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NETWORK GENESIS OF TECHNOLOGICAL CONVERGENCE

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Abstract

Under protracted structural crisis conditions the necessity of development of conceptual framework, helping to achieve positive changes of social-economical system of Russian economy, becomes crucial for critical re-evaluation and new scientific decision making. This article describes the issue of transition to prospective technological scheme through development of converging technologies. The meaning of convergent technologies is defined, including their development principles. As pathbreaking scientific-and-technological progress stage a possibility of applying NBIC-convergence is considered, which has been transformed into NBICS-convergence in the context of Russian economical reality, completed with Humanities and Social studies. As the most adapted to converging technologies the author emphasizes network structures as business activity mechanism. Various network structures classifications are considered; network structures classification into educational, scientific and innovation, infrastructural and integration structures has been analysed most closely. Integration network structures are supposed to be the most important nowadays, particularly integration network structures as the most effective and adapted to converging technologies. Converging technologies diffusion in application context can be realized using "Triple Helix" model. Tomsk city is considered to be as a good illustrative example of successful implementation of the „Triple Helix" concept with the main leading universities actively cooperating with the government and real economy business organisations. Necessity for governmental influence in innovative product markets grouping, infrastructure management, improvement of cooperation among research-and-technology process participants, legal system development, as well as creating in whole positive environment for innovative activities is especially emphasized.

Keywords: Converging technologies, NBICS-convergence, network,structural changes.

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1. Introduction

At the current stage, the risk of technological and structural degeneration in Russian economy has not been overcome. Used market economy model has resulted in crush of technological leadership program, whereas negative structural changes are dominating in economic structure. Enormous national resource potential builds up nonequivalent result. Under growing external and internal shocks, expansion of economic system neoliberal entropy, structural-technological anti-drive builds system risks for the upward development tendency of Russian society.

2. Problem Statement

Technological basis of Russian economy lost its benefits on certain technological schemes already at times of centrally planned economy, and with the coming market economy – was partly destroyed with its multiplier no longer guaranteeing leading positions in the world market. Though intellectual and educational-and-research potential combined with correct industrial, research-and-technology, clear progressive structural policy – all together can influence current dynamics, contributing to technological crisis therapy.

Necessary change-over to prospective technological scheme can be carried out within the context of research-and-technology governmental policy evolution by applying of NBICS-convergence, implying considerable synergetic effects as a result of interaction of the research and technological fields, as well as introduction of great number of breakthrough technological solutions and new fields of their application.

3. Research Questions

The term „converging technologies "was first used in the works of the American sociologist M. Castells in 90th of the XX century, who emphasized the effect of the "growing convergence of particular technologies in highly integrated system, with the old isolated technological trajectories becoming simply undistinguished". Aside from that he mentioned the tendency to merging of engineering practices into a new unified whole, stressing the „technological converging extending to the growing mutual dependency between the biological and microelectronic revolutions, both in material and methodological context" (Castells, 1998).

In general modern understanding, converging technologies can be characterized as interpenetration of the nano-, bio-, information and cognitive sciences and technologies, resulting in synergetic effect capable of taking economy system to the path-breaking research-and-development phase. Such interconnection of the mentioned technology groups was named NBIC-convergence (based on the capitals: N-nano; B-bio; I-info; C-cogno). The definition was set in 2002 by Mihail C. Roco and William S. Bainbridge in their report «Converging Technologies for Improving Human Performance» wrote for World Technology Evaluation Center (WTEC). The report brings a focus on two main aspects of NBIC-convergence. The first, which can be notionally called technological, suggests opening up of divers technological innovations and transformation of human civilization development mechanism on a whole due to synergetic consolidation of the mentioned research-and-development fields on nanotechnological

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basis. The second one is focused on possible effects of the technological development, particularly on human transformation, „humans improvement“, „human functionality“ and „human expansion“.

