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Nanotechnology policy in Russia: Can an emerging technology push a country onto a new development trajectory?

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Abstract

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Russia sees nanotechnology as one of the major technological platforms that could help it achieve the established growth objectives. Despite certain lag, the country managed to shape a full-fledged nanotechnology policy by 2011. Among other, detailed analysis of the nanotechnology sector of Russia's innovation policy may point out important weaknesses and strengths of the country's national innovation system that can provoke new understandings about how innovation systems work in different institutional and cultural environments. Major conclusions and recommendations include necessity to increase concentration of resources, pay more attention to the endogenous resources and build up on the former Soviet scientific potential. Business must be provided with more opportunities to invest into high-risk innovation projects to boost private engagement and accelerate market formation.

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1. Introduction

Russia is one of the rapidly developing countries that are widely known as emerging markets today. In 2001 Goldman Sachs coined the concept of BRICs – Brazil, Russia, India and China – that it predicted to surpass the leading economies by 2050.

Nevertheless, for the last decade we have learned relatively little about the mechanisms of success and failure in these countries. All of them have huge territory and population as well as fast-growing economies that sometimes show two-digit rates of GDP growth per year and surprise the world by their increasing budgets and public spending. In the meantime, most of these countries are believed to be desperately struggling against corruption, striking social inequality, uneven development of regions and other socio-economic problems attributable to many countries in the developing world.

One more reason for putting the four countries – Brazil, Russia, India and China – into one group is their striving to build up new economies of innovation, small- and medium-size enterprises and efficient entrepreneurship. By diversifying their economies and transiting from resource-driven to investment- and innovation-driven market (to use the World Economic Forum stages of development) these countries either try to break institutionally the development lock-in that impedes their multi-dimensional growth or seek to sustain the weak positive trends towards self-sustained growth (a concept elaborated by Rostow, 1956).

In this paper I am looking at one of these giants – Russia – which seems seriously understudied but retains important creative and science and technology potential largely left to it as a heritage of the Soviet mighty S&T system. In the recent decade Russia set the goal of reducing dependence on its redundant (and quite expensive) natural resources and transiting its economy to the innovation-based foundation (Concept of Long-Term Socioeconomic Development of the Russian Federation until 2020, adopted in 2008).

In its desire to do so, the country seeks to build up new clusters of innovation and support the most advanced technologies of the contemporary period. One of these emerging technologies – nanotechnology – has attracted much attention of the political establishment and got large R&D investment in the last three years. Although Russia joined the club of the so-called ‘nanopowers’ only 6-7 years after the announcement of the U.S. National Nanotechnology Initiative in 2000, today it seems to have shaped a full-fledged nanotechnology policy that involves dozens of institutions, hundreds of researchers and large amounts of R&D spending.

Among other, detailed analysis of this sector of Russia’s innovation policy may point out important weak spots and successful parameters of the country’s national innovation system that can indicate certain new understandings about how innovation systems work in different institutional and cultural environments and hint essential recommendations and mechanisms that can be used in other emerging markets, developing or possibly even developed countries.

In the following three sections of this paper I will concentrate on theoretical and methodological issues. Section 5 will be devoted to a brief overview of Russia’s national innovation system that

represents a large selection of factors and institutions that influence the country's nanotechnology development. Section 6 will focus on nanotechnology policy analysis and present historical, institutional and stakeholder review. The paper will conclude with functional analysis based on the assumptions and data elaborated in the previous sections and propose several policy recommendations.

2. Theoretical foundations

In the present study I propose using both national innovation systems (NIS) and technological innovation systems (TIS) approaches. Despite relative divergence of the concepts they seem relevant for this paper for the reason that NIS holds a potential to explain policy issues at the country level and TIS provides framework for understanding development of the specific nanotechnology field.

Application of the national innovation systems perspective will allow to study the links between government, business and academia in their respective roles in Russia. Moreover, it will focus on the national policy environment, which is a methodological priority for this paper. Nanotechnology policy in Russia is seen as a means to break the development lock-in in order to boost innovation and R&D activity in the country as well as solve broader socioeconomic problems.

Meanwhile, the technological innovation systems approach will provide an opportunity to focus on a specific technological sector and analyze the selection of actors, networks and institutions in the area. As prescribed by Carlsson and Stankiewicz (1991), the Russian nanotechnology TIS will be analyzed both at the structural and functional levels. Key actors and networks will be defined in the policy stakeholder review based on the features of Russia's political system, distribution of power among ministries and regional governments, traits of the country's S&T system and informal links between various actors.

Institutions will be understood here in a broader Veblenian sense and are considered as material and non-material structures that influence "prevalent habits of thought" in relation to nanoscience and nanotechnology in Russia (Veblen, 1934, p. 190). Or, as Carlsson and Stankiewicz (1991) define, institutional infrastructure of a technological system is "a set of institutional arrangements (both regimes and organizations) which, directly or indirectly, support, stimulate and regulate the process of innovation and diffusion of technology" (p. 109). That is, major federal programs, organizations, forums and clusters of innovation that influence nanotechnology development, shape public opinion and distribute resources around specific spheres of nanoscience and nanotechnology (NST).

Proceeding from the NIS and TIS concepts, Russia's nanotechnology policy analysis will be primarily based on the functional approach set forth by Bergek *et al.* (2010). This method provides framework for analyzing different components of the innovation system from the point of view of their functionality. Functions are defined as "processes that have a more direct and immediate impact on the 'goal' of the system, which could be stated as to generate, diffuse and utilize new technology" (p. 121).

So, the authors suggest looking at the innovation system components as functional units providing support for technological development in seven dimensions: knowledge development and diffusion; influence on the direction of search and the identification of opportunities; entrepreneurial experimentation and management of risk and uncertainty; market formation; resource mobilization; legitimation; development of positive externalities. Development in these key dimensions further guide the policy making process.

Bergek *et al.* (2010) argue to have derived these seven functions from a wide range of literature on innovation systems and evolutionary economics as well as political science, organization theory, sociology and else. The authors identify knowledge development and diffusion as the function capturing “the breadth and depth of the (scientific and technical) knowledge base of the TIS and how that knowledge is diffused and combined in the system” (p.121) thus linking this process to the concept of ‘learning’.

