors.

Figure 1. **Share of imports in production costs, by industry** (%)



Source: compiled by the authors.

figures with relevant indicators for certain Western European countries reveals that Russian companies' import consumption is certainly not higher than theirs.

An obvious advantage of the 'share of imports in production costs' indicator is that it provides a very clear idea of the extent of companies' use of foreign products, technologies, and services – which explains the indicator's active application in present-day economic analysis practices (see, e.g., [*Berezinskaya, Vedev*, 2015; *Faltsman*, 2015]). At the same time it would be wrong to argue that this indicator is a completely accurate measure of businesses' actual overall import dependence. Even when consumption is insignificant, import dependence can be very strong indeed, e.g., if there are no real alternatives to the foreign products, technologies, and services. The picture of import dependence and its level would not be complete without qualitative assessments obtained through surveys.

Three quarters of the companies in the sample were import-dependent, to a certain degree; for more than a third of them dependence was high or critical (Figure 2). Interestingly, in about half of the cases, high import dependence was combined with a small share of imports in production costs.

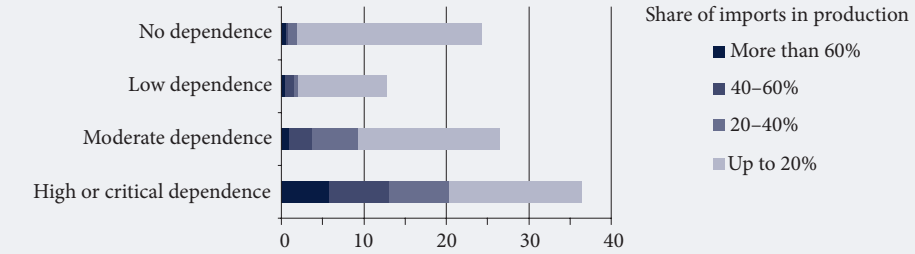
Despite the differences in the scale of companies' use of imports, and in the degree of their actual import dependence, the results of quantitative (Figure 1) and qualitative (Figure 3) assessment for specific industries are rather close to each other. In both cases the highest level of import dependence was noted

Table 2. **Shares of imports in manufacturing industries: international comparison** (%)

	Russia*	Germany**	France**	Spain**	Italy***
All manufacturing	13–31	34	34	43	32
Textile industry	15–34	39	43	46	31
Wood processing, wood products	4–24	36	34	39	27
Pulp and paper industry	21–40	34	37	45	28
Chemical industry	16–35	34	29	55	47
Metallurgical industry	6–22	28	28	39	43
Machinery and equipment production	10–28	25	21	27	27
Production of electronic and optical equipment	19–37	45	24	49	34
Automobile industry	22–41	38	44	63	37
Production of other vehicles and transport equipment	6–21	26	35	48	35

* Average share of imports in production costs in 2015 (survey data).
** Share of imports in output in 2007.
*** Share of imports in output in 2005.
Sources: the authors' calculations, [*Bravo, Alvarez,* 2012].

Figure 2. **Degree of companies' import dependence, and share of imports in production costs** (%)



Source: compiled by the authors.

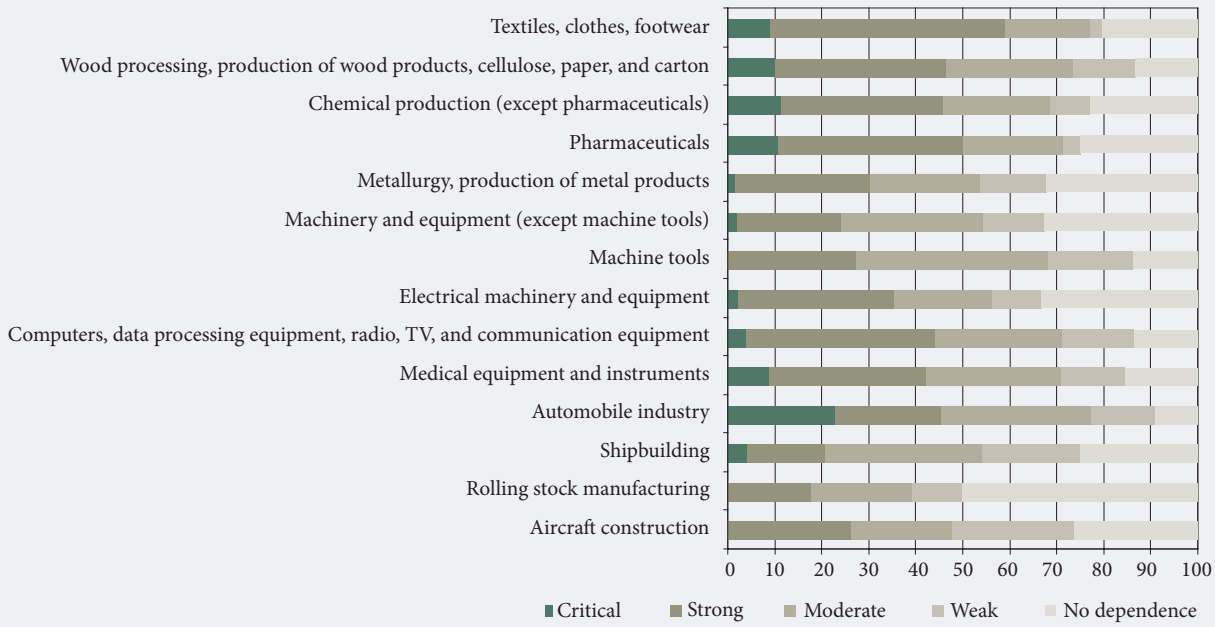
in light and textile industries, pharmaceuticals, automobile and electronic industries. Manufacturers of rolling stock, metallurgical and metal products, machinery and equipment (except machine tools), shipbuilders and aircraft makers are the least import-dependent.

To identify factors affecting companies' import dependence, the parameters of an ordered logistic regression model were estimated, with quantitative (share of imports in production costs) and qualitative assessments of the dependence serving as explanatory variables (i.e. all aforementioned characteristics of the companies included in the sample). Companies' properties measured by these independent variables can be divided into three groups:

- Basic characteristics such as industry (specification 1), or the industry's technological level (specification 2), duration of operations, number of employees, public participation in ownership, membership in an integrated business structure;
- Current state (the company's technological level compared with similar Russian and international firms, and financial state);
- Market position (key customers, competition from Russian and foreign companies, exports into neighbouring and other countries).

The regression analysis revealed (Table 3) that higher levels of import consumption and import dependence alike were typical of three groups of companies: the high-technology sector ones, technological leaders, and companies facing a strong competition from foreign producers. Companies with public participation use imports to a lesser extent, and are less dependent on them.

Figure 3. **Companies' import dependence by industry** (%)



Source: compiled by the authors.

Table 3. **Share of imports in production costs, and companies' import dependence: estimated ordered logistic regression model parameters (%)**

Independent (dummy) variables			Dependent (order)variable			
			Share of imports in production costs		Import dependence	
			Specification			
			1	2	1	2
Industry		Textile, clothes, and footwear production		excl.		excl.
		Wood processing, production of timber, cellulose, paper and carton products		excl.		excl.
		Chemical production (except pharmaceuticals)		excl.		excl.
		Pharmaceutical production		excl.		excl.
		Metallurgy, production of metal products	– **	excl.	– ***	excl.
		Production of machinery and equipment (except machine tools)	– **	excl.	– ***	excl.
		Production of machine tools		excl.		excl.
		Production of electrical machinery and equipment		excl.	– **	excl.
		Production of computers, data processing, radio, TV, and communication equipment		excl.		excl.
		Production of medical equipment and instruments	control	excl.	control	excl.
		Automobile industry		excl.		excl.
		Shipbuilding	– *	excl.	– *	excl.
		Rolling stock manufacturing	– **	excl.	– ***	excl.
		Aircraft construction		excl.	– **	excl.
Industry's technological level		Low	excl.		excl.	
		Medium	excl.	control	excl.	control
		High	excl.	+ ***	excl.	+ ***
Company age		Less than 5 years				
		5 - 10 years			+ *	
		10 - 20 years	control			
		More than 20 years	– ***	– ***		
Number of employees		Up to 100				
		101–200				
		201–500	control			
		More than 500			+ **	+ **
Public participation in ownership			– *	– **	– **	– **
Member of an integrated business structure					+ ***	+ ***
Company's technological level		Backward				
		Advanced	+ **	+ **	+ **	+ ***
Financial situation		Poor				
		Satisfactory	control			
		Good				
Key customers		Businesses			– *	– **
		Population				
		State			– *	– *
Competition on the domestic market	From Russian companies	None				
		Moderate	control			
		Strong				
	From foreign companies	None				– *
		Moderate	control			
		Strong	+ ***	+ ***	+ ***	+ ***
Export	To the former USSR	None			– ***	– ***
		Up to 10% of output	control			
		More than 10% of output			– **	– *
	To other countries	None				
		Up to 10% of output	control			
		More than 10% of output		– *		
Chi-square			113.94***	87.98***	177.49***	144.58***
Maximum variance inflation factor (VIF) value			2.90	1.86	3.05	1.87
N			636		564	

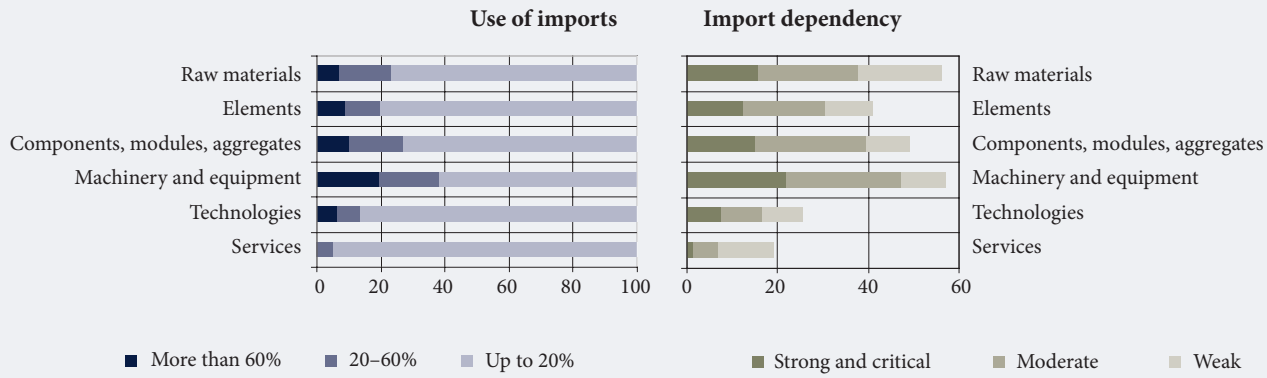
Note: here and below the following significance coefficients were used:

* = 10% significance; ** = 5% significance; *** = 1% significance.

Excl. = variable not included in the specification.

Source: composed by the authors.

Figure 4. **Share of imported products, technologies, and services companies use, and the latter's dependence on these product groups** (%)



Source: compiled by the authors.

In many respects the quantitative and qualitative assessments of import dependence coincide, but there are also important differences between them. For example, companies which have been on the market for more than 20 years tend to have a lower share of imports in their production costs. Large companies and members of integrated business structures show a relatively higher import dependence.

Companies' dependence on main components of imports

In addition to companies' overall import dependence, it would be also interesting to analyse its distribution by the main consumption areas such as materials, components, modules and aggregates, machinery and equipment, technologies, and services. Imports play the most important role, both in terms of their share in relevant consumption categories and the degree of companies' import dependence in machinery and equipment, and the least important — in intangible technologies and especially services (Figure 4).

It should be stressed that the large-scale use of imported machinery and equipment was noted in all industries without exception (Figure 5), but companies' import dependency in different industries significantly varies. For example, light industry, textile, and pharmaceutical companies also significantly depend on imported raw materials; the producers of automobiles, machinery, and equipment depend on imported modules and aggregates (note that in the machine tools industry this group of imported products is even more important than finished machinery and equipment). For the chemical and forest industries, wood processing, pulp and paper, shipbuilding and aircraft construction companies, the import of raw materials is quite important, together with foreign-made aggregates and modules. Manufacturers of medical equipment, instruments, electronics, and communication gear significantly depend on the supply of imported elements. Finally, imports of intangible technologies are particularly important for the automobile, chemical, forestry, wood processing, and pulp and paper industry companies.

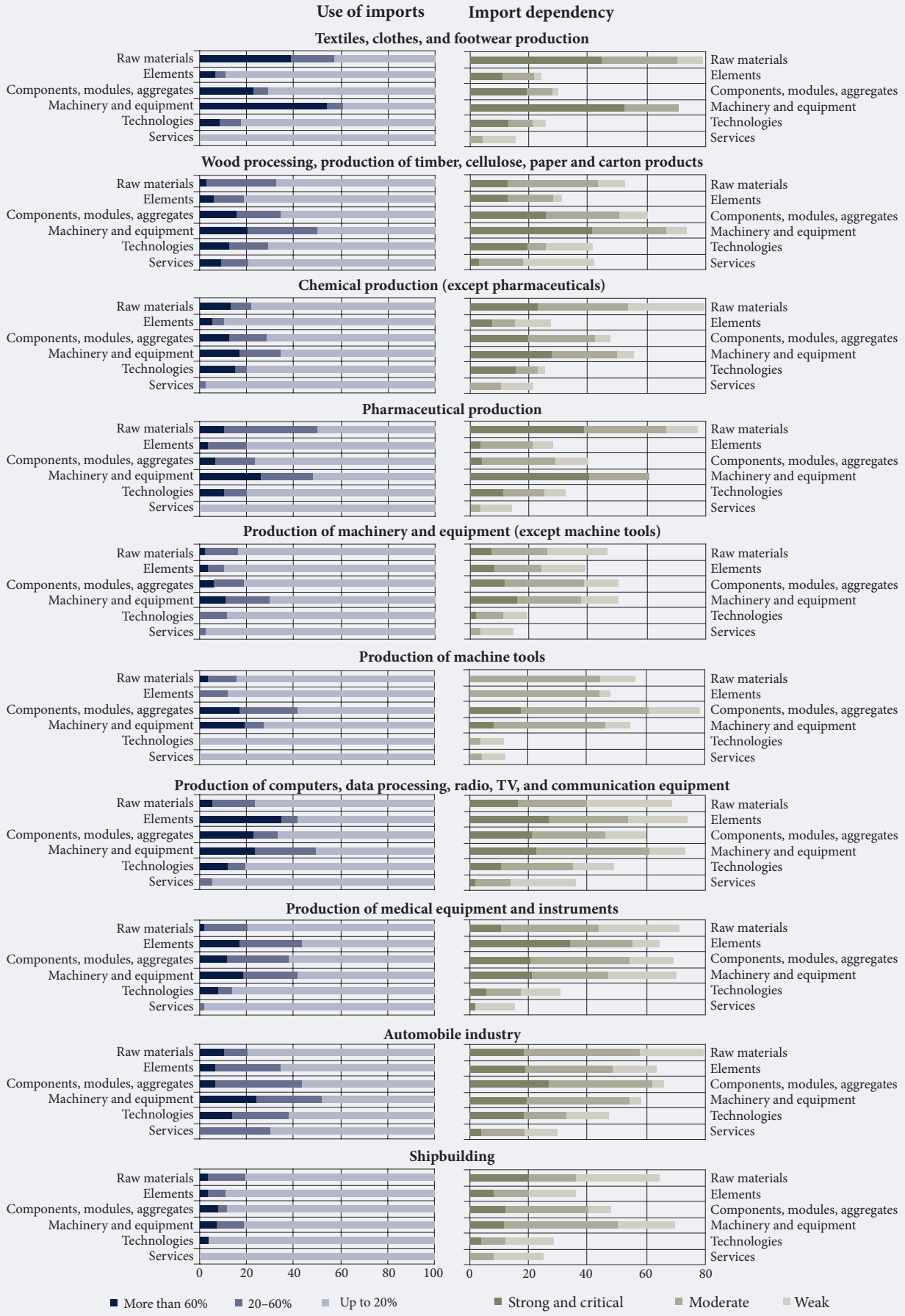
The estimated parameters of the ordered logistic regression models for a quantitative and qualitative assessment of companies' import dependence on each product group (Table 4) allows for making the following conclusions:

- High-technology companies are more dependent on all types of imports under consideration. Low-technology companies also significantly rely on imported machinery, equipment, and services;
- Companies which have been operating for more than 20 years are less dependent on imported technologies and services than others;
- Companies in a healthy financial situation more frequently import intangible technologies;
- Companies' focus on consumer demand is positively linked with their use of imported raw materials;
- Stiff competition from imports forces companies to more actively use imported products and technologies in their production;
- Companies who do not export their products (first of all to the former USSR) are less import-dependent.

Reasons why companies use imports

To successfully implement import substitution plans, it is critically important not only to measure the current level of import dependence (using both quantitative and qualitative assessments), but also to understand the reasons why Russian companies opt for foreign products, technologies, and services.

Figure 5. **Share of imported products, technologies, and services companies use, and the latter's dependence on these product groups, by industry** (%)



Source: compiled by the authors.

:Table 4. Share of imported products, technologies, and services companies use, and the latter's dependence on these product groups estimated parameters of ordered logistic regression models

Independent (dummy) variables			Dependent (order)variable											
			Share of imports used(consumed)						Dependence on imports					
			Raw materials	Elements	Components, modules, aggregates	Machinery and equipment	Technologies	Services	Raw materials	Elements	Components, modules, aggregates	Machinery and equipment	Technologies	Services
Industry's technological level		Low	+ ***			+ ***		+ **				+ ***	+ **	+ **
		Medium	control						control					
		High	+ **	+ ***	+ **	+*	+ *		+ **	+ ***		+ *	+ ***	+ ***
Duration of operations		Less than 5 years										– **		
		5 - 10 years	control											
		10 - 20 years							control					
		More than 20 years	– **		– *		– ***	– ***					– ***	– ***
Public participation in ownership														– *
Number of employees		Up to 100										– **		
		101–200		+ **				– ***						
		201–500	control						control					
		More than 500												
Membership in an integrated structure				+ ***	+ ***	+ **	+ **			+ **	+ ***	+ ***	+ **	+ **
Company's technological level		Backward												
		Advanced	+ *	+ **				+ **			+ *			
Financial situation		Poor		– ***		– ***	– *					– ***		– *
		Satisfactory	control						control					
		Good					+ **						+ **	+ **
Key customers		Businesses			– ***	– **		+ *			– **	– *	– **	
		Population	+ **	– ***				+ ***	+ ***	– ***	– *			
		State				– **		+ **	– *			– *		
Competition on the domestic market	From Russian companies	None	+ *											
		Moderate	control						control					
		Strong		+ ***	+ *	+ **								+ **
	From foreign companies	None	– **		– **	– **								
		Moderate	control						control					
		Strong		+ ***	+ **		+ ***		+ ***	+ **	+ **	+ ***	+ ***	
Export	To the former USSR	None			– **	– **	– **		– **	– **	– **	– ***	– ***	– *
		Up to 10% of output	control						control					
		More than 10% of output					– **					– ***		
	To other countries	None							– *					– **
		Up to 10% of output	control						control					
		More than 10% of output	– *				+ ***		– ***	– *				
Chi-square			77.02***	126.19***	82.51***	117.88***	82.512***	62.40***	91.93***	81.08***	65.58***	141.17***	91.14***	84.53***
Maximum variance inflation factor (VIF) value			2.52	2.42	2.46	2.46	2.43	2.41	1.86	1.85	1.84	1.86	1.84	1.86
N			627	623	624	631	626	636	633	640	634	621	641	637

* = 10% significance; ** = 5% significance; *** = 1% significance

Source: compiled by the authors.

This would allow one to identify the major 'bottlenecks' in Russian supply, which should be turned into priority objectives of the national import substitution policy.

The most common reason companies opt for imported products, technologies, and services is the total absence of Russian alternatives, at least in the respondents' opinion. Russian analogues frequently are not as good as or do not meet the consumer companies' technological requirements. Much less frequently Russian products, technologies, or services cannot compete price-wise, or in terms of delivery and payment. The least important reason according to the respondents was Russian producers' violating intellectual property rights.

An analysis of the reasons why Russian producers opt for imported products, services, and technologies in specific industries (Table 5) reveals that the lack of Russian alternatives is particularly acute in the high-technology sector, namely in pharmaceuticals, computers and electronics, medical equipment and instrument. This issue is least important for the producers of rolling stock.

The insufficient quality of Russian products, technologies, and services compared with foreign analogues and their inability to comply with customers' technological requirements act as powerful incentives to opt for imports for manufacturers of computer equipment and electronics. Also, the low quality of Russian analogues is very important for automobile industry companies, and the inability to meet technological requirements is important for machine tools makers. In addition, the risk of Russian suppliers' violating intellectual property rights is comparatively important to the automotive companies, while the insufficient level of maintenance and technical support services offered by Russian suppliers of products and technologies affects machine tools producers. Chemical and machine tool companies more often

Table 5. **Main reasons of opting for imported products, by industry** (%)

Industries \ Answer options	No Russian alternatives available	Russian alternatives are more expensive	Russian suppliers offer less convenient delivery and payment terms	Higher risk of Russian suppliers' breaching contract terms and conditions	Lower quality of Russian analogues	Russian analogues do not fully meet the company's technological requirements	Russian suppliers do not offer adequate maintenance, support services	Russian suppliers may violate intellectual property rights
Whole sample	60.9	23.9	12.0	8.5	41.6	35.0	9.3	3.5
Textiles, clothes, footwear	71.4	20.4	4.1*	2.0*	20.4***	28.6	6.1	2.0
Wood processing, production of wood products, cellulose, paper, and carton	62.9	20.0	11.4	22.9***	51.4	31.4	14.3	5.7
Chemical production (except pharmaceuticals)	70.7	36.6**	7.3	7.3	36.6	43.9	7.3	4.9
Pharmaceuticals	77.4*	25.8	11.8	0.0*	38.7	38.7	12.9	0.0
Metallurgy, production of metal products	53.1	17.2	9.4	10.9	46.9	39.1	7.8	1.6
Machinery and equipment (except machine tools)	55.6	25.8	8.1	4.8	37.1	25.8**	8.1	1.6
Machine tools	34.6***	38.5*	23.1*	11.5	38.5	57.7**	19.2*	0.0
Electrical machinery and equipment	61.8	16.4	12.7	9.1	34.5	23.6*	5.5	1.8
Computers, data processing equipment, radio, TV, and communication equipment	71.0*	32.3	17.7	14.5*	51.6*	51.6**	4.8	4.8
Medical equipment and instruments	82.1***	16.1	8.9	14.3	51.8	44.6	14.3	7.1
Automobile industry	66.7	33.3	20.0	6.7	56.7*	40.0	13.3	13.3***
Shipbuilding	48.1	25.9	18.5	11.1	40.7	18.5*	7.4	3.7
Rolling stock manufacturing	28.1***	15.6	25.0**	3.1	46.9	18.8**	9.4	3.1
Aircraft construction	50.0	15.4	3.8	0.0	38.5	38.5	11.5	3.8

Note: variance significance (chi-square):* = 10%; ** = 5%; *** = 1%.
Source: compiled by the authors.

than others opt for imports because of the high prices of Russian products, technologies, and services. For the latter group, and for rolling stock manufacturers, delivery and payment terms offered by Russian suppliers play a significant role in their choosing imported alternatives. The risk of Russian partners' breaching contractual obligations is particularly relevant for the forestry industry, wood processing, and pulp and paper companies.

The regression analysis results (Table 6) show that for high-technology companies, the low quality of Russian supply and its inability to meet the technological requirements are also quite important, in addition to lack of Russian alternatives to imported products, technologies, and services. Companies with long market experience frequently experience a lack of Russian analogues, which appears somewhat counterintuitive. One would expect them to have well-established contacts with a steady circle of regular Russian suppliers, as a part of their system of cooperation frequently going back to the Soviet period. At the same time, such companies have problems with the quality of Russian products, technologies, and services, and their inability to match technological requirements less often than other groups do. The described problems, together with insufficient level of maintenance and support services offered by Russian suppliers, and risks of their violating contractual obligations are more important to large businesses.