D. Medvedev and W. Pryde mentioned the following signature features of NBIC-convergence:

- „intensive cooperation among mentioned scientific-and-technological fields“;
- significant synergetic effect;
- coverage of the subject fields under consideration and influence – from atomic materia to intelligent systems;
- identification of tendencies for quantum growth of technological opportunities of individual and social human development – as a result of NBIC-convergence“ (Praid & Medvedev, 2008).

Used nowadays in publications of Russian researchers NBICS has become more and more popular, including the Humanities and Social Studies apart from the four mentioned technology groups. This happens due to the fact, that creation of the brand new technological base is not possible without creation of a new development model not only in fields of science and technology, but also in social sphere, thus resulting in synthesis of science technologies, society and a human being. It's believed, such interaction takes place not spontaneously, but through creation of single harmonious organized system, allowing to reduce time and cost expenses for originally hopeless development sectors (Shevchenko, 2014).

Beside the priority fields of studies forming part of NBICS-convergence, interaction with other studies fields is assumed to exist, resulting in convergence cluster structure. Convergence technologies development should answer a range of principles, as follow:

- development directions of converging technologies should fully meet global strategic national objectives (governmental policy goals) in context of research-and-technology fields, playing significant role in solving issues of structural economy improvements, at the same time ensuring safe and stable social and economic development;
- there should be no any information asymmetry among the participants of the converging technologies development process;
- converging technologies development should take place, primarily, in the context of the Country's technological independence, i.e. concentrated on so-called „critical“ technologies;
- converging technologies should progress with regard to all involved subjects‘ interests, participating in activities: educational, research, development institutions, manufacturing enterprises, end-consumers.

To modern day, there are no any program documents, particularly dealing with converging technologies issues or offering their practical application. September 30th, 2015, the head of NRC Kurchatovsk Institute Mikhail Kovalchuk gave a presentation of „Converging technologies development strategies“ project concept for Federation Council, prepared in cooperation with the National Research Center (NRC) Kurchatov. In this concept converging technologies development is considered as a possibility for solving global problems of socio-economic development, key focus governmental policy directions are identified in context of converging technologies, as well as policy documents mentioned, which could be amended based on the proposed concept. NRC Kurchatov Center has identified specific purposes and goals in reference to converging technologies development, including their implementation mechanisms, built up based on the following three directions: organisational support (with potentional subjects, able to participate in the future joint activities, identified), resources‘ provision (with certain options suggested, assuming active governmental participation), control and coordination system (with specified responsibility centers). Real research and developments within whole spectrum of converging sciences and technologies using X-ray, synchrotron and neutron radiation have been carried since 2009 in Kurchatov Center of NBICS-technologies. Equipped with mega-installation and unique scientific equipment, eight resource centers are functioning, allowing to answer challenges from medical, social, energetic, agricultural and ecology fields (NRC Kurchatovsk Institute ,2017).

Thus far, not only certain preconditions for NBICS-technologies development have been created, but also some experience in their fulfillment (realization of their potential) for change-over to prospective technological pattern has been gained. Such experience systemization, analysis and generalization can well be used for further development and extension of the proposed NRC Kurchatov Center concept.

The most important direction of organizational support for technological improvements is supposed to become application of modern form economic organization opportunities such as network structure. Being one of the most effective modifications among adaptive organizational socio-economic structures, a network structure, from our point of view, is able to create optimal conditions for development of converging technologies.

„Network organization“ term in its modern interpretation was defined by foreign researchers in 90s XX century and is supposed to be a cross-disciplinary, being originated at the intersection of economy, sociology, management and economic geography. Network structure content definition approaches vary greatly, though having synthesized them, it’s possible to determine network structures as a combination of homogenous and heterogeneous independently functioning economic subjects, linked with certain integration relations with the purpose of maximum effective usage of available resources potential, guided by the common long-term goals and operating under common agreed rules, under situational leadership and direct communication channels conditions.