The second function of influencing the direction of choice and the identification of opportunities deals with the problem of lack of information and its varied interpretation among firms. Therefore, the TIS should aim to provide sufficient incentives and pressures to stimulate preferable firms’ behavior and articulate the demand.

Entrepreneurial experimentation and management of risk and uncertainty requires a policy to provide opportunities for using TIS advantages like unique research expertise, or competence in related sectors, or ample supply of skilled labor. The function is based on the assumption that innovation by nature is a high-risk and uncertain endeavor and therefore the government should provide more opportunities for managing risk and uncertainty by the private sector.

Emerging TIS such as nanotechnology are rarely presented with a ready-to-use market and a shaped demand. Therefore, it is important to form ‘nursing markets’ for the nascent technologies and promote market formation in a broader way.

No innovation is possible without proper infrastructure and finance. So, the fifth function – resource mobilization – aims to provide the necessary physical and knowledge infrastructure and financial support for an emerging technology.

Legitimation is important to promote social acceptance and compliance with relevant institutions. As was the case with genetically modified products in Europe, general public can influence development of entire technological innovation systems. Therefore, it is crucial to ensure public engagement at the early stages of development and promote legitimation in the political system including creation of advocacy coalitions.

In order to promote growth of an emerging technology the seventh function – development of positive externalities – needs to be tackled seriously. “Pooled labor markets”, “emergence of specialized intermediate goods and service providers” and “information flows and knowledge ‘spillover’” (p. 127) may be essential in creating favorable environment for the TIS.

All in all, while the functional approach appears quite useful in retrospective policy analysis it lacks certain dynamic characteristics attributable to any policy methodology so far. The main drawback

of the concept is its belief in the policy-makers' overall understanding of which functions they are going to improve by a specific action. Meanwhile, Kay (2006) points that policy process is much more complex and cannot be analyzed by assuming that the stakeholders will always act rationally in accordance with some initially prescribed rules.

Nevertheless, the concept proves to be helpful in providing an alternative view on the policy-making process, which might bring certain positive results in reshaping and rethinking failed policies including nanotechnology policy in Russia. The claims about its dynamic characteristics are also considered quite reasonable compared to other existing approaches.

3. Data

Sources of data involve:

- General socio-economic data including GDP, GDP per capita, population, trade balance and structure, FDI, etc., will be retrieved from the World Bank database.
- Research and development data including R&D expenditure as percent of GDP, number of patent applications, etc., will be retrieved from the World Bank database and Russia's Federal State Statistics Service (Rosstat).
- Nanotechnology-related data including market size estimates, number of involved scientists, quality and number of research facilities, bibliometric data, company indicators, etc., will be retrieved from reports and papers of the major nanotechnology research agencies like Lux Research, articles in major English and Russian-language journals as well as newspapers and online, Russia's official documents and publications.¹

4. Methodology

The major methods to be applied in the present analysis are documentary review, literature review, content analysis and bibliometrics. This selection might be further enhanced by selected interviews with experts and policy-makers in Russia in order to better understand the implicit factors of the nanotechnology policy formation and implementation mechanisms.

The key methodological challenges include:

- Lack of English-language literature on the subject and scarce analytical resources in Russia due to dispersion and underdevelopment of science study institutions in the country, virtual absence of relevant databases and lack of independent research institutions;
- Scanty nanotechnology-related statistical data both nationally and internationally due to methodological issues (including impossibility to count pure nanotechnology effects on the market);
- Presence of wrong data due to poor quality of available resources and their improper interpretation (e.g. Xuan *et al.*, 2009);

¹ Much of the data in the present study is based on own calculations from the figures found in the sources provided.

- Most nanotechnology-related documents and papers on the issue are only available in Russian, which makes both bibliometrical and documentary analysis impossible without due language skills.

5. Russia's national innovation system: a brief overview

In the recent decade Russia has been strongly struggling to re-build its national innovation capabilities after the turmoil of the 1990s. Lack of resources, political, social and economic instability did not allow the country to retain the Soviet scientific and technological potential, which, among other led to the plunge of R&D spending from about 2% in 1990 to 1,05% of GDP in 2000 and the number of researchers per million from 7266 in 1991 to 2912 in 2000 (Kalabekov, 2010; Rosstat, 2010).

The relative stability and welfare of 2000s permitted Russia's leaders to return to the question of modernization and innovation development. A series of economic and political reforms turned the country back into an authoritative state with much political power concentrated in the federal center – Moscow. Most vivid were the 2000 administrative reform to divide the country into 7 big federal districts for better control and the 2004 decision to abolish direct elections of regional governors by replacing them with presidential nominations and regional parliamentary approvals/disapprovals.

Increasing flow of oil dollars returned belief in economic progress and quick recovery. This was evidenced by the quickly growing GDP from \$259,71 bn in 2000 to \$397,95 bn in 2009 (constant 2000 US\$; World Bank, 2011), rise of residents' patent applications from 23377 in 2000 to 27712 in 2008 (World Bank, 2011), and increase in internal R&D expenditure from 1,05% in 2000 to 1,24% of GDP in 2009 (Rosstat, 2010). However, the latter indicator was quite unsteady with a peak in 2003 equaling 1,28% of GDP and a decrease to 1,07% in 2005/2006. Meanwhile, the share of private sector in gross R&D expenditure was only 18,7% in 2000 and 19,5% in 2009 (Rosstat, 2010).

Given growing financial resources in his 2004 State of the Nation Address President Putin set the goals of modernizing the healthcare system, economy, transport infrastructure and military forces. President Putin said that Russia has just recently entered the third phase of its development since 1991 when the country can "rapidly grow and resolve the difficult tensions. And now [in 2004] we have enough experience and necessary resources to set the long-term goals." (President of the Russian Federation, 2004).

Most recent policy initiatives include building up clusters of innovation to promote technology diffusion in Russia. The latest decision aims to establish a high-technology cluster in Skolkovo, near Moscow. This is launched and supported by President Medvedev, which gives it a top priority status.