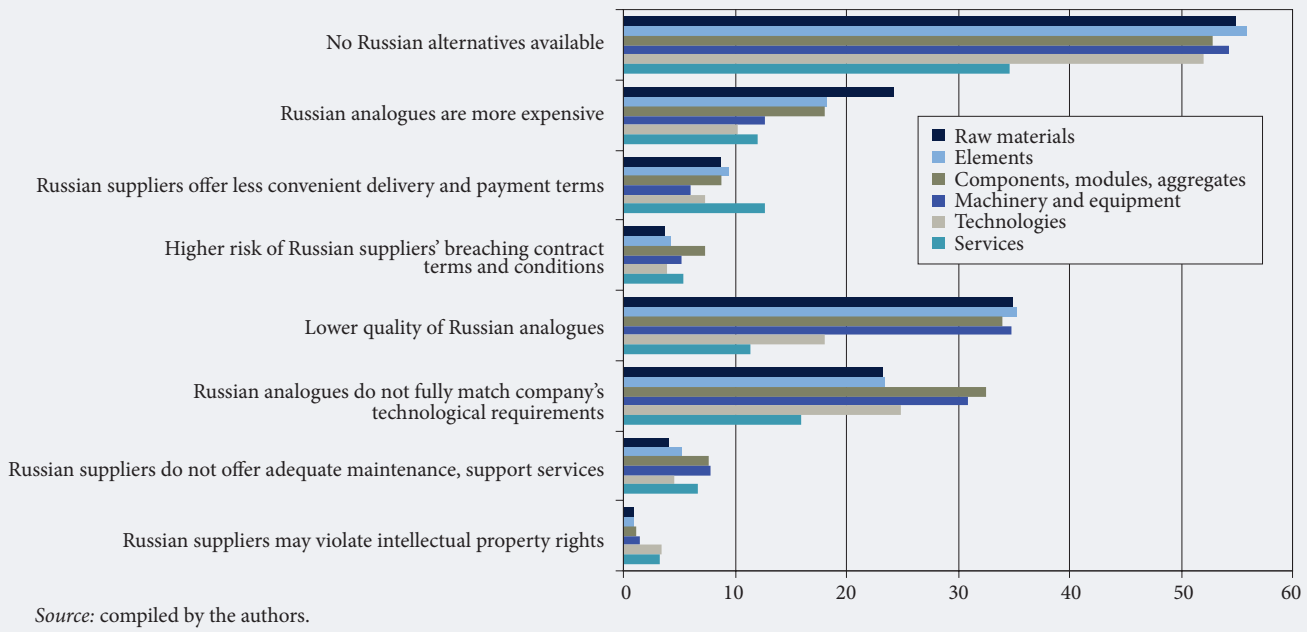
For the members of integrated business structures, the main reason to opt for imports (apart from lack of competitive alternatives) is the less attractive delivery and payment terms offered by Russian suppliers, and the problems with the latter meeting technological requirements (which are quite strict, due to the tight technological integration of vertical production chains).

The previously mentioned high import dependence of companies that are technological leaders is due to several factors such as the higher prices of Russian analogues, risks of Russian suppliers' not carrying out their contractual obligations, the low quality of the supply and its inability to meet technological requirements, and inadequate support and maintenance infrastructure for Russian products, technologies, and services.

Companies exporting their products to the former USSR and those facing strong competition from imports, frequently encounter a total lack of alternatives to imported products, technologies, and services. And if Russian analogues do exist, they are offered at too high a price (the main barrier for companies trying to compete with imports), or do not provide sufficiently high quality (the primary reason exporter companies do not opt for them).

Companies' motivation to use imports is not closely linked with the type of imported products (Figure 6). We can only note that the high prices issue is more frequently mentioned regarding Russian raw materials, and the inability to meet technological requirements — regarding aggregates, modules, machinery, and equipment. Unlike products, Russian technologies and especially services are much less often criticised for their low quality and inability to meet companies' technological requirements. The lack of Russian analogues on the market was least often noted for services, though their potential consumers frequently complained about insufficiently flexible payment terms.

Figure 6. **Main reasons for opting for imported products, technologies, and services** (%)



Source: compiled by the authors.

Table 6. **Main reasons of opting for imported products: estimated parameters of binomial logistic regression models**

Independent (dummy) variables			Dependent (dummy) variable							
			Lack of Russian alternatives	Russian analogues are more expensive	Russian suppliers offer less suitable delivery and payment terms	Higher risk of Russian suppliers' breaching contractual obligations and delivery terms	Lower quality of Russian analogues	Russian analogues do not exactly meet company's technological requirements	Russian suppliers offer insufficient maintenance, technical support services	Russian suppliers may illegally use other people's intellectual property
Industry's technological level		Low		– *						
		Medium	control							
		High	+ ***				+ *	+ ***		
Duration of operations		Less than 5 years		– **				– **		
		5 - 10 years								
		10 - 20 years	control							
		More than 20 years	+ *				– **	–- *		
Public participation in ownership								–- **		
Number of employees		Up to 100						–- **		
		101–200				+ *				
		201–500	control							
		More than 500				+ *	+ *	+ ***	+ *	
Membership in an integrated structure			+ ***		+ *			+ *		
Company's technological level		Outsider	– **							
		Leader		+ *		+ ***	+ ***	+ **	+ **	
Financial situation		Poor								
		Satisfactory	control							
		Good								
Key customers		Businesses	– **	+ **			+ **			
		Population		+ *						+ *
		State				+ **			+ *	
Competition on the domestic market	From Russian companies	None	– *							
		Moderate	control							
		Strong					+ **	– *		
	From foreign companies	None								– *
		Moderate	control							
		Strong	+ ***	+ **				+ *		
Export	To the former USSR	None	– **				– ***	– **		
		Up to 10% of output	control							
		More than 10% of output			+ *					+ *
	To other countries	None								
		Up to 10% of output	control							
		More than 10% of output			– *				– *	
Chi-square			110.64***	44.82***	42.20**	35.60*	70.46***	112.43***	34.,52*	25.30
Maximum variance inflation factor (VIF) value			1.85							
N			658							

Note: variance significance (chi-square). * = 10%; ** = 5%; *** = 1%.

Source: composed by the authors.

Figure 7. **Actions companies take to reduce their import dependence (reference rate by managers of companies using imported products, technologies, and services, %)**

Source: compiled by the authors.

Companies' actions to reduce import dependence

The unfavourable international political and economic situation, combined with risks of it deteriorating even further and amid the government's import substitution initiatives, could prompt Russian companies to take steps to reduce their import dependence. About two thirds of companies included in the sample who use imports have already taken such steps by the time of the survey, and 14% more were planning to do so in the near future. The most common such measure was stepping up procurement from Russian suppliers (Figure 7); about 50% less frequently, but still relatively often, companies took steps to diversify their imports by going to alternative international suppliers. Much less common were attempts to reduce import dependence by setting up new production — which is quite understandable due to associated problems and high costs it involves. Less obvious was the fact that import substitution production was most commonly launched by Russian companies on their own, as opposed to jointly with international partners.

An industry-specific analysis of actions taken by companies (Table 7) shows that the procurement of Russian products, technologies, and services is most frequently stepped up by metallurgic companies, manufacturers of metal products, and rolling stock. The latter, together with car makers and producers of computer equipment, more often set up new production facilities together with foreign partners. Launching new production on one's own is more typical of manufacturers of medical equipment, instruments, and aircraft construction companies. The aircraft manufacturers, as well as metallurgical companies, metal product and rolling stock manufacturers also more actively encourage Russian suppliers to substitute imports.

To identify the factors that determine companies' choice of import substitution strategies, the parameters of binomial logistic regression models were estimated, with a standard set of regressors supplemented by order variables reflecting the degree of companies' dependence on various import components (Table 8).

Large companies, firms competing with other Russian producers, and companies exporting their products at least to the former USSR more often than others take actions to reduce their import dependence. Companies exporting to countries beyond the former Soviet Union are more likely to make efforts to diversify their imports, while firms supplying products to former Soviet republics, on the contrary, take such steps very rarely.

High-technology companies tend to set up their own import substitution production, independently or jointly with foreign firms, and to encourage Russian suppliers to substitute their own imports. At the same time, such companies rarely increased their procurements from Russian producers, at least by the time of the survey. Stepping up procurements in Russia is more typical of companies with public participation, and (somewhat more unexpectedly) of integrated business structures' members. Companies focused on public procurement relatively often diversify their imports, encourage import substitution by Russian producers, and set up their own production, together with foreign partners and on their own. However, that also holds true for companies who mostly sell their products to the population.

Main results of the study

1. Quantitatively, Russian manufacturing companies' consumption of imports is relatively low; it does not exceed Western European figures and frequently remains below them. At the same time a predominant share of Russian manufacturing companies are import-dependent, to a greater or lesser extent.

Table 7. **Actions companies take to reduce their import dependence, by industry (reference rate by managers of companies using imported products, technologies, and services, %)**

Industries \ Answers	No actions taken	Increased procurement from Russian suppliers	Diversification of imports, reducing dependence on specific suppliers/ countries of origin	Setting joint production with foreign companies in Russia	Setting up own production	Encouraging Russian suppliers to substitute imports
Textiles, clothes, and footwear production	25.6	46.5	27.9	0.0	9.3	7.0
Wood processing, production of timber, cellulose, paper and carton products	29.4	41.2	14.7	0.0	11.8	5.9
Chemical production (except pharmaceuticals)	32.4	29.7*	21.6	0.0	16.2	8.1
Pharmaceutical production	33.3	40.7	25.9	0.0	7.4	0.0
Metallurgy, production of metal products	36.7	57.1**	18.4	2.0	6.1	14.3*
Production of machinery and equipment (except machine tools)	36.4	46.5	16.2	4.0	5.1**	2.0**
Production of machine tools	25.0	37.5	12.5	4.2	0.0*	8.3
Production of electrical machinery and equipment	26.1	43.5	23.9	6.5	17.4	8.7
Production of computers, data processing, radio, TV, and communication equipment	26.3	29.8**	24.6	8.8**	8.8	12.3
Production of medical equipment and instruments	30.2	41.5	18.9	3.8	22.6***	9.4
Automobile industry	28.6	53.6	21.4	10.7*	3.6	0.0
Shipbuilding	40.9	50.0	13.6	4.5	4.5	9.1
Rolling stock manufacturing	21.1	63.2*	15.8	10.5	15.8	15.8
Aircraft construction	26.1	39.1	21.7	0.0	26.1**	17.4*

Note: variance significance (chi-square). * = 10%; ** = 5%; *** = 1%.

Source: composed by the authors.

2. The main reason companies opt for imported products, technologies, and services is the lack of Russian alternatives on the market. When this is not the case, the insufficient quality of Russian supply, and its inability to meet companies' technological requirements move to the foreground. Issues related with prices, delivery and payment terms, the level of maintenance and support services offered typically play a less important role in Russian companies' choosing imports over domestic analogues.

3. The current import dependence degree is a point of concern for most of the companies who consume foreign products, technologies, and services, and prompts them to take actions to reduce it. The most common strategy is changing the procurement structure — most frequently in favour of Russian suppliers, and less often to diversify the imports.

4. On the whole, Russian companies most actively acquire (and therefore most strongly depend on) imported machinery and equipment. This is due, on the one hand, to many companies' highly obsolete, in physical and moral terms, capital assets, and on the other, to frequently encountered lack of Russian analogues on the market, their low quality, or inability to fully meet present-day technological requirements, combined with a certain degree of inertia in system integrators' preferences (who are used to working with imported equipment) [*Mekhanik*, 2013; *Kvashnina et al.*, 2013; *Tsukhlo*, 2015]. Note that in manufacturing, as in the Russian economy generally, the procurement of tangible technologies (i.e. machinery and equipment) traditionally accounts for the largest share of companies' expenditures on technological innovation [*Gorodnikova et al.*, 2016].

5. The high demand for foreign-made machinery and equipment is common to all manufacturing industries, but specific industries' import dependence profiles are quite different from each other. For example, raw material imports are crucial for the light and textile industries, chemical and pharmaceutical companies, and shipbuilding. Manufacturers of medical, computer, and communication equipment display a higher demand for elements; imported components, modules, aggregates, and technologies are very much important to car producers. A relatively low level of import dependence was noted for rolling stock manufacturers: they see the lack of Russian analogues for products, technologies, and services they need as less of a problem than others do.

6. High-technology companies are very much import-dependent, in all product groups; they encounter an insufficient supply of Russian alternatives, or the latter's inability to comply with technological requirements more frequently than others. This explains the fact that this sector's companies substitute imports with ready-made Russian solutions less often than firms specialising in other industries do, and more frequently launch own production or encourage their Russian suppliers to do so.

Table 8. **Actions companies take to reduce their import dependence: estimated parameters of binomial logistic regression models**

Independent variables			Dependent (dummy) variable					
			No actions taken	Increased procurement from Russian suppliers	Diversification of imports, reducing dependence on specific suppliers/countries of origin	Setting joint production with foreign companies in Russia	Setting up own production	Encouraging Russian suppliers to substitute imports
Import dependence degree		Raw materials (order)						
		Elements (order)	– **			+ **		
		Components, modules, aggregates (order)					+ ***	
		Machinery and equipment (order)						
		Technologies (order)						
		Services (order)						– ***
Industry's technological level		Low (dummy)				– *		
		Medium (dummy)	control					
		High (dummy)		– ***			+ *	+ *
Duration of operations		Less than 5 years (dummy)						
		5 - 10 years (dummy)			– *			
		10 - 20 years (dummy)	control					
		More than 20 years (dummy)			– *			
Number of employees		Up to 100 (dummy)	+ *					
		101–200 (dummy)						
		201–500 (dummy)	control					
		More than 500 (dummy)	– *		+ *			
Public participation in ownership (dummy)				+ *				
Member of an integrated business structure (dummy)				+ **				
Company's technological level		Backward (dummy)						
		Advanced (dummy)						– **
Financial situation		Poor (dummy)			– *			
		Satisfactory (dummy)	control					
		Good (dummy)			+ **		+ *	
Key customers		Businesses (dummy)						
		Population (dummy)					+ *	
		State (dummy)			+ **	+ ***	+ *	+ **
Competition on the domestic market	From Russian companies	None (dummy)	+*					+ **
		Moderate (dummy)	control					
		Strong (dummy)						
	From foreign companies	None (dummy)						
		Moderate (dummy)	control					
		Strong (dummy)						
Export	To the former USSR	None (dummy)	+ **		– **			
		Up to 10% of output (dummy)	control					
		More than 10% of output (dummy)	+ *					
	To other countries	None (dummy)			+ **	+ **		
		Up to 10% of output (dummy)	control					
		More than 10% of output (dummy)						
Chi-square			62.20***	44.67*	65.73***	41.14	48.05**	55.88***
Maximum variance inflation factor (VIF) value			1.79					
N			561					

* = 10% significance; ** = 5% significance; *** = 1% significance

Source: composed by the authors.

7. A high degree of import dependence was discovered for members of integrated business structures, which may be due to several factors. Firstly, switching to alternative suppliers may simply be impossible due to the 'links' of vertically integrated production chains, since it could lead to technological mismatches with related products. Probably that explains why members of such structures named Russian analogues' inability to match technological requirements as a key reason why they use imports. Secondly, quite a few Russian companies are members of transnational corporations, which, as active players on the global market, widely use international division of labour, while transboundary operations are an integral part of their business. Thirdly, integrated business structures, especially large and very large ones, tend to display a certain degree of inertia in their choice of products, technologies, and services, and suppliers thereof [*Neprintseva*, 2006; *Kaushan, Bogushevskiy*, 2009]. However, in the current economic situation it is the members of integrated business structures who display a tendency towards stepping up procurement from Russian suppliers.

8. Companies with a long history of operations depend on imported technologies and services to a lesser extent than others, due to their established links with Russian R&D organisations, which frequently go back all the way to the Soviet period [see, e.g.: *Simachev et al.*, 2014b].

9. A relatively low consumption of imports and degree of import dependence is displayed by companies with public participation. They are stepping up the procurement of Russian products, technologies, and services, probably not least because of the relevant 'incentives' they receive from the state, via its representatives in these companies' management.

10. Companies who primarily sell their products to individual consumers more actively use imports, first of all imported raw materials. This is important because consumer demand acts as the main driver of new and improved products' supply by Russian companies [*Ivanov et al.*, 2012], which in turn probably affects the latter's demand for imports. A significant incentive for consumer products' manufacturers to use imports is the high prices of Russian analogues, probably aggravated by diminishing purchasing power of the Russian population. Note also that the aforementioned companies relatively often set up their own import substituting production.

11. Successful companies whose technological level is higher than their competitors', and those who export their products (at least in the former USSR republics) tend to have a higher degree of import dependence. In effect this makes such companies more vulnerable to all limitations of imports, external and internal alike.

12. Companies facing strong competition on the domestic market from foreign producers tend to depend on imports more than others. High-technology firms face especially strong competition from imports [*Zudin*, 2015]. This forces Russian producers to impose strict requirements for products, technologies, and services they use in their production processes, which foreign suppliers are more likely to meet. Alternatively, companies borrow successful international practices.

Certain observations and recommendations

Import substitution is a quite common area of economic policy in many countries. There is nothing new about it in Russia either, where this topic, in one form or another, has been relevant since the early 1990s. At first, import substitution policy concentrated on aircraft construction, then on agriculture, automobile industry, and pharmaceuticals. Successes achieved in these fields require, at the very least, a thorough economic evaluation and discussion. However, some qualitative changes achieved in certain industries are very important, such as the groundwork necessary for retaining competencies and promoting the development of specific sectors (aircraft construction); demonstrating the potential of alternative development schemes based on attracting foreign investors and localising production (automobile industry); achieving positive dynamics in dealing with socially sensitive issues (agricultural sector, pharmaceuticals).

In our view, the import substitution strategy being implemented in Russia is aimed not so much at meeting the requirements of the economy as a whole as serving the interests of specific 'backbone' companies; not so much at diversifying and upgrading the Russian economy as dealing with national security objectives. It is hard to determine the reasons for such priority setting: on the one hand, it reflects the economic positions of large Russian monopolies and state corporations, while on the other, the security aspect has always served as an excellent argument to promote various new government support programmes and initiatives. The course towards import substitution could have been chosen due to the government's aspiration to deal with several types of objectives: economic ones (increasing added value on the scale of the entire national economy); innovation (e.g., vertical modernisation of the production chains); sovereignty-related (in particular, ensuring the country's technological independence). All these objectives are optimisation ones because they cannot be accomplished completely: you cannot create all added value within the national economy, and it would be impossible to achieve total technological independence. However, the issue of limits and forms that would make import substitution policy beneficial for the economy, in the medium and long terms, is quite relevant. Of course, unfavourable developments require quick reactive action, frequently in 'manual control' mode, but in economic policy shaping, immediate considerations should be separated from systemic issues and proactive measures.

Attempts to use strategic tools to deal with 'tactical' high-precision, specific objectives usually involve the high risk of a bad bargain.

It is important to make sure that import substitution does not turn into an economic policy goal, as opposed to being its tool. Most of the previous attempts to pursue an industrial policy in Russia were aimed, directly or indirectly, at maximising the share of added value generated inside the country — which determined a predominant focus on the domestic market, with all related risks of protectionism, limitations on competition, and demand by the public sector replacing that by the private one [*Dranev et al.*, 2014]. Meanwhile, just about all examples of successful import substitution policies in other countries implied focusing on global markets, making national economies more open, increasing their export potential, and bringing in strategic foreign investors. Therefore, in our opinion, an efficient import substitution policy does not exclude, but on the contrary, requires accomplishing, in a coordinated way, the objectives of integrating Russian producers into global added value chains, encouraging inflows of advanced knowledge and competencies into the Russian economy, and establishing international technological alliances [*Simachev et al.*, 2014a].

The results of our study show yet again that the micro (company-level) scale should be taken into account together with macro-level data when an import substitution policy is designed, among other things, to anticipate companies' probable reaction to various initiatives. The motives of companies who opt for imported products and technologies over Russian analogues (when the latter are even available) should be considered. This would help to identify major bottlenecks in domestic supply and concentrate the government's efforts on eliminating them by means of the import substitution policy.

Our empirical analysis allowed us to identify the factors which require priority attention — namely the very different nature of import dependence in various sectors of the economy, markets, and companies of different sizes. Accordingly, the degree of companies' import dependence and their motivations for using imports becomes very different. Therefore, different tools for encouraging import substitution should be applied in each specific case, to achieve the desired results efficiently. The effectiveness of standardised, universal solutions here is limited by definition; in addition, import substitution promotion measures need to be constantly adjusted, and a political will to abandon obsolete mechanisms is required.

The idea to introduce targets for a reduced share of imports for specific industries does not seem sensible. The level of companies' import consumption as such is not particularly important without taking into account its contribution to their competitiveness. Much more significant is the issue of businesses' stability when the external environment and market situation change, and the link between import dependence and broadly understood national security aspects, including medical, food and information security, etc. Therefore, when designing and implementing import substitution policy it is critically important to consider not only quantitative indicators reflecting the volume of imports and their share in apparent consumption, but also qualitative import dependence characteristics. In reality, even a significant volume of imports does not always mean high import dependence, and vice versa — a formally modest volume of imports may be crucial if no affordable alternatives to such products, technologies, or services are available.

Since the key reason for using imported products, technologies, and services is the lack of Russian analogues on the market, even taking into account that some of the respondents may have been simply unaware of existing alternatives, at this stage it would not be possible to fully resolve the import dependency problem by switching to a Russian supply. Therefore, the emphasis of import substitution policy should be placed not on the quickest possible overall reduction of the share of imports in Russian companies' consumption, but on setting up new competitive production facilities. Furthermore, demanding quick results would be very short-sighted, and even harmful.

Different categories of consumption, and therefore different sectors generating demand, require different import substitution models. For example, in the case of imported modules and aggregates, the issue of Russian analogues' not being able to meet relevant technological requirements comes to the foreground. Here an efficient strategy to reduce relevant companies' import dependence would be launching one's own production of the required products. The government's attempts to promote the procurement of Russian-made modules and aggregates with price-based incentives would be unlikely to succeed; it would make more sense to help launch the production of the relevant advanced products in Russia, designed in the country or elsewhere. As to the reasons companies opt for imported technologies, the high prices of Russian analogues play an important role here, combined with Russian developers' traditionally inadequate attention to specific customers' needs and requirements, and companies' insufficient awareness of domestic supply [*Simachev at al.*, 2014b]. Accordingly, the emphasis of government policy to promote the use of Russian technologies should be placed on subsidising their procurement by manufacturing companies, developing the R&D sector players' competences for working with the business sector clients, and promoting the advanced technological solutions they offer to potential customers.

Our analysis revealed that high-technology and export-focused companies tend to have the highest degree of import dependence. In their case, it is primarily due to the lack of Russian analogues, or the latter's low quality and/or inability to meet companies' technological requirements. Therefore, steps to enforce import substitution – tough or soft ones (such as recommendations) alike — can hinder the diversification of the economy, the growth of high-technology exports, and technological modernisation.

Helping Russian producers create or extend the supply of import-substituting products, technologies, and services should not turn into discrimination of consumer companies, particularly since, as our study reveals, successful high-technology firms would have the highest chances of being discriminated against. Attempts to thrust Russian products and technologies on companies using administrative methods, customs and tariff regulation, or by other means would almost inevitably result in their reduced competiveness, first of all, for leader companies. Therefore, any 'enforced import substitution' appears to be harmful, fraught with adverse economic consequences.

Russian import substitution policy commonly involves attempts to restore, upgrade, and build missing *production* elements of the national economy, i.e., it has a predominantly *vertical* nature. However, without accompanying horizontal steps to promote the development of specific critical technologies and the emergence of new areas of knowledge, develop missing research competences, it would have an inevitably limited 'shelf life', it would systematically lag, and focus mainly on price competitiveness. All this generates an expansion of an economy that is highly sensitive to currency fluctuations. On the contrary, a *proactive import substitution policy* is needed, which is focused on emerging markets.

This paper is based on, and further advances the results of the study "Monitoring and analysis of research and human potential of Russian R&D organisations focused on the development of import-substituting critical technologies, and preparing proposals on providing S&T and personnel support for projects aimed at setting up and developing import substituting production" (unique project identifier: RFMEFI57315X0010), carried out by OJSC "Inter-Departmental Analytical Center" funded by a subsidy provided by the Russian Ministry of Education and Science.

References

Amsden A. (2004) Import substitution in high-tech industries: Prebisch lives in Asia! *CEPAL Review*, vol. 82, pp. 75–89.

Aschhoff B. (2010) Who gets the money? The dynamics of R&D project subsidies in Germany. *Journal of Economics and Statistics*, vol. 230, no 5, pp. 522–546.

Baer W. (1972) Import Substitution and Industrialization in Latin America: Experiences and Interpretations. *Latin American Research Review*, vol. 7, no 1, pp. 95–122.

Berezinskaya O., Vedev A. (2015) Proizvodstvennaya zavisimost' rossiiskoi promyshlennosti ot importa i mekhanizm strategicheskogo importozameshcheniya [Dependency of the Russian Industry on Imports and the Strategy of Import Substitution Industrialization]. *Voprosy Ekonomiki,* no 1, pp. 103–115 (in Russian).

Bodrunov S., Rogova E. (2014) O bazovykh printsipakh formirovaniya importozameshchayushchei promyshlennoi politiki v Rossii [On basic principles of import substituting industrial policies in Russia]. *Aktual'nye problemy ekonomiki i upravleniya,* no 4 (4), pp. 7–12 (in Russian).

Bravo A., Álvarez M. (2012) The import content of the industrial sectors in Spain. *Banco de Espana Economic bulletin*, April, pp. 81–92. Available at: http://www.bde.es/f/webbde/SES/Secciones/Publicaciones/InformesBoletinesRevistas/BoletinEconomico/12/Abr/Files/art3e.pdf, accessed 12.05.2016.

Bruton H. (1998) A Reconsideration of Import Substitution. *Journal of Economic Literature*, vol. 36, pp. 903–936.

Chenery H., Syrquin M. (1975) *Patterns of development: 1950–1970*, London: Oxford University Press.

Cristobal K. (1990) *Reflections on the Latin American Contribution to Development Theory* (Working Paper no 82), Rotterdam: Institute of Social Studies. Available at: repub.eur.nl/pub/18931/wp82.pdf, accessed 23.05.2015.