Network is supposed to be, firstly, a new legal form of organization of economic activity participants‘ interaction and integration, as well as an institution, defining interaction and integration rules of such economic subjects, sharing similar value paradigms. Independent subjects, acting on equal conditions, make up an economic network, building their relations based on partnership elements and on common ownership principals, at network level. Economic network balances all participants centralization and decentralization. It offers mobility, flexibility, stability and effectiveness according to new conditions and requirements (Tyutyushev, Gasanov, Vasechko, 2011).

One of the first network structures classifications, supposed to be a classic one as of today, was proposed by R. Miles and C. Snow. It divides all networks into three categories: internal, stable and dynamical. Internal network implies fragmentation into certain business types and their interaction as with independent market subjects. Stable network implies a type of network organisation, with the company focused on several key activities, outsourcing secondary activities. Key feature of the dynamical organisation implies as many outsourced activities as possible, with the key business competence staying in company’s hand (for instance, modern technology) (Miles & Snow, 2009).

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There are many network structures classifications existing in science literature, based on different factors: organisation form, role played in economic systems, business segment, group of participants, availability or absence of internal competition and barriers to entry etc. Considering network structures within the system „research-education-manufacturing“ from key factor of network development point of view, it is reasonable to identify educational, high-tech, infrastructural and integration network structures (Shevashkevich, 2013).

Educational network structure implies group of organisations, co-hosting educational projects. In case of such network structure, horizontal network technologies prevail, including the following goals: enhancing mobility level of students and teachers, inter-institutional cooperation of universities, common principals of advanced standing (acknowledgement of educational outcomes), improvement of access level to higher education, further improvement of quality and attraction of European Higher Education, as well as support of successful graduate employability. Educational network structure aims from one side the development of the common European united area of higher education; from the other side – building communication channels with real economy sector, major scientific centres. To date such forms of network cooperation as consortium of universities, academic institutions, business community organisations, cluster formations (including universities, scientific and innovation centres and RDC (research and development centres), small enterprises and objects of scientific-and-technological infrastructure) along with Associations of Educational and Scientific Institutions are successfully used (Parfenova, 2014).

Scientific-innovation network structure is an institutionally formed scientific network, with the main goal of the scientific network being informational communication and knowledge exchange, whereas the main goal of the scientific-innovation network is the transformation of scientific knowledge into a certain product (commodities) in the market. Talking about the scientific network, a range of key features can be identified as follow: high qualification entry barriers, unlimited number of network participants, absence of clear activity organisation parameters, self-regulation, positive effect from network expansion scale growth, absence of materiel operation principles. Typical for scientific-innovation network are priority focus for improvement of manufacturing competitiveness, consumer orientation, absence of fuzzy network boundaries, presence of coordinators and investors.

Creation of the network structure in scientific and innovation fields will allow improving basic structural parameters of economic growth, making strategic sunrise industries competitive, guaranteeing macro economical stability by extending knowledge and technologies reproduction process and enhancement of scientific research results efficiency. The following key goals can be specified: search for new technological solutions, cross-disciplinary research surveys, development of the industrial-technology base, corresponding staffing support, increase of knowledge-intensive business rate, clear definition of scientific and technological priorities, creation of new models of science and business interaction, high-technology economic sectors clusterization etc. Scientific-innovation network provides a basis for Research and Advanced Development (R&D), also allowing maximum rapid realisation of the complete innovation development cycle thanks to high concentration of competencies, information resources, experimental and scientific facilities etc. In this context universities are supposed to be the most important elements of the network structure, acting as developers of vast flow of innovations being

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of great interest for real economic sector. The core task is the commercialization of the scientific-and-technological potential of universities implying transfer of technologies from scientific developments into business by building of scientific-innovation networks based on universities complexes (foremost national research and entrepreneurial universities) (Barinov & Zhmurov, 2007).

Infrastructure networks imply complex of diverse conditions, providing macroeconomic stability and economy growth and meeting needs of all subjects of the national innovation system to the maximum. Infrastructure networks include information networks, transport, communications, financial and institutional networks.

