Russian Nanotechnology R&D: Thinking big about small scale science

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The main purpose of this report is to provide an assessment of Russian nanotechnology up to 2010 and of Russia's plans for the coming decade. There are three central research questions in this study.

a) How extensive, in absolute and relative terms, is the Russian nanotechnology effort regarding investment, research, innovation and commercialisation?
b) What are Russia's strengths and weaknesses in the field of nanotechnology? What obstacles are there and what are the opportunities for boosting nanotechnology development in Russia?
c) How feasible are its current plans?

The report provides an overview of the expanding field of nanotechnology in general and in Russia in particular. First government initiatives are described. Second an assessment of Russian nanotechnology capability is made, by comparing Russian investment, research publications and patenting activity with a sample of other countries. Third, Russia's potential for innovation and commercialisation of nanotechnology is assessed and the prospects of intelligence service support to the Russian nanotechnology effort are discussed. Finally, the feasibility of the Russian nanotechnology effort is assessed on the basis of its identified strengths and weaknesses, followed by tentative conclusions on the future impact of Russian nanotechnology on security policy.

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RUSSIAN NANOTECHNOLOGY R&D

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Thinking big about small scale science

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Photo on cover page: Russia’s Prime Minister Vladimir Putin (left), accompanied by Head of Russia s Nanotechnology Agency (RUSNANO) Anatoly Chubais, visits an exhibition, displaying the products produced by means of nanotechnology, in Moscow September 10, 2010. REUTERS Ria Novosti Pool Alexei Nikolsky

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Abstract

In recent years, nanotechnology has risen on the Russian policy agenda and it has often been mentioned as a key factor in the process of modernisation and innovation. Undoubtedly, nanotechnology is promising for science, industry and society, but to what extent will Russia be able to benefit from a national effort in this field? The main purpose of this study is to provide an assessment of Russian achievements in the field of nanotechnology research and development up to 2010 and its plans for the coming decade.

The report provides an overview of the expanding field of nanotechnology in general and in Russia in particular. First government initiatives are described. Second an assessment of Russian nanotechnology capability is made, by comparing Russian investment, research publications and patenting activity with a sample of other countries. Third, Russia's potential for innovation and commercialisation of nanotechnology is assessed and the prospects of intelligence service support to the Russian nanotechnology effort are discussed. Finally, the feasibility of the Russian nanotechnology effort is assessed on the basis of its identified strengths and weaknesses, followed by tentative conclusions on the future impact of Russian nanotechnology on security policy.

Key words:
Russian Federation, nanotechnology, nanoscience, research and development (R&D), patenting, innovation, commercialisation, intelligence services, security policy.

Sammanfattning

Under de senaste åren har nanoteknologi ofta nämnts när regeringsföreträdare diskuterat modernisering och innovation i Ryssland. Nanoteknologi är onekligen lovande och har potentiellt stor inverkan på samhället i framtiden. I vilken utsträckning kan då Ryssland förväntas att kunna dra nytta av en nationell satsning på nanoteknologi? Det övergripande syftet med denna rapport är att tillhandahålla en bedömning av den ryska satsningen på nanoteknologi fram till 2010 och planerna för det följande decenniet.

I rapporten ges en överblick över nanoteknologiområdet i allmänhet och rysk nano-utveckling i synnerhet. Först beskrivs statliga initiativ på området. Sedan diskuteras rysk förmåga inom nanoteknologifältet genom jämförelser med andra länder avseende investeringar, forskningspublikationer och patent. Därefter analyseras landets potential för innovation inom och kommersialisering av nanoteknologi och de ryska underrättelsetjänsternas förmåga att stödja en satsning inom nano-området. Avslutningsvis bedöms genomförbarheten av den ryska satsningen på nanoteknologi mot bakgrund av de styrkor och svagheter som observerats. Detta följs av tentativa slutsatser rörande nanoteknologisatsningens säkerhetspolitiska implikationer.

Nyckelord:
Ryssland, nanoteknologi, forskning och utveckling (FoU), patent, innovation, kommersialisering, underrättelsetjänster, säkerhetspolitik

Preface

On becoming president of the Russian Federation, Dmitrii Medvedev launched an ambitious political programme of modernizing the country's economy and industry. Among the technology sectors, nanotechnology was singled out for specific attention. This technology had a special aura of being a promising, if at times slightly enigmatic, research field. It also quickly became something of a buzzword in Moscow among both politicians and analysts, often with only limited insight into what the technology could deliver in terms of future economic growth and as a driver in the modernization process of the country's research and development (R&D) and industry.

The research project RUFS at FOI, which specializes in analysing Russian foreign, defence and security policy in a broad perspective, decided in 2009–2010 to follow Medvedev's modernization policy. A series of studies of individual technological spheres identify the major features of the initiative. Previous FOI reports include one by Roger Roffey on the development of biotechnology in Russia and one by Susanne Oxenstierna on the civilian nuclear industry. Modernization – or the lack thereof – has also been a recurring topic in FOI reports and memos on how Russia handled the economic crisis, and, of course, feature prominently in assessments of the future of Russia's defence industry.

This report assesses how Russia's nanotechnology program will affect political and economic modernization in Russia. Since the author is a political scientist by training, the study has greatly benefited from the useful and constructive comments of Professor Steven Savage at a seminar in December 2010. Furthermore, Roger Roffey has proffered

advice on sources for Russian research and development and expert comments on nanobiotechnology. Dr. Susanne Oxenstierna commented on a draft and made useful suggestions about how to streamline the argument and Dr. Kristina Westerdahl shared her experience in nano-biotechnology research. Maria Lindhagen and her colleagues at the FOI library gave excellent advice on nano-related literature and Jan Leijonhielm provided inspiration and support to the study at an early stage of the research. Dr. Johannes Malminen also put a lot of effort into improving the report. The Swedish Ministry of Defence, which commissioned the study, organized a series of seminars on the topic of modernization and showed an early and steady interest in examining modernization through in-depth studies. Finally, Andrew Mash language edited the report and Sanna Aronsson assisted greatly in the final editing.

Carolina Vendil Pallin, Project manager for RUFS

Stockholm 28 March 2011

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Acronyms and abbreviations

BRIC	Brazil, Russia, India and China
CAS	Chinese Academy of Sciences
CIS	Commonwealth of Independent States
CPI	Corruption Perception Index
EPO	European Patent Office
EU	European Union
EUR	Euro, European Monetary Union currency
FGUP	*Federalnoe Gosudarstvennoe Unitarnoe Predpriiatie*, Federal State Unitary Enterprise (Russian Federation)
FP	Framework Programme
FSB	*Federalnaia Sluzhba Bezopasnosti Rossiiskoi Federatsii*, Federal Security Service of the Russian Federation
FTP	Federal Target Programme
ICT	Information and communications technologies
KGB	*Komitet Gosudarstvennoi Bezopasnosti*, Committee for State Security, Soviet Security Service
LED	Light emitting diodes
nm	nanometers
NNI	National Nanotechnology Initiative (USA)
NRC	National Research Centre (Russian Federation)
OECD	Organisation for Economic Co-operation and Development
ONR	Office of Naval Research (USA)
PCT	Patent Cooperation Treaty
PPP	Purchasing power parity
R&D	Research and development

RF	Russian Federation
RAN	*Rossiiskaia Akademiia Nauk,* Russian Academy of Science
RUB	Russian Federation Rouble
S&T	Science and technology
SVR	*Sluzhba Vneshnei Razvedki*, Foreign Intelligence Service of the Russian Federation
USD	United States Dollar
WTO	World Trade Organisation

Executive summary

Nanotechnology has the potential to become the most important technological advance of this century. It promises scientific and industrial progress in a large number of fields and is expected to produce important commercial markets in the future. With the application of nanotechnology, a wide range of products with a potentially huge impact on society can be developed. For instance, inexpensive and reliable products that improve public health, public safety and the energy supply are envisaged as well as products with military applications.

Nanotechnology took off comparatively late in Russia. It was only in 2007 that a more comprehensive government effort was launched in the field. Russian ambitions were nevertheless high. Over RUB 100 000 million was allocated to enable Russia to become a prominent nanotechnology nation by 2015. Among the main goals stated were:

- To develop a competitive sector for nanotechnology research and development (R&D) by 2011;
- To have established Russian companies in the global high technology market by 2015; and
- To create a new technological base for the economy of the Russian Federation by 2025.

In 2010, state institutions were the principal actors in the field of nanotechnology in Russia, with the RUSNANO state corporation spearheading nanotechnology innovation and its commercialisation. The main focus of Russian nanotechnology efforts has been the development of a domestic infrastructure for nanotechnology research and development as well as for innovation, commercialisation and manufacturing of nano-products. This can be expected to remain the major theme in the coming decade.

The Russian government stands out as one of the largest investors in the world in nanotechnology research. However, government spending on R&D is often ineffective and the investment needs are greater in Russia than in many other countries. Furthermore, private investment in nanotechnology is limited, probably due to the adverse investment climate in Russia. All in all, the Russian Federation was probably not among the world leaders in total nanotechnology investment in 2010. More importantly, Russia seemed to lag behind in research outputs per unit invested.

In 2010, Russia seemed to be losing ground in nanoscience and nanotechnology research. Although prolific in terms of the number of scientific publications, its poor performance regarding the quality of the research publications and of nanotechnology patenting should be a cause for genuine concern. However, Russia does enjoy a relatively strong position concerning international collaboration in both nanotechnology research and patenting. Increased cross-border cooperation could mitigate Russia's decline in the international rankings.

Despite its high ambitions, the Russian Federation remains far from achieving a competitive advantage internationally regarding innovation and commercialisation that could boost domestic nanotechnology. In fact, it may have greater problems in this area than many other countries, due to the Russian business climate and the widespread corruption.

The Russian intelligence services can provide support to national nanotechnology science and industry, but this may do more harm than good. Conducting industrial espionage and counterespionage could raise barriers to cooperation with foreign scientists, engineers and businessmen both inside and outside Russia. This would threaten Russia's primary comparative strength and thus risk undermining Russian nanotechnology development.

In conclusion, reaching the ambitious goals Russia set out in 2007 appeared unrealistic in 2010. Both the quantity and the quality of

Russian research seem too low to enable Russia to become a prominent nanotechnology nation within a decade. The lack of experience in innovation and commercialisation and its underdeveloped industrial infrastructure make the mass production of nanotechnology items difficult to achieve. Furthermore, Russian industrial policy has so far not encouraged the inflow of foreign investment and know-how. Consequently, establishing Russian companies in the global high technology market and creating a new technological base for the economy of the Russian Federation appear difficult to attain.

Russian nano-science and the domestic nanotechnology industry may not have any significant impact on Russian security policy in the decade to 2020, and possibly not for the following decade either. Domestic nanotechnology will not be a panacea for Russia's ills, at least not in the coming decades. Inevitably, the potential impact of the efforts in the field of nanotechnology – or any other scientific field – on Russia's security policy plays a secondary role to a more important issue. For the modernisation of Russia's economy and society, however, a revolution in politics seems more urgent than one in technology.

1 Introduction

> The tasks in the area of nano-industry have been, and are still, very important. There is talk of our country reaching a prominent position in this direction of scientific progress, of creating leading production with vast output on the world market.
>
> *Prime Minister Vladimir Putin, August 2009*[1]

In 2007, nanotechnology became the buzzword in Moscow whenever innovation policy was on the agenda. Undoubtedly, nanotechnology has considerable promise for the future, but will it be a panacea for furthering Russia's interests? Will nanotechnology salvage Russian science and industry, become an engine for innovation driving the economy and give Russia an edge in defence research – and in the decades to come improve Russia´s security policy standing?

This chapter presents the objective of the study and the main research questions, as well as methodological issues pertaining to the study. It also presents the structure of the report and reading suggestions, in order to facilitate for the different readers that might find this report interesting.

1.1 Objective and research questions

The main purpose of this report is to provide an assessment of Russian nanotechnology up to 2010 and of Russia's plans for the coming decade. There are three central research questions in this study.

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[1] Prime Minister Vladimir Putin (2009) 'V. V. Putin provel soveshanie po voprosy 'O realisatsii 'Strategii razvitiia nanoindustrii'' [Putin held meeting on the issue of 'Realisation of the 'Strategy of the development of the nano-industry'']', *RF Government Administration*, on the Internet: http://premier.gov.ru/events/news/4753/ (published: 19 August 2009; retrieved: 1 June 2010).

a) How extensive, in absolute and relative terms, is the Russian nanotechnology effort regarding investment, research, innovation and commercialisation?
b) What are Russia's strengths and weaknesses in the field of nanotechnology? What obstacles are there and what are the opportunities for boosting nanotechnology development in Russia?
c) How feasible are its current plans?

1.2 Method and sources

The study assesses the performance of Russian nanotechnology research and development (R&D) in comparison with a sample of other countries. Nine countries provide useful points of reference for assessing Russian performance. The countries selected are: the United States, in its capacity as world leader in the field; Germany and France, which represent European countries successful in the area of nanotechnology;[2] Japan and South Korea, which have a corresponding position in Asia; China, India and Brazil, which were included in the light of their rapidly growing nanoresearch activity and because they are often lumped together with Russia under the BRIC label; and, finally, Poland, which was chosen in its capacity as another former communist country with ambitions in the field of nanotechnology.

Although comparable data is not always available, this study collects data on performance in nanotechnology R&D from these nine countries in order to provide a basis for evaluating different aspects of Russia's performance. For example, publication and citation bibliometrics can be used to assess the research performance of Russia in comparison with the other countries. The study uses a selection of reports on nanotechnology publications

[2] The United Kingdom is not included for methodological reasons because in some datasets it is divided into England, Scotland and Wales, which complicates comparisons.

and citations. The main data source is the Science Citation Index/Social Science Citation Index that the US Office of Naval Research has assembled and analysed.[3] This is complemented by the findings of an Organisation for Economic Co-operation and Development (OECD) nanoscience study[4] and two EU-funded studies.[5]

An analysis solely based on scientific publications, however, is not sufficient to provide an understanding of the socio-economic impacts of scientific discoveries. Therefore, this study analyses patents. It is a useful way to examine the flow of knowledge from science to technology. Patents are one of the more direct and measurable outputs of R&D and other inventive activities. The analysis of patent applications in this study is based on applications filed at the European Patent Office (EPO) and under the Patent Cooperation Treaty (PCT). The PCT statistics allow wider international comparison. Nanotechnology data have also been compiled and presented by the OECD. The EPO statistics provide reliable and detailed information on nanotechnology patenting (see Appendix A for a brief discussion on using EPO statistics).

As is often the case with a new field of research, empirical analyses of nanotechnology suffer from the limited access to reliable and comparable data. The analysis has to strike a balance between using up-to-date information to illustrate the current state of Russia's scientific output, and using older data sets that allow

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[3] Kostoff *et al.* (2006) *Structure of the Global Nanoscience and Nanotechnology Research Literature*, Office of Naval Research.
[4] Igami and Saka (2007) *Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science*, OECD, Paris, STI Working Paper, 2007/1.
[5] Hullmann (2006) *The economic development of nanotechnology – an indicators based analysis*, CORDIS; and Noyons et al. (2003) *Mapping Excellence in Science and Technology across Europe: Nanoscience and Nanotechnology*, Centre for Science and Technology Studies, Leiden University, the Netherlands, October 2003.

comparisons over time and between different countries. These difficulties have been mitigated by collecting data from different sources and pre-selecting them on the basis of the reliability of the source, the plausibility of the methodology and consistency with other data.

1.3 Structure

This report begins with an overview (chapters 2 and 3) of the expanding field of nanotechnology in general in and in Russia in particular. Chapter 2 provides a definition of nanotechnology and describes the main actors and the expected benefits of this new technology. The chapter is recommended for readers with little previous knowledge about nanotechnology. The following chapter describes Russian government initiatives and nanotechnology institutions in some detail. Chapter 3 is recommended in its entirety for anyone interested in a detailed picture of the organisational aspects. For others, reading the chapter conclusion is suggested.

The overview is followed by an assessment of Russia's nanotechnology capabilities, comparing Russian investment (chapter 4), research publications and level of patenting activity (chapter 5) with the sampled countries. Both chapters go into some detail, in particular the discussion of publications and patenting in chapter 5. For a reader with a more general interest in the topic, the concluding sections in these chapters are recommended.

Thereafter, chapter 6 first assesses Russia's potential for innovation and commercialisation and then discusses the prospects of the intelligence service providing support to the Russian nanotechnology effort. The chapter is recommended for readers interested in Russian innovation or intelligence issues. For others, the chapter conclusion is suggested.

Finally, the report analyses the likely success of the Russian nanotechnology effort based on its observed strengths and weaknesses. Chapter 7 also provides some tentative conclusions on the future impact of Russian nanotechnology on security policy. This chapter is recommended to anyone with an interest in Russian politics as well as to those who want a somewhat more thorough outline than the executive summery provides.