Table 1. Major Russia's economic and R&D indicators in 2000-2009

| | 2000 | 2005 | 2009 |
|--|--------|--------|--------|
| GDP (billions, constant 2000 US\$) | 259,71 | 349,85 | 397,95 |
| GDP per capita (constant 2000 US\$) | 1775 | 2443 | 2805 |
| Gross R&D expenditure (as % of GDP) | 1,05 | 1,07 | 1,24 |
| - Including private sector R&D expenditure (as % of GDP) | 0,2 | 0,22 | 0,24 |
| High-technology exports (billions, current US\$) | 4,19 | 3,69 | 5,11* |
| Technological trade balance (millions US\$) | 20 | | 1000,8 |
| Civil-use high-technology goods exports (as % of world market) | | 0,45** | 0,25* |
| Patent applications (residents) | 23377 | 23644 | 27712* |
| Researchers per million population | 2912 | 2740 | 2602 |
| R&D personnel (people) | 887729 | 813207 | 742433 |
| including: | | | |
| - private sector | 590646 | 496706 | 432415 |
| - public sector | 255850 | 272718 | 260360 |
| - higher education (e.g. universities) | 40787 | 43500 | 48498 |
| - non-profit sector | 446 | 283 | 1160 |

Source: adapted from World Bank, Rosstat, Ministry of Economic Development of the Russian Federation.

* Data available for 2008.

** Data available for 2003.

Nevertheless, recent economic and political reforms seem not to have broken the development lock-in established in the 1990s. System inertia made almost all government efforts useless with the corruption perception index equaling 2.1 out of 10.0 and putting the country between Papua New Guinea and Tajikistan (Transparency International, 2010). The recent economic crisis was also ruinous making Russia's economy fall by 6,6% of GDP in 2009 (Rosstat, 2010). The export structure of the country remains almost intact with serious disbalance between primary and secondary-sector goods. Energy resources provided for 66,65% of Russia's exports, while machinery gave only 5,83% in 2009 (Federal Customs Service of the Russian Federation, 2010).

R&D indicators also showed signs of lock-in with the number of researchers per million continuing to fall from 2912 in 2000 to 2602 in 2009 (Rosstat, 2010). Interestingly, the biggest drop of R&D personnel was observed in the private sector while public and non-profit sectors stayed almost intact or showed growth: 26,8% fall in the private sector compared to 1,8% and 260% (!) increase in the public and non-profit sectors respectively (Rosstat, 2010). The technological trade balance has been steadily degrading from \$20 mln profit in 2000 to \$1000,8 mln deficit in 2009. Share of Russia's civil-use high-technology goods exports fell from 0,45% in 2003 to 0,25% of the world market in 2008. Small and medium enterprises (SMEs) in the innovation sector get far less government support than in developed countries: Russia spends \$180 mln compared to \$2 bn allocated for the U.S. Small Business Innovation Research and Small Business Technology Transfer Programs (Ministry of Economic Development of the Russian Federation, 2010).

To support this point of view Russia's Ministry of Economic Development recently released a draft of the country's innovative development program "Innovative Russia-2020". The document states that Russia did not manage to create "innovative climate" in the country. "Despite serious efforts to support innovative activity, the government did not succeed in breaking existing negative trends of development." (Ministry of Economic Development of the Russian Federation, 2010, p. 14). The country has achieved less than a third (!) of the objectives set for the first stage of the Russian Strategy of Science and Innovation Development until 2015.

6. Nanotechnology policy

6.1. Historical review

Given the ongoing development lock-in evidenced by the previous section Russia's leadership made a decision to apply emerging technologies as a means for improving the situation and boosting the country's innovation growth.

The policy making process took about four years before it was established as an official government strategy in the form of federal programs and new institutional mechanisms. The first reaction to the U.S. National Nanotechnology Initiative launched in 2000 was inclusion of the nanotechnology-related research and development into the List of Critical Technologies of the Russian Federation (President of the Russian Federation, 2002). According to the content analysis of presidential speeches, 2003 was the first year when the country's leader used the very term 'nanotechnology' in public relating to the broadening economic cooperation with France (based on my own data analysis). Later on, in 2006 all the relevant technologies were included in the special section of the List of Critical Technologies under the title "Nanotechnology and nanomaterials" (President of the Russian Federation, 2006). In 2004 the Russian government adopted the Concept of Nanotechnology Development until 2010.

In 2006 a special Program on Coordination of Nanotechnology and Nanomaterials Development was developed and adopted. The Program set forth the key government agencies responsible for NST development. The Russian Ministry of Education and Science was put in charge of leading, coordinating and implementing the program. The Russian Science Center 'Kurchatov Institute of Nuclear Physics' became the head scientific coordinator of the program.

Nevertheless, the real work on NST development began only in April 2007 when President Putin signed an initiative on the Strategy of Nanoindustry Development (President of the Russian Federation, 2007). The document ordained the government to develop a federal program to support nanoscience and nanotechnology development. It also envisaged establishment of the new state corporation to facilitate the commercialization of NST applications. As a result, in 2007 and 2008 the Russian government the Federal Program "Development of Nanoindustry Infrastructure for the period of 2008-2010" (now prolonged till 2011) and the Program of Nanoindustry Development until 2015. In July 2007 the new state corporation Rosnanotekh (now Rusnano) was finally established to support "expansion state companies in commercialization or close to commercialization phase" (Kiselev, 2010). According to its founding documents, the

corporation was able to invest only up to 50% of the project and was meant to become an efficient mechanism of public-private partnership in the field of nanoscience and nanotechnology.

Lately there has been a motion to refurbish the Rusnano corporation into a joint stock company. According to the company's President Anatoly Chubais, Rusnano will be reorganized into a JSC which will make it more open and transparent. Also, the new division will be created to support national infrastructure projects in the field of nanotechnology. This will take the form of a not-for-profit "Foundation for Infrastructure and Education Programs".²

In April 2010 the Russian Prime Minister Putin signed the resolution on creation of the National Nanotechnology Network (Government of the Russian Federation, 2010a). This decision is also aimed at constructing a viable infrastructure and network connections among its participants in Russia.