4. Purpose of the Study

Of major importance to date are supposed to be integration network structures, guaranteeing the interaction among science, education and manufacturing. The number of participants of such network structure model is practically unlimited: these can be any organisations, which activities allow to combine knowledge from the same subject area, for instance, educational, research, engineering and design institutions and industrial enterprises. In such a case, participants' activities of such integration network must cover the whole innovation cycle: „fundamental research R&D – trial production – high-volume production - commercialization".

Integration network structures have the following key features:

- subjects of the network use common advanced experience and scientific progress (knowledge) in a certain subject area, new products and production technical innovations, allowing full-scale integration of science, education, manufacturing. Constant experience exchange takes place within the subject area, increasing level of intra-network process organization: common standards of knowledge definition, their formalization and archiving, uniform information technologies for knowledge retrieval for new projects, allowing to keep network structure maximum adaptable to ever-changing market demands at any time;
- constant information exchange and cooperation of network participants within the network structure, as well as with the end-consumers. Quest for new sectors of new products application is of interest for any organization – participant of the network, as company's competitiveness growth is based particularly on key competences development and search for a wide range of fields for effective application of the one or another key competence. Network integration allows to accumulate intellectual efforts of the participants while searching for target task solution;
- long-term cooperation orientation, development of common innovation-driven programs, stimulating effective cooperation of all network participants. Participation in network also implies transfer of management technologies and, primarily, operational management decisions. The results of management technologies transfer include improvement of management activity of network participants, as well as unification of management process quality standards, which provides room for generation of synergetic effect potential;
- interaction based on strategical partnership of all network structure participants, allowing to generate potential for complex problem solving on promotion of competitiveness in

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modern economy. Such interaction is realized in particular by means of implementation of information and communication technologies, which in turn, require network approach for their effective application (Makoveeva, 2012).

For effective interaction of scientific, educational structures and business sector, improvement of the information flows among network participants, as well as open access for all participants to research and developments results are of great importance. Though, in such a case, risk of opportunist behavior exists, coming from single network participants to one another, which can be avoided with help of responsibilities, mainly real and procedural, to be taken over by the partners.

An ultimate goal of the integration network structure is supposed to be an acquisition of the business result from implementation of the innovations in the market by maximum speed-up manufacturing of the products, made on the basis of a new product platform and new knowledge deepening. Integrated relations among network subjects in particular allow reaching synergies effects due to networking cooperation, coherence and coordination of activities of all participants.

Unfortunately, as of today's date, business enterprises show not enough interest to investments in high-tech industries, thus governmental interference in innovation products of information-network environment market grouping becomes really necessary. Especially, key issue implies the necessity of governmental interference in organization of infrastructure, creation of environment, favourable for innovation activities development. Building effective relationships among manufacturers and innovation consumers, as well as among the investors and manufacturers, is to be carried out by the network subjects: technology parks, business incubators, innovation-technological centres as structures, providing infrastructural components of business organization and coming under direct governmental influence.

5. Research Methods

One of the possibilities of constructive interaction among the government, business and science, which can operate as integration network structure, is so called "Triple Helix" model. Such concept, introduced in England by Henry Etzkowitz and Loet Leydesdorff in the beginning of XXI century, assumes close collaboration among the government, business and universities, whereas each of the helix elements has its clearly specified functionality: government initiates contractual relationships, business – focusing on manufacturing, with the university being considered as a generator of novel knowledge and technologies. However, to date, the university strives to enhance its role as a resource for knowledge-intensive industries, instead of being simply the source of high-qualified personnel and knowledge, transforming into scientific complex with its science-based companies, research-and-development institutions, design development offices, laboratories, business-incubators, research parks etc. As a result, the university can become the point of economic growth of the region, providing the possibility for interdisciplinary research with orientation to development of converging technologies.