The report has two appendices with additional information. Appendix A contains a discussion of why European Patent Office statistics have been used in this study and a brief characterisation of the available dataset. This may be of interest to anyone interested in methodological issues related to studying patent statistics. Appendix B provides additional details on the RUSNANO corporation management and may be of interest for a reader focusing on people involved in the strategic management of RUSNANO.

2 Nanotechnology: What is it and why the hype?

Nanotechnologies can change Russia's economy.
First Deputy Prime Minister Sergei Ivanov, April 2007[6]

When a technology is in vogue among policymakers and in the media, it is often spoken about rather carelessly. However, a systematic analysis of nanotechnology requires at least a brief definition, a discussion of the main players and an outline of its major potential benefits in order to frame the topic. For example, what exactly is referred to as nanotechnology or nanoscience? Who are the main actors and why all the hype? This chapter provides a general introduction to the field of nanotechnology by probing these questions.

2.1 Nanotechnology: A definition

Nanotechnology is not just the next step in miniaturisation. It is the gateway to a qualitatively new technology. There are high expectations around it because it allows multiple properties to be optimized simultaneously leading, for instance, to potentially completely new medical applications.[7] In other words, simply defining nanotechnology in a range of nanometres is insufficient.

> Broadly speaking, nanotechnology is the development and use of techniques to study physical phenomena and construct structures in the physical size range of 1 to 100 nanometers (nm), as well as the incorporation of these structures into applications. Although size is a convenient way of defining the area, it alone is not enough to distinguish the nanoscale material from microscopic material. For example, there is no line of demarcation that separates structures at 120

[6] World News Connection 'Russian Govt to Invest Over Rbl 4 Bln in Nanotechnologies in 2007'.
[7] Observation by Dr. Steven Savage at the report seminar on 6 December 2010 at the FOI.

> nm from those of 100 nm. In practice, nanotechnology has more to do with the investigation of novel properties that manifest themselves at that size scale, and of the ability to manipulate and artificially construct structures at that scale.[8]

There are several definitions of nanotechnology,[9] but for the purpose of this study it is sufficient to define it as the ability to exploit the properties of materials at the nanoscale. It should be noted that, in general, nanoscience is concerned with small dimensions, but nanotechnology is not necessarily so. Nanotechnology can be applied to very large structures such as bridges or ships.

The nanotechnology area covers a wide range of scientific research and it is therefore useful to look at different subareas, or subfields, when assessing nanotechnology R&D. In 2010, there was still no consensus on how to divide the nanotechnology field into subfields, and there was some dispute about whether nanotechnology was a single technological field.[10]

A 2006 report published by the European Commission Research Directorate identified four major subareas: nanomaterials, nanoelectronics, nanobiotechnology and nanotools.[11] A 2007 OECD-report lists six subfields: electronics, optoelectronics, medicine and biotechnology, measurements and manufacturing, nanomaterials, and environment and energy.[12] At the same time, the European Patenting Office uses six, not entirely corresponding, sub-classifications of nanotechnology patents: nanobiotechnology;

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[8] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 31.

[9] For an overview of definitions of nanotechnology, see Igami and Okazaki (2007) *Capturing Nanotechnology's Current State of Development via Analysis of Patents*, OECD, Paris, STI Working Paper, 2007/4, p. 3.

[10] *Ibid.*, p. 11.

[11] See for instance Hullmann *The economic development of nanotechnology*

[12] Igami and Okazaki *Capturing Nanotechnology's Current State of Development via Analysis of Patents*, p. 3.

nanotechnology for information processing, storage and transmission; nanotechnology for materials and surface science; nanotechnology for interacting, sensing or actuating; nano-optics; and nanomagnetics.[13]

For the purpose of this report it is sufficient to divide nanotechnology into four sub-fields. In the chapter on Russian nanotechnology research (chapter 5), the discussion on nanotechnology sub-fields centres on four areas: nanomaterials; nanoelectronics, including nanomagnetics, nano-optics and optoelectronics; nanobiotechnology, including medicine; and nanotools. This covers all the above-mentioned subfields except environment and energy. Using these four sub-fields allows a closer analysis of the burgeoning nanotechnology research field.

The sub-field of *Nanomaterials* promises to bring a new dimension to all areas where materials play a role, not only through the ability to make materials lighter and/or stronger, but also by finding new uses – as the shift in scale from micro to nano often encompasses a change in the characteristics of a material.

Nanoelectronics is expected to have a major impact on information and communication technologies (ICT) by allowing further miniaturization and continuing Moore's law of the doubling of data storage and processing capacities every 18 months.

Nanobiotechnology promises to revolutionise the field of medicine by improving pharmaceuticals and diagnostics, and could have a major impact on agriculture and the food industry, as well as any industrial process dependent on biotechnology.

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[13] For the EPO nanotechnology classification, see *e.g* the Espacenet website (classification search engine): http://v3.espacenet.com/eclasrch?ECLA=/espacenet/ecla/y01n/y01n.htm (accessed March 2011).

Nanotools refers to instruments and devices that have the capacity to study or manipulate objects on a nano scale, such as electron microscopes and ultra-precision instruments.

2.2 The main players in nanotechnology

In the early 21st century, the United States, Japan, Germany and South Korea are the leading countries in nanotechnology development, but China is moving into the top tier. The USA and Japan will remain the top nations in nanotechnology for many years to come, but their lead will erode as developed countries, such as South Korea, and developing countries, such as China, India and Russia, catch up.[14]

Many countries have publicly expressed their ambitions in nanotechnology. For example, South Korea has the ambition to become one of the top three countries in the field of nanotechnology and South Korean scientists drew up a national roadmap for nanotechnology R&D in 2008.[15] Russia has also expressed great ambitions. In July 2007 Russia's Minister for Education and Science, Andrei Fursenko, stated that Russian investment in the development of nanoscience and nanotechnology infrastructure would allow Russia to become the world's nanotechnology leader.[16] Even if this goal is beyond the reach of Russia, the ambition to become a world leader indicates both the intention of the Russian government and the importance it assigns nanotechnology development.

[14] Business Wire (2007) 'Top Nations in Nanotech See Their Lead Erode', on the Internet: http://www.businesswire.com (published: 9 March 2007; retrieved: 15 September 2007).
[15] Korea Times (2008) 'Nanotechnology Roadmap Unveiled', *The Korea Times* on the Internet: http://www.koreatimes.co.kr/www/news/tech/tech_view.asp?newsIdx=17333&categoryCode=129 (published: 15 January 2008; retrieved: 7 April 2008).
[16] World News Connection (2007b) 'Russian Govt To Invest Over Rbl 4 Bln In Nanotechnologies In 2007', original source Itar-Tass (published: 11 July 2007; retrieved: 15 September 2008).

2.3 The promise of nanotechnology

In the words of an EU official, nanotechnology has the potential to become the most important technological advance of this century.[17] Nanotechnology could boost science and industry in a large number of fields. In 2007, the Russian government expected nanotechnology to have an impact on Russian materials – metals, alloys, fibres, ceramics and composites – as well as on the energy, medical and pharmaceutical industries.[18] In the wake of the financial crisis of 2008, experts hailed nanobiotechnology as one of the most promising drivers of economic recovery, and this was duly noted in Russia.[19]

A RAND Corporation report from 2006 on the state of global technology in 2020 discussed future trends in nanotechnology in five areas of research: sensor technology, biotechnology, electric power, electronics and manufacturing.[20] According to the report, nanotechnology is uniquely positioned to enable new capabilities in sensor technology, providing unprecedented levels of sensitivity and selectivity and thus, for instance, improving threat detection.

Nano-enabled sensor technologies were also deemed likely to have a large impact on the area of nanobiotechnology. According to the RAND report, advances in this field promise to improve drug delivery, diagnosis, surgical methods and even prosthetics. The future impact on society could be substantial, but it depends on the

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[17] Renzo Tomelli, the head of the European Commission Science Directorate’s Nano S&T Unit, in Hullmann *The economic development of nanotechnology*.

[18] World News Connection (2007b) ‘Russian Govt To Invest Over Rbl 4 Bln In Nanotechnologies In 2007’.

[19] See for instance Shmeleva (2009) ’Nano-bio-technologii vytachshat mir iz ekonomicheskoi yamy [Nanobiotechnology saves the world from the economic crisis]’, *Rossiiskaia Gazeta*, on the Internet: http://mon.gov.ru/press/smi/5329 (published 29 April 2009; retrieved: 21 June 2010).

[20] RAND (2006) *The Global Technology Revolution 2020, In-Depth Analyses: Bio/Nano/Materials/Information Trends, Drivers, Barriers, and Social Implications*, Rand Corporation, National Security Research Division, Appendix B: Nanotechnology trends to 2020.

social acceptability and perceptions of the risks of various nanotechnologies. Nano-enabled power solutions, such as on-device power sources and improved battery capacity, were thought to have the potential to significantly affect many aspects of how technology influences society.

According to the report, nanotechnology has great potential to produce advances in the design and production of integrated circuits and processing chips, enabling computing devices to be embedded in all manner of consumer goods. However, this technology still presents challenges linked to high production costs and the tight tolerances required in the semiconductor industry.

Finally, even though scientists have long sought to manufacture at the molecular level, the RAND report believed it unlikely that finished commercial products with complex functionality would be fabricated using molecular manufacturing methods in the next 15 years.

In sum, nanotechnology research is becoming an increasingly important part of global research activities. The number of nanotechnology papers increased disproportionately relative to other technical disciplines between 1991 and 2005.[21]

2.3.1 A promising market and a growing industry

In the future, nanotechnology is expected to provide important commercial markets. Nano-enabled products worth over USD 50 billion were sold in 2006, according to a US research company.[22]

[21] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 40. For an in-depth (thousand pages) and detailed study of nanotechnology research compiled by a European research analysis company, see Cientifica, *Nanotechnology Opportunity Report*, (3rd edn), Cientifica Ltd, June 2008.

[22] Business Wire, 'Top Nations in Nanotech See Their Lead Erode', reporting on a 2007 report entitled *Profiting from International Nanotechnology* by Lux Research.

However, estimates of the size of the future market are considerably larger.

In a November 2006 assessment of the economic development of nanotechnology made by Angela Hullmann,[23] a scientist at the European Commission, the forcast is that the market will expand from a modest USD 150 billion in 2010 to a stunning USD 2.6 trillion in 2014. Hullmann concluded that the latter scenario implies that in the future the market for nanotechnology products will be larger than that for information and communication technologies (ICT). It would also exceed the projected market for biotechnology products by ten times. The various forecasts in the report differed signifycantly from each other, but Hullmann underscored that they all predicted a substantial increase in the market for nanotechnology products, beginning in the early 2010s. The Russian President, Dmitrii Medvedev, referring to independent experts, stated in 2009 that the global nanotechnology market was predicted to reach USD 250 billion that year and USD 2–3 trillion by 2015.[24]

The commercial prospects are matched by estimates of the potential number of jobs to be created in the nanotechnology industry. Small and medium-sized enterprises are expected to contribute the most to the creation of new job opportunities. Estimates range from about two million jobs in nanotechnology by 2015, with an additional 5 million in related support roles, to a more optimistic 10 million in manufacturing jobs related to

[23] Hullmann *The economic development of nanotechnology.*

[24] President of Russia (2009) 'Vystupleniie na otkritii II Mezhdunarodnogo foruma po nanotekhnologiiam [Speech at the opening of the 2nd International Nanotechnology Forum]', *RF Presidential Administration*, on the Internet: http://www.kremlin.ru/transcripts/5675 (published: 6 October 2009 ; retrieved: 1 June 2010).

nanotechnology by 2014. The latter would represent some eleven percent of all manufacturing jobs.[25]

Expectations in Russia are also considerable. In October 2009, Medvedev stated that in the period to 2015 the annual trade volume of Russian nano-industry products would reach RUB 900 billion, a quarter of which would be exports.[26] A development plan for Russian nano-industry from 2007 expected an increase in Russia's share of the global market from 0.07 percent to 3 percent by 2015. A corresponding increase in export revenues was also expected, from RUB 4 billion in 2008 to RUB 180 billion in 2015. [27]

2.3.2 Prospective products of importance to society

The application of nanotechnology could lead to the development of a wide range of products with a potentially huge impact on society. From a security policy perspective, products that affect public health, public safety and energy-related issues as well as products with military applications are of particular interest.

Two important areas for public health, where nano-products may have a significant impact, are medicine and fresh water supply. Medical applications represent one of the most promising areas for the use of nanomaterials.[28] These include targeted drug delivery

[25] Hullmann *The economic development of nanotechnology*, p. 17.

[26] President of Russia 'Vystupleniie na otkritii II Mezhdunarodnogo foruma po nanotekhnologiiam [Speech at the opening of the 2nd International Nanotechnology Forum]'. This was a restatement of the expected results of the Development Programme for the Nano-industry of the Russian Federation to the year 2015 approved by the RF Government in December 2007.

[27] RF Government (2007b) *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], RF Government Administration, on the Internet: http://mon.gov.ru/work/nti/dok/str/nano15.doc (published: 25 December 2007; retrieved: 21 June 2010), Appendix 2.

[28] RAND *The Global Technology Revolution 2020, In-Depth Analyses*, p. 176 (Appendix C).

systems,[29] enhanced diagnostics and detection, non-invasive surgery techniques and tissue engineering.

Nanotechnology could also develop nano-fibre membranes able to filter out bacteria and viruses from water, as well as improve desalination methods.[30] Certainly, this would help in improving public health. However, there may also be health risks with nano-products. For example, little is known today about how nano-particles interact with the human body.

Nanotechnology products that detect or reduce hazards and assist the emergency services could improve public safety. For instance, lighter, smaller and highly functional sensory systems providing accurate, low-cost detection from distributed surveillance platforms, such as buildings, transportation hubs or vehicles could detect hazardous substances in the air. Nanotechnology could also provide new tools for the decontamination of toxic substances, making them more benign to humans and the environment. It could also reduce the production of hazardous materials and waste from manufacturing and processing industries.

The emergency services could benefit from enhanced protective clothing (integrated decontamination activity, and cooling or heat resistant properties) and improved masks and filters. Moreover, remote-controlled vehicles in emergency response teams could reduce the risk to human lives in collapsed buildings and other hazardous locations as well as allowing access to confined spaces.

Moreover, nano-enabled products could lead to the production of cheap and widely available energy. Improvements in battery and solar power technologies as well as increased efficiency in current energy sources could reduce the cost of energy and provide electricity to isolated areas. Further advances in the miniaturization

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[29] For more on nano-enabled drug delivery systems, see *Ibid*., Appendix E.
[30] *Ibid*., p. 175 (Appendix C).

of technical products and electronic components would also reduce energy consumption.

Several of the products mentioned above have military applications too. The use of nanotechnology promises to enhance war-fighting capabilities and it might perhaps even call for at least a partial rethink of military strategy. In his February 2008 address to the Expanded Meeting of the State Council on Russia's Development Strategy to 2020, the then-President, Vladimir Putin, stated that new breakthroughs in nanotechnology could lead to revolutionary changes in weapons and defence.[31]

Certain aspects of warfare could be improved through the use of nanotechnology. For example, it could increase protection and effectiveness, while simultaneously preserving or even improving the mobility of platforms, weapon systems, and command and control as well as for the individual soldier. Platforms could receive increased protection by developing stronger armour, improved chemical and biological warfare defence systems, as well as greater stealth through improved multi-spectral signature reduction (i.e. camouflage).[32] Subsystems could also receive increased protection, such as transparent, hardened ceramic materials for sensors on missiles and platforms.

Protection for soldiers could be improved by the development of multifunctional battledresses. They could have improved ballistic

[31] President of Russia (2008) 'Vystupleniie Prezidenta Rossiiskoi Federatsii V. V. Putin na zasedanii Gosudarstvennogo soveta "O strategii razvitiia Rossii do 2020 goda"', Moskva, 8 Fevralia 2008 goda [Speech by the President of the Russian Federation at the meeting of the State Council on Russia's Development Strategy through to 2020 on 8 February 2008]', on the Internet: http://www.mid.ru/brp_4.nsf/sps/531C812CE37C337AC32573EA00271F54 (published: 9 February 2008; retrieved: 13 February 2008).

[32] For instance, high temperature radar absorbing materials for applications in exhausts on aircraft are one example of possible advances using nanotechnology. Another is the development of a nanocoating capable of dispersing the electrostatic charge that tends to accumulate and anchor debris on the canopies of aircraft. RAND *The Global Technology Revolution 2020, In-Depth Analyses*, p. 175 (Appendix C).

protection and multi-spectral signature reduction as well as biological and chemical sensors. Nanotechnology could also provide oil- and flame-resistant coatings for soldiers' gloves,[33] and self-decontaminating surfaces for soft materials, in other words active surface coatings that can neutralise chemical agents and destroy biological agents.