Debowicz D., Segal P. (2014) Structural Change in Argentina, 1935–1960: The Role of Import Substitution and Factor Endowments. *The Journal of Economic History*, vol. 74, no 1, pp. 230–258.

Demidenko S. (2015) Importozameshchenie: Opyt Azii [Import substitution: Asian Experience]. *Praktika upravleniya,* no 4, pp. 22–25 (in Russian).

Dranev Ya., Kuznetsov B., Kuzyk M., Pogrebnyak E., Simachev Yu. (2014) *Opyt realizatsii promyshlennoi politiki v Rossiiskoi Federatsii v 2000-2012 gg.: institutsional'nye osobennosti, gruppy interesov, osnovnye uroki* [Experience in Implementing Industrial Policy in the Russian Federation in 2000-2012: Institutional Features, Interest Groups, Main Lessons], Moscow: RANEPA. Available at: http://ssrn.com/abstract=2443928, accessed 05.08.2016 (in Russian).

Fal'tsman V. (2015) Forsirovanie importozameshcheniya v novoi geopoliticheskoi obstanovke [Forcing the implementation of import substitution in the new geopolitical environment]. *Problemy prognozirovaniya,* no 1, pp. 22–32 (in Russian).

Fier A., Heneric O. (2005) *Public R&D Policy: The Right Turns of the Wrong Screw? The Case of the German Biotechnology Industry* (ZEW Discussion Paper no 05-60), Mannheim: Centre for European Economic Research (ZEW).

Franko P. (2007) *The Puzzle of Latin American Economic* (3rd ed.), Lanham, MD: Rowman & Littlefield Publishers, Inc.

Gorodnikova N., Gokhberg L., Ditkovskii K., Kuznetsova I., Lukinova E., Martynova S., Ratay T., Rosovetskaya L., Fridlyanova S. (2016) *Indikatory innovatsionnoi deyatel'nosti: 2016: statisticheskii sbornik* [Indicators of Innovation in the Russian Federation: 2016: Data Book], Moscow: HSE (in Russian).

Irisova O. (2013) Inogda oni vozvrashchayutsya [Sometimes they come back]. *World Economic Journal* (electronic journal). Available at: http://world-economic.com/ru/articles_wej-332.html, accessed 18.04.2016 (in Russian).

Ivanov D., Kuzyk M., Simachev Yu. (2012) Stimulirovanie innovatsionnoi deyatel'nosti rossiiskikh proizvodstvennykh kompanii: novye vozmozhnosti i ogranicheniya [Fostering Innovation Performance of Russian Manufacturing Enterprises: New Opportunities and Limitations], *Foresight-Russia,* no 2, pp. 18–41 (in Russian).

Kaushan K., Bogushevskii S. (2009) Integratsiya kak forma adaptatsii rossiiskikh predpriyatii k sovremennym rynochnym usloviyam [Integration as a form of Russian enterprises adaptation to the current market conditions]. *Vestnik Volgogradskogo gosudarstvennogo universiteta, Seriya 3: Ekonomika. Ekologiya,* no 2, pp. 138–141 (in Russian).

Kondrat'ev A. (2014) Importozameshchenie: dve storony odnoi monety [Import substitution: Two sides of the same coin]. *Biznes Rossii* (electronic journal). Available at: http://businessofrussia.com/dec-2014/item/975-kondratyev.html, accessed 21.02.2016 (in Russian).

Kozyreva E., Novikova N. (2015) Opyt realizatsii politiki importozameshcheniya i eksportnoi orientatsii v zarubezhnykh stranakh [Experience of import substitution policy in Brazil and Taiwan]. *Vestnik TvGU/Seriya: Ekonomika i upravlenie,* no 3, pp. 241–247 (in Russian).

Kravchenko N. (2015) Istoriya importozameshcheniya [History of import substitution]. *ECO*, no 9, pp. 73–91 (in Russian).

Kurre J. (2011) *Building Erie by Buying Erie: An Import Substitution Strategy for Erie County*, Erie, PA: Economic Research Institute of Erie, Penn State Erie, The Behrend College. Available at: http://www.planerieregion.com/uploads/PDF/Import%20Substitution%20Strategy%20Building%20Erie%20By%20Erie.pdf, accessed 17.05.2016.

Kvashnina I., Obolenskii V., Shuiskii V. (2013) *Vneshneekonomicheskie faktory modernizatsii rossiiskoi ekonomiki* [External economic factors of the Russian economy modernization], Moscow: RAS Institute of Economics. Available at: http://inecon.org/docs/Obolensky_paper_2013.pdf, accessed 21.02.2016 (in Russian).

Kwon J. (2010) *Import Substitution at the Regional Level: Application in the United States*, Atlanta: Federal Reserve Bank of Atlanta. Available at: http://www.frbatlanta.org/documents/news/conferences/10smallbusiness_kwon.pdf, accessed 17.05.2016.

Mekhanik A. (2013) Stanok dlya novogo uklada [The machine tool for the new mode]. *Ekspert* (electronic journal), no 7 (839). Available at: http://expert.ru/expert/2013/07/stanok-dlya-novogo-uklada/, accessed 19.04.2016 (in Russian).

Narula R. (2002) *Switching from Import Substitution to the New Economic Model in Latin America: A Case of Not Learning from Asia* (Strategic Management Society Working Paper no 4), Maastricht: Maastricht University.

Neprintseva E. (2006) Vertikal'naya integratsiya: stimuly i preimushchestva [Vertical integration: Incentives and benefits]. *Upravlenie kompaniei,* no 7, pp. 73–76 (in Russian).

Ogujiuba K., Nwogwugwu U., Dike E. (2011) Import substitution industrialization as learning process: Sub Saharan African experience as distortion of the "good" business model. *Business and Management Review*, vol. 1, no 6, pp. 8–21.

Panicz U. (2015) Reshoring as a form of relocation of economic activity – US firms case study gaining (Chapter 9). *Enterprises in Unstable Economy* (ed. B. Prusak), Gdansk: Gdansk University of Technology, pp. 94–107. Available at: ftp://ftp.zie.pg.gda.pl/RePEc/gdk/chapte/ENTIME2015_CH_9.pdf, accessed 12.07.2016.

Pobyvaev S., Tolkachev S. (2015) Reindustrializatsiya v ES i SShA [The re-industrialization in the United States and the EU]. *World of New Economy,* no 2, pp. 29–36 (in Russian).

Prebisch R. (1950) *The Economic Development of Latin America and Its Principal Problems // Economic Commission for Latin America*, Lake Success, NY: United Nations Department of Economic Affairs. Available at: http://archivo.cepal.org/pdfs/cdPrebisch/002.pdf, accessed 18.06.2015.

Rodrigues M. (2005) Import Substitution and Economic Growth. *Journal of Monetary Economics*, vol. 57, no 2, pp. 176–188.

Simachev Yu., Kuznetsov B. (2014) Evolutsiya gosudarstvennoi promyshlennoi politiki v Rossii [Evolution of State Industrial Policy in Russia]. *Journal of the New Economic Association*, no 22, pp. 152–179 (in Russian).

Simachev Yu., Kuzyk M., Feigina V. (2014b) Vzaimodeistvie rossiiskikh kompanii i issledovatel'skikh organizatsii v provedenii NIOKR: tretii ne lishnii? [R&D Cooperation between Russian Firms and Research Organizations: Is There a Need for State Assistance?]. *Voprosy Ekonomiki,* no 7, pp. 4–34 (in Russian).

Simachev Yu., Kuzyk M., Kuznetsov B., Pogrebnyak E. (2014a) Rossiya na puti k novoi tekhnologicheskoi promyshlennoi politike: sredi manyashchikh perspektiv i fatal'nykh lovushek [Russia on the Path Towards a New Technology Industrial Policy: Exciting Prospects and Fatal Traps]. *Foresight-Russia*, vol. 8, no 4, pp. 6–23 (in Russian).

Tsukhlo S. (2015) Teper' bez emotsii: chto meshaet importozameshcheniyu v Rossii [No emotion: What hinders the implementation of import substitution in Russia]. *RBK* (electronic journal). Available at: http://www.rbc.ru/opinions/economics/28/10/2015/56309c699a7947c537e05f9e, accessed 30.04.2016 (in Russian).

Vatolkina N., Gorbunova N. (2015) Importozameshchenie: zarubezhnyi opyt, instrumenty i effekty [Import substitution: international experience, instruments and effects].*St. Petersburg State Polytechnical University Journal. Economics,* vol. 6, no 233, pp. 29–39 (in Russian).

Zhu T. (2006) *Rethinking Import-substituting Industrialization. Development Strategies and Institutions in Taiwan and China* (UNU-WIDER Research Paper no 76), Helsinki: UNU-WIDER.

Zil'berman M., Strovskii L. (2009) Vliyanie obmennogo kursa na protsess importozameshcheniya v usloviyakh mirovogo finansovogo krizisa [Impact of the exchange rate on the process of import substitution in the context of the global financial crisis]. *Bulletin of Ural State Technical University. Series Economics and Management,* no 3, pp. 75–82. (in Russian).

Zudin N. (2015) Vzaimosvyaz' tekhnologicheskogo urovnya sektora s kharakteristikami kompanii i gosudarstvennoi podderzhkoi [Relationship of the technology level of sector with company characteristics and public support]. *Innovations,* no 6, pp. 61–70 (in Russian).

Knowledge-Intensive Business Services in Russia: 2014–2015 Crisis Aftermath

Veronika Belousova [a]
Associate Professor and Head, vbelousova@hse.ru

Nikolay Chichkanov [a]
Research Assistant, nik.chichkanov@gmail.com

[a] Department for Methodology of Budget Planning, Institute for Statistical Studies and Economics of Knowledge, National Research University Higher School of Economics, 11 Myasnitskaya str., 101000 Moscow, Russian Federation

Abstract

In recent years, knowledge-intensive business services (KIBS) have become extremely important in the knowledge-based economy. KIBS concentrate a well-qualified workforce and create high levels of value-added services, serve as a driver for the innovation-based development of many countries [*Santos-Vijande et al.,* 2013]. However, the growth rates of this sector in Russia considerably fell after the 2008 crisis; some KIBS-industries could not even reach pre-crisis volumes of production and the share of this sector in GDP significantly declined [*Berezin, Doroshenko,* 2015]. The crisis trends in Russian economy at the end of 2014 and at the beginning of 2015 had a strong negative impact on KIBS.

We show that the share of companies with decreasing revenues has dramatically grown in all industries. The demand side has also changed: the client base is now more unstable and customers more regularly fail to fulfill contract obligations. An industry analysis reveals significant divergences in the rates and trajectories for development of Russian KIBS industries. However, the sector heterogeneity might be also found in KIBS of other countries. The paper is based on both survey of 656 Russian KIBS producers and in-depth interviews with 24 leading KIBS experts.

Keywords: service economy; knowledge-intensive business services; crisis; industrial analysis; knowledge-intensive business services producers; knowledge-intensive business services consumers.

DOI: 10.17323/1995-459X.2016.4.46.58

Citation: Belousova V., Chichkanov N. (2016) Knowledge-Intensive Business Services in Russia: 2014–2015 Crisis Aftermath. *Foresight and STI Governance*, vol. 10, no 4, pp. 46–58. DOI: 10.17323/1995-459X.2016.4.46.58.

The service sector plays a key role in most of today's developed economies. The World Bank estimated its contribution to GDP and employment in various developed countries (such as Canada, the US, Japan, and Australia) in excess of 70% in 2012–2013 [Quandl, 2016a]. A similar situation was observed in Russia, among various other aftereffects of the catch-up development paradigm: the service sector's contribution to the nation's GDP in 2013 amounted to 59.78%, and its share of the total employment in 2009 was 62.3% [Quandl, 2016a, 2016b]. One of the most important segments of the service sector is *knowledge-intensive business services (KIBS*); it has the highest innovation potential and acts as a driver of the whole sector's growth [*Santos-Vijande et al.,* 2013]. Since the KIBS market players mostly work with international companies [*Zieba,* 2013], their operations affect the whole economy [*Asikainen,* 2015]. Finally, the sector traditionally employs a large share of highly skilled personnel and generates steadily growing added value created by 'smart' labour producing knowledge-intensive services [*Muller, Zenker*, 2001].

Scholars usually adopt an integrated approach when assessing the KIBS sector's role in innovation. On the one hand, the sector's companies act as a kind of brokers who help to find and process information, and bring together other participants of the innovation process [*Muller, Doloreux,* 2009; *Consoli, Elche-Hortelano,* 2010]. Their activities directly affect the rate of innovations' dissemination, since they deal with large and small companies in various regions [*Doloreux, Shearmur,* 2013]. Researchers note that competition forces players in different market segments to increase their specialisation and protect their niches [*Aslesen, Isaksen,* 2010]. The knowledge-intensive services sector offers increased opportunities for outsourcing advertising, audit, and other services, thus helping companies strengthen their competitive advantages by concentrating on producing unique products. At the same time, in recent years the sector's companies increasingly often acted not just as brokers but also as actual innovators [*Muller, Doloreux,* 2009; *Doloreux et al.,* 2010], making use of their access to their clients' data, accumulated knowledge and experience. The latter allows one to adapt products and services to specific clients' needs to the maximum extent possible, abandoning uniform approaches [*Doloreux, Shearmur,* 2010].

A specific feature of the KIBS sector is the actual 'production process' which typically involves very close interaction with clients, thus allowing one to speak of 'coproduction'. Coproduction and client relations issues as "inherent components of innovation and production processes" [*Asikainen,* 2015, p. 81] remain at the core of numerous international [*Corrocher et al.,* 2009; *Bettiol et al.*, 2011] and Russian [*Doroshenko et al., 2013; Doroshenko et al.,* 2014] studies. The authors of a review of Russian KIBS companies' operations in 2005–2013 [*Berezin, Doroshenko*, 2015] noted that in 2010–2012, the post-recession recovery in most industries of the sector was slow, while its contribution to GDP fell to 2.5–2.8% (compared with 3.8–4.1% before the crisis). Such services as engineering, design, and development have never managed to return to the level of 2008. The 2008 crisis had a very negative overall effect on the sector: in various industries the output fell by between 25% and 60%.

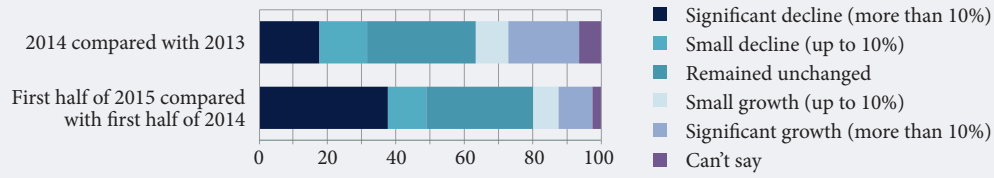
The most recent expert assessments of the KIBS sector's output and growth rates in 2005–2015, for the whole sector and its ten segments, can be found in [*Berezin,* 2016]. According to the author, growth rates in various segments of the sector started to differ in 2014. Three groups of markets were identified through an expert survey, based on their rouble-denominated nominal revenues' growth rates. The first group (design services) displayed a relatively high growth rate of this indicator; in the second group (advertising, marketing, ICT, and engineering services) costs were growing at a higher rate than revenues; and in the third group (audit, consulting, and leasing services) revenues started to decline as early as the second half of 2014. The data presented in the study allows one to divide the above segments into growing, moderately declining, and rapidly declining ones. According to the experts, differentiation of these markets has increased during the first half of 2015, with the 'depth of decline' becoming the main criterion for their classification. The reduction of rouble-denominated revenues in marketing, audit, consulting, engineering, and ICT services was rather small (5–7%) while in design, financial, and HR services it was quite significant (up to 30%).

The objective of our study is to analyse the trends in the knowledge-intensive services sector between the end of 2014 and the first half of 2015 — a period marked by adverse developments in the Russian economy. According to the Federal Statistics Service (Rosstat), in the first and second quarters of 2015 GDP fell by 2.79% and 4.52% compared with the relevant periods of 2014, respectively [Rosstat, 2016a]. Inflation increased significantly, reaching 4.8% in the fourth quarter of 2014 and 7.4% in the first quarter of 2015 [Rosstat, 2016b]; the average monthly rouble-to-dollar exchange rate steadily dropped between November and January, by 13%, 21%, and 17%, respectively [CBR, 2016a]. The amount of bank loans issued to companies to upgrade their production capacity has noticeably decreased between 1 January, 2014 and 1 January, 2015, both in absolute (from 1,004 trillion to 918.0 billion roubles) and relative terms (from 10% to 9.3% of companies' total capital investments) [CBR, 2016b].

Empirically, the study is based upon the data collected over the course of the ongoing Monitoring of Knowledge-Intensive Business Services in Russia (Monitoring), a study conducted by the HSE Institute of Statistical Studies and Economics of Knowledge (ISSEK) since 2006 jointly with Romir Research Holding in the scope of the HSE Basic Research Programme[1]. 656 Russian companies — producers of

[1] See https://www.hse.ru/monitoring/intel for more (last accessed on 02.05.2016).

Figure 1. **Turnover (revenue) growth of the knowledge-intensive services sector companies in 2014 — the first half of 2015 (%), n = 656**



Note: This and subsequent figures and tables are compiled by the authors using data from the HSE ISSEK study "Monitoring of Knowledge-Intensive Business Services in Russia".

knowledge-intensive services were surveyed in 2015, the respondents included managers and leading staff members. The sample was designed on the basis of a pilot survey of 50 respondents conducted to test the specially developed toolset. It strictly matched the survey's objectives and methodology and was representative (it covered all segments of the sector). The industry's geographical diversity was also taken into account: the sample proportionally reflects each Russian region's share of the gross regional product (GRP) in the combined GRP of the 14 most economically developed regions of the country.

The sector's quantitative characteristics were supplemented with a qualitative analysis: 24 in-depth interviews were conducted with leading experts in the relevant fields holding senior positions at industrial associations and major self-regulating organisations. Each of the experts had a very good understanding of the current state of and prospects for the relevant segments, while the total number of the respondents was determined taking into account the results of similar international studies[2]. For example, according to Kathy Charmaz's calculations, for small projects 25 respondents are enough to make a qualitative study reliable [*Charmaz,* 2006, p. 114]. Judith Green and Nicki Thorogood agree with her; they note that after 20 interviews respondents' input becomes noticeably less original [*Green, Thorogood,* 2004, p. 103–104]. Abbie Griffin and John Hauser revealed that 90% of all clients' needs can be met by conducting 20–30 in-depth interviews [*Griffin, Hauser,* 1993, p. 23]; having analysed 100 studies, Stanley Bruce Thomson sets the ceiling for the number of respondents at about the same level (30 interviews) [*Thomson,* 2011, p. 50].

Our study is structured in the following way: the first section presents indicators for measuring KIBS producers' performance. The second section analyses changes in their customers' behaviour, i.e. factors affecting demand. Results of the sector's analysis and main conclusions are presented in the final section.

Producers of knowledge-intensive business services in 2014-2015

The overall negative situation in the Russian economy cannot avoid affecting the KIBS sector as well. If after 2014 about a third of the companies participating in the survey reported an increase of their annual rouble-denominated revenues, after the first six months of 2015 their share had almost halved. At the same time, the share of companies who have managed to maintain their turnover level remained practically unchanged. Thus, the reduced number of companies whose business has grown was due to the significantly larger number of firms whose revenues have shrunk. The share of market players whose rouble-denominated turnover has dropped significantly (by more than 10%) grew from 18% to 38%. Changes in companies' turnover growth rates are shown in Figure 1.

The KIBS sector's costs structure is quite unusual: personnel costs account for about 50% of them in all aforementioned segments. The lowest level of this indicator is noted in IT consulting services (45.2%), the highest — in audit and management consulting (53.18%). The median value for 8 out of 10 industries is 50%, and for the remaining two — 45%. The data collected through a quantitative survey conducted in the framework of the Monitoring study is presented in Table 1.

According to the surveys, at just over a half of the sector's companies, the number of staff and the average rouble-denominated wage remained unchanged between the autumn of 2014 and late summer of 2015. The reduction of the number of employees and the average rouble wage was reported by almost 30% and 23% of the companies, respectively (see Table 2).

The experts, the participants in the in-depth interviews, have also confirmed the overall negative trends in the sector. Most of them noted that though big players in the knowledge-intensive services market on the whole have retained their positions, some of them did experience certain contraction. In this context, this means various forms of cost optimisation such as wage cuts, layoffs, moving to smaller premises, etc. The shares of small and medium companies who had to leave the market are much larger. According to

[2] Other opinions about what sample size can be considered sufficient also exist; the most comprehensive review of relevant sociological studies can be found in [*Rozhdestvenskaya*, 2012, pp. 70–73].

Table 1. **The share of the knowledge-intensive services sector companies' personnel costs, including wages/salaries, bonuses, benefits, taxes, and deductions, n = 656**

	Adv	Cons	Aud	IT	HR	Eng	Fin	Law	Dev	Web
Number of companies	71	65	65	67	59	70	63	59	72	59
Average value (%)	48.42	45.20	53.18	49.19	45.85	46.41	47.78	48.36	45.53	46.92
Median value (%)	50.00	45.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	45.00
Standard deviation	15.26	14.41	16.08	15.07	15.78	16.01	14.47	14.71	12.93	19.45

Note: The following industry designations are used in this and subsequent tables: Adv — advertising; Cons — information and communication consulting services; Aud — audit and management consulting services; IT — information technology consulting services; HR — human resources consulting services; Eng — engineering services; Fin — financial intermediation; Law — legal services; Dev — development and real estate services; Web — web-related, design and digital services.

the respondents, in many cases this was due to such companies' origins: they were created at the peak of economic growth, they could not cope with a recession and had to discontinue operations. However, in most cases this was a temporary measure, until the economy's next upward swing. Some of the small companies were absorbed by larger ones, employees of others became freelancers or 'came home' — i.e., got hired by their old employers' clients. This is particularly common in legal services, HR consulting, and management.

No noteworthy new players appeared in any of the sector's segments — which some of the experts believed was perfectly natural in a stagnating economy. Stagnation is not total, however: medium and small companies not only leave the market but also enter it. Another trend noted by the experts was professionals' "circulating" within a stable pool: when a company closes down some of its employees begin to engage in freelance work, or companies may split into several smaller ones. These factors ensure a steady labour supply for segments like HR and legal services. However, these processes do not always involve the emergence of new service providers.

Demand trends

The main users of knowledge-intensive services are other companies, so the sector's players are somewhat dependent on their clients' financial situation. During the first six months of 2015, only half of the companies received full payment for services provided on time, in line with previously signed contracts. Customers of another 24% of companies did not pay on time up to 10% of the contract value. 16% more of the respondents reported aggregate unpaid debt of between 11% and 20% of the total contract value (Figure 2).

The experts identified several trends in the structure of KIBS companies' clients (Table 3). Firstly, the recession could not but affect demand — the number of new customers is shrinking. However, in most industries a degree of substitution does take place: new entrants come to replace the players who have left the market, mostly from the ranks of former clients — 'new customers in old industries'. Car makers are most frequently mentioned among those leaving the market, while the majority of new entrants is made up of agricultural and pharmaceutical companies.

Another noticeable trend is major budget cuts, and therefore reduced procurement by many existing customers. On the other hand, the client base in certain industries of the sector — such as IT, legal, HR services, etc. did not experience any significant changes. However, the experts also noted that clients became more demanding about the services they order, while the average order value and the rate of inquiries' conversion into actual orders keep dropping.

Thirdly, the importance of the public sector as a steady buyer of IT services is growing. Government agencies and state-owned companies are becoming new clients on the advertising, engineering, and

Table 2. **Breakdown of the knowledge-intensive services sector companies by change of the number of employees and the average rouble wage between early autumn of 2014 and late summer of 2015 (%), n=656**

Change of the number of employees		Change of the average rouble wage	
Small reduction (under 5%)	8.84	Small reduction (under 5%)	5.18
Reduction (5–20%)	14.63	Reduction (5–20%)	13.57
Significant reduction (over 20%)	6.25	Significant reduction (over 20%)	4.57
Remained unchanged	52.44	Remained unchanged	56.10
Small increase (under 5%)	2.75	Small increase (under 5%)	4.12
Increase (5–20%)	4.88	Increase (5–20%)	7.77
Significant increase (over 20%)	2.44	Significant increase (over 20%)	1.37
Can't say	7.77	Can't say	7.32

Figure 2. **Breakdown of the knowledge-intensive services sector companies by the share of accounts receivable in the total contract value during the first six months of 2015 (%), n = 656**

design services markets. In the latter case, increased demand was noted not just by government agencies as such (including the Ministry of Defence, Ministry of Culture, etc.), but by their staff members acting as individuals.

The experts' conclusions on the whole match the above data. Indeed only a third of the companies managed to keep their client base during the last 18 months, while a quarter of the players have lost 5–10% of their former clients, and almost 16% more companies lost 11–20% of their customers. At the same time, only one company in five were unable to attract any new clients; most of the firms (about 61.6%) did find new customers, with the latter's share in the companies' client base growing by 5–10% or by 11–20%. Client base dynamics are shown in Figure 3.