Tomsk city is an illustrative example of a successful practical implementation of the „Triple Helix" concept. In September 2012 a Russian Division of International „Triple Helix" Association was opened by the support of Innovation Institute of TUSUR, and in 2014 based on National Research Tomsk Polytechnic University (NR TPU) a XII Conference of International Triple Helix Association „The Triple Helix and innovation-based economic growth: new frontiers and solutions" was hold. Leading Tomsk

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Universities rapidly develop Research & Advanced Development (R&D). Thus, National Research Tomsk Polytechnic University (NR TPU) conducts developments in biotechnologies and medical devices, prudent natural resources management, information technologies and professional equipment, modification of surfaces and new materials, non-destructive monitoring, water treatment, energetics and power management, machine building, including operating business-incubators with more than 40 operating innovative small enterprises (Tomsk Polytechnic University TPU, 2017). NR TPU actively cooperates with Special Economic Zone (SEZ), Tomsk" in terms of staffing support, research and development, as well as attraction of new companies in SEZ. Educational and Scientific Innovation Complex (ESIC) has been opened in TUSUR, with its orders value reaching around three million US dollar in 2009, whereas the especially opened Institute for Innovation is focused on building the Triple Helix as its strategic direction of activities (Tomsk State University of Control Systems and Radioelectronics, 2017). NR TPU is also actively involved in scientific and innovation activities: to today there is an innovation infrastructure existing in the university, starting from innovation-technological business-incubator up to Tomsk regional Centre of shared-access to scientific equipment as a result of mutual cooperation of Tomsk State University and Institute of Strength Physics and Materials Science of Siberian Branch Russian Academy (Tomsk State University, 2017).

6. Findings

„Critical mass" of both fundamental and applied research and developments of interdisciplinary character within the „Triple Helix" framework generates necessary potential for technological development. An effective form of interaction of three helix subjects can be a network structure, assuming evolution of every participant's functions and having some potential to transfer scientific knowledge into a certain product in the market. In some authors' opinion, the most serious problem in the „Triple Helix" concept practical realization is the necessity to modify governmental activity model with orientation on policy of flexible response.

The task of the government covers not only specification of strategic priority research areas for scientific and technological potential development, scientific agendas and scientific-and-engineering programs development, but also laying the groundwork for establishment of novel type economic structures. Under modern conditions network structures present forms of economic activities, oriented mainly to converging technologies and accelerated development of science-intensive product markets. Shift in emphasis for the benefit of higher value added, high-technology fields is not possible without manyfold increase of investments in Research & Development (R&D). There are two ways of rating countries based on amount of their investments in R&D: comparison of absolute data and in percentage correlation to Gross domestic product (GDP). Unfortunately, Russia doesn't make either of the above mentioned top countries methodology. According to statistics of the UNESCO Institute for Statistics, the top five countries rated on their absolute R&D investments amounts include: USA, Chine, Japan, Finland, Sweden; in percentage correlation: Republic of Korea (4,3%), Israel (4,1%), Japan (3,6%), Finland and Sweden. Whilst Russia with its rate of 1,2% even doesn't reach a leading position in its region – Central and Eastern Europe, Slovenia takes the leading position (2,4%) (UNESCO Institute for statistics, 2017).

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Beside unsufficient funding, there is a whole range of problems, hindering technological development. They can be conditionally divided into external factors, which are supposed to be objective and exogenous specified; and internal factors, which can and must be eliminated by the government as the leading participant of innovation activity. External factors include the following: firstly, economy multistructurality (concurrent existence of pre-industrial, industrial and post-industrial manufacturing), secondly, foreign policy and economic situation, preventing diffusion of the advanced foreign technologies in existing Russian economic productivity model. Though, this factor may as well take the role of the technological modernization driver. One of the major internal factors is the lack of harmonization among the participants of the innovation activity: productive projects do exist, but fragmentarily – scientific research results frequently fail to be transferred to applications, whereas application results are not implemented into specific products. From this process, the second problem results, namely, the lack of functioning innovation-technological infrastructure. Thus, based on statistics from „The Association of Clusters and Technology Parks“ dated from 2016, considered from more than 100 operating technology parks only twenty-five from them are operating effectively (The Association of Clusters and Technology Parks, 2017). Besides that, the period of enterprises /companies/ staying in technology parks is unlimited and makes up to date about 10 years, whereas international standard practise 2-3 years. Another reason, inhibiting technological development, is imperfection of the legal system, particularly in issues of intellectual properties, tax and customs legislation.