The application of nanotechnology could also improve battle effectiveness of platforms, weapons and soldiers. Improved sensors and sensor integration (multiple sensors in one system and/or integration into the platform surface) could increase the effectiveness of military platforms. Nanotechnology could also allow improvements in propulsion and power supply. For instance, advances in these aspects would allow for autonomous (miniaturized) vehicles or aircraft with highly manoeuvrable, low visibility, multi-sensor systems.

The effectiveness of weapons could be increased, making them more powerful and more accurate. Nanotechnology could improve munitions and explosives and provide more advanced sensors and guidance systems. For instance, according to a news report, the use of nanotechnology was a key element in a high yield vacuum bomb that the Russian military presented to the world on 11 September 2007. The vacuum bomb was allegedly the most powerful in the world, but it was claimed that it was smaller than its US counterpart.[34]

From the perspective of modern warfare, perhaps the greatest potential for improving battlefield effectiveness is through the application of nanotechnology to the individual soldier. Soldiers

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33 *Ibid.*, p. 175 (Appendix C).

34 Pervyi Kanal (2007) 'Samaia moshchnaia v mire vukuumnaia bomba, rossiiskie ispytaniia [The most powerful vacuum bomb in the world: Russian testing]' Pervyi Kanal [Channel One], on the Internet: http://www.1tv.ru/news/n108915 (published: 11 September 2007; retrieved 18 September 2007).

could be equipped with robust and reliable lightweight systems that multiply their effect. One example of such a system is sensor, computer, communication and information systems coupled with improved power supply systems. Other areas could be technology for reinforcing the soldier's physical abilities or improving food rations and water supply.

The use of dispersed individual command, control and information systems would not only increase the effectiveness of the individual soldier or platform, but also significantly increase the effectiveness of military units by increasing the opportunities for coordinating and managing human and technical resources. The effect on military units on the battlefield could be further increased by improving mobility without loss of protection or effectiveness in either platforms or weapons, through reductions in weight and size by the use, for instance, of lightweight materials, integrated materials and miniaturisation,.

However, many of these advances in nanotechnology are still only available in research laboratories or in practical use in very high-end products. It may be many years before these discoveries can be transferred into useful commercial or military products. Furthermore, the transition of nano-enabled technologies from the laboratory to manufactured goods is dependent on a number of factors, not least cost, but also integrating nanotechnology into reproducible products, scaling up manufacturing for commercial production and the development of related technologies. In non-military products, two further important factors are market forces and consumer acceptance of nano-enabled technologies.[35]

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[35] RAND *The Global Technology Revolution 2020, In-Depth Analyses*, Appendix B: Nanotechnology trends to 2020.

3 Nanotechnology R&D in Russia

> We are practically ready for a new scientific and technological revolution: a nanotechnology revolution.
>
> *Minister for Science and Education Andrei Fursenko, February 2008*[36]

Nanotechnology is one of several scientific fields in which the Russian government has shown a keen interest. By stimulating research and development (R&D) in promising new technologies the government hopes to foster modernisation and stimulate the diversification of the economic base of the Russian Federation.

The then president, Vladimir Putin, fired the official political starting shot for nano-policy development in April 2007. In his annual address to the Federal Assembly, Putin singled out nanotechnology as the locomotive of Russia's scientific and technological development strategy.[37] Nanotechnology was thought to have the potential to make a great impact on the Russian economy, its industry, society and defence but there were obstacles to successfully developing such technology. The main problem identified in 2007 was the gap between the need for high quality research and development and the critically low level of infrastructure development in the nanotechnology industry. This prevented Russia from becoming a competitor in the growing global nano-industries, according to a Federal Target Programme

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[36] Obraztsov (2008) ''My gotovy k novoi revoliutsii. Nanotekhnologicheskoi' ['We are prepared for a new revolution. A nanotechnology revolution]', *Izvestiia*, on the Internet: http://mon.gov.ru/ruk/ministr/int/4502 (published: 8 February 2008; retrieved: 21 June 2010).

[37] President of Russia (2007b) 'Poslanie Federalnomu Sobraniiu Rossiiskoi Federatsii [Address to the Federal Assembly]', on the Internet: http://www.kremlin.ru/appears/2007/04/26/1156_type63372type82634_125401.shtml (published: 26 April 2007; retrieved: 11 May 2007).

(FTP)[38] for the sector,[39] and called for government initiatives to develop the nano-industry in general and its infrastructure in particular.

This chapter outlines the political and institutional developments in the nanotechnology field in Russia. It describes the major government initiatives and provides an overview of the main Russian nanotechnology institutions.

3.1 Government initiatives

In 2007, the Russian government erupted in a flurry of activity in the nanotechnology sphere. Putin presented a strategy for the development of the nano-industries on 24 April 2007,[40] two days before the address to the Federal Assembly. The strategy was to be realised through a series of FTPs,[41] among which was one specifically dedicated to the development of nanotechnology and the creation of new government bodies. It created a governmental

[38] Federal Target Programmes are among the main instruments for implementing government policy regarding the long-term development of Russia's economy and society. An FTP coordinates activities in a particular field and can consist of several sub-programmes. Since 2006, the Russian Federation has had six to nine parallel FTPs running. For general official information (in Russian) on FTPs, see http://www.programs-gov.ru/. For particular official information (in Russian) on current and past programmes, see http://fcp.economy.gov.ru/cgi-bin/cis/fcp.cgi/Fcp/Title/1/2010.

[39] RF Government (2007a) *Federalnaia Tselevaia Programma 'Razvitie infrastruktury nanoindustrii v Rossiiskoi Federatsii na 2008–2010 gody'* [Federal Target Programme 'Development of the nano-industry infrastructure in the Russian Federation in the years 2008–2010'], RF Government administration, p. 6.

[40] President of Russia (2007c) *Strategiia razvitiia nanoindustrii* [Strategy for the development of the nano-industry], Pr-688 24.04.2007, RF Presidential Administration.

[41] The other FTPs supporting the realisation of the strategy for nano-industry development were Research and Development in the Prioritized Directions for the Development of the Russian Scientific-Technological Complex in the Years 2007–2012 and The National Technological Base for the years 2007–2011. Additional supporting programmes were the Federal Space Programme for 2006–2015, the State Armament Programme for 2007–2015, the Federal State Programme for Development of the Defence-Industrial Complex of the Russian Federation for 2006–2010, the specialised programme for the Russian Academy of Sciences and the Russian Academy of Sciences in Medicine and the programme of the Russian Fund for fundamental research; RF Government (2008) 'Press-Reliz 16.01.2008 15:00', *RF Government Administration* (retrieved: 29 February 2008).

supervisory body as well as a state corporation for nanotechnology.[42] In late December 2007, the government also approved a Programme for the Development of the Russian Nano-Industry.[43]

Some earlier government initiatives had been taken in the nanotechnology field, but these had received little attention from the media or government officials. For instance, in October 2004 the Russian government included nanotechnology as an item in the Federal Target Programme on Science and Technology and allocated some RUB 4 billion (approximately USD 150 million) for the years 2005 and 2006.[44]

3.1.1 Government supervision

A Supervisory Council for Nano-industry Development (*Nabliudatelnyi sovet po razvitiiu nanoindustrii*) was created by the Russian government, and the then first deputy Prime Minister responsible for science and innovation, Sergei Ivanov, chaired its first meeting on 21 June 2007.[45] The Supervisory Council consisted of a number of ministers, heads of government agencies and services, and deputies from the State Duma and Federation Council as well as industry leaders.[46]

The role of the Supervisory Council was to coordinate the efforts of federal bodies, industry and research organisations and to make

[42] Prime Minister Vladimir Putin 'V. V. Putin provel soveshanie po voprosy "O realisatsii 'Strategii razvitiia nanoindustrii'" [Putin held meeting on the issue of 'Realisation of the "Strategy of the development of the nano-industry"']'.
[43] RF Government 'Press-Reliz 16.01.2008 15:00'.
[44] Tretyakov (2007) 'Challenges of Nanotechnological Development in Russia and Abroad', *Herald of the Russian Academy of Sciences*, Vol. 77, No. 1, p. 18.
[45] World News Connection (2007a) 'Ivanov Chairs First Nanotechnology Council Session; Plans, Funding Outlined' *World News Connection* (published: 25 June 2007; retrieved: 15 September 2007).
[46] Rossiiskaya Gazeta (2007) 'Ekonomika pod mikroskopom [Economy under the microscope]' *Rossiiskaya Gazeta*, on the Internet: http://www.rg.ru/2007/06/22/nano.html (published: 22 June 2007; retrieved: 2 November 2007).

proposals on how to realise government policy in the field of nanotechnology. The council met three times in 2007, to agree its internal rules and the composition of working groups and review its main tasks.[47] The Supervisory Council did not, however, have a visible impact on the development of Russian nanotechnology and was superseded by the Government Commission on High Technology and Innovation (*Pravitelstvennoi komissii po vysokim technologiiam i innovatsiiam*), to which many of the members of the Supervisory Council were appointed. The Commission was initially headed by Ivanov, but Putin later became chair of the Commission with Ivanov as his deputy.

As of 3 March 2010, the Commission consisted of 26 people, including the director of the Kurchatov Institute, Michail V. Kovalchuk, the Minister for science and education, Andrei Fursenko, the Russian Technologies general director, Sergei Chemezov, the president of Russian Railways, Vladimir Yakunin, and Anatolii Chubais, the general director of The Russian Corporation of Nanotechnologies.[48] These men have all appointed to senior management position since Putin first came to power and enjoy a personal relation to Putin.

With Putin as chairman and several of his trusted lieutenants within its ranks, the Commission did not lack political clout. The scientific expertise also seemed to be sufficient in view of the many prominent and respected academics appointed to the Commission. On the face of it, this should provide a sound basis for effective government supervision of Russian high-technology R&D. It remains to be seen if the Commission is for real or merely for show,

[47] RF Government ‘Press-Reliz 16.01.2008 15:00’.

[48] RF Government (2010) ’Pravitelstvennoi komissii po vysokim technologiiam i innovatsiiam [The composition of the Governmental Commission on High Technology and Innovation]’, *RF Government Administration*, No 278-r, on the Internet: http://www.government.ru/media/2010/3/10/28563/file/278.doc (published: 3 March 2010; retrieved: 1 June 2010).

and how much attention it will devote to nanotechnology development.

3.1.2 The Development Programme for Russian Nano-industries

During 2007, the Ministry for science and education formulated a Development Programme for Russian nano-industries to 2015, which was approved by the government on 25 December 2007.[49] The Development Programme was envisaged in the presidential strategy for the development of the nano-industries presented in April 2007. It was planned that a large number of government institutions would participate in implementing the programme. Sergei Ivanov supervised the programme. His deputy was Andrei Fursenko, the Minister for science and education. Another deputy, Michail Kovalchuk, the director of the National Research Centre (NRC) at the Kurchatov Institute, was charged with scientific coordination.[50] The Institute is a federal government agency and Kovalchuk had become its director in 2005.[51]

The aim of the Development Programme was to form a competitive sector for R&D in the field of nanotechnology by 2011. This was meant to make it possible for the Russian Federation to achieve scientific-technical parity with the developed nations in the world. By 2011, new nanotechnology products were to have been developed that could be industrially produced within two to three

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[49] RF Government 'Press-Reliz 16.01.2008 15:00'.

[50] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 6.

[51] The Kurchatov Institute became a National Research Centre in 2010 after having had the status of Russian Research Centre since 1991. See official website: http://www.kiae.ru/index.html; and its English version: http://www.kiae.ru/e/engl.html (as of March 2011). Michail Kovalchuk was in 2010 also director of one of the research institutes that form the NRC Kurchatov Institute, the Kurchatov Centre for Syncrotron Radiation and Nanotechnology according to its official website: http://www.kcsr.kiae.ru/main.php (accessed on 27 December 2010)..

years, and an efficient system for their commercialisation established. The ultimate goals were to have laid the foundations for a large-scale increase in the production volumes of new types of nano-industry products by 2015, and to have established Russian companies in the global high technology market.[52]

In order to achieve these objectives, the Development Programme identified four main tasks: to develop a nano-industry infrastructure on a par with that of economically developed nations; to develop efficient mechanisms for providing competent personnel; to create an infrastructure for harmonisation and standardisation; and, finally, to develop mechanisms for the commercialisation of the scientific results of domestic R&D.

The Development Programme enumerated a number of expected results, or indicators, related to the four main tasks.[53] Among these indicators was an increase in the share of equipment and instruments not older than eight years from 25 percent in 2008 to 70 percent in 2015, an increase in the proportion of researchers aged under 40 from 31 percent in 2008 to 50 percent in 2015, and an increase in the proportion of researchers with doctorates from 2.7 percent to 10 percent during the same period.

In addition, Russia's share of articles published in leading international journals was to increase from 0.2 percent to 4 percent over the duration of the Development Programme. The value of Russian nano-industry production was to increase rapidly from RUB 20 billion in 2008 to RUB 900 billion in 2015. The global market share for Russian nano-products was to increase from 0.07 percent in 2008 to 3 percent in 2015. A corresponding increase in

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[52] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 4.

[53] *Ibid*., Appendix 2.

export revenues was also expected, from RUB 4 billion in 2008 to RUB 180 billion in 2015.

The Development Programme had a total budget of RUB 100 394 million, of which more than two-thirds was for dedicated R&D.[54] Some RUB 30 billion was intended for creating a nano-industry infrastructure, and was almost entirely channelled through the FTP for the Development of a Nano-Industry Infrastructure in the years 2008–2010 (described below). The Development Programme budget was impressive, but its goals were ambitious, as were some of the expected results. By 2010, it seemed unlikely that all the goals and all the expected results would be achieved. Creating an internationally competitive R&D sector for nanotechnology by 2011 had proved difficult, in the light of the lack of qualified personnel and of a nano-research infrastructure. The repercussions of the global financial crisis for the Russian economy in 2009 and 2010 made these undertakings even more difficult.

There had been few, if any, detailed reports on the progress of the Development Programme by 2010. The economic crisis resulted in some of the budget being withheld in 2009 and possibly also in 2010. Since over 40 percent of the total budget allocation was meant to be disbursed in those years, this is likely to have had a serious impact on the programme as a whole – and at the very least on the timetable.

3.1.3 The Federal Target Programme for Nano-development

In September 2006, work started on a FTP for development of the nano-industry infrastructure in the years 2008–2010. In June 2007, Sergei Ivanov warned that insufficient coordination of the FTP threatened to thwart everything achieved in the field and stated

[54] *Ibid*., Appendix 5

that he was prepared to supervise the progress of the work personally.[55] The government finally adopted the FTP on 2 August 2007.[56]

The aim of the programme was the creation of a modern National Nanotechnology Network infrastructure for the development and realisation of the potential of the Russian nano-industry. The Ministry of Science and Education and the Federal Agency for Science and Innovation were to coordinate the FTP, with the participation of the Federal Agencies for Education, Atomic Energy, Industry, Space, Technical Regulations and Metrology as well as the Federal Service for Technical and Export Control.

The National Nanotechnology Network was to consist of the above-mentioned government organisations as well as a number of scientific-educational centres all selected by competition. The lead scientific organisation for the National Nanotechnology Network was to be the NRC Kurchatov Institute.[57] In accordance with the FTP, it was stated to have been chosen in competition with other research organisations, but the reasons for making the Kurchatov Institute the lead scientific organisation were not disclosed. It is, however, one of the largest scientific centres in Russia, in terms of both the number of employees and the scope of research conducted within the centre. Under its banner, a large number of institutes

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[55] AN News (2007) 'Sergei Ivanov gotov kontrolirovat programmu po razvitiio mamo-tekhnologii [Sergei Ivanov prepared to control the nanotechnology development programme]', *AN News*, on the Internet: http://www.annews.ru/news/detail.php?ID=102646 (published: 7 June 2007; retrieved: 13 October 2007.

[56] RF Government *Federalnaia Tselevaia Programma 'Razvitie infrastruktury nanoindustrii v Rossiiskoi Federatsii na 2008–2010 gody'* [Federal Target Programme 'Development of the nano-industry infrastructure in the Russian Federation in the years 2008–2010'].

[57] *Ibid*., p. 10. The Kurchatov Institute was founded on 11 February 1943 and became a Russian Research Centre (also referred to as Scientific Centre) on 21 November 1991. In 2010 it was given the status of National Research Centre; see the official website: http://www.kiae.ru/index32g.html and http://www.kiae.ru/e/engl.html (in English) (as of March 2011).

and research complexes perform research in many areas of modern physics.