A parallel analysis of both these client base trends provides the best picture of what is actually happening in the sector: the recession led to the client base shrinking at 27% of the companies, while the same share of market players managed to retain the number of their customers at a level close to the pre-recession one.

Approximately 38% of the companies reported an increase of their client base. The experts attribute this to the fluctuations of the rouble exchange rate hindering access to services offered by foreign companies, thus prompting customers to switch to Russian suppliers. Another recession-induced factor may also have played a role: after some service providers left the market the remaining players divided their former customers between themselves (while the total number of customers remained unchanged).

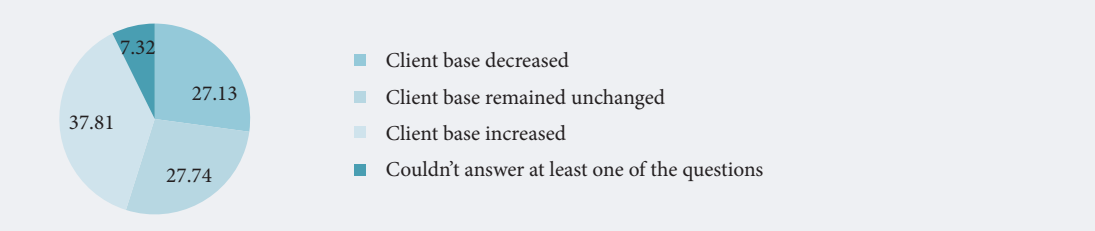
Sector-specific features

The knowledge-intensive services sector is highly diverse, in Europe [*Camacho, Rodriguez,* 2008] and Russia [*Doroshenko et al.,* 2014] alike. The sector's industries are quite different, not just in terms of the underlying knowledge base but also in the nature of services provided [*Freel,* 2010]. Two groups of industries are traditionally identified — professional knowledge-intensive business services (P-KIBS) such as accounting or legal services, and new technological knowledge-intensive business services (T-KIBS) [*Miles,* 1993], e.g. IT-related services [*Muller, Doloreux,* 2009; *Consoli, Elche-Hortelano,* 2010]. T-KIBS largely depend on R&D, while organisational and management approaches and practices play

Table 3. **Breakdown of the knowledge-intensive services sector companies by change in the customer structure between early autumn of 2014 and late summer of 2015 (%), n = 656**

Question to respondents: Please estimate the share of clients (%) who have left the market in the last 18 months out of the total number in the first quarter of 2014		Question to respondents: Please estimate the share of new clients (%) who have entered the market in the last 18 months out of the total number of customers in the third quarter of 2015	
All customers are still there	34.45	No new customers	19.67
5–10%	24.8	5–10%	40.09
11–20%	15.70	11–20%	21.49
21–30%	6.86	21–30%	6.56
31–40%	5.03	31–40%	2.13
41–50%	2.13	41–50%	1.37
More than 50%	4.73	More than 50%	7.32
Can't say	6.25	Can't say	1.37

Figure 3. **Breakdown of the knowledge-intensive services sector companies by change of their client base in 2014 — the first six months of 2015 (%), n = 656**



a key role in providing P-KIBS [*Freel,* 2010]. Recently creative segments of the knowledge-intensive services sector (advertising, design, multimedia, branding, etc.) were included in a category of their own [*Marasco et al.,* 2013].

The above segmentation of the sector was also confirmed by in-depth interviews with Russian experts, many of whom pointed out various industries' specific features. This article will take a look at the expert assessments of changes in the knowledge-intensive services sector broken down by industries. The dynamics of all the aforementioned indicators (revenues, order and customer structures, personnel, wages) are presented in Tables 4–9, by industry. This data is supplemented by analysis of in-depth interviews with experts in specific industries, including PR, knowledge management, design, and development services.

Advertising services

According to the experts, in 2014 the advertising market grew in rouble terms but contracted in US dollar terms, because it directly depends on the overall economic situation. This market's volume allows one to tie customers' advertising expenditures to fluctuations in GDP. One of the experts noted that "when GDP grows, advertising expenditures also grow. If GDP shrinks, advertising expenditures also shrink". In 2015, the market's growth rate was expected to slow down by approximately 10%, with a possible increase of certain players' market shares. These forecasts came true: in the first six months of 2015 the share of advertising companies whose revenues fell by more than 10% was higher than in any other segment of the KIBS sector (see Table 4). At the same time, the share of companies whose revenues grew by more than 10% was also the highest in this segment. Similarly, the number of employees (Table 5) and labour cost (Table 6) indicators have also shown contradictory dynamics. Possibly that was the reason the experts did not describe the situation on the advertising market as a crisis.

Our study shows that most of the new players in this industry are 'pocket' advertising agencies, or were set up following companies' splitting up, or registered as affiliates of existing firms. Whether such processes can be interpreted as the emergence of new market players remains an open question.

As to clients, on the one hand, companies have been cutting their advertising costs due to fluctuations of the rouble's exchange rate, while on the other, local advertisers have stepped up their activities to

Table 4. **Breakdown of the knowledge-intensive services sector companies by revenue growth, by industry (%), n = 656**

2014 compared with 2013 (%)											
	Adv	**Cons**	**Aud**	**IT**	**HR**	**Eng**	**Fin**	**Law**	**Dev**	**Web**	**All**
Significant decrease (more than 10%)	20.8	15.4	19.7	17.9	10.2	32.4	10.9	25.4	16.2	5.1	17.6
Small decrease (less than 10%)	9.7	16.9	9.1	13.4	16.9	8.5	15.7	25.4	14.9	11.9	14.0
Remained unchanged	26.4	32.3	36.4	26.9	39.0	36.6	37.5	20.3	23.0	42.3	31.7
Small increase (less than 10%)	13.9	9.2	9.1	11.9	6.8	5.6	15.6	5.1	12.2	5.1	9.6
Significant increase (more than 10%)	25.0	21.6	19.7	23.9	18.6	8.5	15.6	17.0	24.3	33.9	20.7
Can't say	4.2	4.6	6.0	6.0	8.5	8.4	4.7	6.8	9.4	1.7	6.4
First six months of 2015 compared with first six months of 2014 *(%)*											
	Adv	**Cons**	**Aud**	**IT**	**HR**	**Eng**	**Fin**	**Law**	**Dev**	**Web**	**All**
Significant decrease (more than 10%)	48.6	40.0	37.9	31.3	33.9	46.5	21.9	44.1	48.6	18.6	37.7
Small decrease (less than 10%)	8.4	15.4	12.1	11.9	8.4	8.4	14.1	13.6	9.5	11.9	11.3
Remained unchanged	22.2	33.8	39.4	37.3	44.1	28.2	42.2	20.3	17.6	30.5	31.2
Small increase (less than 10%)	11.1	6.2	1.5	6.0	6.8	5.6	10.9	3.4	13.5	8.5	7.5
Significant increase (more than 10%)	9.7	3.1	7.6	9.0	6.8	8.5	9.4	15.2	6.7	25.4	9.9
Can't say	0.0	1.5	1.5	4.5	0.0	2.8	1.5	3.4	4.1	5.1	2.4

Table 5. **Breakdown of the knowledge-intensive services sector companies by change in the number of employees between early autumn of 2014 and late summer of 2015, by industry (%), n = 656**

	Adv	Cons	Aud	IT	HR	Eng	Fin	Law	Dev	Web	All
Significant decrease (more than 20%)	9.7	3.1	7.6	7.4	6.8	12.7	6.2	3.4	2.7	1.7	6.3
Decrease (5–20%)	19.5	16.9	15.2	7.5	8.4	12.7	12.5	30.5	18.9	3.4	14.6
Small decrease (less than 5%)	11.1	10.8	9.1	3.0	6.8	4.2	15.6	8.5	12.2	6.8	8.9
Remained unchanged	40.3	50.8	51.5	55.2	62.7	54.9	56.3	49.1	45.9	61.0	52.4
Small increase (less than 5%)	1.4	7.7	1.5	3.0	3.4	2.8	1.6	1.7	1.4	3.4	2.7
Increase (5–20%)	8.3	4.6	0.0	9.0	5.1	1.4	3.1	3.4	8.1	5.1	4.9
Significant increase (more than 20%)	2.8	1.5	3.0	1.5	1.7	0.0	0.0	3.4	2.7	8.5	2.4
Can't say	6.9	4.6	12.1	13.4	5.1	11.3	4.7	0.0	8.1	10.1	7.8

promote sales in their home region and neighbouring ones. Still, if on the whole advertising companies' client base was replenished in line with the overall situation in the sector (Table 7), in terms of retaining former customers the industry significantly lagged behind others. Therefore, the share of advertising firms who have managed to keep all their clients is more than 33% smaller than the average for the KIBS sector (Table 8).

Large advertising agencies increasingly often take small companies' orders. If clients with a budget below a certain level used to be cut-off by default, this hardly ever happens now. The experts stressed that there was no evidence of customers returning to the advertising market.

Marketing services

Accurately estimating the volume of the marketing services market is not an easy task because customers spend a significant proportion of their budgets not on the market, but in-house by recruiting personnel or through subcontracting. There was also the double count problem — when the same contract was included in the parent company's, its regional partners', and subcontractors' accounting report, i.e., the nominal budget turns out much larger than the actual one. In certain areas, e.g., direct marketing, customers' budgets indeed were cut, while in others they remained unchanged. In turnover terms, the speed of sales is particularly important during a recession, so funds were allocated from the budgets to increase it by using various marketing techniques usually the budgets are not revised. Another feature of this industry is emergence of a separate 'digital marketing' segment.

When assessing the volume of the marketing services market, the experts noted the 'Olympic Games effect' referring to the significant amounts of money allocated in 2014 to fund the projects related with the Sochi Winter Olympics. Compared with that year, the contraction of the market in 2015 was significant — while compared with 2013 it was more modest, at about 10%. The surveyed experts attributed this to recession-induced uncertainty and even panic among clients. Providers of marketing services very much depend on their customers; when the latter have financial problems, they tend to cut marketing budgets before anything else, so the overall economic situation directly affects this industry.

PR services

Similar to the previous case, problems with assessing this market's volume are associated with the need to separate market trends from companies' internal activities. For companies, maintaining their own PR departments, creating content and organising events on their own absorb about 70–75% of the relevant budgets. Still, according to the experts, in rouble terms the market grew by 15–20% in 2013; no growth was noted in 2014, but no decline either. Forecasts for 2015 envisaged either zero growth or a decline of

Table 6. **Breakdown of the knowledge-intensive services sector companies by growth of the average rouble-denominated wage between early autumn of 2014 and late summer of 2015, by industry (%), n = 656**

	Adv	Cons	Aud	IT	HR	Eng	Fin	Law	Dev	Web	All
Significant decrease (more than 20%)	6.9	4.6	6.1	4.5	3.4	8.5	1.6	3.4	5.4	0.0	4.5
Decrease (5–20%)	22.2	13.9	13.6	4.5	13.5	15.5	15.6	11.8	20.3	1.7	13.6
Small decrease (less than 5%)	5.5	9.2	4.6	3.0	0.0	5.6	4.7	8.5	6.8	3.4	5.2
Remained unchanged	38.9	55.4	54.5	64.2	69.5	52.1	65.6	66.1	40.5	61.0	56.1
Small increase (less than 5%)	5.6	1.5	1.5	3.0	6.8	2.8	6.2	3.4	5.4	5.1	4.1
Increase (5–20%)	12.5	7.7	9.1	11.9	3.4	4.2	1.6	3.4	8.1	15.2	7.8
Significant increase (more than 20%)	4.2	0.0	0.0	0.0	0.0	0.0	1.6	3.4	1.3	3.4	1.4
Can't say	4.2	7.7	10.6	8.9	3.4	11.3	3.1	0.0	12.2	10.2	7.3

Table 7. **Breakdown of the knowledge-intensive services sector companies by share of new customers brought in between early autumn of 2014 and late summer of 2015, by industry (%), n = 656**

Question to respondents: Please estimate the share of new customers (%) brought in during the last 18 months in comparison with the total number of your company's clients in the third quarter of 2015											
	Adv	Cons	Aud	IT	HR	Eng	Fin	Law	Dev	Web	All
No new customers	19.4	16.9	25.8	17.9	25.4	36.6	17.2	13.6	9.5	13.5	19.7
5–10%	34.7	46.2	39.4	35.8	44.1	38.1	43.7	45.8	39.2	35.6	40.1
11%–20%	26.4	27.7	24.2	28.3	11.8	12.7	17.2	22.0	20.3	23.7	21.5
21–30%	4.2	1.6	6.1	7.5	11.9	2.8	12.5	3.4	8.1	8.5	6.5
31–40%	2.8	1.5	1.5	6.0	0.0	1.4	1.6	0.0	1.3	5.1	2.1
41–50%	1.4	1.5	0.0	0.0	0.0	2.8	1.6	1.7	1.3	3.4	1.4
More than 50%	8.3	4.6	3.0	4.5	5.1	5.6	6.2	13.5	16.2	5.1	7.3
Can't say	2.8	0.0	0.0	0.0	1.7	0.0	0.0	0.0	4.1	5.1	1.4

up to 10%. PR is one of the few industries where new market players did emerge. One of the segment's specific features is the inefficiency of cost-cutting strategies. The experts did not see any grounds to speak about a crisis in this industry, because major players were quite optimistic while the fears of small and weak participants were inevitable and not connected with the recession.

In IT consulting services, the share of companies whose revenues significantly fell during the first six months of 2015 was 40%, or slightly more than the sector's average (Table 4). The share of companies whose revenues have slightly increased was below average, and of those who achieved more than 10% growth was the lowest among all industries of the sector — 67% below the average value. Possibly this was due to the 'Olympic Games effect' noted by the experts. Almost a quarter of the companies operating in this industry have a share of unpaid bills between 11% and 20%, while the average figure for the KIBS sector is 33% smaller (Table 9).

Audit services

Audit is compulsory in many industries, so a certain share of the market remains unchanged regardless of the economic situation. In particular, the voluntary audit market remains highly stable. At the same time, since 2015 companies have been gradually abandoning their previous focus on reporting to international standards. Cost-cutting in the industry is based on optimising business processes without any significant personnel cuts. Generally, the industry's main challenges are associated not so much with the overall economic recession as with the regulator's policies; therefore, the latter sets the vector for the industry's development.

The experts' assessments were confirmed by quantitative data. The share of audit and management consulting companies, which received full payment from their customers on time (53%) is higher than the average for the KIBS sector (49.5%) (Table 9). Typically, the industry boasts the largest share of companies who have managed to retain all their customers (44.0%, against the 34.5% average for the sector). However, the share of companies who were unable to bring in new partners is also quite large (25.8%, against the 19.7% average for the sector) (Tables 7 and 8). The number of employees (Table 5) and labour cost (Table 6) dynamics are in line with the sector's averages.

Management consulting services

The surveyed experts noted that two contradictory trends collided in 2014: the number of potential customers' enquiries significantly grew (by 50–65%), while the rate of their conversion into actual orders

Table 8. **Breakdown of the knowledge-intensive services sector companies by share of customers lost between early autumn of 2014 and late summer of 2015, by industry (%), n = 656**

Question to respondents: Please estimate the share of customers (%) who have left the market during the last 18 months compared with the total number of your company's clients in the first quarter of 2014											
	Adv	Cons	Aud	IT	HR	Eng	Fin	Law	Dev	Web	All
All our customers are still there	22.2	36.9	44.0	40.3	37.3	35.2	39.1	27.1	24.3	40.7	34.5
5–10%	27.8	30.8	21.2	32.8	23.7	16.9	26.6	20.3	14.9	35.6	24.8
11–20%	22.2	16.9	10.6	7.4	23.7	14.1	15.6	23.7	13.5	10.1	15.7
21–30%	9.7	1.5	7.6	3.0	3.4	9.9	3.1	10.2	14.9	3.4	6.9
31–40%	6.9	3.1	12.1	3.0	3.4	7.0	3.1	1.7	5.4	3.4	5.0
41–50%	5.6	0.0	0.0	6.0	0.0	1.4	0.0	3.4	4.0	0.0	2.1
More than 50%	2.8	4.6	3.0	4.5	0.0	5.6	1.6	11.9	12.2	0.0	4.7
Can't say	2.8	6.2	1.5	3.0	8.5	9.9	10.9	1.7	10.8	6.8	6.3

Table 9. **Breakdown of the knowledge-intensive services sector companies by share of bills not paid on time during the first six months of 2015, by industry (%), n = 656**

Question to respondents: Please estimate the share of amounts due to your company but not paid on time (%) in the total contract value for the first six months of 2015											
	Adv	**Cons**	**Aud**	**IT**	**HR**	**Eng**	**Fin**	**Law**	**Dev**	**Web**	**All**
All contracts fully paid on time	43.0	53.9	53.0	47.7	52.5	36.6	39.1	47.5	73.0	47.4	49.5
Less than 10% of contract value not paid 10%	30.6	15.4	19.7	22.4	23.7	22.6	40.6	28.8	13.5	30.5	24.5
11–20% of contract value not paid	15.3	24.6	15.2	14.9	11.9	26.8	10.9	18.6	6.8	10.2	15.6
21–30% of contract value not paid	6.9	4.6	4.6	6.0	3.4	5.6	1.6	1.7	4.0	5.1	4.4
31–40% of contract value not paid	0.0	0.0	0.0	1.5	0.0	2.8	1.6	0.0	0.0	3.4	0.9
41–50% of contract value not paid	1.4	0.0	4.5	1.5	1.7	0.0	0.0	1.7	0.0	0.0	1.1
More than 50% of contract value not paid	0.0	1.5	0.0	0.0	1.7	1.4	0.0	1.7	0.0	0.0	0.6
Can't say	2.8	0.0	3.0	6.0	5.1	4.2	6.2	0.0	2.7	3.4	3.4

decreased. The average order value (the average bill) also fell, while the overall market volume decreased by 10%. The same trends continued in 2015. New players do emerge, but as one-off niche occurrences. The main problem appears to be that management of most companies see management consulting as something unnecessary — the first thing to go when the economic situation deteriorates.

Knowledge management services

'Old' and 'new' player concepts are not applicable at this market, which is just emerging and remains quite small. The overall number of relevant companies is very low, the market can hardly be seen as independent and is usually included in the auditing, consulting, or HR segments. If significant growth was noted here in 2014, in 2015 the market contracted, with turnover falling to a fraction of its previous size.

The industry's key problem is that relevant budgets in most companies are controlled by HR departments and are seen as costs, not investments, i.e., the first to be cut. The experts believe, however, that players in this market can overcome the recession quite quickly if they adopt 'smart entrepreneurship' logic and create added value through efficient cooperation, inclusion, and monetisation.

IT services

The experts confirmed that the currency in which the IT services market is measured is crucially important. The Russian market is a part of the global one, the largest international companies are present here, and leading Russian players view themselves in the global context. Accordingly, the market's volume should be estimated using the relevant global currency, US dollars, not roubles. Though a certain amount of growth was noted in the industry in 2014 (the share of companies whose rouble revenues' growth rate was higher than the sector's average, see Table 4), estimates in US dollars vary from 3–4% growth to 10–12% decline. Estimates of the industry's development in 2015 also very much depend on the exchange rate fluctuations; this is where the main effect of the recession was felt.

At the end of 2014, some of the customers stepped up their procurement activities, fearing the rouble would fall even further, new sanctions would be imposed banning supplies/imports of equipment, etc. A certain positive impulse was created by the import substitution initiatives, and by players' migration from western venues to Russian ones due to adoption of the legislation on personal data storage. These factors may partially explain the relatively high share of companies operating in this industry who have managed to bring in new clients in 2014 and during the first half of 2015 (Table 7). Due to the same reason, despite obvious economic problems the rouble-denominated turnover kept growing — which allowed the experts to speak not about a recession but a certain "volatility" in the industry. However, customers' budget cuts have affected the IT services industry too: growth here largely depends on the growth of GDP. Accordingly, further growth of this market cannot be expected before we see positive GDP dynamics.

HR services

Medium and small companies have been quickly disappearing in this industry in recent years, due to their absorption by larger firms, leading professionals' opting to work remotely for their former clients or as freelancers. Still, new players do emerge in the industry. According to the respondents, HR companies are trying to make good use of their internal potential, and the current demand for high-quality HR services is even higher than it was in 2013. This might explain why all companies covered by the Monitoring study, firms specialising in this industry had the highest shares of those who have managed to retain the level of sales (44.1% against 31.2% average for the sector, see Table 4), the number of employees (62.7% and

52.4%, respectively, Table 5), and the average wage (69.5% and 56.1%, respectively, Table 6). However, the market fell in 2015, by between 20% (an optimistic expert assessment) and 40–50% (according to the pessimists).

The unfavourable developments in the economy prompted customers to optimise their costs, first of all labour costs. But as one of the experts noted, "the cuts were about money, … not about jobs". The way HR services are provided has also changed, up to a point. Company owners demand unorthodox solutions which their in-house HR departments (often staffed by insufficiently skilled workers) are frequently unable to provide. Therefore, HR companies experienced a relatively smaller loss of revenues, less significant layoffs (Tables 4 and 5) and wage cuts (Table 6). The experts noted a shortage of relevant competences on the market, and HR companies' inability to quickly restructure, offer new services, and prove how essential they are.

Engineering services

The events of recent years only promoted demand for services like engineering design of production facilities, upgrading existing installations, etc. Still, the experts noted a very low level of clients' enquiries turning into actual orders in this market — whose current volume is estimated to be much smaller than its potential. The current recession, economic and political challenges do exacerbate the situation, but they did not create it. The main risks are associated with the evolution of the consumer profile and preferences. The market for engineering design of production facilities is one of the few whose prospects look quite optimistic. Growth rate here depends not so much on the overall economic situation as on more fundamental factors, such as refocusing government support towards sectors with higher potential. The experts also pointed out the insufficiently clear definition of engineering as a concept, and the resulting legal uncertainty.

A certain dependency on the order portfolio remains on the investment and construction engineering services market. The launch or completion of major projects in this field can significantly affect employment — which explains the highest share of engineering companies who in the first six months of 2015 have conducted major layoffs (12.7% against the 6.3% average for the KIBS sector) and significantly cut wages (8.5% against 4.5%, respectively) (Tables 5 and 6). Another specific feature of this industry is many companies' inability to meet clients' demands. Major players set up subsidiaries which, after the flow of orders from the parent company dries up, fail to survive on their own or diversify; their business rapidly deteriorates and in many cases, ends in bankruptcy. The investment and construction engineering services market is also highly inertial: many companies engaged in the Sochi Olympics projects still exist de jure, though do not actually function de facto — which was confirmed by the Monitoring study. So, in 2014 the share of this segment's companies who have reported more than a 10% reduction in revenue was almost two times higher than the average for the sector (32.4% against 17.6%, respectively). During the first six months of 2015, this gap narrowed, but the share of companies whose turnover has dropped remained one of the highest (Table 4).

Due to the inertia, short-term forecasts for the investment and construction engineering services industry do not look favourable. The reduced volatility of the rouble, and the launch of new public investment programmes could contribute to this market's recovery. The improved overall economic situation may also lead to the stabilisation of customers' strategies and long-term plans, which would allow the market players to balance their portfolios and increase the stability of their businesses. The recession seems to have affected these companies' customers more than others: during the first six months of 2015 the share of engineering companies whose bills were fully paid on time was the lowest in the KIBS sector: just 36.6%, against the 49.5% average (Table 9). The engineering services segment also has the highest share of companies (36.6%) with no new partners added to their client base (Table 7).

Financial intermediation services

The problems players in this segment face are similar to the ones experienced in certain other industries. Many service types are not clearly defined in legislation, with no regulations on licensing, certification, or prudential supervision. The number of credit brokers has noticeably decreased against this background, though due to low entrance barriers the experts did not see this trend as a sign of crisis for the industry. Furthermore, the credit brokerage market displays quite unusual overall dynamics: during quiet periods demand for such services drops, in line with increasing general literacy of entrepreneurs and individual consumers alike, while during a recession the number of customers grows because the potential for finding required financial resources on their own diminishes. This market was expected to contract to a fraction of its size in 2015 compared with 2014, due to reduced overall credit availability. However, the recession was not too deep compared with other industries. The share of financial brokers whose turnover fell more than 10% in the total number of the segment's companies is almost the lowest in the KIBS sector. Note that if in 2014 it was 10.9% (against the 17.6% average for the sector), in the first six months of 2015 the gap became much wider. Amid the economic recession, the share of financial brokers whose turnover was declining reached 21.9%, with the average value for the sector being 37.7% (Table 4).

The growth rate of the insurance brokerage market in 2015, in rouble terms, slowed down from 20% (the 2013–2014 level) to 7–8%; in US dollar terms it fell even more. The decline began in 2014 (2%) and continued in 2015, reaching almost 40%. The experts noted a stronger inertia on the leasing services market: the reduced number of companies set up in 2014–2015 will become apparent only a year or two later, by 2017. Also, since the growth of the leasing services market directly depends on the overall level of investments in the economy, in rouble terms the market may recover as early as next year, but in US dollar terms its volume would remain 50%–67% times lower.