7. Conclusion

In factor system, influencing structural changes in economy, the most dominant is converging technologies development. Facilitation of their transfer is supposed to be of great importance, as development of whole new products based on the latest scientific achievements can help to ensure technological parity for Russia with other developed countries as well as economic turn to advanced technological horizon. Building of network structures in Russian economy is supposed to be a synergetic environment, contributing to development of converging technologies and their implementation. Up to date the necessity for structural economic improvements and considerable changes of technological component, as one of the most dominant in economic policy, are plainly required. At first sight, adverse conjuncture in the market of energy sources and sanctions situation for Russia can finally become an impulse for transition from the position of the technology-dependent country to the Country with the status of technology leader.

References

Barinov, V., & Zhmurov, D. (2007). Development of Network formations in innovative economy (Master's thesis). *Management in Russia and Abroad, 1*, 20-30.

Castells, M. (1998). *End of Millennium, The Information Age: Economy, Society and Culture* (Master's thesis, Cambridge). Oxford: Blackwell.

Makoveeva, V. (2012). Network interaction: the key factor of education, science and business integration (Master's thesis). *Vestnik Journal of Tomsk State University, 354*, 163-166.

Miles, R., & Snow, C. (2009). *Organizational Strategy, Structure, and Process* (Master's thesis). Academy of Management.

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Corresponding Author: M. Klimovich
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NRC Kurchatovsk Institute (Unpublished master's thesis). (n.d.). Retrieved April 20, 2017, from http://rc.nrcki.ru/pages/main/about/index.shtml

Parfenova, S. (2014). Network model of research engineering (Master's thesis). *Science.Innovations.Education, 16*, 78-89.

Praid, V., & Medvedev, D. (2008). The Phenomenon of NBIC-convergences: Reality and expectations (Master's thesis). *Filosofskie nauki, 1*, 97-116.

Shevashkevich, D. (2013). Innovation network formation of structures as a condition of transition to new technological order (Master's thesis). *Vestnik of Saratov State Socio-Economic University, 2*, 156-158.

Shevchenko, Y. (2014). *Convergence of science, technologies and humans: philosophical analysis* (Master's thesis). Rostov-na-Donu.

The Association of Clusters and Technology Parks (Unpublished master's thesis). (n.d.). Retrieved May 15, 2017, from http://nptechnopark.ru/news/assotsiatsija-nazvala-25-samykh-effektivnykh-tekhnoparkov-rossii/

Tomsk Polytechnic University (Unpublished master's thesis). (n.d.). Retrieved May 15, 2017, from http://inno.tpu.ru/ru/prodcuts-and-services/

Tomsk State University (Unpublished master's thesis). (n.d.). Retrieved May 20, 2017, from http://www.tsu.ru/science/

Tomsk State University of Control Systems and Radioelectronics (Unpublished master's thesis). (n.d.). Retrieved May 20, 2017, from http://2i.tusur.ru/?page_id=97

Tyutyushev, A., Gasanov, M., & Vasechko, D. (2011). Clusters as innovation economic network structures (Master's thesis). *Vestnik of Tomsk State Pedagogica lUniversity, 12*, 121-127.

UNESCO Institute for statistics (Unpublished master's thesis). (n.d.). Retrieved May 30, 2017, from http://www.uis.unesco.org/_LAYOUTS/UNESCO/research-and-development-spending/