The main public platform to communicate Russia's NST development was launched in 2008 and took the form of an annual Nanotechnology International Forum. The Third Forum took place on November 1-3, 2010, and was traditionally addressed by the President of the Russian Federation Dmitry Medvedev. In his concluding speech Rusnano President told about success stories and future plans of the corporation and overall nanoindustry development in Russia. Basically, the country is now focused on four main sectors of NST development: green, alternative and renewable energy; pharmaceuticals; biotechnology; new materials and technologies (Kiselev, 2010).

In his speech on November 3, 2010, Chubais talked in more detail about these four sectors concentrating on successes in energy efficiency, nanoelectronics, solar energy, nanocoating, nanomedicine, laser-construction and carbon nanotubes. In these fields, he argued, Russia is undergoing a transition from laboratory research to industrial production.

6.2. Stakeholder review

Carlsson and Stankiewicz (1991) suggest analyzing the technology policy from three main points of view: actors, networks and institutions. Given the decision to apply both NIS and TIS approaches I will limit these three pillars to the national level, which seems mandatory given that technologies could spill over and develop across national boundaries in the contemporary globalized world. Therefore, I propose overlapping two methodological frameworks and try to define key stakeholders in the government, business and academia domains then analyzing them from the view of actors, networks and institutions.

To begin with, the major actors and nanotechnology lobbyists in Russia include people closely associated with the government. There are at least two reasons for that: first, section 5 already described the political changes in Russia in the course of 2000s which made the country an authoritarian state with the highly centralized political power; and second, despite its ample

² Vedomosti. (2010). "Rusnano will get trilliards" – Rusnano President Anatoly Chubais' (in Russian). 21 December 2010.

resources the business is more interested in supporting good relations with Russia's leadership in the aftermath of the Khodorkovsky case, which means lack of decision-making freedom.

Academia mostly plays the facilitator role with several lobbying initiatives on the part of interested entities. Unlike in the United States, both basic and applied research is much dependent on the government and its financial support. So, the policy discourse is aimed at decreasing the role of government in R&D rather than vice versa (see for example Nelson, 1959; Dasgupta and David, 1994). However, there is a common policy ground on the desire to enhance private sector research and development, which is an urgent task of both developed countries and emerging markets.

Table 2. Comparison of major economic and nanotechnology-related indicators of Russia, United States and China in 2009

| | Russia | USA | China |
|---|--------|----------|---------|
| GDP (billions, constant 2000 US\$) | 397,95 | 11250,7 | 2937,55 |
| GDP per capita (constant 2000 US\$) | 2805 | 37016 | 2206 |
| Gross R&D expenditure (as % of GDP) | 1,24 | 2,67** | 1,49** |
| Gross nanotechnology-related R&D expenditure (millions US\$) | 504 | 3700* | |
| High-technology exports (billions, current US\$) | 5,11* | 231,13* | 381,35* |
| Patent applications (residents) | 27712* | 231599* | 194579* |
| Nanotechnology patents issued | 338 | 6729* | |
| Researchers per million population | 2602 | 4663*** | 1071** |
| R&D personnel in the sector of nanoscience and nanotechnology | 14500 | ~150000* | |
| Number of nanotechnology publications (08.2008-07.2009) | ~2700 | ~21000 | ~20100 |
| Domestic market for nanotechnology products (billions US\$) | 2,7 | 80* | |

Source: adapted from World Bank, Rosstat, Forfas (2010), Roco (2010), Shapira and Wang (2010), Kachak *et al* (2010).

* Data available for 2008.

** Data available for 2007.

*** Data available for 2006.

Thus, *the major authority* in the field rests with the President of the Russian Federation who launched the initiative on nanotechnology development in 2007 and now continues to publicly support it. Prime Minister Putin is also increasingly interested in Russia's innovative development as he recently became head of the Government Commission for High Technology and Innovation thus strengthening its status and broadening its powers.³

The leaders' closest allies in the NST development are members of the Presidential Council on Science, Technology and Education and the recently established Presidential Commission for Modernization and Technological Development of Russia. The former mostly includes academic and education leaders, distinguished scientists and public figures. The latter is a more operational body having meetings about once a month and comprises top-level government officials and heads of state corporation in the field of innovation. Members of the Government Commission for

³ Kommersant. (2010). 'Commission for Innovation changed its formula' (in Russian). 4 March 2010.

High Technology and Innovation also have much influence on the innovation agenda as it allocates about 10% of the federal budget (about \$37 bn in 2010).

Specifically in the field of nanotechnology most active lobbyists are Anatoly Chubais, Rusnano President; Mikhail Kovalchuk, Head of the Russian Science Center “Kurchatov Institute of Nuclear Physics”; and Andrey Fursenko, Minister of Education and Science.

Anatoly Chubais even attributed the very idea of creating the Rusnano corporation to Mikhail Kovalchuk, an influential scientist from St. Peterburg, in his Vedomosti interview on December 21, 2010.⁴ Schiermeier (2008) also wrote about Kovalchuk’s great influence on the now Prime Minister Vladimir Putin given that his brother – successful banker Yuri Kovalchuk – has “close personal ties to Putin” (p. 702). The third of the company – Andrey Fursenko – is a long-lasting Minister of Education and Science. Although recently there have been a lot of scandals in Russia around the new high-school national test system as well as overall degradation of the country’s education system, Fursenko remains well seated with most of the nanotechnology and innovation development federal programs going through his Ministry. To prove his strong position, Fursenko’s brother was recently appointed as head of the Russian Football League which allegedly has abundant financial resources.

However, there seems to be ongoing ‘battle’ between Putin’s and Medvedev’s supporters in the 2012 election run-up. The recent publication of “Innovative Russia-2020” program by the Ministry of Economic Development hints that Minister Nabiullina, a close Medvedev’s ally, is struggling to build up influence on the country’s development strategy and decrease the roles of Andrey Fursenko and Vice-Premier, Minister of Finance Alexey Kudrin, both strong Putin’s proponents.