Legal services

One of the consequences of the recession in this industry was an outflow of its personnel into large companies' legal departments. The share of companies who have laid off 5–20% of their staff in the total number of firms is much higher than in any other industry (at 30.5%), and twice as high as the average for the KIBS sector (Table 5). Many customers, first of all corporate ones, prefer to make do with their own legal departments, and contract external firms only to deal with particularly complex problems. Of the ten industries covered by the Monitoring study, only in two was the share of companies who have managed to retain all their customers between 2014 and the summer of 2015, lower than the legal services segment (Table 8). The industry has one of the highest shares of companies who have lost more than half of their client base during the same period (11.9%, against 4.7% average for the sector). The companies are also changing their strategies, which is not very obvious due to the closed nature of their activities. Still, some changes can be detected. For example, law firms started to engage external experts more frequently, to consult on their development strategies (such as marketing), or even offer products based on a blend of IT and legal services.

A distinctive feature of the legal services market is the large number of new entrants combined with the fragmentation of companies, including large ones. This probably explains the relatively significant client base fluctuations: the segment features one of the highest values for the share of companies who have lost more than 50% of their clients, and the share of new customers of such firms comprises more than 50% of the client base (Table 7). Any person with relevant education can become a provider of legal services, so the oversupply of such professionals (pointed out by the experts) does not help the industry's development because it creates an excess supply of low-quality services. This is one of the biggest challenges for the sector, meeting which requires further consolidation of the legal services industry as a whole.

Development and real estate services

Most of the developer companies still remained on the market at the beginning of 2015, having cut their costs and laid off personnel, but the experts predict mass bankruptcies in the industry in the very near future. In all three groups of companies which have resorted to cutting wages (by less than 5%, 5–20%, and more than 20%), and in two out of three groups of firms which had to lay off staff (by less than 5%, and 5–20%), the share of companies in this segment is higher than the sector's average (Tables 5 and 6). Excess demand was noted at the end of 2014, probably caused by the volatility of the rouble, but starting in the second quarter of 2015 a serious recession became evident in the industry. The turnover in the home real estate segment fell by 30–40%, and in the commercial real estate segment — to a fraction of its previous volume. This was probably the reason the industry's performance in 2014 was on a par with the sector's average or even higher regarding the share of companies which managed to increase their rouble-denominated revenues by about 10% (Table 4). In the first six months of 2015, the situation became radically different: as in advertising, the development and real estate services industry showed the highest share of companies whose turnover fell by more than 10% (48.6%).

In terms of customers' attitude, the industry in question is among the most secure ones: 73% of companies (much more than in any other KIBS industry) reported that during the first six months of 2015 they received full payment for services provided on time (Table 9). However, the experts noted that customers were unwilling to pay the prices charged by sellers. Accordingly, realtors have to convince the latter that prices are not going to return to the previous level in the near future, so they have to bear certain losses. Against this background, the client base remains highly volatile: the segment features particularly high shares of companies who have lost a significant portions of former clients, and of those who have managed to attract new ones (Tables 7 and 8).

According to the experts, this market will not start to recover before the rouble-to-dollar exchange rate fluctuations return to within 10% a year. The current recession in the industry may be considered a continuation of the 2009 crisis, and the experts link hopes for full recovery with introducing a legal requirement to conduct all real estate operations through realtor agencies or licensed realtors.

Design services

Providers of design services do not have to be specially registered, so this market is hard to assess. Thousands of new firms come and go every year, plus a multitude of small players and freelancers. There is no clear competition in the industry since each designer in effect sells their own unique vision. Not

just some of the second echelon companies had to leave the market, but also some quite reputable performers — this was due to the fact that demand is shrinking while the economic and political situation frequently forces potential customers to abandon their plans to invest in an office in Russia.

A downside of excessive supply is low product quality (similar to the aforementioned situation in the legal services market), which creates demand for services to repair faulty work. As in the advertising services market, designers became more willing to take on small-scale orders. Due to a significant reduction of the overall number of orders (by 30%), and of their average value (by 25%), the market contracted in 2015 by about 50%. According to other estimates, the decline was not that big but still quite significant, between 25–40%, and very much uneven: some companies' turnover has dropped by as much as 80%, while others have retained their revenues — but had to perform much more work to achieve that. The experts link recovery prospects with the stabilisation of political and economic situation. The significant positive impact the Sochi Olympics and the Kazan World Student Games have made on the market may be soon repeated due to Russia hosting the 2018 FIFA World Cup.

Web and digital services

This segment appears to be the most successful and dynamic in the sector. In 2014, a third of the players reported a more than 10% growth of rouble-denominated revenues (against the 20.7% average for the sector). The 'mirror' situation also looks similar: the share of web and digital services companies whose revenues have dropped by more than 10% in 2014 is 50%-83% smaller than in other segments of the sector, and 67% smaller than the KIBS sector average (Table 4). No changes were noted during the first six months of 2015 either: the share of companies whose revenues have dropped by more than 10% was 18.6% (against the 37.7% average for the sector), while the share of companies whose revenues grew by more than 10% reached 25.4% - much more than the sector's average of 9.9%. Accordingly, layoffs (Table 5) and wage cuts (Table 6) affected the industry less significantly than other segments of the KIBS sector.

Professionals suggested a long time ago that digital services should be viewed as a separate category at the junction of the internet and other KIBS sector segments (such as HR, marketing, advertising services and so on). In this case, the internet and social media are seen as a specific area of companies' operations. In most industries that was where the experts noted emergence of new service types on the market. At the same time, the internet and social media remain an interactive environment inside which various specific areas emerge and grow, such as the internet of things (internet-based management and control systems as a type of IT services), internet advertising providing direct feedback from clients, or innovative legal services such as domain name protection.

Conclusion

Our study examined the effect of the late 2014 — early 2015 recession over the Russian knowledge-intensive business services sector. We have analysed indicators reflecting the performance of companies who provide such services. We established that during the first six months of 2015 the share of companies whose rouble-denominated turnover (revenue) fell more than 10% has doubled, reaching 37.7%. Given the volatile exchange rate of the rouble during the period in question, the experts suggested that the performance of certain industries (for example, IT services) also be assessed using foreign currency. The employment and wage dynamics were studied too, as major (amounting to up to 50% of the total) cost items for the sector's companies.

Particular attention was paid to demand for knowledge-intensive services. We established that less than half of the companies receive payment for services provided in full and on time. Changes in the client base were analysed, including the emergence of new clients and loss of old ones. Following the logic of modern empirical studies, we analysed each of the sector's industries individually. The results confirmed the hypothesis about the high diversity in the KIBS sector. The decline in such segments as engineering or real estate and development services looks particularly severe even against the background of the overall contraction of the sector. The situation in the digital services segment appears to be more optimistic, the decline here was significantly less serious than the average values for the sector.

The study demonstrated that the KIBS sector was negatively impacted by the recession. The less than optimal development during the period following the 2008 crisis (see [*Berezin, Doroshenko,* 2015]) aggravated the situation even further. This trend is evident in all industries, despite significant differences between them. The sector's companies were rather optimistic about their own future though, which the experts attributed to the fact that in effect they have reached the bottom. In other words, in the current situation, even a slight improvement may be seen as noticeable growth. However, currently this sector, with its potentially high productivity, added value, and innovation potential, remains a hostage of an economic situation that does not allow it to start growing. We have to expect that the knowledge-intensive services sector will continue to contract.

This paper is based on the study "Monitoring of Knowledge-Intensive Business Services in Russia" conducted in the framework of the Basic Research Programme at the National Research University Higher School of Economics (HSE) and supported within the framework of a subsidy by the Russian Academic Excellence Project "5-100".

References

Asikainen A-L. (2015) Innovation modes and strategies in knowledge intensive business services. *Service Business*, vol. 9, no 77, pp. 77–95.

Aslesen H.W., Isaksen A. (2010) Knowledge-Intensive Business Services as knowledge mediators in different regional contexts: The case of Norway. *Knowledge-intensive Business Services: Geography and Innovation*, Burlington, VT: Ashgate Publishing, pp. 99–122.

Berezin I. (2016) Ekspertnye otsenki ob"ema i dinamiki rynkov intellektual'nykh uslug v Rossii 2005-2015 [Expert assessment of the amount and dynamics of intellectual services markets in Russia 2005-2015]. *Marketing v Rossii 2016. Spravochnik Gil'dii Marketologov* [Marketing in Russia 2016. Marketers Guild Guide] (ed. I. Berezin), Moscow: Marketers Guild, pp. 33–70 (in Russian).

Berezin I., Doroshenko M. (2015) Kolichestvennye i kachestvennye izmeneniya na rynke intellektual'nykh uslug v Rossii 2005-2013 [Quantitative and qualitative changes on the market on intellectual services in Russia in 2005–2013]. *Marketing v Rossii 2015* [Marketing in Russia 2015] (ed. I.S. Berezin). Moscow: Marketers Guild, pp. 85–128.

Bettiol M., Di Maria E., Grandinetti R. (2011) Market extension and knowledge management strategies of knowledge-intensive business services. *Knowledge Management Research & Practice*, vol. 9, pp. 305–314.

Camacho J.A., Rodriguez M. (2008) Patterns of innovation in the service sector: Some insights from the Spanish innovation survey. *Economics of Innovation and New Technology*, vol. 17, no 5, pp. 459–471.

CBR (2016a) *Dinamika ofitsial'nogo kursa zadannoi valyity* [Dynamics of official course of specific currency]. Available at: http://www.cbr.ru/currency_base/dynamics.aspx, assessed 02.05.2016.

CBR (2016b) *Obzor bankovskogo sektora Rossiiskoi Federatsii (internet-versiya)* [Review of the Russian banking sector (online-version)]. Available at: http://www.cbr.ru/analytics/bank_system/obs_1601.pdf, assessed 02.05.2016.

Charmaz K. (2006) *Constructing grounded theory: A practical guide through qualitative analysis*, Thousand Oaks, CA: Sage.

Consoli D., Elche-Hortelano D. (2010) Variety in the knowledge base of Knowledge Intensive Business Services. *Research Policy*, vol. 39, pp. 1303–1310.

Corrocher N., Cusmano L., Morrison A. (2009) Modes of innovation in knowledge-intensive business services evidence from Lombardy. *Journal of Evolutionary Economics*, vol. 19, no 2, pp. 173–196.

Doloreux D., Freel M., Shearmur R. (2010) Introduction. *Knowledge-intensive Business Services: Geography and Innovation*, Burlington, VT: Ashgate Publishing, pp. 1–18.

Doloreux D., Shearmur R. (2010) Exploring and comparing innovation patterns across different knowledge intensive business services. *Economics of Innovation and New Technology*, vol. 19, no 7, pp. 605–625.

Doloreux D., Shearmur R. (2013) Innovation Strategies: Are Knowledge-Intensive Business Services Just Another Source of Information? *Industry and Innovation*, vol. 20, no 8, pp. 719–738.

Doroshenko M., Miles I., Vinogradov D. (2013) *Knowledge intensive business services as generators of innovations* (HSE WP BRP «Science, Technology and Innovation» no 12), Moscow: NRU Higher School of Economics.

Doroshenko M., Miles I., Vinogradov D. (2014) Knowledge Intensive Business Services: The Russian Experience. *Foresight and STI Governance*, vol. 8, no 4, pp. 24–39.

Freel M. (2010) Knowledge-Intensive Business Services users and uses: Exploring the propensity to innovation-related cooperation with Knowledge-Intensive Business Services. *Knowledge-intensive Business Services*, Burlington, VT: Ashgate Publishing, pp. 75–98.

Green J., Thorogood N. (2004) *Qualitative methods for health research* (1st ed.), London: SAGE Publications Ltd.

Griffin A., Hauser J. R. (1993) The voice of the customer. *Marketing Science*, vol. 12, no 1, pp. 1–27.

Marasco A., Masiello B., Izzo F. (2013) Client involvement and innovation in Creative-Intensive Business Services: A framework for exploring co-innovation in advertising agency-client relationships. *Economies et Sociétés*, vol. 47, no 3–4, pp. 445–478.

Miles I. (1993) Bringing computer power to the consumer market. *Technology Analysis & Strategic Management*, vol. 5, no 2, pp. 151–172.

Miles I. (2011) Servisnye innovatsii v XXI veke [Service Innovation in the Twenty First Century]. *Foresight-Russia*, vol. 5, no 2, pp. 4–15 (in Russian).

Muller E., Doloreux D. (2009) What we should know about knowledge-intensive business services. *Technology in Society*, vol. 31, pp. 64–72.

Muller E., Zenker A. (2001) Business services as actors of knowledge transformation: The role of KIBS in regional and national innovation systems. *Research Policy*, vol. 30, no 9, pp. 1501–1516.

Quandl (2016a) *Services share of GDP by country (from World Bank cross country data)*. Available at: https://www.quandl.com/collections/economics/services-share-of-gdp-by-country, accessed 02.05.2016.

Quandl (2016b) *Services share of employment by country (from World Bank cross country data)*. Available at: https://www.quandl.com/collections/economics/services-share-of-employment-by-country, accessed 02.05.2016.

Rosstat (2016a) *Natsional'nye scheta* [National accounts]. Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/accounts/#, assessed 02.05.2016.

Rosstat (2016b) *Tseny* [Prices]. Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/tariffs/#, assessed 02.05.2016.

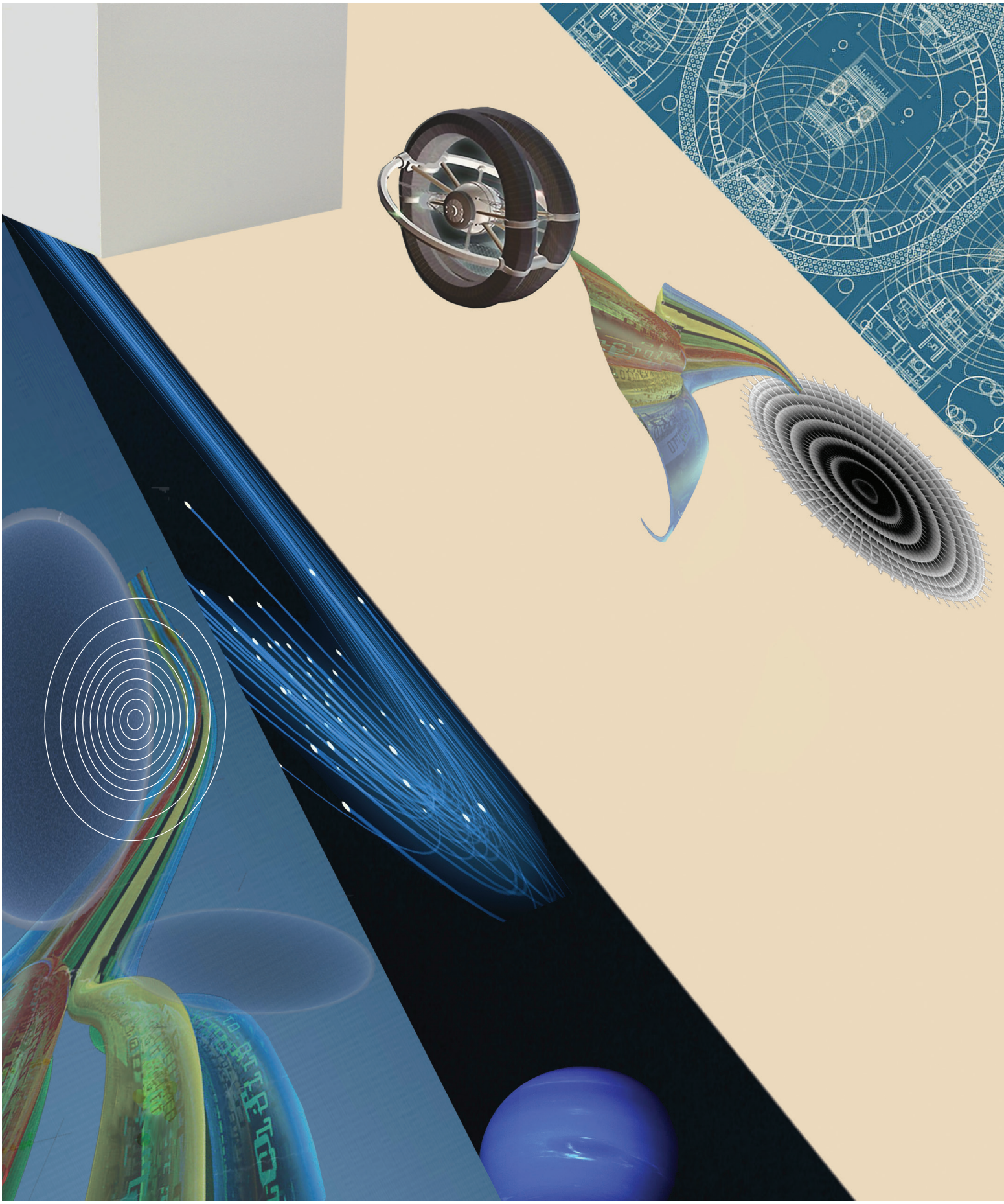
Rozhdestvenskaya E. (2012) Biograficheskii metod v sotsiologii [Biographical method in sociology], Moscow: NRU Higher School of Economics.

Santos-Vijande M.L., González-Mieres C., López-Sánchez J.A. (2013) An assessment of innovativeness in KIBS: Implications on KIBS' co-creation culture, innovation capability, and performance. *Journal of Business & Industrial Marketing*, vol. 28, pp. 86–102.

Thomson S.B. (2011) Sample Size and Grounded. Theory. *JOAAG*, vol. 5, no 1, pp. 45–52.

Zieba M. (2013) *Knowledge-Intensive Business Services and their role in the knowledge-based economy* (GUT Working Paper Series A (Economics, Management, Statistics) no 7/2013 (7)), Gdansk: Gdansk University of Technology.

INNOVATION



Is Flexible Labor Good for Innovation? Evidence from Russian Firm-level Data

Larisa Smirnykh [a]

Deputy Head of Laboratory and Professor, Faculty of Economic Sciences, lsmirnykh@hse.ru.

[a] National Research University Higher School of Economics,
26 Shabolovka str., Bldg 4, Office 4332, 119049 Moscow, Russian Federation

Abstract

The level of innovation activity of the Russian enterprises is inferior to the level of innovation activity of enterprises in developed countries. At the same time, Russian enterprises actively use fixed-term contracts, which help them to reduce the labour costs and adapt to changes in demand, to increase the flexibility of labor and improve the selection of employees at the workplaces. Fixed-term contracts can contribute to innovation, because they enhance the flexibility of labor relations and create savings in the use of workers. However, fixed-term contracts can reduce the likelihood of innovation because they reduce investment in human capital, leading to a reduction in labor productivity. Which trends dominate in labour relations is the subject of this study. For the study, we was used the data about enterprises from the annual Russian Enterprises Survey in 2014. The sample is representative for Russia and includes small, medium and large enterprises with more than 30 employees in seven sectors (mining, industry, construction, transport and communications, trade, finance, business services). For the analysis, we used bivariate probit model, Heckman correction model and probit model with continuous endogenous regressor (the share of workers with fixed-term labour contracts). The results showed that fixed-term contracts have a positive effect on the innovation activity of enterprises only when they are used in a limited quantity. With an increase in the percentage of workers in enterprises with fixed-term contracts, the likelihood of innovation activity of enterprises declines.

Keywords: innovative activity of enterprises; types of innovation; fixed-term contracts; non-standard employment; human capital and innovation; investment; Russia

DOI: 10.17323/1995-459X.2016.4.60.70.

Citation: Smirnykh L. (2016) Is Flexible Labor Good for Innovation? Evidence from Russian Firm-level Data. *Foresight and STI Governance*, vol. 10, no 4, pp. 60–70. DOI: 10.17323/1995-459X.2016.4.60.70.

In terms of innovation activity level, Russia (at 10.1%) significantly lags behind not just the leading developed nations (the relevant value for Germany is 66.9%), but also most of the Central and Eastern European countries, where this indicator's value ranges between 20–60% [*Gorodnikova et al.,* 2015]. At the same time Russian companies use fixed-term employment contracts on a scale comparable with the global average, more or less on a par with the UK, the US, Canada, Japan, Germany, France, and Italy [*Farah, Iodice*, 2013]. In 2008–2013 the average share of such contracts in the aforementioned countries was 9%. In Russia it amounted to 14% in 2008 , and in 2013 it fell to 9%. A third of Russian companies use fixed-term employment contracts [*Smirnykh*, 2014], which helps them adapt to changing demand, increase probation period for job candidates, cut layoff costs, and use temporary workers as a buffer to maintain the human capital of their permanent staff [*Atkinson*, 1987; *Kalleberg*, 2001; *Cappelli, Neumark*, 2004; *Booth et al.*, 2002].

The connection between the level of companies' innovation activity and their use of fixed-term employment contracts is due to reduced risks the latter provide, by increasing employment flexibility and reducing labour costs, combined with lower employment security [*Bassanini, Ernst*, 2002; *Scarpetta, Tressel*, 2004]. At the same time this employment format creates no motivation, for employers and employees alike, to invest in human capital, which reduces companies' innovation activity [*Laursen, Foss*, 2003; *Michie, Sheehan*, 2003; *Kleinknecht et al.*, 2006; *Arvanitis*, 2005; *Lucidi, Kleinknecht*, 2009][1]. There is no consensus among scholars regarding which of the above effects prevails. Some cite data that suggest fixed-term employment contracts negatively affect companies' innovation activity [*Franceschi, Mariani*, 2014; *Bentolia, Dolado*, 1994; *Autor et al.*, 2007; *Dolado et al.*, 2012; *Cappellari et al.*, 2012]. Others, on the contrary, provide evidence in favour of a positive correlation between these phenomena [*Malgarini et al.*, 2011; *Bassanini, Ernst*, 2002a, 2002b; *Scarpetta, Tressel*, 2004; *Zhou et al.*, 2011; *Jacob*, 2010; *Ichino, Riphahn*, 2005; *Zhou et al.*, 2010; *Bartelsman et al.*, 2010; *Nicoletti, Scarpetta*, 2003].

Russian data about the connection between use of fixed-term employment contracts and the level of companies' innovation activity is very scarce, with no studies conducted in this field to date. However, it is known that the main incentive for companies' opting for such arrangement is survival, while the main limiting factors include "shortage of the companies' own funds" (75%) and "insufficient financial support by the state" (47%) [*Kuznetsova, Roud*, 2011]. Our study was focused on fixed-term employment contracts as a labour market factor affecting companies' innovation activity, and describing employer/employee relations on the micro-level. The hypothesis about such an impact was tested using data collected during an all-Russian representative survey conducted in 2014, covering small, medium, and large companies in seven industries. The bivariate probit, Heckman, and binary probit models with a continuous endogenous regressor were used in our calculations (shares of workers on fixed-term employment contracts).

Structurally, the paper includes an introduction and three sections. The first section presents a review of literature describing, in a logical sequence, theoretical and empirical justifications of fixed-term employment contracts' negative and positive impact on companies' innovation activity. The second section describes methodology of the study, data sources, construction of variables, and analysis techniques that were used. The third section presents results and their interpretation.

Literature review

Fixed-term employment contracts' impact on companies' innovation activity varies under different circumstances. Scholars' opinions about the nature of this impact also vary: some believe that the increased use of such contracts encourages companies' innovation activities, while others hold the opposite opinion [*Franceschi, Mariani*, 2014; *Bentolia, Dolado*, 1994]. The latter's arguments are based on the premise that since companies are not very much interested in investing in training their temporary employees (if at all) [*Acemoglu, Pischke*, 1999; *Booth et al.*, 2002], these employees therefore remain low-skilled and frequently change jobs, such companies' specific levels of human capital and innovation activity also remain low [*Al-Laham et al.*, 2011]. Returns on investments in staff training only increase in the framework of long-term employment relations, while with fixed-term employment contracts they fall [*Wood, de Menezes*, 1998]. Another negative consequence of using fixed-term employment contracts is low labour productivity [*Autor et al.*, 2007; *Dolado et al.*, 2012; *Cappellari et al.*, 2012], due not only to the reduced quality of human capital but also to lower employment security, ultimately leading to employees' reduced loyalty to their employer [*Spender*, 1996]. Temporary workers have no interest in supporting the management's initiatives, including those aimed at stepping up the company's innovation activity [*Lorenz*, 1999].

Researchers who insist that fixed-term employment contracts affect companies' innovation favourably, adhere to an opposite opinion. They state that innovation activities, on the contrary, are hindered by permanent employment arrangements [*Malgarini et al.*, 2011; *Hopenhayn, Rogerson*, 1993; *Bassanini, Ernst*, 2002a]. Strict employment laws and high job security reduce labour mobility, hindering the redistribution of jobs from stagnating or declining sectors of the economy to emerging and dynamic ones [*Nickell, Layard*, 1999]. Complex and expensive layoff procedures and employment security guarantees do not allow companies to flexibly adjust their workforce, and cut labour costs by applying labour-saving

[1] We view labour productivity and companies' innovation activity as synonyms, following examples set by other researchers [*Arvanitis*, 2005; *Bartelsman et al.,* 2012], and due to a positive correlation between these phenomena [*Griliches*, 1998; *Hall,* 2011].

innovations [*Bassanini, Ernst*, 2002b; *Scarpetta, Tressel*, 2004]. Fixed-term employment contracts provide an opportunity to do so, and gradually increase innovation activity – since they promote labour mobility and better job matching. A flexible labour market offers job seekers better chances of finding a job where they could work most productively — which would positively affect overall productivity. High labour mobility provides a better supply of new workers and new ideas for companies, ultimately leading to their increased innovation activity.