As the leading scientific organisation for the National Nanotechnology Network, the NRC Kurchatov Institute coordinated the work in the area of nanotechnology and nanomaterials in Russia. The Kurchatov Institute also became the leading organisation for the FTP in the subfield of nano-biotechnology.[58]

The main tasks set in the FTP were to provide special equipment and instruments, facilitate information sharing within the National Nanotechnology Network and create a regulatory mechanism and guidelines to promote nano-industry production and exports. To these ends, RUB 27.73 billion was allocated for the years 2008–2010. Close to RUB 25 billion was to come from the federal budget, of which 15 billion was to be capital investment.[59] The main part of the allocation, close to RUB 17 billion, was intended for developing an inventory of instruments and special equipment.[60]

Of the RUB 15 billion in capital investment, more than one-third was supposed to go to the Kurchatov Institute. In addition, RUB 4.7 billion was supposed to go to five other research entities organised as federal state unitary enterprises. Thirty-five state research institutes were to split the remaining RUB 5 billion.[61] No monetary resources were allocated to organisations outside the government sphere. The prioritized sub-fields in the nanotechnology field were nano-electronics, nano-engineering, nano-materials (functional nano-materials for energy and space use, and construction and

[58] *Ibid*., Appendix 1.
[59] The main part of the financing was to be channelled through the Federal Agency for Science and Innovation and the Federal Agency for Education. For details, see *Ibid*., Appendix 4.
[60] *Ibid*., Appendix 3.
[61] *Ibid*., Appendix 5.

composite nano-materials), nano-biotechnology and nanotechnology for security systems.

The government expected the FTP to result in the creation of a new generation of nanomaterials and nanotechnology for use in key areas of science and technology, such as energy saving, industrial production, health care and the food industry as well as in national security and defence. Among the expected results was an increase in the share of nano-products supported by the FTP to 75 percent of total domestic production. Furthermore, the government expected that the participants in the FTP to register 80 nano-patents per year. Within the National Nanotechnology Network, the proportion of scientific personnel with a minimum of three years experience of nanotechnology research was expected to be at least 70 percent.

The Russian government had developed a number of key indicators to monitor the realisation of the goals of the FTP.[62] The proportion of organisations with access to the nano-industry infrastructure was expected to increase from 40 percent in 2008 to 90 percent in 2010. Similarly, the proportion of young scientists and specialists in the personnel of participating organisations in the National Nanotechnology Network was to increase from 40 percent in 2008 to 80 percent in 2010. The average age of the scientific and special equipment used by the organisations within the network was to decrease from 12 years in 2008 to five years in 2010. Furthermore, the number of newly created positions for highly qualified workers was expected to increase from 500 in 2008 to 2500 in 2010.

In March 2010, a Ministry of Science and Education meeting assessed progress in accomplishing the aims of the FTP. According to a statement provided to the Ministry Collegium, practically all the means budgeted for had been received in 2008 and the target

[62] *Ibid*., Appendix 2.

indicators were said to have been met in the main. For 2009, the budgeted federal means had been received but some RUB 450 million from extra-budgetary sources had not. Federal money had also been withheld from related areas, due to adjustments in the state budget in the wake of the financial crisis. The FTP set out that 32 scientific educational centres in the field of nanotechnology were to be established by the end of 2010. In 2008 13 such centres had been established, but the budgeted means for 10 more centres planned for 2009 had been withheld and consequently no additional centres had been established.[63]

Nonetheless, according to the official statement referred to above, several of the key target indicators were reached or even surpassed in 2008 and 2009. For instance, the share of young scientists and specialists making up the personnel of organisations participating in the network reached 75 percent in 2009, close to the 80 percent planned for the end of 2010. However, one important indicator was far from fulfilled. The number of newly created positions for highly qualified workers had only increased from 367 in 2008 to 820 in 2009, far from the target of 500 and 1500 new positions, respectively. The 2010 target of 2500 new positions seemed a long way off.[64]

Developments related to the average age of the scientific and special equipment in organisations in the nano network also seemed to be a cause for concern. It was announced that the 2009 target of an average of eight years had been met, but the trend

[63] RF Ministry of Science and Education (2010) 'Spravka po voprosy 'O khode vypolneniia federalnoi tselevoi programmy 'Razvitiie infrastruktury nanoindustrii v Rossiiskoi Federatsii na 2008—2010 gody' i zadachakh na 2010 god' [Statement on the issue of 'The realization of the federal target programme for 'The development of the nanoindustry infrastructure in the Russian Federation in the years 2008 to 2010' and the tasks for year 2010']', *Ministry of Science and Education*, on the Internet: http://mon.gov.ru/files/materials/6782/10.03.03-spravka2.pdf (published: 3 March 2010; retrieved: 18 June 2010)., p. 2.

[64] *Ibid*., p.8–9.

seemed to be moving in the opposite direction. In 2008 the plan had stipulated an average age of 12 years, but the reported average age for that year was five years. Instead of decreasing, the average age was increasing.[65] The target set for this key indicator must be considered rather ambitious. Ageing equipment is a major problem in Russian industry and the continually increasing number of organisations in the network made it more difficult to reach the target of an average age of five years by 2010.

Another objective of the FTP was to increase the number of nanotechnology patents in Russia. However, despite the fact that tens of thousands of consultations with patent officers were reported by specialists from organisations within the network in the latter half of 2009 alone,[66] there was no statement about whether the target of registering 80 nano-patents per year had been met.

According to the notes from a Ministry of Science and Education meeting on the realisation of the FTP, an insufficient energy supply to the *Zelenograd* synchrotron facility near Moscow was a significant problem for the realisation of the FTP in 2009.[67] An even bigger problem, however, was the withholding of more than 15 percent of the federal budget in 2009.[68] In July 2009, the Ministry of Science and Education announced that the FTP would be extended to the end of 2011, to allow all the centres planned in the National Nanotechnology Network to be established.[69] The reductions in funding in 2009 and 2010 meant that important parts of the

[65] *Ibid*., p. 9.
[66] *Ibid*., p. 6.
[67] *Ibid*., p. 11. A synchrotron facility is central to research into new materials, as it can shed light on the structure and electronic properties of materials at the micro and nano scales.
[68] *Ibid*., p. 12.
[69] Vzgliad Gazeta (2009) 'FTsP po razvitiio nanoindustrii budet prodlena na 2011 god [The FTP on nanoindustry development it to be prolonged to the year 2011]', *Vzgliad Gazeta*, on the Internet: http://www.vz.ru/news/2009/7/29/312587.html (published: 29 July 2009; retrieved: 1 June 2010).

programme could not be fulfilled as planned, and the decision to prolong the FTP came as no surprise.

According to a statement by the director of the Federal Agency for Science and Innovation, Sergei Mazurenko, made in connection with the extension of the FTP, 14 scientific centres formed the core of the National Nanotechnology Network. Mazurenko stated that 290 scientific organisations, with a turnover of RUB 900 million, used services provided by the network in 2008. He also stated that 49 scientific organisations were part of the FTP.[70] None of the figures presented by Mazureko made it possible to evaluate the expected results or key indicators of the FTP. No details were provided in relation to these.

The entire FTP seems to have been elaborated in less than a year, and its goals for the development of the nano-industry infrastructure in the years 2008–2010 were set rather high. Furthermore, the global economic crisis had a severe impact on the 2009 state budget in Russia, which, in turn, negatively affected the FTP. As 2010 drew to a close, the Russian government needed to decide whether the FTP could reach its goals in 2011, if additional funding was called for or if the FTP should just be allowed to slip into oblivion to be replaced by a new government initiative on the development of Russian nano-industry.

3.1.4 The Russian Corporation of Nanotechnologies

The Russian Corporation of Nanotechnologies (*Gosudarstvennaia Korporatsiia Rossiiskaia korporatsiia nanotekhnologii*)[71] was created in July 2007 by federal law.[72] It is more usually referred to as

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[70] *Ibid*.
[71] The corporation website is found at http://www.rusnano.com/Home.aspx.
[72] Russian Federation (2007) *O Rossiiskoi korporatsii nanoteknologii* [On the Russian Nanotechnology Corporation], Federal Law No 189-F3, Russian Federation.

RUSNANO.[73] The company is controlled by a supervisory board and a Director General.[74] Anatoli Chubais was appointed Director General of RUSNANO in September 2008, after his predecessor, Leonid Melamed, left the post.[75]

The corporation was created as a government agency and, according to its founding instrument, was intended to work to develop government policy and an innovative infrastructure in nanotechnology. It was also tasked with implementing projects designed to establish long-term nanotechnology and nano-industries. The company was created in the form of a non-commercial state organisation, but was exempted from the ordinary means of control of non-commercial state organisations in Russia. RUSNANO was also exempted from the legal rules concerning bankruptcy.[76] RUSNANO may be a temporary solution. According to President Dmitrii Medvedev, RUSNANO – like all other state corporations – was created for a limited period and will either be privatised or abolished after this period.[77]

According to its 2008 long-term strategy, the mission of RUSNANO was to develop state policy in the field of nanotechnology, with the object of placing Russia among the world leaders in the field. This was to be accomplished by gaining a leading position in the global nanotechnology products market, receiving recognition in

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[73] Initially it was called Rusnanotekh and in Russian it is called ROSNANO.

[74] For some additional information on RUSNANO's management, see Appendix B.

[75] Leonid Melamed was released from his post by Presidential Decree 1400 as of 22 September 2009, and Anatolii Chubais was appointed General Director by Presidential Decree 1401 of the same date.

[76] RBK (2008) 'Rosnanotekh ozhidaet vyruchki v 5 mlrd rub. [RUSNANO is expecting dividends of 5 bln Rubles]', *RBK*, on the Internet: http://mon.gov.ru/press/smi/4495 (reposted by RF Ministry of Science and Education) (published: 5 February 2008; retrieved: 1 June 2010). Another peculiarity of the company is that when RUSNANO was created a large share of the funding came from the money received by the state from an auction of stocks and shares in the expropriated oil giant YUKOS.

[77] Financial Times (2008) 'FT interview: Dmitry Medvedev', *Financial Times*, on the Internet: www.ft.com (retrieved: 25 March 2008, reposted on Johnson's Russia List #62 2008).

international nanotechnology circles and substantially contributing to global science and knowledge in the field. The main tasks defined in its strategy to 2020 are the commercialisation of the products of nano-industries and the coordination of innovation activity in the nano-industry sphere.[78]

RUSNANO was intended to become the fundamental institute for developing innovation processes in the field of nanotechnology.[79] As neither nanotechnology industry nor nanoscience was particularly developed in Russia when the company came into being, the main focus for RUSNANO was to develop nanotechnology infrastructure and to provide scientific forecasting, roadmaps, standardisation and certification documents. RUSNANO also arranged the annual International Nanotechnology Forum (*Mezhdunarodnyi forum po nanotekhnologiiam*)[80] in Moscow from 2008.

The main instrument for achieving the tasks envisaged in the long-term strategy was investment projects.[81] In late 2007, RUSNANO reported that the company planned to make investments totalling RUB 217.5 billion in the period 2008–2015. Of this, RUB 34 billion was to come from sales revenues and RUB 53.5 billion from investments with extra-budgetary means. Of the RUB 130 billion government investment, some 70 percent was dedicated to

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[78] RUSNANO Supervisory Board (2008) Strategiia deiatelnosti gosudarstvennoi korporatsii ‘Rossiiskaia korporatsiia nanotekhnologii’ do 2020 goda [Strategy for the affairs of the state corporation 'Russian nanotechnology corporation' up to year 2020], Protocol of 29 May 2008 (part I), *RUSNANO*, pp. 3–4.
[79] *Ibid*., p. 5.
[80] For more information on the International Nanotechnology Forum, see the official website: http://www.rusnanoforum.ru/Home.aspx.
[81] RUSNANO Supervisory Board (2008) Strategiia deiatelnosti gosudarstvennoi korporatsii ‘Rossiiskaia korporatsiia nanotekhnologii’ do 2020 goda [Strategy for the affairs of the state corporation 'Russian nanotechnology corporation' up to year 2020], p. 6.

developing nano-industry production and creating a market for nano-products.[82]

According to the RUSNANO strategy to 2020, expected results in the short term (2008–2010) were the formation of a competitive R&D sector in the field of nanotechnology and of an efficient system for the commercialisation of intellectual property. In the medium term (2008–2015), RUSNANO hoped to create the conditions for large-scale growth in the volume of nano-industry products as well as access for specialised Russian companies to the world market in high-technology. The long-term aim (2008–2025) was the creation of a new technological base for the Russian economy.[83]

The aims of the RUSNANO strategy to 2020 were ambitious and appeared unrealistic even before the global financial crisis hit Russia. According to the strategy, the main indicators for assessing the achievement of the goals set for the company to 2015 were: the volume of Russian nano-industry products manufactured as a result of projects with RUSNANO participation was to correspond to a value of RUB 300 billion by 2015; and that domestic RUSNANO-supported nanotechnology production should have a 1 percent share of the global high technology market.[84]

In September 2010, Chubais gave the government a progress report on RUSNANO’s first three years and its strategy to 2015.[85] Chubais

[82] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], Appendix 6.

[83] RUSNANO Supervisory Board ‘Strategiia deiatelnosti gosudarstvennoi korporatsii ‘Rossiiskaia korporatsiia nanotekhnologii’ do 2020 goda [Strategy for the affairs of the state corporation 'Russian nanotechnology corporation' up to year 2020]’, p. 11.

[84] *Ibid*., p. 12.

[85] Chubais (2010) ’ROSNANO: Itogi trekh let i strategiia do 2015 goda [RUSNANO: Results of three years and strategy up to year 2015]’, *ROSNANO*, on the Internet: http://www.rusnano.com/Document.aspx/Download/27919 (published: 10 September 2010 ; retrieved: 15 September 2010).

stated that from 1 April 2008 to 1 September 2010 the company had received a total of 1758 applications for the financing of nanotechnology projects. Of these, 1037 applications had been turned down, 308 were under initial consideration and 320 were under final consideration. The number of nanotechnology projects initiated was still rather small in September 2010, as only 93 applications had been granted financing by the Supervisory Board. Of the 93 approved investment projects, 82 were related to nanotechnology production and 11 were infrastructure projects. The three most popular subfields for the approved investment projects were: nano-materials, 31 projects; nano-photonics, 15 projects; and nano-medicine, 14 projects. In addition, 31 nanotechnology education projects had been granted financing.[86]

Among the projects financed by RUSNANO was a technology transfer project with a Chinese company, Thunder Sky Group. Large-scale production of lithium-ion batteries for cars and buses was to be established in Russia. The share of the world market for electric vehicle batteries in 2012 was to be 22 percent in 2012, decreasing to 17 percent by 2014. Another project aimed to produce next-generation laser receivers/emitters for optical fibre communications. Russia's share of the world market for these products was expected to grow from 2.5 percent in 2012 to 18 percent in 2015.[87] It is difficult to assess the feasibility of these projections, but the expected high rates of growth in world market shares are striking.

One target was that the total value of nanotechnology products manufactured annually in Russia would exceed RUB 900 billion by 2015. One-third of this volume was to be from projects with

[86] *Ibid*., pp. 4–5.
[87] *Ibid*., pp. 15 and 21.

RUSNANO's participation.[88] Russia's share of the world nanotechnology market was expected to grow from 0.07 percent in 2008 to 3 percent in 2015.[89] It is doubtful whether Russia will manage to reach this share in the light of its weak starting point and the fierce competition from other countries.

In his 2010 report to the government, Chubais discussed the future of RUSNANO. He suggested that RUSNANO should be split after 2011, reorganising it into a joint-stock company and a non-commercial fund. The former would focus on investment projects for manufacturing nano-products, while the latter would handle investment in infrastructure and education.[90]

3.2 Russian nanotechnology institutions

In information distributed at a government meeting in January 2008, it was stated that 150 scientific organisations with a total of some 20 000 researchers were involved in Russia in fundamental nanotechnology R&D. According to a press release from the meeting, some 75 organisations manufacturing nano-industry products had a turnover of RUB 7 billion per year.[91] According to a statement by Prime Minister Vladimir Putin, almost 1000 enterprises were active in the nano-industry sector in August 2009.[92]

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[88] As expressed in the RUSNANO 2008 strategy; RUSNANO Supervisory Board 'Strategiia deiatelnosti gosudarstvennoi korporatsii 'Rossiiskaia korporatsiia nanotekhnologii' do 2020 goda [Strategy for the affairs of the state corporation 'Russian nanotechnology corporation' up to year 2020]', p. 12.

[89] Chubais 'ROSNANO: Itogi trekh let i strategiia do 2015 goda [RUSNANO: Results of three years and strategy up to year 2015]' pp. 2–3.

[90] *Ibid*., p. 26.

[91] RF Government 'Press-Reliz 16.01.2008 15:00'

[92] Prime Minister Vladimir Putin 'V. V. Putin provel soveshanie po voprosy 'O realisatsii "Strategii razvitiia nanoindustrii"' [Putin held meeting on the issue of 'Realisation of the "Strategy of the development of the nano-industry"']'.