The Ministry of Defense also has its share of the innovation and nanotechnology pie but doesn’t seem to be too active in political lobbying.

Other influential actors can be found at the regional level with Tomsk, Kaluga and Perm being among the most innovative locations. Consequently, the governors of these regions have the biggest influence on innovation and particular nanotechnology policy with the Tomsk governor Kress having especially strong ties with President Medvedev.

All three regions pursue different innovation strategies. Kaluga was among the first to provide favorable economic conditions for the high-tech foreign companies creating special zones and infrastructure for their development in the region. Perm and Tomsk are more endogenous in their development routes. The former build up its innovation capacity on the strong industrial base and the latter grew from the university spin-offs and strong academic facilities. In his other interview Chubais also claims that Yakutia presents another model of innovative development in Russia, which is exogenous and is based on technology imports and strong external relations.⁵

⁴ See footnote 2.

⁵ Vedomosti. (2010). ‘Chubais: the goal of innovative development should not be an auxiliary but the very foundation’ (in Russian). 20 December 2010.

Business stakeholders are mostly big enterprises with strong ties in the government. Sitronics, part of AFK “Systema” holding, is a high-technology company aimed at producing RFID nanochips in partnership with X5 Retail Group and Rusnano. On November 3, 2010, Rusnano President Anatoly Chubais promised to establish production of such chips at the scale of 90 nm only by 2012, when the developed world will already be far ahead with the present capacity being already at the scale of 32 and 65 nm (Chubais, 2010).

Companies Angstrom and Mikron are also aimed at producing nanochips but failed to start any viable production mostly due to management failures. Interestingly, Rusnano continues to invest huge amounts of money into foreign partnerships hoping to import top-level technology from abroad. The corporation is building up relations with PG Photonics, has just bought 25% of Plastic Logic to establish the company’s new production facility in Zelenograd, near Moscow⁶, and has established cooperation with the Israeli Micro Components Ltd. on L.E.D. component production.⁷

The range of *academic stakeholders* is quite diverse. The key players are named in the Federal Program “Development of Nanoindustry Infrastructure in the Russian Federation for the period of 2008-2011”. These include head organizations in specific objective areas of the Program, namely nanoelectronics; nanoengineering; functional nanomaterials and high-purity substances; nanomaterials for energy; nanomaterials for spacecrafts; nanobiotechnology; constructive nanomaterials; composite nanomaterials; nanotechnology for security systems. Respective coordination institutions are Lukin Scientific Research Institute of Physics Problems; National Research University Moscow Institute of Electronic Technology; Baykov Institute of Metallurgy and Materials Science of the Russian Academy of Sciences; JSC “Bochvar High-Technology Scientific Research Institute for Inorganic Materials”; National Research Nuclear University “MIFI”; Keldysh Research Center; Russian National Center “Kurchatov Institute of Nuclear Physics”; Central Scientific Research Institute of Construction Materials “Prometey”; Technological Institute of Extra-Hard and New Carbon Materials; All-Russian Scientific Research Institute of Aviation Materials; Central Scientific Research Institute of Chemistry and Mechanics (Government of the Russian Federation, 2010b, Appendix 1).

It is important to note that most of these academic and research institutions belong to the system of specific government agencies, including Ministry of Industry and Trade, Ministry of Education and Science, Russian Space Agency and other. Therefore, it is difficult to study them as a purely academic component of the national innovation system.

Other academic and more independent stakeholders include St. Petersburg State University, Tomsk State University, Perm State Technical University, Belgorod State University and others. These institutions host big nanotechnology-related events including international conferences and establish specialized nanotechnology facilities sponsored by the government programs.

⁶ Rusnano. (2011). ‘Rusnano and Plastic Logic establish a plastic electronics production facility in Zelenograd’ (in Russian). 18 January 2011. Available at: <http://www.rusnano.com/Post.aspx/Show/29930> [accessed 19/01/2011].

⁷ Preqveca.Ru. (2011). ‘First Russian-Israeli project got Rusnano investment’ (in Russian). 9 January 2011. Available at: <http://preqveca.ru/news/3691/> [accessed 19/01/2011].

The National Research University “Higher School of Economics” (HSE) and the New Economic School (NES) enjoy special status among all academic institutions in the sphere of innovation. HSE Rector Yaroslav Kuzminov is husband of the Minister of Economic Development and an influential economist while the NES leadership has much impact on Medvedev’s innovation policy and holds many posts in the country’s top-level consulting bodies.

6.3. Institutional review

Since the presidential initiative on nanoindustry development in 2007 Russia has created several institutions, which have increasing impact on the TIS networks and other institutions in the broader sense. These include:

- 1) Federal Programs “Development of Nanoindustry Infrastructure for the period of 2008-2011” and “Nanoindustry Development until 2015” as well as other national programs with general innovation impact including the Federal Program “Research and Teaching Staff of Innovative Russia for the period 2009-2013”, “Research and Development of the Priority Areas of Science and Technological Development of Russia for the period 2007-2012”, etc. These programs have created a new kind of relationship between policy stakeholders and dramatically increased investment into the field. They also pushed forward creation of new standards and regulations for nanotechnology in Russia and enabled statistical observation of this technology area. Thus, in 2007 gross R&D expenditure in the “nanosystem and nanomaterials industry” totaled 11,64 bn roubles (\$388 mln), in 2008 – 11,03 bn roubles (\$368 mln), and in 2009 – 15,11 bn roubles, or \$504 mln (State University Higher School of Economics, 2009; Rosstat, 2010).

Federal programs also drastically increased the number of involved actors and led to reorganization of existing ministries, government agencies, universities and research institutions. However positive this reorganization has been, it still seems to be oriented on exogenous technological development and new knowledge creation rather than full usage of endogenous resources. For example, an old and huge scientific base in Novosibirsk, which occupies 5th place among the country’s 83 regions in the number of R&D personnel with 21622 people employed in 2009 (Rosstat, 2010), is weakly used in NST development thus making existing tacit knowledge and Soviet-time facilities fade away at a rapid pace. Clery (2010) also wrote about several “free economic zones” created in the course of 2000s which are still almost empty today while huge money are invested into the new Skolkovo project.