The effectiveness of production in no small measure depends on companies' ability to survive (cyclic) economic shocks and seasonal fluctuations of demand. A tightly regulated labour market (high employment security, limitations on layoffs or replacement of personnel) negatively affects companies' productivity [*Hopenhayn, Rogerson*, 1993] and innovation activity [*Bassanini, Ernst*, 2002a]. Some authors believe that low job security encourages employees to work more productively, due to the fear of losing their jobs [*Jacob*, 2010; *Ichino, Riphahn*, 2005]. Permanent employees insured against layoffs by various employment guarantees and high layoff costs to employers may tend to try to avoid hard work, and even demand pay raises and extra benefits. There is no need to elaborate upon the negative consequences of such behaviour for companies' financial situation [*Malcomson*, 1997; *Zhou et al.*, 2011]. When trade unions are strong enough, workers may also have a less-then-optimal influence on the distribution of revenues — e.g. channelling some of it into remunerations. All this may have an adverse effect on innovation [*Malcomson*, 1997]. Investments in innovation are highly uncertain, and involve significant risks. The opportunity to hire staff on a temporary basis allows companies to cut layoff costs to practically zero [*Zhou et al.*, 2011]. Companies' innovation activity is likely to be the higher the more confident they are of their ability to painlessly cut staff in the case that a project fails [*Bartelsman et al.*, 2010], which again confirms the thesis about a correlation between the use of fixed-term employment contracts and companies' innovation activity [*Nicoletti, Scarpetta*, 2003].

The widely diverging assessments of fixed-term employment contracts' impact on companies' innovation do not allow for definitely evaluating this correlation in Russia. Though a group of innovative companies did emerge in Russia in recent years, the country still significantly lags behind developed economies in this area [*Gokhberg, Kuznetsova*, 2009]. Compared with the latter nations, the Russian labour market has a number of very distinctive features [*Kapeliushnikov*, 2009], in particular a wide variety of techniques that economic agents use to adapt. Part-time employment, administrative leave, delayed payment of wages, the growing informal sector, and increasing application of various unconventional employment formats — all of these and more are used quite widely. Among other things, unconventional employment formats include fixed-term employment contracts, which ten years ago became commonplace in Russia [*Kapeliushnikov*, 2009]. Since the beginning of this upward trend in the economy this employment format not only has not been put aside but instead continued to spread, covering a significant portion of the workforce. Today the scale of Russian companies' use of fixed-term employment contracts is comparable with several European countries [*Smirnykh*, 2014]. But does this trend reflect a positive impact on companies' innovation activity? It is our aim to find out.

Methodology of the study

Fixed-term employment contracts' effect on companies' innovation activity was studied in the framework of the survey "Interaction of internal and external labour markets" conducted in 2014 by the HSE Laboratory for Labour Market Studies. Data was collected by interviewing managers of companies included in the all-Russian representative sample designed using two criteria: companies' size and industry. 2,003 companies employing more than 30 workers were included in the sample in 2014, specialising in seven industries: mining; manufacturing; the generation and distribution of electricity, gas, and water; construction; transport and communications; wholesale and retail trade; financial services; and real estate, including leasing and related services. This survey was particularly suitable for the purposes of our study because it provided information about both relevant issues: companies' use of fixed-term employment contracts, and their innovation activities. The non-panel sample was adjusted annually, while the questionnaire remained almost 90% unchanged; it included a series of retrospective questions, the answers to which allow for a comparison of each year's situation with others.

The companies' innovation activity variable was calculated on the basis of answers to the question "Which of the innovation activities listed below did your company invest in in 2013–2014?". A commonly accepted approach in international statistical practice was applied in our calculations, according to which 'innovative' and 'innovation-active' companies are not the same. The former *implement* certain types of innovations, while the latter are firms that conduct innovation activities, regardless of whether the activity resulted in the implementation of an innovation or not [OECD, 2005; UIS, 2013]. We chose to use the Rosstat approach which defines organisations' innovation activity as the degree of their participation in innovation generally, or in its specific types, during a certain period of time [Rosstat, 2016]. Accordingly, in our survey a company was considered innovation-active if during 2013–2014 it invested in innovation generally, or in the creation of specific innovation types.

The level of companies' innovation activity is usually understood as the share of companies that created technological, organisational, or marketing innovations in the total number of companies in the country, industry, or region surveyed during a certain period [Rosstat, 2016]. We have used a similar definition:

the share of companies that have invested in at least one innovation in the total number of the surveyed companies. However, the figures we obtained were bound to differ from the Rosstat ones[2] because our sample included not just mining and manufacturing companies but also covered such industries as construction, finance, trade, business services, transport and communications[3]. Also, Rosstat calculates the level of innovation activity separately for medium and large (annually), and small companies (once every two years). We did not divide our sample this way.

We decided not to classify companies' innovation activities, because of two reasons. Firstly, if a company "participated in an innovation activity by investing in it," that does not mean an innovation was actually created; therefore dividing such activities into completed and initiated ones does not seem possible. Secondly, in their answers company mangers frequently cited two, three, or more kinds of innovation activities they have invested in, both completed and still at the development stage, which ruled out trying to assess their overall completeness.

Three kinds of indicators were calculated on the basis of answers to the question about companies' use of fixed-term employment contracts. First, companies where the share of workers on fixed-term employment contracts was greater than zero were considered companies with fixed-term employment contracts, while the actual indicator was presented in the binary variable form: 1 = the company does use fixed-term employment contracts, 0 = the company does not use fixed-term employment contracts. Second, the rate of such contracts' use was calculated as the share of workers on such contracts in the company's total number of employees. Third, on the basis of the second indicator an order variable was calculated, reflecting the rate of fixed-term employment contracts' application. Five levels were used, with the lowest indicating less than 1% of workers on fixed-term employment contracts (1:≤1%), and the highest — more than 40% of such workers (5:>40%).

Fixed-term employment contracts are not an organisational innovation, and we did not consider them as such. Almost 98% of the 2014 survey participants used them — which means this kind of contracts is nothing new to most companies, so according to the Oslo Manual's criteria they cannot be viewed as organisational innovations [OECD, 2005]. The latter include only certain kinds of fixed-term employment contracts used for labour leasing or outsourcing purposes. In international statistics, labour leasing and outsourcing are counted as specific kinds of fixed-term employment contracts [OECD, 2002, pp. 170–171]. However, the data we have used allows for distinguishing them from other kinds of such contracts, while workers on fixed-term employment contracts did not include those 'leased' or employed as outsourcers. Therefore including fixed-term employment contracts in any of these innovation types would not be correct.

Control variables were built on the basis of data collected via a survey of companies taking into account standard specifications applied to assess their innovation activity. Company size was determined on the basis of the average number of employees on the payroll. According to the current legislation,[4] companies with up to 100 employees were classified as small; with 101–500 workers — as medium; and with more than 500 — as large. Almost 70% of the companies included in the 2014 sample were small ones, 23.17% — medium, and 7.14% — large (Table 1). The companies in the sample belong into the following industries (sorted by their share in the total, in descending order): wholesale and retail trade (30.10%), manufacturing (21.32%), business services (20.77%), construction (11.28%), mining (5%), financial services (5%), transport and communications (6%) (Table 1). Controlling interest in an overwhelming majority of the companies (94%) was owned by Russian or foreign entrepreneurs, i.e. they belonged to the private sector; in about 5% of the surveyed firms, state participation in ownership exceeded 50%, i.e., they were state-owned companies. The average age of the companies included in the 2014 sample was 14 years. Technologically, most of them (62.64%) were on a par with the industry's average level[5], almost 30% were above it, and about 8% below it. In their averaged out employment structure 44% were manual workers; gender-wise, 32% were women.

A regression analysis was conducted in several stages. At the first stage the seemingly unrelated regressions technique was applied, using a system of simultaneous bivariate probit model equations:

$$\begin{aligned} y_{i1} &= \beta X_{i1} + \varepsilon_{i1} \\ y_{i2} &= \beta X_{i2} + \delta Z_{i2} + \varepsilon_{i2} \end{aligned}, \qquad (1)$$

[2] According to the All-Russian Classification of Economic Activities (OKVED), a sample of organisations to be surveyed using federal statistical observation form No. 4-innovation "Information about organisations' innovation activities" should include organisations engaged in the following economic activities: mining (Section C); manufacturing (Section D); production and distribution of electricity, gas, and water (Section E) (except electricity trading (code 40.13.2); trading in gaseous fuel delivered through distribution networks (code 40.22.2)); communication (code 64); activities involving application of computer equipment and information technologies (code 72); research and development (starting from the 2011 report) (code 73); provision of other services (code 74) [Rosstat, 2016].

[3] The Rosstat sample includes only business services related to application of computer equipment, development of software, etc. In our sample the list of relevant companies was much more extensive.

[4] Federal law "On promoting small and medium entrepreneurship in the Russian Federation" No. 209-FZ of 24 July, 2007. Text available at: www.consultant.ru/document/cons_doc_LAW_52144/, last accessed on 08.11.2016.

[5] Companies technological level means availability of equipment and technologies, their age, frequency of upgrading, and need to modernise. These indicators' values ranged for various companies in the industry between 1 (significantly below others) to 5 (significantly above others).

Table 1. **Descriptive statistics**

Variable	Number of observations	Average value	Standard deviation
Innovations (1=yes) (%)	1995	41.60	49.30
Innovation types:			
new or significantly improved products	1995	9.27	29.01
new or significantly improved production technologies	2003	9.54	29.38
R&D	1995	5.56	22.93
acquisition of machinery and equipment due to introduction of new products, etc.	2003	17.92	38.36
acquisition of new technologies (patents, licenses, etc.) due to launch of new products, etc.	2003	7.94	27.04
staff training, retraining, and upgrading	1995	19.50	39.63
construction (acquisition), repair, conversion of buildings and premises	1995	1.00	9.96
Companies with the following number of innovations:			
1	1995	24.46	43.00
2	1995	9.37	29.15
3	1995	5.06	21.93
4	1995	1.35	11.56
5	1995	1.05	10.21
6	1995	0.30	5.48
Average number of innovations per company which did create innovations	830	1.70	1.05
Companies with fixed-term employment contracts *(%)*	1959	36.60	48.18
Share of employees on fixed-term employment contracts (all companies) *(%)*	1959	13.43	25.12
Share of employees on fixed-term employment contracts (companies with fixed-term employment contracts) *(%)*	717	36.70	29.51
Companies with employee leasing (outstaffing) agreements *(%)*	1964	2.70	16.21
Share of employees on leasing (outstaffing) agreements (all companies) *(%)*	1964	0.36	3.59
Share of employees on leasing (outstaffing) agreements (companies with employee leasing (outstaffing) agreements) *(%)*	53	13.49	17.46
Investments (Yes=1) *(%)*	1907	42.53	49.45
Company age (*years*)	1987	14.25	15.56
Share of manual workers on the payroll *(%)*	1935	43.70	30.18
Share of women on the payroll *(%)*	1732	32.14	27.91
Company size:			
<100 employees	2003	69.70	45.97
101–500 employees	2003	23.17	42.20
>501 employees	2003	7.14	25.75
Ownership:			
private Russian-owned company	1957	91.82	27.41
private foreign-owned company	1957	2.15	14.50
state-owned company	1957	4.80	21.39
mixed ownership	1957	1.23	11.01
Company's technological level compared with other companies in the industry:			
significantly below average	1906	3.15	17.47
slightly below average	1906	4.98	21.77
average	1906	62.64	48.39
slightly above average	1906	19.62	39.72
significantly above average	1906	9.60	29.47
Industry:			
mining	2003	4.99	21.78
manufacturing	2003	21.32	40.97
construction	2003	11.28	31.65
wholesale and retail trade	2003	30.10	45.88
transport and communications	2003	6.44	24.55
financial services	2003	5.09	21.99
business services	2003	20.77	40.58

Source: calculated by the author.

where y_{i1} is a binary variable (1=yes, 0=no) measuring companies' innovation activity; y_{i2} is a binary variable (1=yes, 0=no) measuring companies' use of fixed-term employment contracts; X_{i1} and X_{i2} are control variables (companies' size, age, ownership, industry); Z_{i2} are variables which correlate with y_{i2}, but not with y_{i1}(share of women, share of manual workers)[6]; β, δ are coefficients measuring impact of explanatory variables; $\varepsilon_{i1}, \varepsilon_{i2}$ are accidental errors; and $i = 1,...N$ is the number of observations (companies).

At the second stage the supposition about self-selection-induced bias of assessments was checked, and a self-selection probit (*heckprob*) model applied, according to which the dependent variable (innovation activity) is observable if:

$$y_i^{probit} = (y_i^* > 0), \tag{2}$$

where $y_i^* = \beta X_i + u_{i1}$ is the unobservable probability of innovation activity, (3)

and the following selection condition is true:

$$y_i^{select} = (\gamma z_i + \beta X_i + u_{i2} > 0), \tag{4}$$

$$u_{i1} \sim N(0;1);\ u_{i2} \sim N(0;1);\ corr(u_{i1}; u_{i2}) = \rho, \tag{5}$$

where X_i are control variables (companies' size, age, ownership, industry); y_i^{select} is the use of fixed-term employment contracts (investments); z_i is the share of women, the share of manual workers (a change in financial situation during the current year, company's age); β, γ are coefficients measuring the impact of explanatory variables; u_{i1}, u_{i2} are accidental errors; and i=1,...N is the number of observations (companies). If ρ=0, companies were selected randomly so reliable data may be obtained using a simple probit model.

At the final third stage, a positive correlation was estimated between the number of employees on fixed-term employment contracts and companies' innovation activity. Since this type of contracts serves as endogenous regressor in the innovation activity equation, the equations system based on the endogenous regressor, the binary probit model (*ivprobit*)[7] takes the following form:

$$\begin{aligned} y_{i1}^* &= \beta y_{i2} + \gamma X_{i1} + u_i \\ y_{i2} &= \prod_1 X_{i1} + \prod_2 X_{i2} + v_i \end{aligned}. \tag{6}$$

y_{i1}^* is unobservable, unlike y_{i1} for which the following is true:

$$y_{i1} = \begin{cases} 0 & y_{i1}^* < 0 \\ 1 & y_{i1}^* > 0 \end{cases}, \tag{7}$$

where i=1,...N is the number of observations (companies); y_{i2} is the endogenous regressor's vector (the share of fixed-term employment contracts); X_{i1} is $1 \times k_1$ vector of exogenous control variables (companies' size, age, ownership, industry); X_{i2} is $1 \times k_2$ vector of the instruments (share of women, share of manual workers) which correlate with y_{i2} but do not correlate with y_{i1}^*; β, γ are structural parameters' vectors; Π_1, Π_2 are abridged parameter matrixes; and u_i, v_i are accidental errors.

Instrumental variables were chosen to match the requirement for their correlation with the endogenous regressor, and lack of such with a dependent variable. In the data set under consideration, such variables as the share of women and the share of manual workers matched these requirements more than others (in most cases they increase the probability of companies' using fixed-term employment contracts) [*Petrongolo*, 2004; *Portugal, Varejao*, 2009; *Pfeifer*, 2014; *Davis-Blake, Uzzi*, 1993]. At the same time no correlation was found between companies' innovation activity and the shares of women and/or manual workers on their payroll, i.e. companies with a high level of innovation activity are equally likely to have high or low shares of the above employee groups.

Results

37% of Russian companies use fixed-term employment contracts; the number of employees on such contracts is steadily growing, and in 2014 reached 13% of the total workforce (Table 1), while in the early 2000s it remained at about 5% [*Gimpelson*, 2006]. The highest share of workers on fixed-term employment contracts was noted at small enterprises (40%), compared with 33% at medium and 27% at large companies. A descriptive analysis reveals that companies that use fixed-term employment contracts show a higher level of innovation activity (51%) than those who do not use this form of employment (36%) (Table 2).

The averaged-out values presented above do not reflect the diverse effects of companies' specific characteristics, i.e., they provide an incomplete picture of the nature of companies' innovation activity

[6] These variables do not correlate with innovations, but do correlate with fixed-term employment contracts. Women and manual workers are often employed on fixed-term contracts, so the more staff companies have, the more extensively they use this kind of employment contract.

[7] This is a recursive model where y_{i2} is inserted in the equation for y_i^*, but y_i^* cannot be inserted in the equation for y_{i2}.

Table 2. **Fixed-term employment contracts and companies' innovation activity** (%)

Innovation-active companies	Fixed-term employment contracts		Total
	No	Yes	
No	63.54	48.88	58.18
Yes	36.46	51.12	41.82
Total	100	100	100
Source: calculated by the author.			

and its correlation with the use of fixed-term employment contracts. Therefore we conducted a regression analysis; the results of its first stage have shown that data obtained by applying a model for simultaneous assessment of two equations (innovation activity and fixed-term employment contracts), or bivariate probit model (*biprobit*), turns out to be more complete and more reliable than data generated using a standard probit model (Table 3). The Wald test results (significance of 38.72***) confirm the hypothesis about a correlation between unobserved remainders of the two equations, and similar characteristics of companies which do apply fixed-term employment contracts, with innovation activity. Thus, the level of the latter directly depends on the type of employment contracts used, but at the same time is also affected by self-selection, i.e. influenced by two overlaying effects:

1) a cause-and-effect relationship which directly reflects fixed-term employment contracts' impact on companies' innovation activity;
2) a false impact not directly connected with companies' innovation activity.

The self-selection effect biases the estimates, which can be corrected using the Heckman model. Our calculations (ρ>0) showed that the latter provides more reliable results than the simple bivariate probit model, which confirms that companies' self-selection factor affects their innovation activity (Table 4). The self-selection may have been due to the 'investments effect'[8], since companies that did make investments

Table 3. **Bivariate probit model** (***biprobit***)

Variable	Innovation activity (1=yes)		Fixed-term employment contracts (1=yes)	
Company size (1=<100)	Coef.	Std. Err.	Coef.	Std. Err.
101–500	0.08	0.08	0.02	0.08
>501	0.41***	0.14	0. 09	0.14
Company age (*years*)	0.00	0.00	0.00*	0.00
Ownership (1=private Russian-owned company):				
private foreign-owned company	–0.44*	0.25	–0.31	0.26
state-owned company	–0.17	0.16	0.01	0.17
mixed ownership company	–0.07	0.31	–0.13	0.32
Industry (1=mining):				
manufacturing	0.03	0.17	0.15	0.17
construction	–0.20	0.18	–0.06	0.19
wholesale and retail trade	–0.22	0.17	–0.22	0.17
transport and communications	–0.46**	0.20	–0.24	0.21
financial service	–0.04	0.21	0.10	0.22
business services	–0.09	0.17	0.05	0.18
Company's technological level compared with other companies in the industry (1=significantly below average):				
slightly below average	0.01	0.24	–0.29	0.25
average	–0.04	0.19	–0.22	0.19
slightly above average	–0.02	0.20	–0.19	0.20
significantly above average	–0.02	0.22	–0.25	0.22
Share of manual workers (%)			0.00	0.00
Share of women (%)			–0.01***	0.00
Constant	–0.13	0.25		
/athrho	0.27***	0.04		
rho	0.26	0.04		
Wald test of rho=0, chi2(1)	38.72***			
Wald chi2(34)	123.46***			
Log pseudolikelihood	–1942.22			
Number of observations	1520			

Significance: * — p<10%; ** — p<5%; *** — p<1%.

Source: calculated by the author.

[8] On the basis of answers to the survey question "Were there any major investments made in 2014 (2013) in your company's development (construction, reconstruction, repair, IT, capital repair of buildings/premises, upgrading of equipment, etc.?", a dummy variable was constructed: 1=there were investments, regardless of the size; 0=no investments were made. The source of investments did not matter: they could have been made by the company itself, or by others.

Table 4. **Probit model with self-selection (*heckprob*)**

Variable	Coefficients	Robust standard errors
Innovations (1=yes)		
Company size (1=<100):		
101–500	0.12	0.12
>501	0.50**	0.21
Company age (*years*)	0.00	0.00
Ownership (1=private Russian-owned company):		
private foreign-owned company	–0.46	0.43
state-owned company	–0.02	0.22
mixed ownership	5.13***	0.35
Industry (1=mining):		
manufacturing	0.06	0.22
construction	–0.05	0.24
wholesale and retail trade	–0.06	0.22
transport and communications	–0.24	0.28
financial services	–0.02	0.28
business services	0.01	0.23
Company's technological level compared with other companies in the industry (1=significantly below average):		
slightly below average	0.03	0.30
average	–0.08	0.23
slightly above average	0.14	0.25
significantly above average	–0.09	0.27
Investments (1=yes)	0.32***	0.10
Constant	–0.94***	0.34
Fixed-term employment contracts (1=yes)		
Share of manual workers (%)	0.00	0.00
Share of women (%)	–0.01***	0.00
Company size (1=<100):		
101–500	0.10	0.08
>501	0.16	0.14
Company age (*years*)	0.00*	0.00
Constant	–0.25***	0.07
/athrho	0.97**	0.35
Rho	0.75	0.15
Number of obs	1557	
Censored obs	1047	
Uncensored obs	510	
Wald chi2(17)	1327.17***	
Log pseudolikelihood	–1282.984	
Wald test (rho=0) chi2(1)	7.7**	

Significance: * — p<10%; ** — p<5%; *** — p<1%.
Source: calculated by the author.

demonstrated a stronger correlation between the use of fixed-term employment contracts and innovation activities (0.18) than those who avoided making investments (0.07) (Table 5).

The third stage of analysing the nature and extent of fixed-term employment contracts' effect on companies' innovation activity revealed that in Russia the latter is inversely proportional to the share of employees on such contracts (Tables 6–7). Fixed-term employment contracts positively affect companies' innovation level only if the former's application is limited to a certain scale (Figure 1). In particular, companies'

Table 5. **Fixed-term employment contracts and companies' innovation activity: effect of investments**

Model	Maximum value d*y*/d*x*	Standard error
Heckprobit [1]	0.04**	0.02
Probit if invest=1	0.07*	0.04
Probit if invest=0	0.18***	0.03

Significance: * — p<10%; ** — p<5%; *** — p<1%.
[1] Selection equation: investments = changes in financial situation during the current year, company age.
Source: calculated by the author.

Table 6. **Probability of companies' innovation activity depending on the share of employees on fixed-term contracts (*ivprobit*)**

Variable	Coefficients	Robust standard errors
Share of employees on fixed-term employment contracts (*%*)	–0.02***	0.00
Company size (1=<100):		
100–500	0.05	0.13
>500	0.11	0.25
Company age (*years*)	0.00	0.00
Ownership (1=private Russian-owned company):		
private foreign-owned company	–0.23	0.44
state-owned company	–0.48**	0.25
mixed ownership	0.00	0.00
Industry (1=mining):		
manufacturing	–0.04	0.22
construction	0.01	0.25
wholesale and retail trade	–0.23	0.22
transport and communications	–0.25	0.27
financial services	–0.34	0.30
business services	–0.17	0.23
Company's technological level compared with other companies in the industry (1=significantly below average):		
slightly below average	0.09	0.34
average	0.03	0.26
slightly above average	0.31	0.27
significantly above average	–0.03	0.32
constant	1.00**	0.38
/athrho	0.88***	0.27
/lnsigma	3.33***	0.03
Rho	0.71	0.14
Sigma	28.06	0.84
Wald test chi2(1)	10.56***	
Wald chi2(16)	84.21***	
Log pseudolikelihood	–2939.39	
Number of observations	543	

Significance: * — p<10%; ** — p<5%; *** — p<1%.

Source: calculated by the author.

innovation activity reaches its peak if the share of employees on such contracts does not exceed 5% of their total payroll. Increasing this share further produces the reverse effect (Figure 1).

On the whole, it could be argued that the share of fixed-term employment contracts positively correlating with the company's innovation activity will vary in different industries and groups of firms. Establishing its optimal values for particular company profiles and sizes requires further research.

Conclusion

In terms of companies' innovation activity level, Russia noticeably lags behind developed countries. Progress in this area can be encouraged not just by providing direct public support but also by establishing rules and norms (i.e. labour market regulatory mechanisms) aimed at making this market more flexible, optimising employers' costs, and extended application of fixed-term employment contracts and other

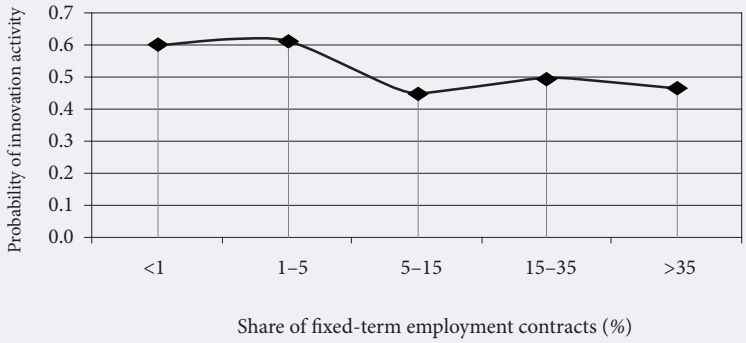
Table 7. **Probability of companies' innovation activity depending on the share of employees on fixed-term contracts: maximum values** (*ivprobit*)

Variable	Maximum value (d*y*/d*x*)	Standard error
Share of employees on fixed-term employment contracts (*%*)	–0.01***	0.00
Levels by the number of employees on fixed-term employment contracts (1≤1%; 5>40%)	–0.15***	0.04

Significance: * — p<10%; ** — p<5%; *** — p<1%.