In 2010, the leading organisation in nanotechnology research – as well as in other fields of science – was the Russian Academy of Sciences (*Rossiiskaia Akademiia Nauk*, RAN). In 2006, RAN was responsible for the majority of nanotechnology research papers published by Russian institutions.[93] Another beacon, of course, was RUSNANO. A third central actor in Russian nanotechnology seems to be the National Research Centre, Kurchatov Institute. Alongside it, some 40 nanotechnology research institutions were enumerated in the above-mentioned FTP for the development of nano-industry infrastructure.[94]

The top five institutions in budgetary terms in the FTP, apart from the NRC Kurchatov Institute, were: the Federal State Unitary Enterprise (*Federalnoe Gosudarstvennoe Unitarnoe Predpriiatie*, FGUP) Central Science-Research Institute for Construction Materials 'Prometei'; the FGUP Central Science-Research Institute for Chemistry and Mechanics; the FGUP F.V. Lukin Science-Research Institute for Physical Problems (the home of the 'Zelenograd' synchrotron facility); the FGUP Keldysh Research Centre; and the FGUP A. A. Bochvar All-Russian Science-Research Institute for Non-Organic Materials. Apart from Prometei, which is based in St Petersburg, all these institutions are located in Moscow.

Apart from the Academy of Sciences, major Russian nanotechnology institutions are hard to find on the international arena. Nanoforum is a nanotechnology database that focuses on European countries (www.nanoforum.org). Nanoforum is an Internet gateway financed by the European Commission, which in June 2010 comprised 2502 registered organisations. More than half of these organisations (1295) were based in Germany, while the

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[93] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 52.

[94] See RF Government *Federalnaia Tselevaia Programma 'Razvitie infrastruktury nanoindustrii v Rossiiskoi Federatsii na 2008–2010 gody'* [Federal Target Programme 'Development of the nano-industry infrastructure in the Russian Federation in the years 2008–2010'], Appendix 5.

United Kingdom had 180 entries – more than 1000 fewer. France came third with 138 organisations registered. Three of the total 2,502 entries were Russian: the private company NT-MDT Co., specialising in nanotools; and two Russian universities – St Petersburg Electro-technical University (International Projects Department) and Tomsk State University (Innovate-Technological Scientific-Educational Centre).[95]

The database is first and foremost related to European Union projects, such as the Framework Programmes (FP), which explains the limited Russian participation. Poland had 25 entries in June 2010, but the number of entries for Russia and Poland had not substantially increased since 2005, while Germany had almost doubled its number of registered organisations in the same period.[96] However, the number of entries for France and the United Kingdom did not substantially increase between 2008 and 2010, suggesting that Nanoforum is of interest mainly to Germany. Nonetheless, it is useful to take a closer look at the Russian organisations in this network, as European countries in general and Germany in particular can be regarded as potential partners in the field of nanotechnology.

According to the information provided to Nanoforum, NT-MDT has been creating equipment for nanotechnology research since 1992. The range of products includes probe nano-laboratories (NTEGRA) and modular nano-factories (NANOFAB) for processing and quality assurance of micro- and nano-electronic devices. The company stated that it sold its products in 52 countries and had installed more than 1600 devices in scientific institutions

[95] The list over Russian organisation contains four posts, but the St Petersburg Electrotechnical_University (International Projects Department) was for some reason listed twice.
[96] See Hullmann *The economic development of nanotechnology*, Figure 14, p.21.

and universities in most of the Asian and European countries as well as Israel, the USA and Russia.[97]

The St Petersburg Electro-technical University (ETU 'LETI') describes itself as a leading Russian university that has been successfully collaborating on European projects since FP4 (1996). The University's research teams were in 2010 involved in two projects within FP7 (CP NANOINTERFACE, CSA ICPCNanoNet), two projects within FP6 NMP thematic priority (NoE METAMORHOSE, STREP NANOSTAR), six projects with the International Science and Technology Centre and three projects with INTAS.[98]

Finally, the Tomsk State University (Innovation-Technological Scientific-Educational Centre) stated that it develops technologies for processing submicronic and nanopowders of metals, organic and inorganic compounds. According to the information on Nanoforum, its basic areas of activity are the production of powders in the micrometer, submicronic and nanometer particle's size range and the production of refractory compounds (nitrides, carbides) by self-propagating high-temperature synthesis.[99]

3.3 Conclusions on nanotechnology in Russia

Nanotechnology took off comparatively late in Russia. It was only in 2007 that the government launched a comprehensive effort in the field. Several government programmes were approved and a state-

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[97] www.nanoforum.org, as of June 2010; see also the NT-MDT official webpage: http://www.ntmdt.com/.

[98] www.nanoforum.org, as of June 2010; see also the official webpage: http://www.eltech.ru/english/. The research areas included: metamaterials, nanostructured oxides materials, nanostructured membranes, ferroelectrics multi-component structures, ferroelectric microwave tunable components, fractal structures, nanocomposits, sol-gel processing, nanobiotechnology diagnostics, fullerenes.

[99] www.nanoforum.org, as of June 2010 (however not updated since at least March 2008).

owned nanotechnology corporation, RUSNANO, was founded. Nanotechnology had been the object of government attention since at least 2004, but the measures taken in 2007 seem to have been developed in a rather short time – in some cases less than a year.

Russia's ambitions were high. In less than a decade, Russia was to become a nanotechnology nation to be reckoned with and nanotechnology would make a sizeable contribution to the Russian economy. Substantial sums were devoted to the effort. Over RUB 100, 000 million was allocated in an overarching government development programme up to 2015. It is doubtful, however, whether the targets set can be met within the timeframe even if the programmes are fully funded according to plan.

In 2010, the principal actors in the field of nanotechnology in Russia were state institutions. The Russian Academy of Science (RAN) was the dominant actor in nanoscience and nanotechnology research, as it is in most other scientific fields. The RUSNANO state corporation was spearheading nanotechnology innovation and commercialisation. The Kurchatov Institute is the third major player, which was given a central role in nanotechnology R&D. The only private nanotechnology institution that seemed to enjoy a strong standing in 2010 was NT-MDT, a company which specialises in instrumentation for nanotechnology development.

In this context, it should be noted that one option for Russia could be to rely on an institutional collaboration with the EU on R&D and innovation. [100] Close cooperation with leading nanotechnology countries such as Germany and France could stimulate Russian nanotechnology development. Cooperation in this field has so far been considered a success from a policy perspective but, as in many

[100] For an overview of Russian Federation collaboration with the EU on R&D, including nanotechnology R&D, see Roffey (2010) *Biotechnology in Russia: Why is it not a success story?*, Stockholm, The Swedish Defence Research Agency (FOI), April 2010, pp. 39–44.

other fields, it remains to be seen whether practical results will match expectations.

The main direction of Russia's nanotechnology efforts has been to develop the domestic infrastructure, and this will probably remain a major theme in the coming decade. One-third of the RUB 100, 000 million allocated to the Development Programme for the Nano-Industry was devoted to developing the industry's infrastructure. The remaining two-thirds has been dedicated to R&D, but a large part of that will probably have to be invested in research infrastructure.

4 Investments in nanoscience and nanotechnology

> This [nanotechnology] is the area of activity where the state will spare no money.
>
> *President Vladimir Putin, July 2007*[101]

Investment in research and development (R&D) can be a useful indicator of a country's efforts in a scientific field. The volume of spending in a particular field of science is an important indicator on R&D performance. It should however be kept in mind that the correlation between dedicated funding and the emergence of new products is not necessarily strong. Research spending is nevertheless of interest to measure, not least because low levels of investment make progress less likely.

In the following we will try to assess the Russian effort in the field of nanotechnology from the aspect of investments. How does Russia compare with other countries on government and corporate spending on nanotechnology? Where does the funding go? What were the effects of the global economic crisis on nanotechnology spending in Russia? This chapter describes public investment in the field of nanotechnology and estimates the level of private funding.

Nanotechnology is a very young research field in investment terms. The US National Nanotechnology Initiative (NNI), which was launched by former president Bill Clinton and started work in 2001, became something of a starting point in the global race for major nanotechnology research programmes. According to a US research company, USD 12.4 billion was invested in nanotechnology R&D

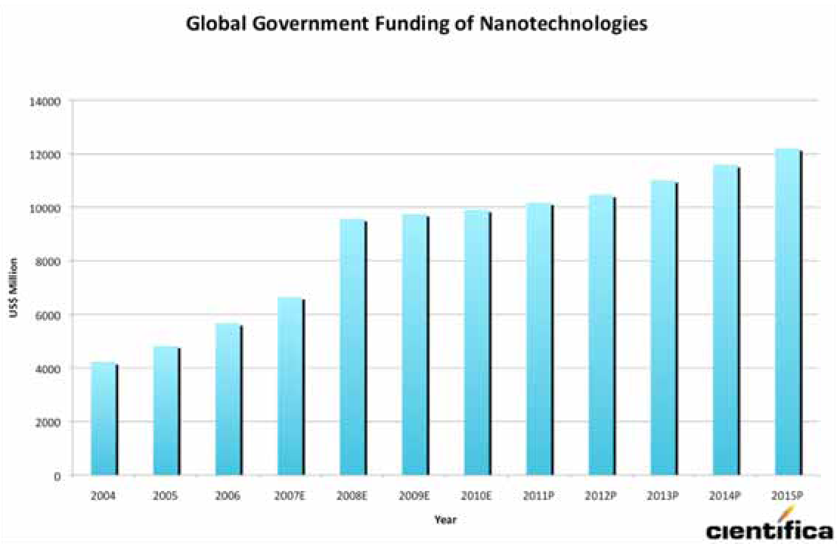
[101] World News Connection 'Russian Govt to Invest over Rbl 4 Bln in Nanotechnologies in 2007'.

worldwide in 2006, of which government spending amounted to USD 6.4 billion, up from USD 5.9 billion in 2005.[102]

4.1 Government spending

From 2004 to 2008, governments worldwide invested nearly USD 40 billion in nanotechnology research. Annual spending had increased from some USD 2 billion in 2004 to an estimated USD 9.75 billion in 2009. However, according to an analysis by the European research analysis company Cientifica, the annual rate of growth in funding is expected to slow considerably in the coming years due to a repositioning of nanotechnology from a pure research discipline to an applied one (see Figure 4.1).[103]

Figure 4.1. Evolution of Global Nanotechnology Funding, 2004-2015



Source: Cientifica (2009) *Nanotechnology takes a Deep Breath ... and Prepares to Save the World!*, Cientifica Ltd, April 2009.

[102] Business Wire 'Top Nations in Nanotech see their Lead Erode'
[103] Cientifica (2009) *Nanotechnology takes a Deep Breath ... and Prepares to Save the World!*, Cientifica Ltd, April 2009, p. 2–3.

In 2006 the undisputed world leader in government spending on nanotechnology was the USA, which allocated USD 1.78 billion from federal and state funds, followed by Japan (USD 975 million) and Germany (USD 563 million). However, when the investment levels were adjusted for purchasing power parity (PPP), China ranked second, with government funding levels equivalent to USD 906 million in 2006.[104]

In Europe, the European Commission was the largest single funding organisation of nanotechnology research between 2004 and 2006, investing an estimated EUR 1.3 billion in projects under the Sixth European Framework Programme for Research and Technological Development (FP6).[105] Under the Seventh Framework Programme (FP7), EUR 3.5 billion was dedicated to nanoscience, nanotechnologies, materials and new production technologies in the period 2007 to 2013.[106] However, the EU member states together accounted for a much larger share of public expenditure on nano research than the Commission. Furthermore, the Commission and the member states together were on an equal footing with the USA regarding public funding of nanotechnology in 2005, spending well over EUR 1500 million.[107]

According to Cientifica, however, the landscape of global government funding is changing:

> In 2004 the three major economic regions, the EU, Japan and the United States, who together made up 85% of global R&D spending, dominated government funding. By 2009 this has shrunk to 58% of global spend,

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[104] Business Wire 'Top Nations in Nanotech See Their Lead Erode', reporting on a 2007 report entitled *Profiting from International Nanotechnology* by Lux Research.
[105] Hullmann *The economic development of nanotechnology*, p. 14.
[106] European Commission (2007) 'Seventh Framework Programme (FP7) Nanosciences, nanotechnologies, materials & new production technologies (NMP)', *European Commission*, on the Internet: http://cordis.europa.eu/fp7/cooperation/nanotechnology_en.html (published: 8 August 2007; retrieved: 21 June 2010).
[107] Hullmann *The economic development of nanotechnology*, pp. 14–15.

> and is predicted to shrink still further (though not in dollar terms) reflecting the emergence of countries such as China and Russia as major nanotechnology players.[108]

This raises the question of government spending on nanotechnology in Russia. [109] After a largely lost decade after the break-up of the Soviet Union, nanotechnology research began to develop in Russia in the early 2000s. In 2002, a Scientific Council for Nanomaterials was founded at the RAN Presidium. In the same year, the RAN basic research programme allocated funding for nanotechnology research. These funds were rather limited, but were complemented by nanotechnology research programmes funded by the Russian Foundation for Basic Research, the Ministry of Defence, the Ministry of Atomic Energy, the Federal Space Agency and the Ministry for Industry and Energy. Together, the funding was estimated to have totalled USD 20–25 million per year, 30 times smaller than the level of US federal funding.[110]

In 2004, nanotechnology research was further strengthened in Russia by the inclusion of nanosystems and nanomaterials in the Federal Target Programme (FTP) on science and technology (S&T). In 2005, some USD 70 million was allocated and in 2006 roughly USD 80 million was provided for nanotechnology research by the programme.[111] When the Russian nanotechnology effort was initiated in 2007, the original plan was to invest RUB 4.2 billion in nanotechnology research and development in that year.[112] Another RUB 6 billion was to be allocated for nano-industry development in

[108] Cientifica *Nanotechnology takes a Deep Breath ... and Prepares to Save the World!*, p. 5.
[109] For an overview of Russian R&D funding with public means in general, see Roffey *Biotechnology in Russia: Why is it not a success story?*, pp. 52–3.
[110] Tretyakov 'Challenges of Nanotechnological Development in Russia and Abroad', , p. 18.
[111] *Idem*.
[112] World News Connection 'Russian Govt To Invest Over Rbl 4 Bln In Nanotechnologies In 2007'.

2007.[113] However, government investment increased rapidly as the federal programmes got under way.

The Development Programme for Nano-Industry in the Russian Federation to the Year 2015 envisaged total investment of RUB 100,394 million in the period 2008 to 2015. This massive level of spending was to be concentrated in the first half of the period – three-quarters of the investment was to be made in 2008–2011, leaving only roughly RUB 25 billion for the last four years of the programme.[114] However, the share of extra-budgetary funding was expected to increase from 28 percent in 2008 to 53 percent in 2015.[115] The consequences of the global financial crisis of 2008 on the spending plans are unknown, but the contraction of the Russian economy probably had a negative effect on both budgetary and extra-budgetary funding.

The FTP for the Development of Russia's Nano-Industry Infrastructure was included in the total budget of the Development Programme. In the FTP, RUB 27.733 billion was allocated for the years 2008–2010, of which 15 billion was to be for capital investment.[116] When the programme was extended to 2011, RUB 5 billion was allocated for the extra year. However, this provided no additional funding as the sum was equal to the money cut from the

[113] World News Connection 'Ivanov Chairs First Nanotechnology Council Session; Plans, Funding Outlined'.

[114] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], Appendix 5.

[115] *Ibid*., Appendix 2.

[116] The main part of the financing was to be channelled through the Federal Agency for Science and Innovation and the Federal Agency for Education. For details, see RF *Government Federalnaia Tselevaia Programma 'Razvitie infrastruktury nanoindustrii v Rossiiskoi Federatsii na 2008–2010 gody'* [Federal Target Programme 'Development of the nano-industry infrastructure in the Russian Federation in the years 2008–2010'], Appendix 4.

federal budget in 2009 and 2010.[117] In real terms, this meant a reduction in the overall budget for the FTP, since running expenses and inflation in the additional year were not covered. This indicates that the nanotechnology FTP – and probably other FTPs and the Development Programme – were affected by the economic crisis.

In addition to the investments made within the FTP for the Development of the Nano-Industry, some RUB 16 billion was allocated in the FTP for 'Research and Development in the Prioritized Directions for the Development of the Russian Scientific-Technological Complex in the Years 2007–2012'. This sum was roughly one-third of the entire budget of the FTP for the period. Total government investment in nanotechnology R&D through federal and government programmes – not including the FTP for the Development of the Nano-Industry – was planned to reach RUB 10 billion in 2008 and RUB 12 billion in 2009.[118] These investment plans may also have been adversely affected by the economic crisis in Russia.