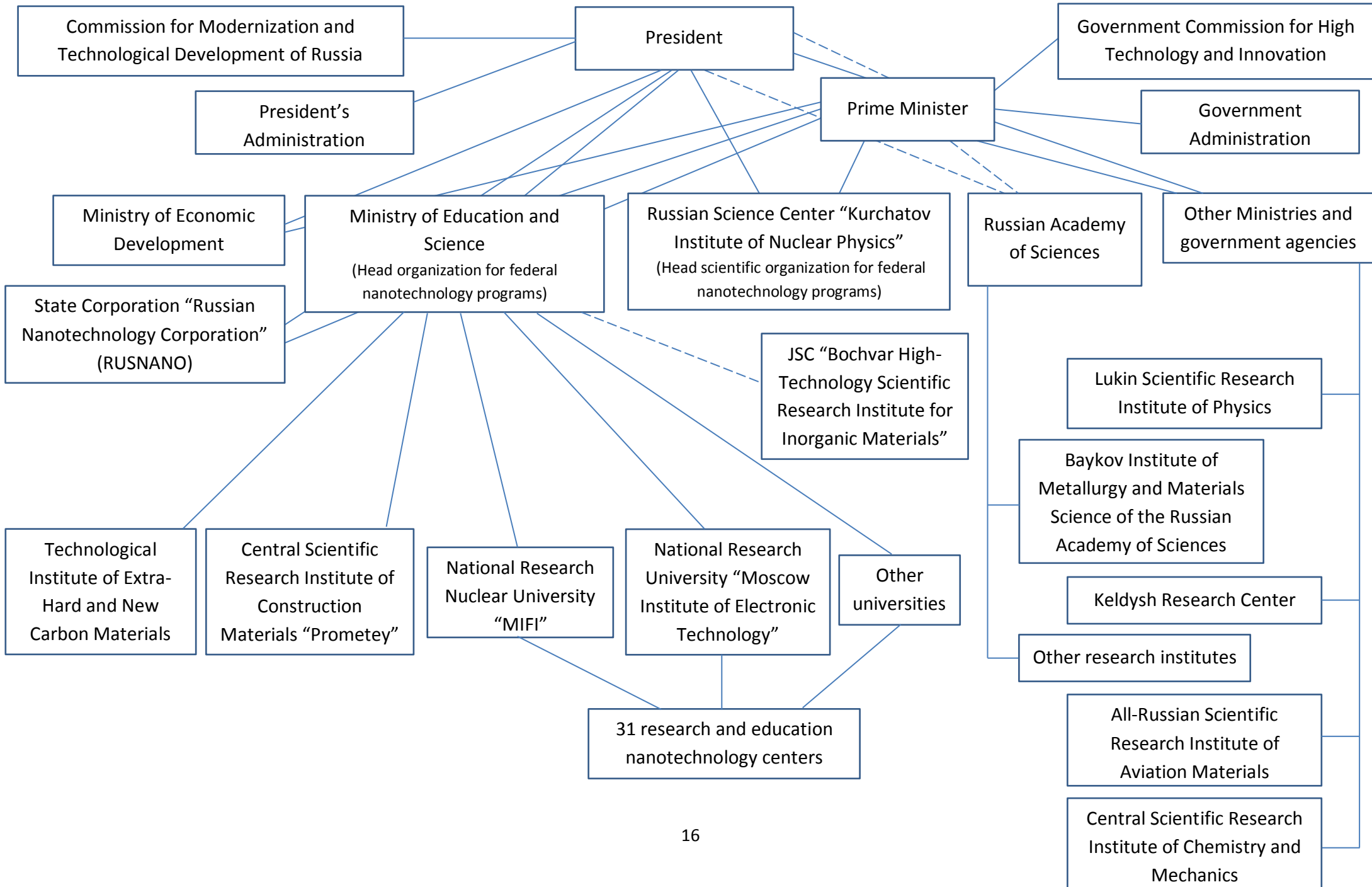
- 2) Rusnano corporation, a facilitator in the commercialization phase of nanotechnology development. Rusnano became one of the most efficient nanotechnology developers and promoted understanding of the field among ordinary citizens. The corporation also contributed to developing the nanotechnology infrastructure by supporting new research centers and production facilities. Successes of the corporation may be evidenced by private sector investment totaling 50,6% of total R&D expenditure in the field in 2007. However, important to say that 81,4% (!) of these are subsidized by Russia’s federal budget (State University Higher School of Economics, 2009).

- 3) Annual Nanotechnology International Forum, which serves as a communication platform for NST researchers, policy-makers and social scientists and promotes international collaboration with foreign colleagues. The Forum is traditionally addressed by the Russian President and is considered to be an important conference both for national and international research institutions and individual scientists. It also serves as a crucial instrument of knowledge dissemination and broader public engagement.

Institutional and policy drawbacks show low interest to the field on the part of social scientists. Unlike the U.S. NNI and European nanotechnology programs Russia did not explicitly include the study of ethical, legal and societal implications (ELSI) into its policy initiatives virtually marginalizing the relevant research. Therefore, the main source of information and analysis for ELSI students rests with the monitoring government agencies, which regularly review the policy and publish their findings.

Another drawback is in the progress monitoring and policy evaluation system. Dementyev (2009) writes that the reviewing bodies are the same as the implementing agencies, which may lead to statistical and qualitative 'misinterpretations' or even frauds in order to ensure the program going on. Among other, this situation can be one other reason for the Ministry of Economic Development struggling hard to regain control over research and innovation policy in Russia.

Table 3. Provisional organizational chart of the Russian nanotechnology policy



6.4. Functional analysis

a) Knowledge development and diffusion

The function of nanotechnology knowledge development and diffusion in Russia seems on the right track despite certain pitfalls. Centers of excellence are created across the country with most recent ones opened in Belgorod and Tomsk. Many established research institutions, including the Russian Academy of Sciences, actively participate in the new programs with an aim to build up their research capacity. More and more news appear about nanotechnology projects in Biisk, Kazan, Khabarovsk, Kalinigrad and other cities.