Source: calculated by the author.

Figure 1. **Probability of companies' innovation activity depending on the share of employees on fixed-term contracts**



Source: compiled by the author.

unconventional employment arrangements. The effect of fixed-term employment contracts on Russian companies' innovation activity was comprehensively analysed in our study for the first time ever. Over the last seven years, the share of such contracts remained high, frequently exceeding the level of certain European countries. The results of further increasing the flexibility of the Russian labour market by an even more active use of this mechanism may turn out to be ambiguous.

A regression analysis of companies' characteristics revealed that those who do use fixed-term employment contracts frequently turn out to be innovation-active. However, if the share of workers on such contracts in the companies' total payroll increases, the companies' innovation activity declines. It reaches its peak level when about 5% of the company's total workforce are employed on fixed-term contracts. Increasing this share may lead to reduced quality of human capital required for innovation. Thus, companies' innovation activity requires not just flexible employment arrangements but also a certain level of workers' skills, which for permanent employees can be upgraded through workplace training.

The results of our study may help design labour market regulation initiatives to reduce barriers hindering companies' innovation activities. Liberalising labour legislation, and improving employment policy should create incentives to develop and implement innovations. At the same time it would be impossible to cover in a single study the full range of issues related with application of flexible employment arrangements and companies' innovation activity to increase their competitiveness. Subsequently we will have to find out whether the application of fixed-term employment contracts and other employment arrangements affects companies' innovation activities during periods of economic growth and recession in a different way. The hypothesis that flexible compensation mechanisms, widely applied by Russian companies as an important adaptation technique, affect their innovation activity in a way similar to that of fixed-term employment contracts, also requires verification. All these issues remain relevant, and require further research in the context of innovation policy shaping.

This work is an output of a research project implemented as part of the Basic Research Programme at the National Research University Higher School of Economics (NRU HSE).

References

Acemoglu D., Pischke J.–St. (1999) Why Do Firms Train? Theory and Evidence. *The Quarterly Journal of Economics*, vol. 113, no 1, pp. 79–119.

Al-Laham A., Tzabbar D., Amburgey T.L. (2011) The dynamics of knowledge stocks and knowledge flows: Innovation consequences of recruitment and collaboration in biotech. *Industrial and Corporate Change*, vol. 20, no 2, pp. 555–583.

Arvanitis S. (2005) Modes of labor flexibility at firm level: Are there any implications for performance and innovation? Evidence for the Swiss economy. *Industrial and Corporate Change*, vol. 14, no 6, pp. 993–1016.

Atkinson J. (1987) Flexibility or fragmentation? The United Kingdom labor market in the eighties. *Labor and Society*, vol. 12, no 1, pp. 87–105.

Autor D., Kerr W., Kugler A. (2007) Do Employment Protections Reduce Productivity? Evidence from U.S. States. *Economic Journal*, vol. 117, no 521, pp. 189–217.

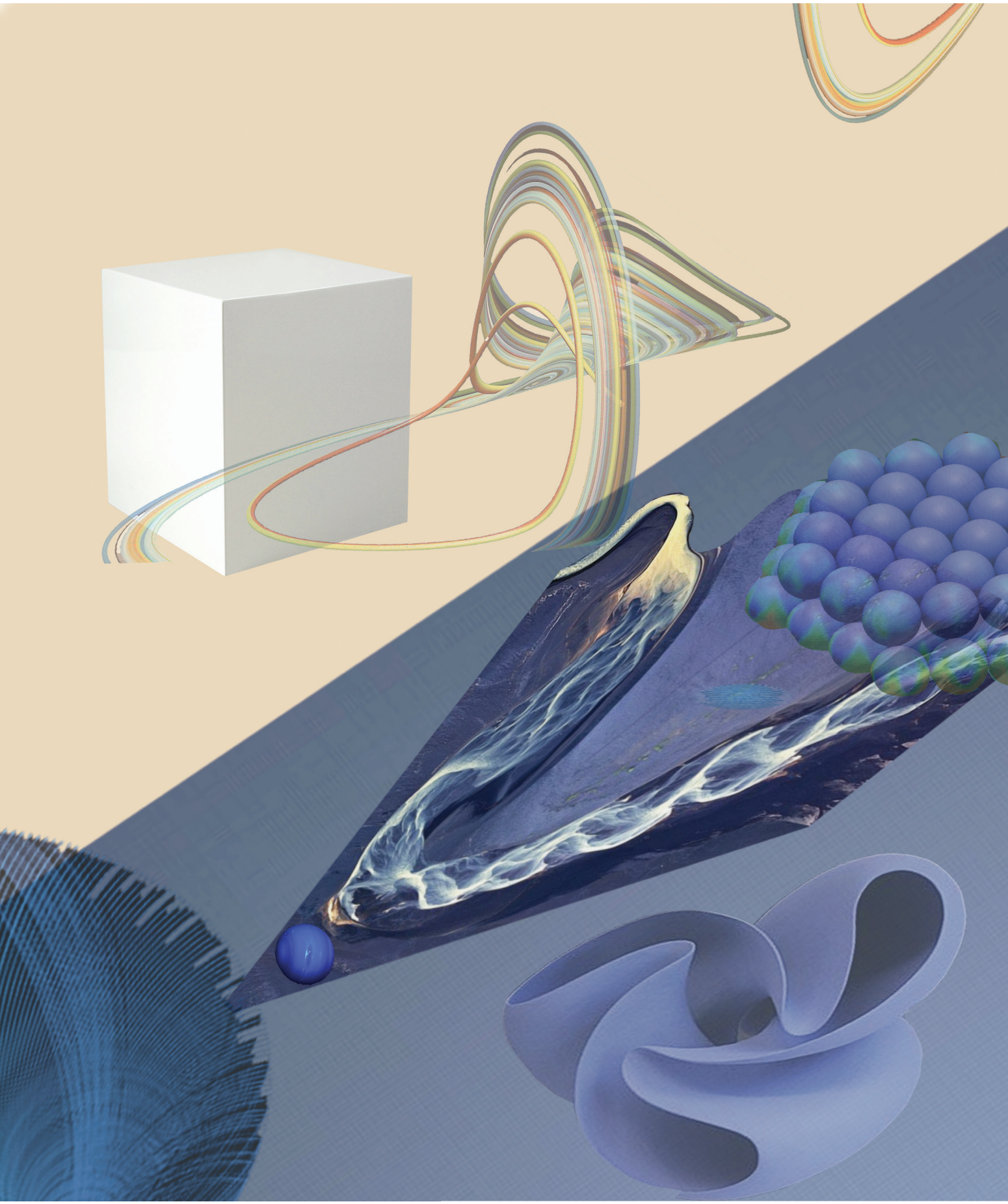
Bartelsman E., Gautier P., de Wind J. (2010) *Employment Protection, Technology Choice, and Worker Allocation* (IZA Working Paper no 4895), Bonn: Institute for the Study of Labor (IZA).

Bassanini A., Ernst E. (2002a) Labor market regulation, industrial relations and technological regimes: A tale of comparative advantage. *Industrial Relations*, vol. 11, pp. 391–426.

Bassanini A., Ernst E. (2002b) *Labour Market Institutions, Product Market Regulation, and Innovation* (OECD Working Paper no 316), Paris: OECD.

Bentolila S., Dolado J. (1994) Spanish labour markets. *Economic Policy*, vol. 9, no 18, pp. 53–99.

Booth A.L., Francesconi M., Frank J. (2002) *Labor as a buffer: Do temporary workers suffer?* (IZA Discussion Paper no 673), Bonn: Institute for the Study of Labor (IZA).
Cappellari L., Dell'Aringa C., Leonardi M. (2012) Temporary Employment, Job Flows and Productivity: A Tale of Two Reforms. *The Economic Journal*, vol. 122, no 562, pp. 188–215.
Cappelli P., Neumark D. (2004) External churning and internal flexibility: Evidence on the functional flexibility and core-periphery hypotheses. *Industrial Relations*, vol. 43, no 1, pp. 148–182.
Davis-Blake A., Uzzi B. (1993) Determinants of Employment Externalization: A Study of Temporary Workers and Independent Contractors // Administrative Science Quarterly, vol. 38, no 2, pp. 195–223.
Dolado J., Ortigueira S., Stucchi R. (2012) *Does dual employment protection affect TFP? Evidence from Spanish manufacturing firms* (CEPR Discussion Paper no 8763), London: Center for Economic and Policy Research.
Farah D.-M., Iodice A. (2013) *Trud vne pravovogo polya* [The work outside the legal field]. *Uroven' zhizni naseleniya regionov Rossii* [Quality of Life of the Russian Population], no 10, pp. 13–14 (in Russian).
Franceschi F., Mariani V. (2014) *Flexible Labour and Innovation in the Italian Sector*, Rome: Bank of Italy. Available at: http://www.bancaditalia.it/pubblicazioni/altri-atti-convegni/2014-innovazione-italia/Franceschi-Mariani.pdf, accessed 19.10.2016.
Gimpelson V. (2006) Vremennaya i nepostoyannaya zanyatost' [Temporary and unstable employment]. *Nestandaratnaya zanyatost' v rossiiskoi ekonomike* [Non-typical employment in the Russian economy] (eds. V. Gimpelson, R. Kapelyushnikov), Moscow: HSE (in Russian).
Gokhberg L., Kouznetsova I. (2009) Innovatsii v rossiiskoi ekonomike. Stagnatsiya v preddverii krizisa? [Innovation in the Russian Economy: Stagnation before Crisis?]. *Foresight-Russia*, vol. 3, no 2, pp. 28–46 (in Russian).
Gorodnikova N., Gokhberg L., Ditkovskiy K., Kuznetsova I., Lukinova E., Martynova S., Ratay T., Rosovetskaya L., Fridlyanova S. (2015) *Indikatory innovatsionnoi deyatel'nosti: 2015. Statisticheskii sbornik* [Indicators of Innovation in Russian Federation: 2015. Data Book], Moscow: HSE (in Russian).
Griliches Z. (1998) *R&D and Productivity. The Econometric Evidence*, Chicago: University of Chicago Press.
Hall B.H. (2011) *Innovation and Productivity* (NBER Working Paper no 17178), Cambridge, MA: National Bureau of Economic Research.
Hopenhayn H., Rogerson R. (1993) Job Turnover and Policy Evaluation: A General Equilibrium Analysis. *The Journal of Political Economy*, vol. 101, no 5, pp. 915–938.
Ichino A., Riphahan R.T. (2005) The Effect of Employment Protection on Worker Effort: A Comparison of Absenteeism During and After Probation. *Journal of the European Economic Association*, vol. 3, no 1, pp. 120–143.
Jacob B. (2010) *The Effect of Employment Protection on Worker Effort: Evidence from Public Schooling* (NBER Working Paper no 15655), Cambridge, MA: National Bureau of Economic Research.
Kalleberg A.L. (2001) Organizing flexibility: The flexible firm in a new century. *British Journal of Industrial Relations*, vol. 39, no 4, pp. 479–504.
Kapelyushnikov R.I. (2009) *Konets rossiiskoi modeli rynka truda?* [End of the Russian labor market model?], Moscow: Fond Liberal'naya missiya [Liberal Mission Foundation] (in Russian).
Kleinknecht A., Oostendorp R.M., Pradhan M.P., Naastepad C.W.M. (2006) Flexible labour, firm performance and the Dutch job creation miracle. *International Review of Applied Economics*, vol. 20, № 2, pp. 171–187.
Kuznetsova T., Roud V. (2011) Faktory effektivnosti i motivy innovatsionnoi deyatel'nosti rossiiskikh promyshlennykh predpriyatii [Efficiency Factors and Motivations Driving Innovative Activity of Russian Industrial Enterprises]. *Foresight-Russia*, vol. 5, no 2, pp. 41–42 (in Russian).
Laursen K., Foss N.J. (2003) New Human Resource Management Practices, Complementarities, and the Impact on Innovative Performance. *Cambridge Journal of Economics*, vol. 27, no 2, pp. 243–263.
Lorenz E.H. (1999) Trust, contract and economic cooperation. *Cambridge Journal of Economics*, vol. 23, no 3, pp. 301–316.
Lucidi F., Kleinknecht A. (2010) Little innovation, many jobs. An econometric analysis of the Italian productivity crisis. *Cambridge Journal of Economics*, vol. 34, no 3, pp. 525–546.
Malcomson J.M. (1997) Contracts, hold-up, and labour markets. *Journal of Economic Literature*, vol. 35, no 4, pp. 1916–1957.
Malgarini M., Mancini M., Pacelli L. (2011) *Temporary Hires and Innovative Investments* (University of Torino Working Paper no 19), Torino: University of Torino.
Michie J., Sheehan M. (2003) Labour market deregulation, 'flexibility' and innovation. *Cambridge Journal of Economics*, vol. 27, no 1, pp. 123–148.
Nickell S., Layard R. (1999) Labour market institutions and economic performance. *Handbook of Labour Economics* (eds. O. Ashenfelter, D. Card), Amsterdam: Elsevier Science, pp. 2985–3028.
Nicoletti G., Scarpetta S. (2003) *Regulation, productivity, and growth: OECD evidence* (World Bank Policy Research Working Paper no 2944), Washington, D.C.: World Bank.
OECD (2002) *OECD Employment Outlook*, Paris: OECD.
OECD (2005) *Oslo Manual — Guidelines for Collecting and Interpreting Innovation Data*, Paris: OECD.
Petrongolo B. (2004) Gender Segregation in Employment Contracts (CEP Discussion Paper no 637), London: Centre for Economic Performance.
Pfeifer C. (2009) Fixed-Term Contracts and Employment Adjustment. An Empirical Test of the Core-Periphery Hypothesis with German Establishment Data. *The Economic Record*, no 85(268), pp. 92–107.
Portugal P., Varejao J. (2009) *Why Do Firms Use Fixed-Term Contracts?* (IZA Discussion Paper no 4380), Bonn: Institute for the Study of Labor (IZA).
Rosstat (2016) *Nauka i innovatsii. Ofitsial'naya statistika* [Science and Innovation. Official statistics]. Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/science/#, accessed 15.06.2016 (in Russian).
Scarpetta S., Tressel T. (2004) *Boosting Productivity via Innovation and Adoption of New Technologies: Any Role for Labour Market Institutions?* (World Bank Policy Research Working Paper no 3273), Washington, D.C.: World Bank.
Smirnykh L. (2014) Srochnye trudovye dogovory: vliyanie na dvizhenie rabochei sily i rabochikh mest [Fixed-term employment contracts: The impact on the movement of labor and employment]. *Uroven' zhizni naseleniya regionov Rossii* [Quality of Life of the Russian Population], no 4, pp. 28–36 (in Russian).
Spender J.C. (1996) Knowledge and the Firm: Overview. *Strategic Management Journal*, vol. 17, pp. 45–62.
UIS (2015) *Summary Report of the 2013 UIS Innovation Data Collection* (Information Paper no 24), Montreal: UNESCO Institute for Statistics.
Wood S., de Menezes L. (1998) High commitment management in the UK: Evidence from the Workplace Industrial Relations Survey and Employers' Manpower and Skills Practices Survey. *Human Relations*, vol. 51, no 4, pp. 485–517.
Zhou H., Dekker R., Kleinknecht A. (2010) The impact of labour flexibility and HRM on innovation. *Innovation in Business and Enterprise: Technologies and Frameworks* (eds. L. Al-Hakim, C. Jin), Hershey, PA: IGI Global, pp. 150–161.
Zhou H., Dekker R., Kleinknecht A. (2011) Flexible labor and innovation performance: Evidence from longitudinal firm-level data. *Industrial and Corporate Change*, vol. 20, no 3, pp. 941–968.



Patent-Based Technology Life Cycle Analysis: The Case of the Petroleum Industry

Mohammad Dehghani Madvar [a]
Researcher and Expert, dehghani.madvar@gmail.com

Hossein Khosropour [b] (corresponding author)
Consultant and Expert, khosropourh@gmail.com

Abdollah Khosravanian [c]
Researcher and Expert, khosravanian_a@che.sharif.ir

Maryam Mirafshar [d]
Graduate Student, mirafshar.maryam@gmail.com

Adel Azaribeni [c]
Researcher and Expert, Azaribeni_adel@che.sharif.ir

Morteza Rezapour [e]
Head of IP Unit, rezapourm@ripi.ir

Behrouz Nouri [e]
Head of Technology Strategies Unit, Noorib@ripi.ir

[a] Department of Renewable Energy, University of Tehran, 16 Azar str., Enghelab sq., Tehrān, Iran.

[b] Young Researchers and Elite Club, Central Tehran Branch Islamic Azad University, No. 136, Forsat Sr., Eskandari St., Azadi Ave., Tehran, Tehran Iran

[c] Department of Chemical and Petroleum Engineering, Sharif University of Technology, Azadi ave., Tehrān, Iran

[d] Allameh Tabatabai University, Dehkadeh-ye-Olympic, Tehrān, Iran.

[e] Research Institute of Petroleum Industry, West Side of Azadi Sports Complex, 1485733111 Tehrān, Iran.

Abstract

Decisions for determining the current stage of technology life cycle (TLC) based on reliable data, are necessary. The inherent links between patents and science and technology make them essential sources for data on any technology. In the light of this, and considering the importance of patent information for the firm's strategic decisions, we have attempted to use patent data as a source of information to identify the level of a technology in the S-Curve. This paper starts with the literature review of the life cycle and the role of patents at the various stages of technology development, and then focuses on a technology trend analysis framework using patent data, and discusses the life cycle of CO_2 injection technology in the upstream sector of the global oil and gas industry. In the final section, the results are presented based on an analysis of patent data on CO_2 injection technology as were recommendations concerning the application of the methodology in future studies as it might be an effective tool for better analyzing any desired technology.

Keywords: technology life cycle; S-curve; patent analysis; CO_2 injection.

DOI: 10.17323/1995-459X.2016.4.72.79.

Citation: Madvar M.D., Khosropour H., Mirafshar M., Khosravanian A., Azaribeni A., Rezapour M., Nouri B. (2016) Patent-Based Technology Life Cycle Analysis: The Case of the Petroleum Industry. *Foresight and STI Governance*, vol. 10, no 4, pp. 72–79. DOI: 10.17323/1995-459X.2016.4.72.79.

Patents provide one of the most important ways to the improve the competitive strategy of an enterprise's business concept and its technology strategy. The monitoring of patenting activities helps identify the status of a technology in its life cycle; and determine competitive or collaborative relations among companies in certain areas, which can provide valuable information for developing strategies for R&D and marketing activities [*Dou*, 2004]. Patent analysis provides a practical forecasting tool for decision makers in the public and private sectors [*Amy, Charles,* 2008]. Patent analysis can provide a picture of the growth pattern of a technology (as emerging, maturing or declining). Due to the tendency for tracing technological changes and their influence on industries, there is an increasing demand for the use of Technology Forecasting (TF) methods to improve policy planning and implementation. TF predicts the direction and speed of change in technological trends, facilitating the early detection of revolutionary technologies [*Chen et al.,* 2011]. Such an early detection of weak signals helps researchers prepare for the turbulent future of an industry as well as technology and TF is therefore an unavoidable process for devising successful policies which can meet both public and private needs.

The oil and gas industry is one of the key sectors in the economy and the fact that technological changes have become an indisputable fact in this industry motivated us to choose a segment of this sector for technological forecasting using life cycle tools [*Daim et al.,* 2006].

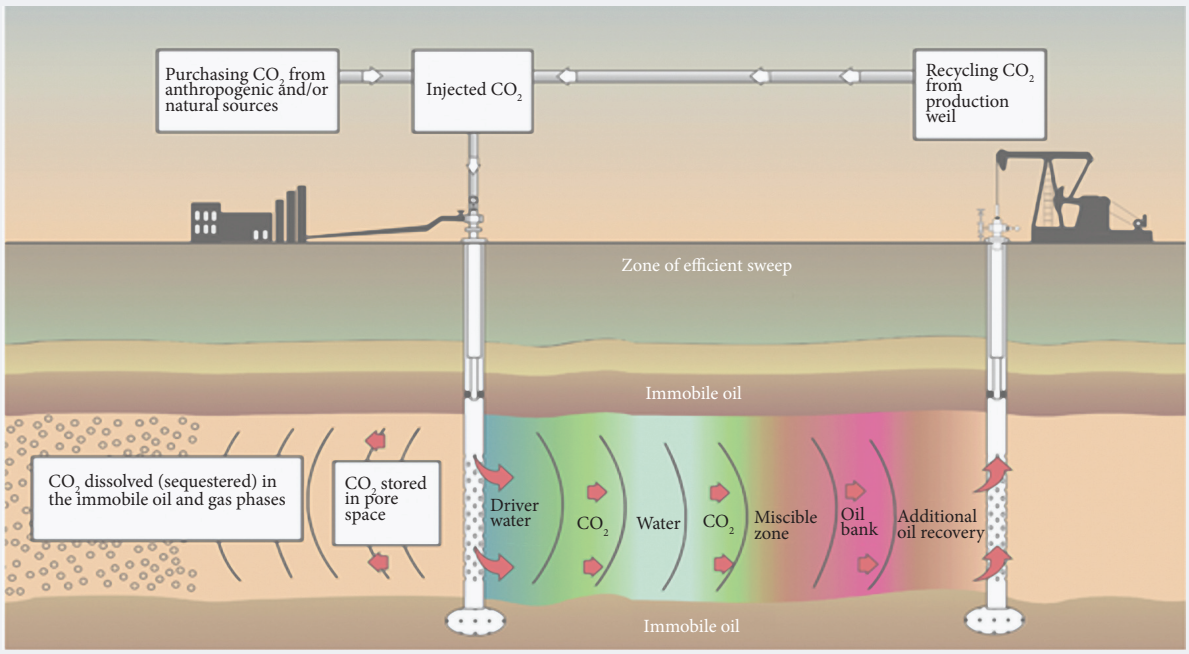
Among the technologies used in the upstream sector of the oil and gas industry, Enhanced Oil Recovery (EOR), also known as tertiary production, is a prominent area. CO_2 injection (Figure 1), more specifically speaking, is quickly becoming the preferred method of EOR in many fields, due to the ease of CO_2 transport through pipelines (from areas where it is abundant to the fields where it is needed). In addition, there is the overall advantage of recycling this greenhouse gas by injecting it into reservoirs for EOR [*Malik, Islam,* 2000].

The concept of technological life cycles

The S-Curve is a mathematically based model which is used in a variety of fields including physics, biology and economics. According to Arthur Little's definition, the characteristic of the emerging stage is a new technology with low competitive impact and low integration in products or processes [*Little*, 1981]. During the growth stage, there are pacing technologies with high competitive impacts that have not yet been integrated in new products or processes. At the maturity stage, some pacing technologies turn into key technologies, they are integrated into products or processes, and maintain their high competitive impact [*Mogee*, 1991]. As soon as a technology loses its competitive impact, it becomes a base technology and enters the saturation stage and may be replaced by a new technology (Figure 2).

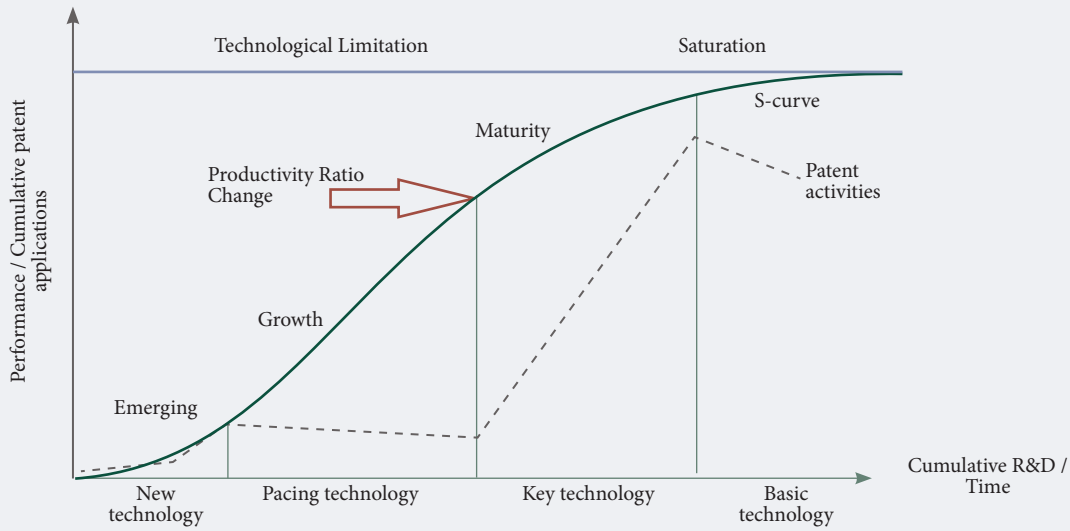
As made clear in Figure 2, the most critical issues under consideration are the 'Technological Limitation' and 'Productivity Ratio Change'. Productivity Ratio Change is defined as a turning point developed by any new capability. This development is is produced at an established company. The other term is defined as a

Figure 1. **CO_2 Injection**



Source: [DOE, 2011].