When RUSNANO was founded in 2007,[119] the government provided RUB 130 billion from the Russian stabilisation fund to capitalise it. [120] In late 2007, RUSNANO reported plans for total investments of RUB 217.5 billion in the period 2008–2015. Of that sum, RUB 130 billion was government investment, RUB 34 billion was to come from company sales revenues and the remaining

[117] RIA Novosti (2009) 'Finansirovanie FTsP po nanoindustii v 2011 godu sostavit 5 mldr rub - Fursenko [Financing of the FTP on nano-industry for year 2011 comprise 5 bln Rubles - Fursenko]', *RIA Novosti News Agency* (republished by RF Ministry of Science and Education), on the Internet: http://mon.gov.ru/press/smi/5606/ (published: 19 August 2009; retrieved: 21 June 2010).

[118] RF Government 'Press-Reliz 16.01.2008 15:00'

[119] Prime Minister Viktor Zubkov (2008) 'Vystuplenie V. Zubkova na zasedanii Pravitelstva 17.01.2008 [Speech by V. Zubkov at the government meeting]', *RF Government Administration*, on the Internet: http://www.government.ru/government/governmentactivity/mainnews/archive/2008/01/17/8304713.htm (published: 17 January 2008; retrieved: 13 March 2008).

[120] Financial Times (2007) 'Russia torn over how to invest its oil riches', *Financial Times*, on the Internet: www.ft.com (published: 18 September 2007; retrieved: 12 October 2007).

RUB 53.5 billion was to come from investments using extra-budgetary means.[121]

In September 2010, Director General Chubais reported that RUSNANO planned to invest a total of RUB 123 billion of its own capital in the 93 nanotechnology projects granted investment at that time. In addition, RUSNANO had attracted RUB 179 billion from co-investors, bringing the total planned investment to RUB 302 billion. The period in which these investments were to be spread over was not stated, but it is likely that the sums announced were for investments up to 2015. This would mean that the planned investment volume had significantly increased on that of 2007.[122]

The investments in RUSNANO co-financed nanotechnology projects does not seem to have been affected by the aftermath of the 2008–09 global financial crisis, at least not in the short term. In 2008–10 RUSNANO exceeded the expected total volume of investment by over 40 percent and managed to attract co-investors (see Table 4.1). The company and its co-investors invested almost one-third of the total planned RUB 302 billion despite the financial crisis.

[121] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], Appendix 6.
[122] Chubais ’RUSNANO: Results of three years and strategy up to year 2015’, p. 6.

Table 4.1. Investment in RUSNANO nanotechnology projects, 2008–10 (RUB millions)

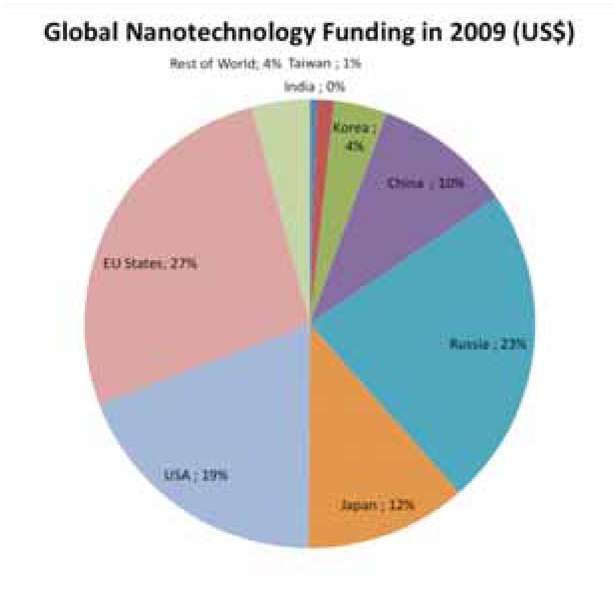
Investments	Planned	Actual (estimated)
RUSNANO investment in production projects	45	61.6
Co-investors financing of production projects	9.5	24.6
Investments in infrastructure and education projects	11.5	7.8
Total investments	**66**	**94**

Source: Chubais, Anatolii (2010) 'ROSNANO: Itogi trekh let i strategiia do 2015 goda [RUSNANO: Results of three years and strategy up to year 2015]', ROSNANO, on the Internet: http://www.rusnano.com/Document.aspx/Download/27919 (published 10 September 2010, retrieved 15 September 2010), pp. 7–8.

In October 2009, President Dmitrii Medvedev claimed that Russia had the largest government investment programme in the world in the area of nanotechnology. He stated that in the period to 2015 the Russian government would allocate RUB 318 billion.[123] President Medvedev's statement seems to be supported by a comparison of global nanotechnology funding by Cientifica. An estimate of global nanotechnology funding in 2009 showed Russia in second place after the funding of the 27 EU member states and the European Commission is combined. The Russian share of global public nanotechnology funding was 20 percent, one percent ahead of the USA. Japan and China trailed behind with 12 percent and 10 percent shares, respectively (see Figure 4.2.).

[123] President of Russia 'Vystupleniie na otkritii II Mezhdunarodnogo foruma po nanotekhnologiiam [Speech at the opening of the 2nd International Nanotechnology Forum]'.

Figure 4.2. Share in global nanotechnology funding (2009)

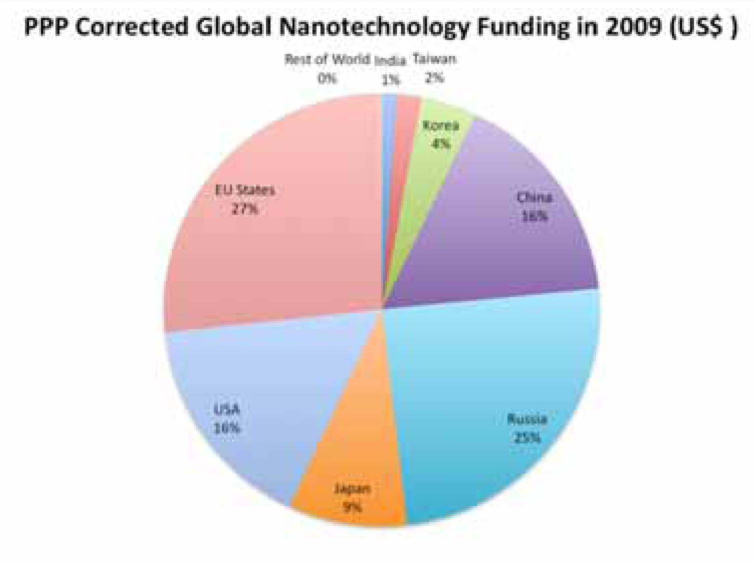


Source: Cientifica *Nanotechnology takes a Deep Breath ... and Prepares to Save the World!*

After these amounts are adjusted for PPP, Russia's position becomes even stronger, representing a quarter of global funding (see Figure 4.3). However, the Chinese share also increases significantly when corrected for PPP.

These figures confirm that Russia had the largest governmental investment programme in the world in the area of nanotechnology in 2009. The EU as a whole had a larger share in both raw funding and when corrected for PPP, but no single country spent more than Russia on nanotechnology in 2009. There are, however, at least two reasons for not being over-optimistic about the outcomes from Russia being a world leader in government spending on nanotechnology.

Figure 4.3. Share in global nanotechnology funding, PPP adjusted



Source: Cientifica *Nanotechnology takes a Deep Breath ... and Prepares to Save the World!*

First, figures on government funding should be considered with caution. Government plans on research spending may be revised and means withheld, as was the case in Russia in the wake of the financial crisis. Even if all the money is allocated to an investment programme, this does not mean that the entire sum is spent. As Cientifica points out in its 2008 Nanotechnology Opportunity Report, academic bickering and bureaucratic tugs-of-war can result in the allocated budget being largely unspent.[124] There are also good reasons for fearing that the selection and management of government financed research projects were hampered by the level of corruption among state officials. Russia is plagued by

[124] Cientifica (2008) *The Nanotechnology Opportunity Report, 3rd edition*, Cientifica Ltd, June 2008, p. 35.

widespread and endemic corruption.[125] In addition, government spending tends to be less effective than private funding when it comes to innovation and commercialisation. According to the 2008 Cientifica report, the value of commercially useful research generated by government funding is only one-tenth of the money actually spent.[126] One reason for this, however, is that government funding often goes to basic research, which is not primarily aiming for commercialisation.

A second reason for caution is that government nanotechnology funding in Russia differed significantly in character from that of countries such as the USA, Germany and Japan.

> Russia and China are ten and five years behind the US respectively, and much of the budget will be going on basic infrastructure such as buildings and equipment rather than on academic brainpower. While China looks impressive, much of the work done in Chinese universities tends to be rather derivative rather than innovative (in marked contrast with the work done by Chinese students in US universities!) and is focused on building up basic knowledge. However give these emerging economies another five years and they may become a real challenge.[127]

A large part of Russia's public nanotechnology funding has so far gone to creating infrastructure and laying the foundations for nanotechnology research. Creating roadmaps and standards, educating personnel and buying machinery and instruments will

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[125] See the Transparency Internationals Corruption Perception Index data in Most of the comparable countries in the Corruption Perception Index (CPI) more or less maintained their position over the years. Poland gained several positions, from 67 in 2004 to 41 in 2010. Brazil and China fell slightly in the rankings, but the number of countries surveyed may have contributed to this. This, however, was not the case for Russia.

Figure 6.1. Transparency International Corruption Perceptions Index, Rankings for selected countries, 2004–10 and Figure 6.2. Transparency International Corruption Perceptions Index scores for selected countries, 2004–10.

[126] Cientifica *The Nanotechnology Opportunity Report, 3rd edition*, p. 36.

[127] *Ibid*., p. 38.

improve the long-term prospects for nanotechnology in Russia, but will not yield any sizeable rewards in the short to medium term.

4.2 Private funding of nano R&D

Private sector funding of nanotechnology research by far outstrips government spending worldwide. Corporations invested USD 5.3 billion in nanotechnology R&D in 2006, an increase of 19 percent on 2005. The USA came top here as well, investing USD 1.93 billion, and Japan was not far behind with USD 1.70 billion (corrected for PPP). Japan was closely followed by China, with an estimated USD 1.65 billion at PPP in corporate spending on nanotechnology R&D – an incredible 68 percent increase on its 2005 total.[128]

In 2006, the global chemical industry alone invested some USD 2.9 billion in nanotechnology research. This was almost three times the amount of US government spending on nano-research in the same year. Furthermore, while global public funding of nanotechnology research was set to increase at a relatively modest pace, corporate spending was already growing rapidly. In 2010, chemical industry funding was expected to grow by 25–30 percent annually up to 2012.[129]

It should be noted that the increase in private sector funding was entirely due to the growth in corporate spending. According to the Cientifica 2008 report, venture capital investment in nanotechnology research dried up as it became obvious that even the most promising nanotechnology products would take a long time to mature.[130] The balance between public and private spending varies greatly in different countries. Europe was far behind in private spending on nanotechnology research in 2005, with only one-third of the total of national funding, while in the

[128] Business Wire 'Top Nations in Nanotech See Their Lead Erode'
[129] Cientifica *The Nanotechnology Opportunity Report, 3rd edition*, p. 34.
[130] *Ibid.*, p. 38.

USA private sources surpassed 50 percent and in Japan they accounted for almost two-thirds of total national spending on nanotechnology research.[131]

It has unfortunately not been possible to assess the amount of private sector funding for nanotechnology research in Russia. No reliable data on private sector corporate spending have been found, which makes it very difficult to draw solid conclusions. There is, however, every reason to assume that funding from public means and spending by state-owned companies outweigh private investment in nanotechnology R&D.

The often challenging business climate for foreign investors in Russia almost certainly hinders the flow of international capital for nanotechnology research into Russia. Huge sums of money would be needed over a long period of time to develop nanotechnology products in Russia. Foreign investors are likely to prefer to invest in countries where their investments are better protected.

4.3 Conclusions

Russia stands out as one the largest investors in nanotechnology research, but this situation is not without its problems. In 2009, the Russian Federation was the world leader in government spending on nanotechnology, in particular in PPP-corrected terms. However, government spending can often be ineffective and Russia is no exception in this regard. Furthermore, investment needs, in particular for scientific and industrial infrastructure, are greater in Russia than in many other countries. It is natural that the government is the main investor under such circumstances, but this means that the outputs of the investment will be substantially less per invested unit than in countries with well developed infrastructure.

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[131] Hullmann *The economic development of nanotechnology*, p.15.

As is mentioned above, there is not sufficient data to assess the volume of private sector investment in nanotechnology in Russia, but the levels of domestic and international private corporate funding are probably lower than the level of government investment, due to the adverse investment climate in Russia. Private capital will also face the same problem of the dilution of funding, as infrastructure development will demand a large share of the investment irrespective of its source. The Russian Federation was probably not among the world leaders in total, government plus private, nanotechnology investment in 2010. More importantly, Russia seemed to be seriously outstripped by nations with a more mature nanotechnology sector when it came to actual research per invested currency unit. It should be noted, however, that given continued heavy investment in nanotechnology infrastructure, future investment will provide more outputs per Rouble spent. The chapters below analyse the outputs of Russian nanotechnology efforts. Chapter 5 uses scientific publications and nanotechnology patents to analyse Russia's research performance.

5 Research in nanoscience and nanotechnology

Our goal is to secure a leading position for Russia
in this new global industry.
Prime Minister Viktor Zubkov, January 2008[132]

Investment in reseach and development (R&D) is one of the main inputs to a country's effort in a technological field and is thus important to measure. However, it is outputs that really matter when assessing the impact on the economy and society. Scientific publications and patent applications are early indicators. The final output is innovative and commercially competitive products, which is the topic of chapter 6 below. This chapter compares Russian research to that of other countries. How well does Russia perform in publications and patenting? What are its strengths and weaknesses? In late 2007, the Russian government lamented the fact that the USA had more than ten times as many nanotechnology research centres as Russia. It also expressed concern that Russia appeared to be far behind the USA in terms of the number of articles on nanotechnology published in scientific journals and of international nanotechnology patents.[133]

In 2010, two Russian scientists, Andre Geim and Konstantin Novoselov, were awarded the Nobel Prize in Physics for groundbreaking experiments on the two-dimensional material graphene. This did not constitute a success for Russian domestic nanotechnology, however, as they had carried out the award winning research at Dutch and British universities. It illustrates one

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[132] Prime Minister Viktor Zubkov 'Vystuplenie V. Zubkova na zasedanii Pravitelstva 17.01.2008 [Speech by V. Zubkov at the government meeting]'.

[133] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 7.

of the main problems that Russia was facing in attempting to stimulate R&D in this and other technology areas.

This chapter assesses Russian research in nanoscience and nanotechnology in comparison with other countries. A country's standing in research can be estimated by the number and quality of scientific articles published in well-established academic publications and the degree of international patenting. A high share of international publications and patents within a scientific field indicates that a country is performing well within that field, while a small share points to the opposite. However, there are problem with basing the assessment of a country's position in international science on such data. Almost all well-established academic publications are in English, which gives preference to English-speaking researchers. Furthermore, in some parts of the world the thresholds for patenting scientific discoveries are very low, whereas in other parts it is not customary.

Russia has long been at disadvantage both regarding research language and patenting traditions. This has to be acknowledged, but does not hinder an assessment of Russia's standing as a nanoscience nation. Patenting and publications is still a viable measure in a high-technology field such as nanotechnology. Furthermore, international collaboration and cross-border knowledge flows are also highly important for the development of domestic science in this field. International academic publications and patenting provides reliable data on cross-border cooperation.

In the following, quantitative and qualitative aspects of scientific publication will be addressed (section 5.2) followed by a discussion of patenting (section 5.3). International collaboration is discussed in each of the sections. Both publication and patent activity are discussed in some detail, but at the end of each section the main conclusions are presented. The chapter also ends with some general conclusions on Russian nano research (section 5.4). First of all, however, a brief background in Russian nanoscience is provided in section 5.1.

5.1 Background and historical development

Russia has a long and often successful history of research and development in the natural sciences. [134] Nanotechnology has a much shorter history, but was part of the research programme in the late Soviet era. Soviet scientists were well aware of early foreign nanotechnology research, and they contributed to the scientific understanding of the field. Academician Yurii Tretiakov asserted in a 2007 article that 'many basic studies, without which the development of state-of-the art nanotechnologies would have been unthinkable, were conducted for decades by the scientific schools of Academicians V.A. Kargin, P.A. Rebinder and B.V. Deryagin and Nobel Prizewinner Zh.i. Alferov'.[135]

Tretiakov also highlighted the achievements of Soviet scientists in so-called chemical assembly as well as in ultradispersible nanopowders and materials. However, Russian scientists had reduced their activity in the final decade of the 20th century, due to the upheavals following the collapse of the Soviet Union. The field of nanotechnology was no exception and Russian research was put on the backburner at a time when important breakthroughs were being made in nanotechnology research in Japan and the USA.[136]

Lacking the means to acquire the extremely expensive equipment needed for the visualisation and fabrication of nanotechnology products, the majority of Russian scientists could not contribute to international science. The small number of Russian researchers who collaborated with foreign colleagues were in a better position. Tretiakov noted in 2007 that in 1999 'there was not a single squid

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[134] For an overview of the development of science during the Soviet era and in contemporary Russia, see Roffey *Biotechnology in Russia: Why is it not a success story?*, pp. 17–29.