All in all, 3,9% of all country's researchers were working in the field of nanoscience and nanotechnology in 2009, 338 NST-related patents were issued in 2009, and the government sponsored creation of 31 (!) research and education nanotechnology centers in major country's universities in the last two years (Rosstat, 2010; Kachak *et al*, 2010; Government of the Russian Federation, 2010b, Appendix 5). However, the main concern is that many of these universities have never had good scientific facilities and academic expertise especially in the field of nanoscience and nanotechnology.

b) Influence on the direction of search and the identification of opportunities

Rusnano plays the major role in forming directions of nanotechnology development in Russia. It supports NST research and provides basic business functions for start-ups in the sector. When companies apply for Rusnano funding it takes about 1-1,5 years to make the final decision. In the meantime, the corporation carries out the entire business analysis of the project from the marketing, financial, management and forecast points of view. The scheme works well for SMEs. Big businesses may come to the corporation with their own progressive ideas (e.g. Sitronics or Micran).

Rusnano also influences the direction of search by establishing partnerships with specific foreign companies. As mentioned above, the corporation supports companies in several priority areas: green, alternative and renewable energy; pharmaceuticals; biotechnology; new materials and technologies. These are consistent with the President's policy goals. On the one hand, this limits the choice of development routes for NST companies but on the other, makes this development more focused at the national level.

c) Entrepreneurial experimentation and management of risk and uncertainty

Entrepreneurial risk and uncertainty are much reduced in Russia by the project co-investment scheme provided by Rusnano. Given that many business decisions are dependent on relations with the Russian leadership, support of the frond-end institutions could trigger experimentation and presents more incentives towards starting a nanotechnology initiative. Although the role of private sector in the area is still low it has been increasing lately due to the rising activity of the Rusnano corporation. Opening of new centers of excellence across the country could also prove an important facilitator in experimentation in the long run. However, the current situation indicates

that it will take certain amount of time, resources and effort before these newly-established institutions will prove worthy.

d) Market formation

The nanotechnology market formation in Russia is going quite slowly and is heavily subsidized by the government. Rusnano plays the major role in its development. According to the Ministry of Education and Science (Kachak *et al*, 2010), in 2009 the domestic nanotechnology market reached 81 bn roubles (\$2,7 bn) and the amount of NST product exports equaled 11,3 bn roubles (\$377 mln).

Russia's President Dmitry Medvedev expects the nanotechnology market in Russia to reach 900 bn roubles (\$30 bn) by 2015, and 25% of the Russian NST products will be exported abroad (President of the Russian Federation, 2009).

Nevertheless, despite these optimistic reports and figures Russia holds only 0,5% of the world high-technology market while United States have 60% and Singapore – 6% (Boyarintsev *et al*, 2009).

e) Resource mobilization

The R&D spending in the field of nanotechnology and nanoscience reached 15,11 bn roubles (\$504 mln) in 2009. President Medvedev reasonably said that the Russian government nanotechnology investment program is one of the largest in the world and emphasized that the government plans to endorse for the needs of NST development in Russia a total of 318 bn roubles (\$10,6 bn) by 2015 (President of the Russian Federation, 2009).

Nevertheless, private sector lags behind in nanotechnology investment: 81,4% of its R&D spending in the field of nanotechnology is subsidized by the federal budget (see above).

f) Legitimation

The main policy instrument of public engagement and dissemination is the annual Nanotechnology International Forum. It is widely covered in media and attracts much public attention. Rusnano also carries out other enlightenment programs including exhibitions, public lectures, etc. All of these events are widely accessible via the company's website and news feeds. The country's largest Russian Information Agency "Novosti" has just started a new section on innovation and nanotechnology in late 2010. According to own content analysis of the Russian presidential speeches in 2000-2010, the number of references to nanotechnology-related terms dramatically increased since 2006 reaching 13-15 references in public speeches a year.

The ongoing campaign in favor of nanotechnology led to increased awareness about NST among ordinary citizens. According to the polls of the Russian Public Opinion Research Center, 43% of Russians heard about nanotechnology and its applications and 81% of citizens believed that they

will be useful for the human development⁸. In 2009 Russians put nanotechnology at the 9th place out of 23 in the list of most important scientific discoveries of the 20th century with 4% of citizens pointing at this technological area⁹.

g) Development of positive externalities

The Russian government pays much attention to development of positive externalities for NST. It struggles to build up efficient clusters of innovation in Skolkovo, Zelenograd, Obninsk, Tomsk, Perm, etc. It is also pushing the labor market for nanotechnology researchers, engineers and other personnel. However, as stated in section 5, many of these policy actions fail because of poor policy design and development lock-in that seems to be more dependent on cultural and institutional framework of the NIS rather than lack of finance.

Another goal that the government pursues is development of viable business and research infrastructure, which is still lagging behind because of the country's huge territory and underdevelopment of information and communication technologies. According to the World Economic Forum (2010), only 42,4% of Russians have access to Internet (52nd place out of 139) of whom 9,2% have broadband Internet subscription, and, among other, this fact hinders proper communication between scientists in different regions of the country.

Table 4. Functional matrix of Russia's nanotechnology policy

| | Positive | Negative |
|---|---|---|
| a. Knowledge development and diffusion | <ul style="list-style-type: none"> - 3,9% of all researchers are engaged in nanoscience and nanotechnology - 338 NST patents issued in 2009 - 31 research and education centers opened in universities | <ul style="list-style-type: none"> - many involved research and education institutions do not have high quality profile - not all capable endogenous resources are used - many decisions seem to be made as a result of lobbying rather than rationality |
| b. Influence on the direction of search and the identification of opportunities | <ul style="list-style-type: none"> - Rusnano plays crucial role in investment and development of specific NST areas - foreign companies specialized in certain areas are invited for joint ventures and to open R&D centers | <ul style="list-style-type: none"> - much stress is made on foreign achievements without big attention to already existent capabilities in Russia |
| c. Entrepreneurial experimentation and management of risk and uncertainty | <ul style="list-style-type: none"> - Rusnano co-invests public money into NST projects to reduce the risk and uncertainty - newly created centers of excellence may improve experimentation mechanisms | <ul style="list-style-type: none"> - role of business is still marginal - entrepreneurs prefer to invest in more traditional projects rather than high-risk NST endeavors |

⁸ Russian Public Opinion Research Center. (2008). 'Nanotechnology: what is it and why do we need them?' (in Russian). Press release No. 1004. 15 July 2008. Available at: <http://wciom.ru/index.php?id=268&uid=10390> [accessed 20/01/2011].