Figure 2. **Scheme of integration for technological S-curve and patent activities**



Source: [*Ernst,* 2003].

technology, which due to finite improvement, becomes mature, thus it is called Technological Limitation. Process innovation often occurs at this level.

S-Curves are acquired by using a regression model that examines the non-linearity between the dependent variable (to be forecasted) and time. The most commonly used equation was described by Intepe and Koc [*Intepe, Koc,* 2012] as:

$$Y_t = \frac{L}{1 + ae^{-bt}}, \tag{1}$$

Where coefficients a and b describe, the location and shape of the curve respectively, and L is the asymptotic maximum value of Y_t. Models based on initial data for a growth curve are quite valid if the exact curve and upper limit have been identified.

Technological forecasting by patent documents

Since patents provide exclusive rights and legal protection for assignees and inventors, they play an important role in the development of technology. On the other hand, considering the fact that the patenting process is costly and can take several years, filing a patent generally means there is optimism concerning the economic or technical contribution of the technology being patented.

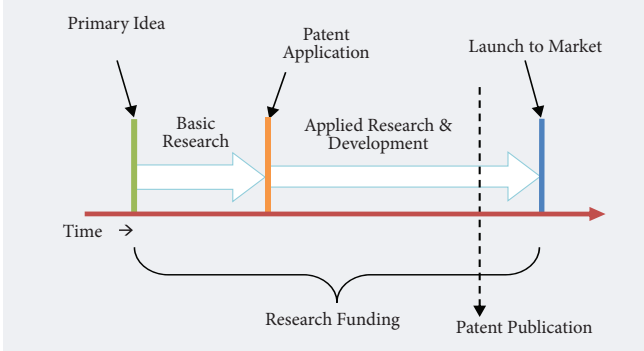
Patent analysis is used for deriving information about a particular industry or technology, which can be used in forecasting activities. The rate of growth of the number of patents on a technology generally follows a similar trend resembling the S-curve pattern. In the early stages of a technology, the number of patents issued is very limited, next a period of rapid growth follows when the number of field and issued patents increases and finally a plateau is reached [*Amy, Charles,* 2008].

Using the number of patent applications, grants, as well as the abandoned, nullified or expired patents can help on obtain insight into the development of a technology. Each technological development goes through three stages starting with intellectual activity and finally getting to the market. The first transition stage starts with the dawn of the primary idea and continues with basic research, which can be filed as a patent. In the next step the filed patent will be published based on the R&D, which is final step before commercializing and then proceeding to the market (Figure 3).

As shown in Figure 2, in most models, patenting is attributed to the invention and development phase and is considered an output indicator of R&D activities, and as the models show, there is always a positive relationship between the extent of R&D and the number of patents. The number of citations that a patent gets can also be correlated with its economic and technological value. Since the cited patents, unlike in the case of articles, are preferred to be kept as low as possible by the applicant, in order to avoid possible overlapping arguments by the examination bodies, the number of citations made in a patent is also a very important indicator.

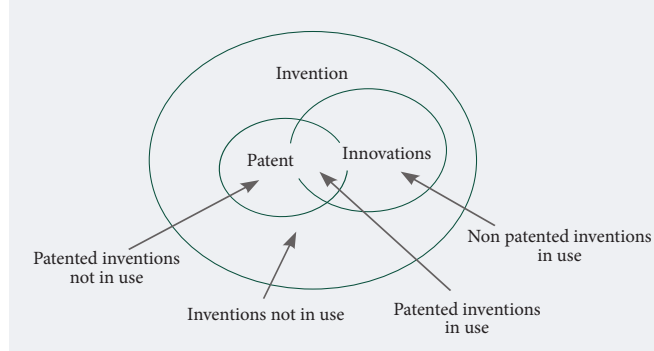
Patent citations can be used for studying the relationships between a company's activity and the other companies that cite the patents. It should be noted that an even smaller share of creativity can turn

Figure 3. **Technological development steps vs. patent**



Source: compiled by the authors.

Figure 4. **The relationship between patenting, invention and innovation**



Source: [*Basberg*, 1987].

into an innovation and in the future some innovations may become inventions and then only some of those inventions will be patented. Patents obviously contain some innovations; a patent may also contain inventions without any commercial value.

Methodology of the study

The technological life cycle curve is a parametric estimation-based tool for forecasting the future of technology by using growth curves. This method is helpful for estimating and anticipating the level of technological growth at each stage in the life cycle [*Gao et al.,* 2013].

In this paper, in order to illustrate the life cycle of technology used during carbon dioxide injection for enhanced oil recovery, the information of patents has been used. To identify relevant patents at first, we tried to interview experts in order to extract key words related to technology and its use in enhanced oil recovery. At the end of this stage, a list of key words was identified. Based on the list, in the next step by using key codes (extracting International Patent Classification (IPC)[1] and Cooperative Patent Classification (CPC)[2] codes using patents) or through the relationship between the identified codes, the main and related codes were extracted.

Finding the relationship between the key codes (Family codes) was the next step that led to the analysis stage. In this step using Orbit software[3] the relationship between the codes and their transposition is analyzed and identified (Figure 5).

As can be seen in Figure 6, the most patents related to the carbon dioxide injection technologies are E21B43 and C09K8 codes and fewest patent codes are F23L2900, E21B49 and C10J2300. Table 1 gives an idea of the hierarchical structure of CO_2 injection technology.

Table 1. **International Patent Classification (IPC) of CO_2 injection technology**

Code	Definition
E	Fixed construction
E21	Earth drilling; mining
E21B	Earth drilling, e.g. deep drilling (mining, quarrying E21C; making shafts, driving galleries or tunnels E21D); obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells
E21B43	Methods or apparatus for obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells (applicable only to water E03B; obtaining oil-bearing deposits or soluble or meltable materials by mining techniques E21C41/00; pumps F04)
E21B43/16	Enhanced recovery methods for obtaining hydrocarbons (fracturing E21B43/26; obtaining slurry E21B43/29; reclamation of contaminated soil in situ B09C; {chemical compositions therefor C09K8/58})
E21B43/164	{Injecting CO_2 or carbonated water (in combination with organic material C09K8/594)}

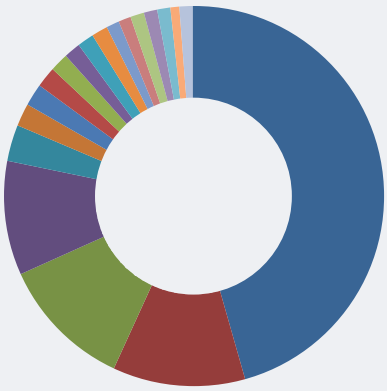
Source: compiled by the authors using International Patent Classification (IPC).

[1] Available at: http://web2.wipo.int/classifications/ipc/ipcpub/#refresh=page, last accessed 17.02.2016.

[2] Established in 2012 by European Patent Office (EPO) in cooperation with U.S. Patent and Trademark Office (USPTO). Available at: http://www.cooperativepatentclassification.org/, last accessed 17.02.2016.

[3] The Orbit is a Questel patent search and analysis software which is web-based patent with unique features. The patent authority coverage is almost all of the countries that have contributed in high technology and also these countries are pioneers in the technology such as the United States, the Great Britain, Korea and so on. Available at: www.orbit.com, last accessed 24.03.2016.

Figure 5. **Transposition of codes**



- E21B43\00 (1294 patents) — Methods or apparatus for obtaining oil
- Y02C10\00 (338 patents) — CO_2 capture or storage
- C09K8\00 (338 patents) — Compositions for drilling of boreholes or wells
- E21B41\00 (295 patents) — Equipment or details not covered by groups E21B15\00 to E21B40\00
- B01DD\00 (85 patents) — Separation of gases or vapours
- Y10S507\00 (60 patents) — Earth boring
- C01B3\00 (56 patents) — Hydrogen
- C10L3\00 (53 patents) — Gaseous fuels
- C01B2203\00 (46 patents) — Integrated processes for the production of hydrogen or synthesis gas
- Y02E20\00 (43 patents) — Combustion technologies with mitigation potential
- F2513\00 (40 patents) — Processes or apparatus for separating the constituents of gaseous
- B01D2257\00 (39 patents) — Components to be removed
- E21B33\00 (35 patents) — Sealing or packing boreholes or wells
- Y02E60\00 (35 patents) — Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
- C01B31\00 (34 patents) — Carbon
- F23L7\00 (31 patents) — Supplying non-combustible liquids or gases
- F23L2900\00 (30 patents) — Special arrangements for supplying or treating air or oxidant for combustion
- E21B49\00 (30 patents) — Testing the nature of borehole walls
- C10J2300\00 (30 patents) — Details of gasification processes

Source: compiled by the authors using IPC and CPC data.

As shown above, the E21B43 code is one of the most applicable codes for carbon dioxide injection, which consists of five sub-groups and the largest number of patents are in the E21B43/16 subgroup. Companies such as Shell, IFP, ExxonMobil and Schlumberger have filed patents under these codes and the lowest number of patents filed were under the E21B43/26 code, filers include Baker Hughes Inc. and Halliburton.

Next, the most relevant patents for CO_2 injection were extracted and the S-Curve was obtained based on this data. Finally, the research framework is given as follows:

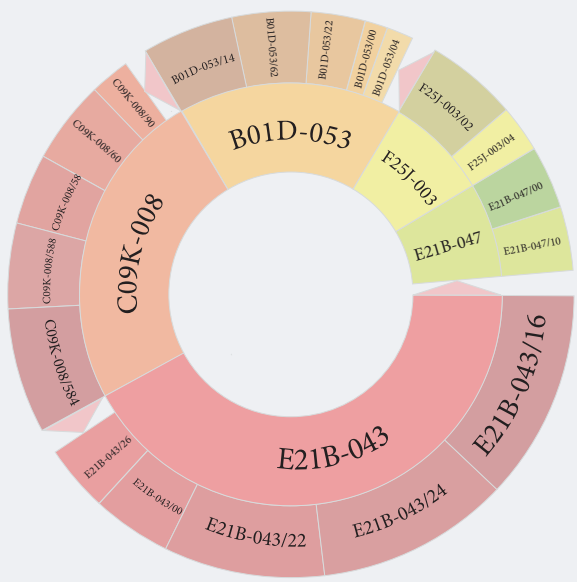
The source of the patent data was the Questel online database[4]. All 1235 patents were collected in the period from 1937 to 2014.

Discussion

A patent application is submitted to the patent office until the exclusive right of a patent is granted to the inventors. The patent application includes a description of the invention and provides information about its orgin. Patent applications generally contain the invention title, the results of experiments and a technical description of the patent. Therefore, it is possible to analyze the process of recording information about the inventors or organizations active in the field of technology.

During the analysis process, assuming that past trends will continue, a very large collection of historical data

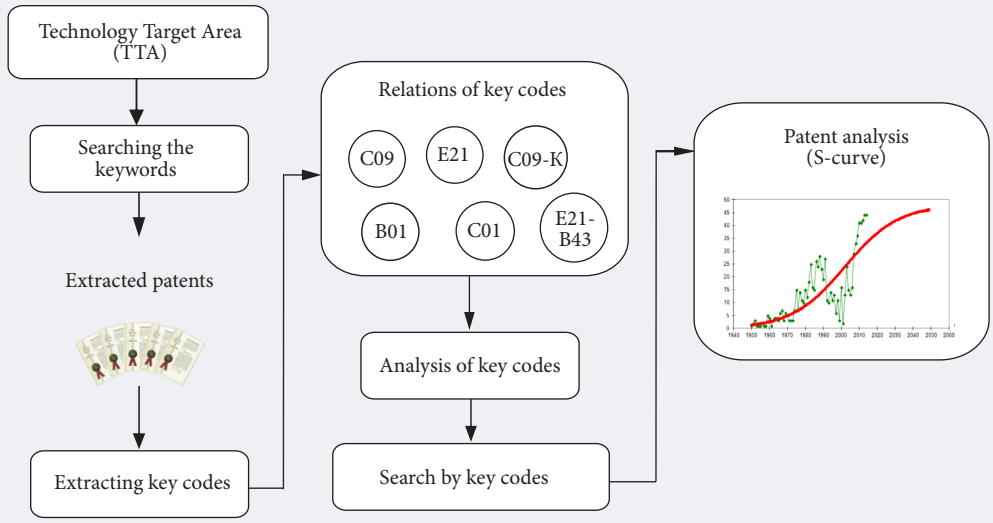
Figure 6. **The relationship between codes**



Source: compiled by the authors using Questel data for 2014.

[4] Available at: http://www.questel.com, accessed 17.02.2016.

Figure 7. **The research framework**



Source: compiled by the authors.

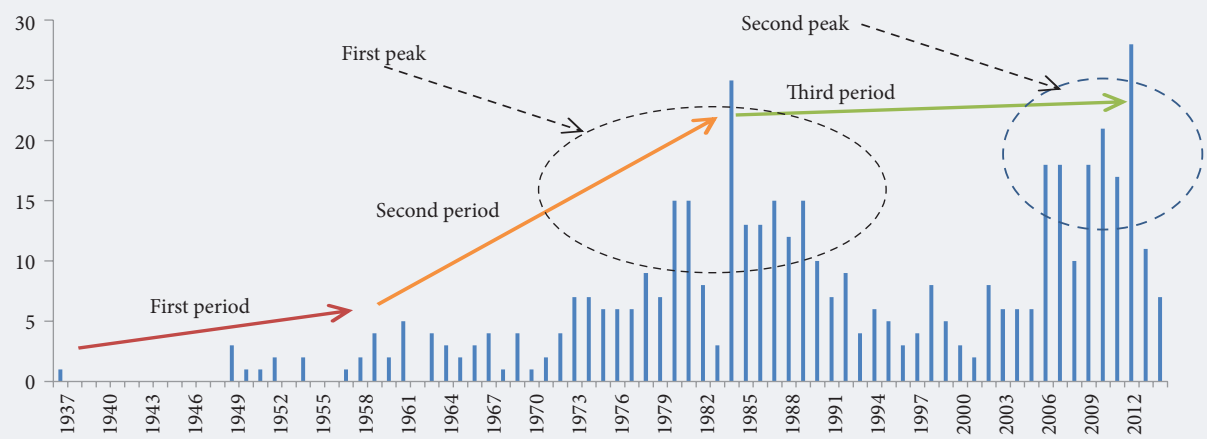
was collected and based on that, a picture of future developments is elaborated upon. These methods are appropriate for predicting the short term trends and providing an initial estimate of long-term developments. Moreover, these methods are used due to their lack of subjectivity.

Based on the data obtained on patents in the field of CO_2 injection technology, we classified the patent applications into three periods. The first period corresponded with the emerging era when the technology was introduced; this stage was between 1937 and 1957 where a weak growth was observed (not a patent filing was observed in the period of 1938–1948). The next period was from 1958 to 1988, when most probably due to oil crises and high oil prices, the number of patents filed increased and hence this period was considered the growth era. During the last period, despite patent fluctuations observed in patenting activities, the growth ratio was constant.

In Figure 8, two peaks are observed, and the distance between them shows increasing attention from researchers, inventors and companies in carbon dioxide injection technology during EOR.

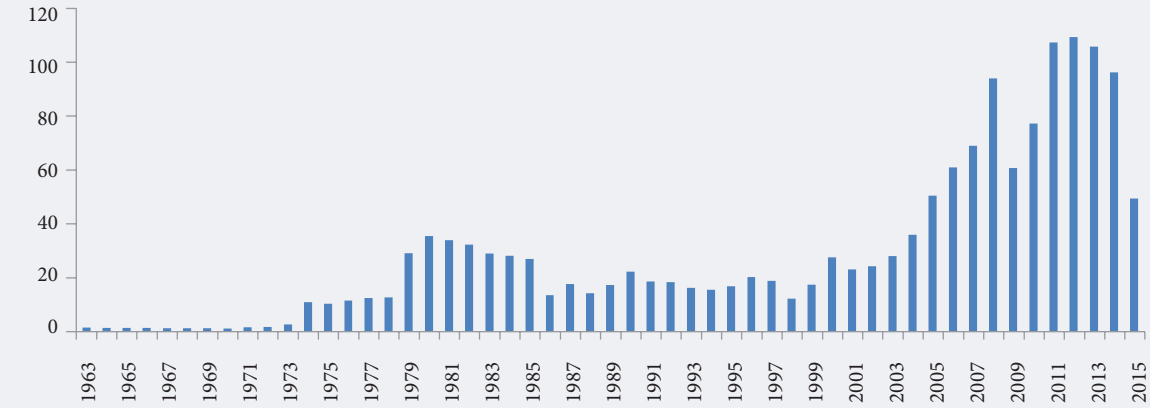
In the first period, which started from 1937 due to a lack of enthusiasm in this technology the number of patents were negligible, the highest number of patents were filed in 1949. The second period began with 5 patents in 1961 and continued to rapidly grow until 1988. The largest number of patents filed in one year was 26, which created a revolution in the technology. This rapid growth can be attributed to various events such as the embargo war which caused large fluctuations in oil prices. Figure 9 illustrates this fact.

Figure 8. **CO_2 injection technology patent application trend**



Source: compiled by the authors.

Figure 9. **Average annual OPEC crude oil price** (*USD per barrel*)



Source: compiled by the authors.

According to Figure 9, the fluctuations in oil prices has a significant effect on technology related to the oil industry, including CO_2 injection technology. The patent application trend clearly follows the oil price, although different issues such as the introduction of renewable energy, environmental challenges and also new technology in this category have had an impact on CO_2 injection technology.

Figure 10 shows the activities of companies over time. In 1957 this rather unknown[5] technology came to the attention of companies.

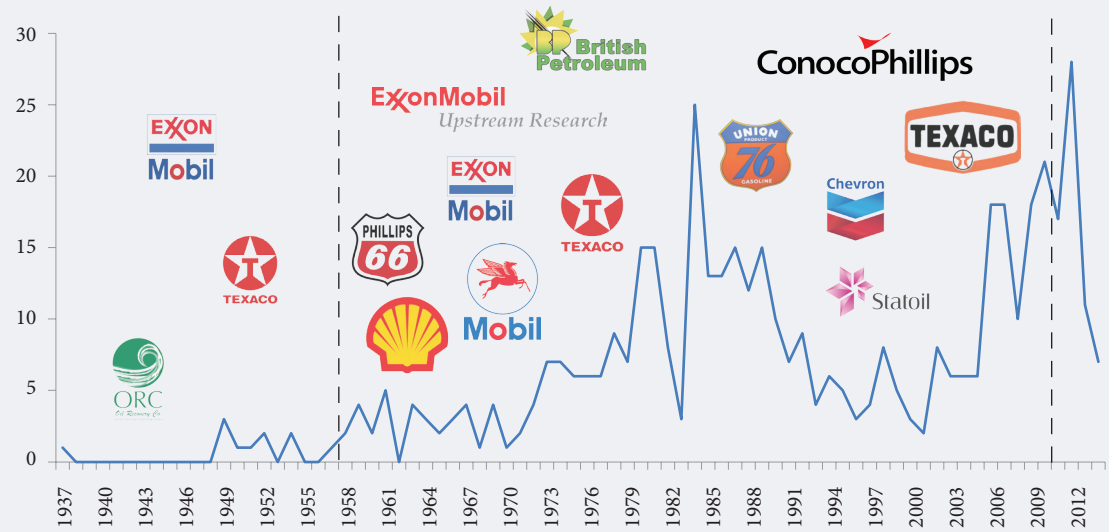
The results of the S-curves modeling for the CO_2 injection technology and the acquired data are shown and discussed below.

According to Figure11, there was slow growth in the number of CO_2 injection patents (and hence technology) between 1937–1957. The inflection points of the S-curve are located between 1985 and 1995 based on the data at hand. Next, the growth slows down and reaches the final saturation point, which is forecast to happen between 2040 and 2050.

Conclusion

A technology forecasting model based on the analysis of a frequent time series was used. We applied the S-Curve model to a CO_2 injection technology forecasting analysis that was constructed using annual

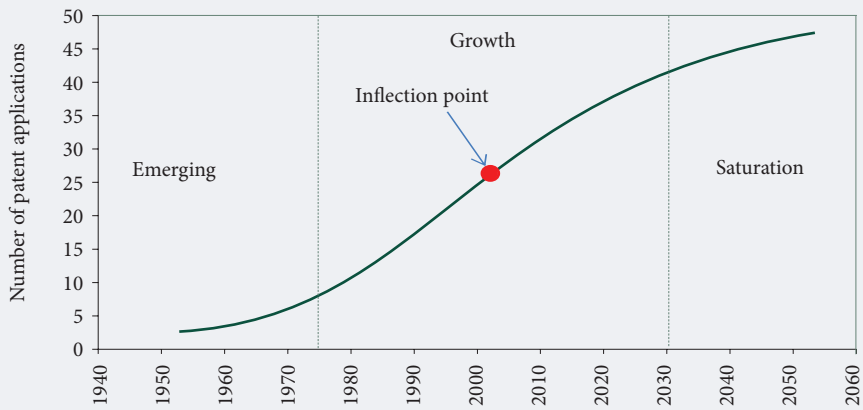
Figure 10. **Dynamics of patent activities of oil and gas companies in relation to CO_2 injection technology (number of registered patent applications per year)**



Source: compiled by the authors.

[5] An unknown technology can be described as a new technology whose attributes are not yet identified.

Figure 11. **The S-curve cycle**



Source: compiled by the authors.

frequency in CO_2 injection technology patents. According to the data obtained based on patenting activities in CO_2 injection technology, we divided patent applications into three periods.

The first period, i.e. the emerging era, includes the introduction of the technology and was found to be around 1937–1957. During this period the patenting activities are characterized by slow growth. Next was the period between 1958–1988 when the growth rates are much higher, most likely due to thenoil crisis and high oil prices. This period is consider the growth era. In last period, despite the fluctuations in patenting activity, the overall growth rates were constant. Based on the trend and life cycle analyses (S-Curve), the CO_2 injection technology can be considered to be in its maturity period and it was forecast to reach saturation between 2040 and 2050.

This research has described an approach and a method for identifying and analyzing the emerging to saturation stages of technologies, based on an analysis of published patent applications. The methods described in this report can be used by firms and their investors to monitor their technology, by placing their patents on S-curves. A firm or investor can evaluate the level of technology based on the S-curve's magnitude and duration. The results of this paper can provide a strong rationale for analysts who intend to use patents in technology forecasting. In this paper, the authors applied the described model to CO_2 injection in EOR. The experimental data were created using frequency by year in CO_2 injection in EOR technology patents.

As a further research, we are interested in improving our work using the latest data mining techniques. Moreover, we plan to use our approach for other emerging technologies in addition to ubiquitous technologies.

References

Amy J.C.T., Charles V.T. (2008) An R&D knowledge management method for patent document summarization. *Industrial Management & Data Systems,* vol. 108, no 2, pp. 245–257. DOI: 10.1108/02635570810847608.

Basberg B.L. (1987) Patents and the measurement of technological change: A survey of the literature. *Research Policy,* vol. 16, no 2, pp. 131–141.

Chen Y.-H., Chen C.-Y., Lee S.-C. (2011) Technology forecasting and patent strategy of hydrogen energy and fuel cell technologies. *International Journal of Hydrogen Energy,* vol. 36, no 12, pp. 6957–6969. DOI: http://dx.doi.org/10.1016/j.ijhydene.2011.03.063.

Daim T.U., Rueda G., Martin H., Gerdsri P. (2006) Forecasting emerging technologies: Use of bibliometrics and patent analysis. *Technological Forecasting and Social Change,* vol. 73, no 8, pp. 981–1012.

DOE (2011) *Improving Domestic Energy Security and Lowering CO_2 Emissions with "Next Generation" CO_2-Enhanced Oil Recovery (CO2-EOR)* (DOE/NETL-2011/1504), Washington, D.C.: U.S. Department of Energy, National Energy Technology Laboratory.

Dou H. J.-M. (2004) Benchmarking R&D and companies through patent analysis using free databases and special software: A tool to improve innovative thinking. *World Patent Information,* vol. 26, no 4, pp. 297–309.

Ernst H. (2003) Patent information for strategic technology management. *World Patent Information,* vol. 25, no 3, pp. 233–242.

Gao L., Porter A. L., Wang J., Fang S., Zhang X., Ma T., Wang W., Huang L. (2013) Technology life cycle analysis method based on patent documents. *Technological Forecasting and Social Change,* vol. 80, no 3, pp. 398–407.

Intepe G., Koc T. (2012) The Use of S-curves in Technology Forecasting and its Application on 3D TV Technology. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering,* vol. 6, no 11, pp. 2491–2495.

Little A.D. (1981) *The Strategic Management of Technology*, Cambridge, MA: Massachusetts Institute of Technology.

Malik Q.M., Islam M.R. (2000) *CO_2 Injection in the Weyburn Field of Canada: Optimization of Enhanced Oil Recovery and Greenhouse Gas Storage With Horizontal Wells*. Paper presented at the SPE/DOE Improved Oil Recovery Symposium, 3-5 April, 2000, Tulsa, Oklahoma.

Mogee M.E. (1991) Using patent data for technology analysis and planning. *Research-Technology Management,* vol. 34, no 4, pp. 43–49.

ISSN 1995-459X

9 771995 459777 >