[135] Tretyakov 'Challenges of Nanotechnological Development in Russia and Abroad', p. 17.

[136] *Idem*.

magnetometer functioning in Moscow and young MSU [Moscow State University] students had to (and still have to) measure their synthesized magnetic nanocomposites in Jena (Germany).'[137] However, basic research in the field of nanotechnology continued throughout the 1990s in several research teams. In 1996, the Institute for Nanotechnologies was established and in 2001 the Nanoindustriia Concern was created. It should also be noted that the NT-MDT nanomeasurement tools, such as scanning probe microscopes, started to gain international recognition. [138]

5.2 Publication activity and research performance

When assessing scientific proficiency on the basis of scientific publications it is important to consider the qualitative as well as the quantitative aspects of publication. Both the number of articles and the number of citations received are thus of interest and are discussed below. Although the primary object of study is national research proficiency, it is important to analyse this in comparison with the scientific outputs of the world leading research institutions. In the end, it is the institutions rather than the countries that perform the research. In order to get an even more detailed picture of scientific proficiency regarding publication activity, the publication trends in the different subfields of nanotechnology were studied. Finally, the degree of international collaboration was also compared.

5.2.1 Quantity: Publication activity

Global nanotechnology research article production has exhibited exponential growth for more than a decade, according to an in-depth study by researchers at the US Office of Naval Research

[137] *Ibid.* , p. 18.
[138] *Idem.*

(ONR).[139] Nano-related publications in the Science Citation Index/Social Science Citation Index grew almost six fold from 11 265 articles in 1991 to 64 737 articles in 2005, using the extensive query developed for the ONR study.[140]

Which countries have the most-prolific institutions in the world, and what are the trends in publication growth? More importantly, where does Russia position itself in overall nanotechnology research and in the different subfields? This section examines the publication activity of countries and institutions as well as activity in various subfields, drawing some preliminary conclusions from the data.

Country trends

Up to 2006, the USA dominated publications on nanoscale science and engineering topics with over 43 000 publications since 1995. China ranked second with more than 25 000 publications, adding over 6000 new entries in 2006, which was more than twice as many as Japan in third place.[141]

In a European Commission research report from November 2006, the figures were lower but US dominance was still unquestionable. The USA published more than 18 000 scientific publications, registered in the Science Citation Index, from 1999 to 2004, with Japan in second place with over 8000 publications. China and Germany followed next with well over 7000 scientific publications registered. Russia had less than 2000 entries, which was half the

[139] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 164. Kostoff *et al.* performed a comprehensive text mining study in 2003–2005 and followed up this study with an updated and expanded study, using a very comprehensive query and sophisticated analytical tools.
[140] *Ibid*., p. 30. The query used is presented in Appendix 2, pp. 270–3.
[141] Business Wire 'Top Nations in Nanotech See Their Lead Erode'

number of French publications and less than South Korea, but more than India and Poland and twice the number of Brazil.[142]

In the ONR study, the USA was closely followed by China in 2005, ahead of Japan and Germany (see Table 5.1). South Korea had also rapidly increased its scientific output. The number of articles attributed to Russia had increased as well, but only marginally, and India was catching up.

Table 5.1 Number of nanoscience/nanotechnology papers, selected countries 2005

Country	Number of papers
US	14750
China	11746
Japan	7971
Germany	5665
Korea	4098
France	3994
Russia	2185
India	2103
Poland	1105
Brazil	932

Source: Kostoff *et al.* (2006) *Structure of the Global Nanoscience and Nanotechnology Research Literature*, Office of Naval Research, p. 70.

All the leading countries in nanotechnology research increased their scientific output from 1991 to 2005, but the ONR study shows that the growth in research had not been uniform. The USA was the world leader in nanotechnology publications, but the most rapid growth in the past decade had taken place in the East Asian nations, most notably China and South Korea. Some of the rapid growth noted in the ONR study – for instance in the case of China – was due to prolific publication rates in domestic journals previously not included in the databases used in the study (Science

[142] Hullmann *The economic development of nanotechnology*, Figure 21, p.27.

Citation Index/Social Science Citation Index), but there was also an underlying increase because of the overall research effort in the field. South Korea started behind China in total nanotechnology publications, but had advanced rapidly and become a second-tier contender in total output.[143]

Older data on nanotechnology publications from the period 1991–2000 further illustrate the ascent of China and South Korea in the rankings for publication activity (see Table 5.2). There was a notable overall increase in publications per year between this data set and the later data sets in Table 5.1. Russia followed the general trend, but was overtaken by South Korea.

Table 5.2. Nanotechnology publications in the SCI database, selected countries 1991–2000

Country	Number of papers
US	9 993
Japan	4 251
Germany	3 634
China	3 168
France	2 673
Russia	1 708
India	636
Korea	579
Poland	387
Brazil	245

Source: Thomson ISI database, 2001 as referenced in Hullmann (2006) *The economic development of nanotechnology – an indicators based analysis*, CORDIS, p. 28.

By 2006, the USA still appeared well ahead of China in numbers of articles produced, but China appeared poised to overtake the USA within a few years if the trends in the ONR report continued.[144]

[143] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, pp. 39 and 164.
[144] See Figure 2A in Kostoff *et al.*, p. 39.

Prolific institutions

In a 2003 report for the European Commission on excellence in nanoscience and nanotechnology, the Russian Academy of Sciences (RAN) came fourth in a ranking of the top ten most published organisations worldwide in 1996–2001. No Western research organisation was rated higher in number of publications, and only two Japanese universities and the Chinese Academy of Sciences (CAS) had a higher number of publications during the research period.[145]

The more comprehensive ONR study from 2006 is even more pleasant reading from a Russian point of view when it comes to publication activity. The RAN was the uncontested runner-up behind its Chinese counterpart in a list of the 30 most-prolific institutions in the world in the field of nanotechnology research in 2005. True, the CAS had more than twice the number of records, with a total of 2916, but the RAN with 1217 research papers was well ahead of third placed CNRS, France, with 824 records.[146]

However, the reason why RAN research paper production was so significant was that its nanotechnology output was more than half the total for the whole of Russia. This indicated that the Russian Academy of Sciences was the principal institution in the field of nanotechnology research in Russia, with significantly diminished participation by other universities and institutions.[147] The situation was mirrored in most other fields of science and reflects the Soviet legacy. During the Soviet era, the Academy of Sciences was the main research organisation, and being a member signified the scientific standing of a researcher.

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[145] See Table 3.5, p. 64 in Noyons *et al. Mapping Excellence in Science and Technology across Europe: Nanoscience and Nanotechnology*.
[146] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 51.
[147] *Ibid*., p. 52.

In fact, the comparison of institutions was somewhat misleading as the RAN and the CAS are not universities, but multi-centre national research institutions. In the case of Russia, the RAN is the only national research organisation of any stature in the field of nanotechnology, while Japan and China have several prolific organisations. Of the most-prolific research institutions, 21 were located in Asia according to the ONR study. China and Japan had the largest number of prolific organisations, with eight and seven institutions, respectively. The seven Japanese institutions on the list together produced over 4000 research publications in 2005, compared to 1217 by the RAN. Furthermore, the USA was the undisputed leader in nanotechnology publications, but only four of its research organisations made it on to the list, which underscores that institutional output data must be considered with care.

Moreover, the RAN did not have any of its scientists listed on the list of the 30 most-prolific nanotechnology research authors and their institutions in the ONR report. Chinese scientists dominated the list, and the CAS employs 11 of the most-prolific nanotechnology scientists.[148]

Nanotechnology subfield publication activity

Even though the USA was the leader in aggregate nanotechnology research production up to at least 2005, China had achieved parity or even taken the lead in some selected sub-areas.[149] The 2006 ONR nanotechnology study contained a thorough analysis of subfield publication activity. In the analysis, 256 thematic clusters were identified and a five-level hierarchical taxonomy was constructed from the clusters, with 16 fourth-level categories. The USA produced most papers in 168 of the thematic clusters, China led in 70, Japan in 15, and India, South Korea and Spain each led in one thematic cluster. Looking at the 16 fourth-level categories, China

[148] *Ibid*., Table 2, p. 47.
[149] *Ibid*., p. 164.

was the publication leader in six, Japan in one and the USA in the other ten. Essentially, China led in materials and nanostructure components, while the USA led in physical science phenomena and biomedical components.[150]

Russia did not have a leading position in any of the thematic clusters in the ONR study. In a brief overview of publication activity in the three main subfields, the 2006 European Commission research report revealed that the majority of the Russian publications were within 'Superconductivity and Quantum Computing', followed by 'Nanomaterials' and then 'Chemical Synthesis'. [151] Interestingly, in 1999–2004, Russia published more scientific publications on superconductivity and quantum computing than France, and almost as many as China, indicating that Russia was relatively strong in this subfield. In the two other subfields, however, Russia managed only slightly better than Poland and Brazil, indicating that Russia was relatively weak in the areas of nanomaterials and chemical synthesis.

Preliminary conclusions on publication activity

Russia was one of the prominent countries in nanotechnology publications up to 2005. However, even though its quantitative output grew, Russia fell behind more prolific countries. The strong international position of the RAN does not compensate for this. Furthermore, none of the most-prolific authors resided in Russia and Russia was not leading in any subfield, even though it positioned itself strongly in superconductivity and quantum computing. It remains to be seen whether the government plans initiated in 2007 can change the picture. The programmes may result in an increased number of nanotechnology articles by Russian scientists. However, in view of the rapidly increasing number of publications worldwide, the government's plans cannot

[150] *Ibid*., pp. 166–7.
[151] Hullmann *The economic development of nanotechnology*, Figure 21, p.27.

be expected to result in a significantly increased share in global publications in the short to medium term.

This has not prevented Russia from setting ambitious goals. The Development Programme for the Nano-industry of the Russian Federation to the year 2015 envisages an increase in the Russian Federation's share of nanotechnology publications in leading international journals from 0.2 percent in 2008 to 4 percent in 2015.[152] Even a tenfold increase to 2 percent may prove difficult to attain, however, in view of the fierce competition in the field of nanotechnology research.

5.2.2 Quality: Research performance

Publication activity does not always provide a full picture of scientific proficiency. Not all scientific publications are of the same quality. Publication does not necessarily create an impact. The number of citations received and appearance in high-impact journals can serve as a good indicator of the quality of a paper and thus the relevance and impact of the research.

Country citations

Studying the overall number of citations, citations per published paper and the share of most-cited nanotechnology papers can provide an insight into the quality of a country's scientific output. However, in doing so, the impact of differing publication practices in the countries of comparison must be considered. According to the ONR study, a clear distinction should be made between the publication practices of the three most-prolific Western nations and their East Asian counterparts, which partly explains differences in scientific impact. The Western countries publish their nanotechnology research in journals with almost twice the

[152] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], Appendix 2.

weighted average impact factors of the East Asian countries, mainly due to the latter publishing a significant amount in domestic low impact factor journals.[153]

This seems to apply to Russia as well. The ONR study pointed out that four of the five most important journals for publication for researchers connected to the RAN were printed in Russia, albeit in English. Furthermore, only one of the most important RAN publications appeared among the top 30 most-cited nanoscience journals in the world.[154] Russian research performance measured in citations of scientific publications per paper was relatively weak. Data from the period 1991 to 2000 reveal that Russia and China, despite their relatively large number of publications, received few citations in comparison to the other countries (see Table 5.3). It is notable that Brazil, which had the lowest number of publications, nonetheless received more citations of its 245 papers than South Korea received of its 579 papers registered in the database.

Table 5.3 Nanotechnology publications and citations in the SCI database, selected countries 1991–2000

Country	Number of papers	Total cites	Cites per paper
US	9 993	92 108	9.22
France	2 673	17 168	6.42
Japan	4 251	26 267	6.18
Germany	3 634	22 373	6.16
Brazil	245	1 253	5.11
India	636	2 005	3.15
Poland	387	969	2.50
Russia	1 708	4 240	2.48
China	3 168	7 653	2.42
South Korea	579	1 243	2.15

Source: Thomson ISI database, 2001 as referenced in Hullmann, *The economic development of nanotechnology*, p. 28.

[153] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 165.
[154] *Ibid*., p. 69.

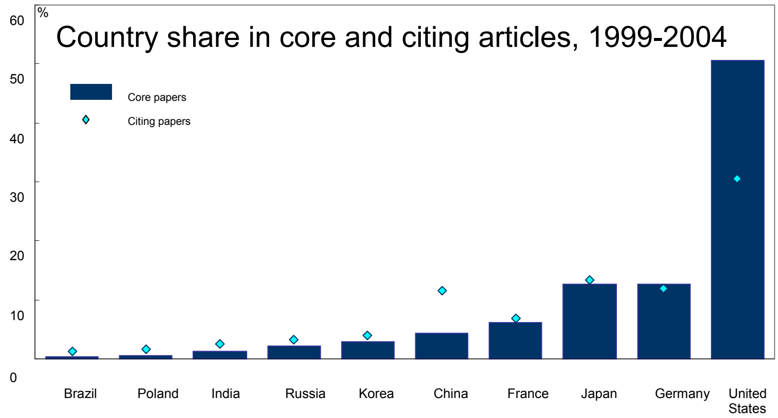
The number of citations per paper is useful for judging scientific proficiency, and in this respect Russian nanotechnology research performed poorly in the 1990s. However, in assessing scientific impact, the total number of citations is even more relevant, and in this respect, Russia maintained its middle field position in the ranking, albeit far behind the world's leading nations.

In a later citation analysis by the OECD, covering three nanotechnology subfields,[155] the USA's advantage in terms of quality was again demonstrated. It had a slightly more than 50 percent share of the most-cited scientific articles (referred to as 'core articles'), indicating a leading role in nanoscience.[156] Most other countries showed a larger share of articles citing core articles (referred to as 'citing articles') than of core articles, and Russia was no exception in this regard. The shares of core articles and citing articles for a selected number of countries are illustrated in Figure 5.1, and US dominance is obvious.

The other countries' shares are somewhat more easily discerned from Figure 5.2. The OECD assessment indicates that Russia was more competitive in nanoscience than India and far more so than Brazil and Poland. However, in absolute terms the 2.2 percent share of core articles and 3.2 per cent share of citing articles in the period 1999–2004 cannot be considered a solid scientific foundation. Russia was far behind Japan and Germany. China had twice the share of core articles and nearly four times as many citing articles. China had the largest gap between core and citing articles in the OECD study.

[155] The analysis examined three research areas 'chemical synthesis', 'superconductivity and quantum computing' and 'nano-materials and devices'. These research areas cover only part of nanoscience in which there has been active research in recent years.
[156] Igami and Saka *Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science.*

Figure 5.1. Share in core and citing articles, selected countries

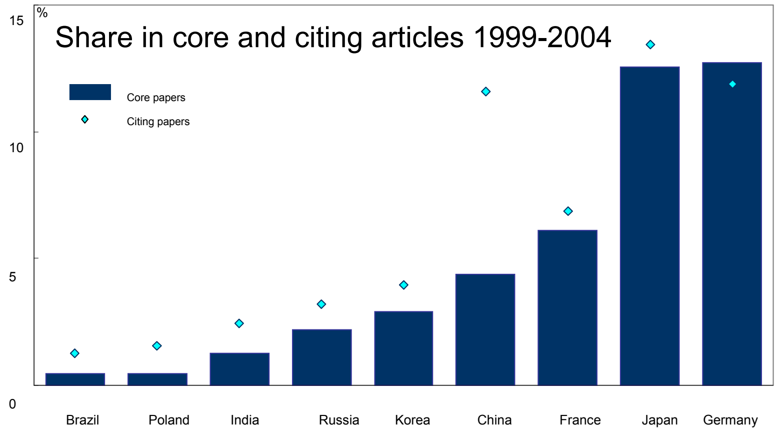


Source: Igami, M. and Saka, A. (2007), Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science, STI Working Paper 2007/1, OECD, Paris as represented in OECD Science, Technology and Industry Scoreboard 2007, p. 153. Data available at http://dx.doi.org/10.1787/118504387323.
Note: Article counts are based on whole counts.