⁹ Russian Public Opinion Research Center. (2009). 'Inventions of the XXI century: which scientific discoveries are expected in future?' (in Russian). Press release No. 1256. 29 June 2009. Available at: <http://wciom.ru/index.php?id=268&uid=12049> [accessed 20/01/2011].

| | | |
|--|---|---|
| d. Market formation | <ul style="list-style-type: none"> - domestic nanotechnology market reached \$2,7 bn and NST product exports equaled \$377 mln in 2009 | <ul style="list-style-type: none"> - Russia plays marginal role at world high-technology market (share of 0,5%) - demand is not well articulated and seems understudied - many commercial nanotechnology projects are heavily subsidized by the government |
| e. Resource mobilization | <ul style="list-style-type: none"> - R&D spending in NST reached \$504 mln in 2009 - government provides ample public funding for Rusnano, federal programs and other projects - President Medvedev promises total of \$10,6 bn invested in NST by 2015 | <ul style="list-style-type: none"> - 81,4% of private R&D expenditure in NST is subsidized by the federal budget - business prefers to invest in traditional projects rather than high-risk nanotechnology endeavors |
| f. Legitimation | <ul style="list-style-type: none"> - Rusnano supports many projects to increase public awareness in NST: annual Nanotechnology International Forum, regular exhibitions, public lectures, etc. - major news agencies devoted special sections for innovation and nanotechnology - President pays increasing attention to nanotechnology in his public speeches - 43% of Russians know about nanotechnology and its applications | <ul style="list-style-type: none"> - nanotechnology is often considered another 'corruption-enabling' box by the general public |
| g. Development of positive externalities | <ul style="list-style-type: none"> - Russia has opened several tax-free 'technical and research zones' to support innovation and nanotechnology development especially by SMEs - government promotes many business and research infrastructure projects | <ul style="list-style-type: none"> - NIS development lock-in has not broken institutionally and culturally yet, despite abundant financial investment - business and research infrastructure projects are often delayed and tainted with multiple corruption scandals - many capable researchers and specialists continue to migrate from Russia - only 42,4% of Russians have access to Internet |

7. Conclusions

The previous three years of NST development in Russia show many successes including rapid knowledge development and diffusion through the newly created and traditional centers of excellence, ongoing legitimation process, broadening sphere of NST application and increasing opportunities as well as huge resource mobilization.

However, Russia still seems to be lagging behind in the entrepreneurial experimentation and risk management as well as market formation for nanotechnology-enabled products. The reasons for this situation are found in the overall innovation system of Russia rather than in the specific field of nanoscience and nanotechnology. Despite hopes that emerging technologies will break the development lock-in of the country many institutional and general social factors hinder growing innovative activity.

Practice shows that the Russian leadership is well aware of these shortcomings and clearly admits the shortcomings of past policy actions. It still considers nanoscience and nanotechnology as one of its main priorities and tries to increase the efficiency of the current policy. Among other, the government is reorganizing its coordinating departments and agencies with more attention paid to the innovation agenda after Prime Minister Putin became head of the Government Commission for High Technology and Innovation. Moreover, the current struggle between the Ministry of Economic Development and other stakeholders might indicate the systemic drawbacks of the policy making and implementation mechanisms. Finally, the country's political establishment made a decision to turn the Rusnano state corporation into a joint stock venture thus giving it more freedom and increasing its transparency.

So, the recent developments demonstrate that the Russian leadership sees main weak spots of the nanotechnology policy system in its design and implementation explicitly reorganizing the institutional mechanisms and coordination bodies. Specifically the policy making process seems intact despite certain struggle between Medvedev's and Putin's supporters but the selection of major stakeholders have not changed much since 2007.

Functional analysis generally supports this position putting more stress on the importance to change policy externalities. Nanotechnology policy meets the same obstacles as the overall research and innovation policy of Russia with business playing marginal role in the development process and the number of researchers and other R&D personnel rapidly decreasing. Therefore, the major challenges are embedded in the national innovation system rather than the TIS.

Besides, nanotechnology market formation and business development are heavily subsidized by the government. Main stakeholders are focused on creating new centers of excellence and bringing foreign companies to build their high-technology facilities in Russia. Such approach may lead to needless dispersion of resources and knowledge without any viable prioritization. The key policy recommendation would be to increase concentration of resources, pay more attention to the endogenous resources and build up on the former Soviet scientific potential, which has not been lost to the end despite the huge generation gap. Although this problem has already been partly understood and included in the policy objectives as evidenced by the knowledge

development and diffusion function, the issue needs more focus and revision. Seemingly, the major obstacle to success resides in the institutional and cultural patterns of Russia's S&T system rather than in lack of finance. Government officials and academic staff often proceeds from the obsolete concepts of planning economy when the budget money should be spent regardless of results and there are no transparent criteria such as return on investment indicators. Although similar problems exist in many developed countries Russia lacks many other mechanisms to monitor quality of research and commercialization such as peer review, research assessment exercises, etc.

The last point of improvement resides in the field of ethical, legal and societal implications of NST development. Russia could follow the path of the developed countries and establish small grant programs or research centers to study these aspects in order to enhance the overall growth of the field.

All in all, nanotechnology policy has not proven to be an efficient means of breaking the development lock-in in Russia yet. System inertia is still strong and difficult to reverse. However, the emerging technology retains chances to play an important role in transforming the country's national innovation system in future given its correct realization and application.

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