US domination of aspects of quality was also evident from the 2006 ONR study. Despite the increased productivity of East Asian countries, the USA continued to generate the most-cited nanotechnology papers. The ONR study identified the 401 most-cited nanotechnology papers from 1991 to 2003, and the USA produced 126 of these, with Germany in second place with 31 papers. Together, the two countries accounted for 40 percent of the most-cited nanotechnology papers, while the high-volume paper producing countries, China and South Korea, together accounted for only 2 percent of the most-cited papers.[157]

[157] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 165.

Figure 5.2 Share of core and citing articles, magnified



Source: Igami, M. and Saka, A. (2007), Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science, STI Working Paper 2007/1, OECD, Paris as represented in OECD Science, Technology and Industry Scoreboard 2007, p. 153. Data available at http://dx.doi.org/10.1787/118504387323.
Note: Article counts are based on whole counts.

France and Japan came a shared third with 19 papers each. Russia's share of the most-cited papers was on a par with China. Five of the 401 most-cited papers were attributed to the Russian Federation, which was 1.25 percent of the total.[158] This was nearly half its share of most-cited articles in the OECD study. Taken together, the two studies highlight the fact that the quality of Russian nanotechnology research is lagging behind that of the leading countries. It should, however, be noted that Chinese and Russian publication practices, which favour domestic journals, partly explain the relatively low share of most-cited papers.

China's share of high-impact nanotechnology papers was arguably small but, perhaps more importantly, increasing. According to the ONR study, China's ratio of high-impact papers to total

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[158] *Ibid*., p. 220.

nanotechnology papers doubled between 1998 and 2002, placing China on a par with advanced nations such as Japan, Italy and Spain. South Korea had advanced even more rapidly over this period to become a second-tier contender in highly cited papers, from an initial position well behind China.[159] For Russia, no such positive trend was noted in the ONR study.

Institution citations

Of the 25 institutions that produced the 401 most-cited nanotechnology papers in the ONR 1991–2003 study, only four were based outside the USA.[160] The Netherlands, France, Japan and Switzerland each had one institution among the top 25.[161] No Russian institution made it on to the list, despite the RAN being the second most-prolific institution by number of papers, according to the same study.

The ONR study also compared share of total nanotechnology publications to share of the 500 most-cited papers in both 1998 and 2002. The RAN was the number one institution in share of publications, with 2.55 percent of the total. However, its share of the most-cited papers was only 0.80 percent, leaving the RAN outside the top 30 in this respect. In 2002, its share of total publications had dropped to 2.36 percent and the RAN had dropped to second to the Chinese Academy of Sciences, which had 3.30 percent. More importantly, the RAN's share of the most-cited papers had dropped to 0.60 percent. The CAS in the meantime had gone from a share of 0.20 percent in 1998 to a 1.80 percent share of the 500 most-cited papers in 2002. The Russian and Chinese figures can be compared to the top institution in terms of share of most-cited papers in 1998. Harvard University had 4 percent of the 500

[159] *Ibid*., p.164.
[160] *Ibid*., p. 165
[161] *Ibid*., p. 221.

most-cited papers, but only 0.38 percent of the total number of nanotechnology publications in that year.[162]

As is mentioned above, the Russian Academy of Sciences was ranked fourth of the top ten most-published organisations worldwide in the field of nanoscience and nanotechnology in 1996–2001, according to a 2003 European Commission report. However, in the perhaps more scientifically important aspects – such as numbers of citations received, citations per publication and percentage of non-cited articles – the RAN was rated second-to-last, only surpassing the CAS, and in percentage of self-citations it was in last place with more than twice as many self-citations (41.1 percent) as each of the three best performing organisations in this respect.[163] This institutional comparison further strengthens the picture of the relatively poor quality of Russian nanotechnology research when compared to the leading nations.

Nanotechnology subfield publication quality

As is mentioned above, Russia did relatively well from a quantitative point of view in one of the three main subfields, superconductivity and quantum computing, in 1999 to 2004. Russia published more scientific publications than France during the period, and almost as many as China.[164] The other two subfields were nanomaterials and chemical synthesis.

However, in terms of publication quality Russia was not among the leading countries in any of the three main research areas in the period of 2001–2006. The OECD Science, Technology and Industry Scoreboard 2009 presented a study of countries' relative share of core scientific articles in the three areas. Russia did not figure among the top 15 countries in any of the subfields. The top four

[162] *Ibid*., 227—30.
[163] Noyons *et al*. *Mapping Excellence in Science and Technology across Europe: Nanoscience and Nanotechnology*, Table 3.5 on page 64.
[164] Hullmann *The economic development of nanotechnology*, Figure 21, p. 27.

countries were Singapore, Switzerland, the USA and Germany, and France, South Korea, Japan and China also made it to the top 15 in all research areas. [165] Even though Russia was relatively prolific in the subfield of superconductivity and quantum computing, it was far behind the leading nations in its share of core articles in all the main subfields.

Preliminary conclusions on research performance

The quantitative achievements of Russian nanoscience and nanotechnology research were not matched by a similar quality of research. Studies indicate that the Russian Federation lagged far behind the leading countries when it came to the quality of its research performance. Russia positioned itself poorly in comparisons of the share of core articles and citing articles for both countries and research institutions. This applied to nanoscience as a whole and to its major subfields. The studies indicate that the quality of Russian research in nanotechnology was comparatively weak.

China and South Korea also performed poorly in aspects of quality, but they both seem to be rapidly improving their research performance and consequently their impact on nanoscience. There were no indications that Russia might be able to follow their lead, and there were few grounds for assuming that Russian nanoscience and nanotechnology research would significantly increase its impact in the short term. Increasing the quality of research is much more difficult and usually takes longer than increasing the quantity of research publications. The government's programmes, even if they were fully implemented, would probably not have an impact on this area in the short to medium term because science needs time to mature.

[165] OECD (2009) *OECD Science, Technology and Industry Scoreboard 2009*, OECD, p. 73.

5.2.3 International research collaboration

The pattern of international research cooperation in a particular scientific field provides clues as to the quality of the research in a country or an institution. The underlying assumption is that leading research institutions seek to collaborate with other institutions at the forefront of science. Historical connections and scientific traditions, as well as cultural and language barriers affect the patterns of international collaboration. Nevertheless, studying cross-border cooperation can shed some light on the quality of research performance in the field of nanotechnology.

Country collaborations

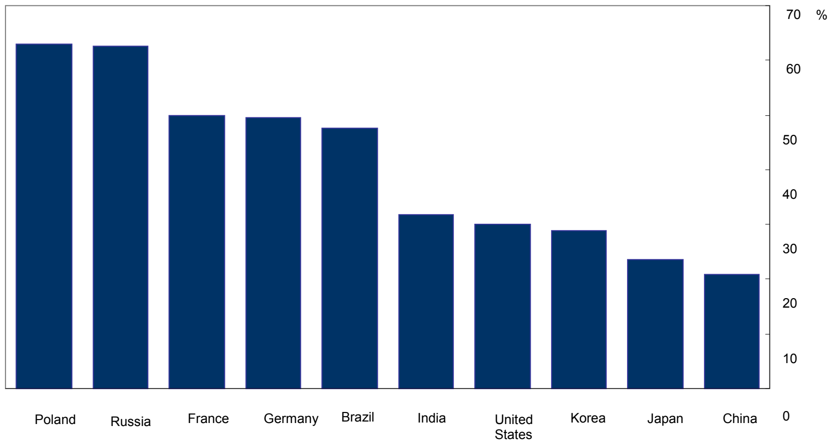
The ONR study indicated that the dominant country co-publishing networks in 2005 were a complex web of mainly European nations and a Western Europe/Latin America group of Romance language nations. A correlation of countries by common thematic research interest revealed two major poles: the USA and China. The US pole was thematically strongly connected to many other countries, while China appeared relatively isolated except for thematic ties to India. The Latin American and Eastern European countries, including Russia, also appeared to be outside the main network.[166]

The OECD study indicated that the small Russian share of published articles in nanoscience was to some extent counterbalanced by the fact that Russia had a comparatively high level of international research collaboration. If this were the case, Russian scientists would be able to accelerate their learning curve by working together with foreign scientists. As is illustrated in Figure 5.3, the Russian Federation rated second in international co-

[166] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, pp. 165–6.

authorship ratio in citing articles in the period 1999–2004, among the countries of reference.[167]

Figure 5.3 International co-authorship ratio in citing articles, selected countries 1999–2004



Source: Igami, M. and A. Saka (2007), Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science, STI Working Paper 2007/1, OECD, Paris as represented in OECD Science, Technology and Industry Scoreboard 2007, p. 153. Data available at http://dx.doi.org/10.1787/118504387323.
Note: Article counts are based on whole counts.

The low ratio for international co-authorship in the case of the USA can probably be explained by its leading role in the field of nanotechnology research. Many of the leading scientific institutions are located in the country and attract prominent researchers to work in the USA. As for the low level of international research collaboration among the Asian countries, the fierce competition

[167] In the OECD study, the Russian Federation comes tenth among the 35 countries in the study, see OECD *OECD Science, Technology and Industry Scoreboard 2007*, p.153

between them tended to keep the flow of knowledge within the national borders.[168]

Measured in number of co-authored articles, Russia's most important collaboration partner among the top five most-prolific countries in 2005 was Germany, according to the ONR study. Russia was the third-largest co-author country after the USA and France. Russia was also the fifth-largest co-author country for South Korea. However, Russia did not make it on to the list of the top five closest collaborating countries for any of the top three most-prolific countries: the USA, China and Japan.[169]

A comparison of the share of co-authored articles in the country total strengthened the picture of Germany as Russia's closest collaborator. In 2005, 13.3 percent of all Russian nanotechnology articles were co-authored with German scientists. However, in this respect Russia came fifth among Germany's collaborators. Again, South Korea was the only other of the top five most-prolific countries where Russia qualified among the top five co-author countries.[170] Taken together, this indicates that Russian international collaboration was comparatively high, but that it was not strongly connected to any of the leading nanotechnology countries apart from Germany.

Institution collaborations

According to the ONR study, the three main institutional co-publishing groups for nanotechnology papers were East Asian: one each from China, Japan and South Korea. Furthermore, publication connectivity among institutions appeared much weaker than common interests or citation connectivity.[171] An institution auto-

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[168] *Ibid*., p. 152.
[169] Kostoff *et al. Structure of the Global Nanoscience and Nanotechnology Research Literature*, p. 71.
[170] *Ibid*., p. 72.
[171] *Ibid*., p. 166.

correlation map of the 30 most-prolific nanotechnology research institutions in the ONR nanotechnology report based on actual co-authorship showed that the RAN was among the one-third of the institutions on the list that lacked an institutional relationships with the others.[172] The picture was the same for the RAN in cross-correlation maps of the institutions based on the use of common terminology,[173] on cited journals,[174] and on cited documents.[175] Most notably, the RAN was one of only three institutions lacking institutional linkages based on the 500 most-cited journals.

This picture of Russian scientific isolation was underscored by the six-factor institution factor matrix generated on the basis of the auto-correlation map of the 30 most-prolific nanotechnology research institutions based on actual co-authorship. Six distinct groupings were identified: a Japan-based group, two China-based groups, a South Korea-based group, a Western European-based group and a multinational group. RAN was one of six institutions that did not belong to any of the groups.[176]

5.2.4 Conclusion: Many publications but few citations

Russia has positioned itself strongly in the number of publications in the field of nanotechnology research and its publications output continues to grow. The Russian Academy of Sciences was one of the most-prolific institutions in the world in this scientific field. However, Russia seems to be falling behind the leading nations in terms of publication and was overtaken by countries with more rapidly increasing publications output.

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[172] *Ibid*., Figure 4A, p. 53. There are three main co-publishing groups: one Chinese, one Japanese and one South Korean, p. 54.
[173] *Ibid*., Figure 4B, p. 57.
[174] *Ibid*., Figure 4C and Figure 4D, pp. 58–9.
[175] *Ibid*., Figure 4E, p. 60.
[176] *Ibid*., pp.63–4.

Russia's poor performance regarding the quality of its nanotechnology research should, however, be of more serious concern. In particular, the weak annual increase in core articles and citing certainly dim the prospects of Russia becoming a leading nation in nanotechnology research any time soon.

This could to some extent be compensated for by Russia's degree of international collaboration, where as a country it performed comparatively well. However, apart from Germany, Russia does not seem to cooperate much with any of the leading nanotechnology countries. The perceived institutional isolation of the RAN further undermines any expectation that international collaboration could serve as a shortcut to rapid nanoscience development in Russia.

The negative development in its share of publications may be addressed, at least to some extent, in the short to medium term by current government programmes for nanotechnology research. Increasing the quality of research is a more important, but also a much bigger, challenge. Only in the long term – 10 to 15 years – can the government's initiatives be expected to yield any substantial results – even if they are fully implemented.

5.3 Patent activity

The quantity and quality of published scientific research is an important measure of research performance, but patenting statistics might say even more about the potential impact of nanotechnology on society. Patents are applied research and may form the basis for new companies and even whole new industries.

Inventive activities in nanotechnology have, according to OECD reports, been gathering momentum since the end of the 1990s. A 2007 report states that:

> International applications for nanotechnology patents, filed under the Patent Cooperation Treaty (PCT), increased steadily from the mid-

> 1980s to the mid-1990s and have risen strongly over the past decade; at 24.2%, the annual growth rate in nanotechnology surpasses that of the overall PCT applications (12.0%) for the period 1995–2004.[177]

In a later study the annual growth rate was not as striking, but still substantially higher than the general rate of annual growth. In the period 1996–2006, the average annual growth rate for nanotechnology patents filed under the PCT was 16.5 percent, while that of overall PCT applications was 11 percent.[178]

The current annual growth rate may be even higher. According to a US research company, nano-related international patent activity increased by 31 percent in 2006, reaching a total of 10 105 patents from the countries in the study.[179] The global financial crisis of 2008–2009 may have put nanotechnology companies under strain. The rate of growth in the number of nanotechnology patents may have been affected because patenting is very costly. It should also be noted that the share of nanotechnology patents in the total number of patents is very small. From 2002 to 2004, a mere 0.9 percent of the total PCT filings were related to nanotechnology OECD-wide.[180]

The 2007 OECD report also provides a picture of the trends in patents in different subfields (see Figure 5.4.) From a rather even distribution in 1995, nanomaterials together with electronic devices and optoelectronics had come to dominate this patenting in 2003, at least in terms of filing international patents.

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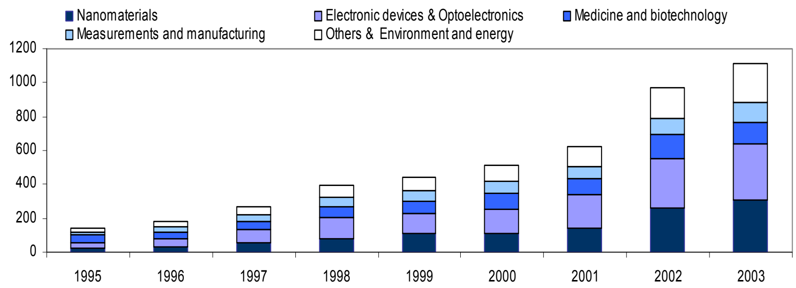
[177] OECD *OECD Science, Technology and Industry Scoreboard 2007*, p. 154.
[178] OECD *OECD Science, Technology and Industry Scoreboard 2009*, p. 70.
[179] Business Wire 'Top Nations in Nanotech See Their Lead Erode'
[180] OECD *OECD Science, Technology and Industry Scoreboard 2007*, p. 154

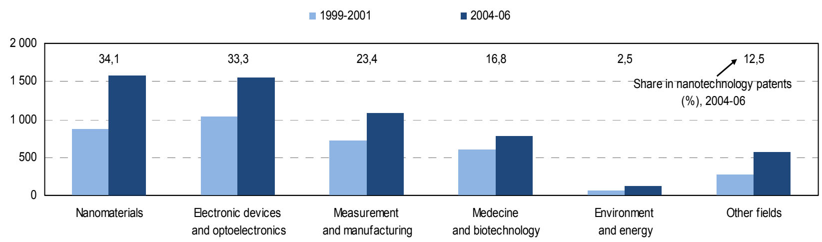
Figure 5.4. Trends in nanotechnology patents by field of application



Source: OECD Science, Technology and Industry Scoreboard 2007, p. 155. Data available at http://dx.doi.org/10.1787/118541047655 .
Note: Patent applications filed under the Patent Cooperation Treaty, international phase, designating the European Patent Office. Article counts are based on priority date.

A 2009 OECD report reinforced the impression that nanomaterials dominated patenting together with electronic devices and optoelectronics. Nanomaterials had established itself as the major field of applications in 2004–2006, as can be seen in Figure 5.5. Measurements and manufacturing were also rising steadily.

Figure 5.5. Trends in nanotechnology patents by field of application, world total

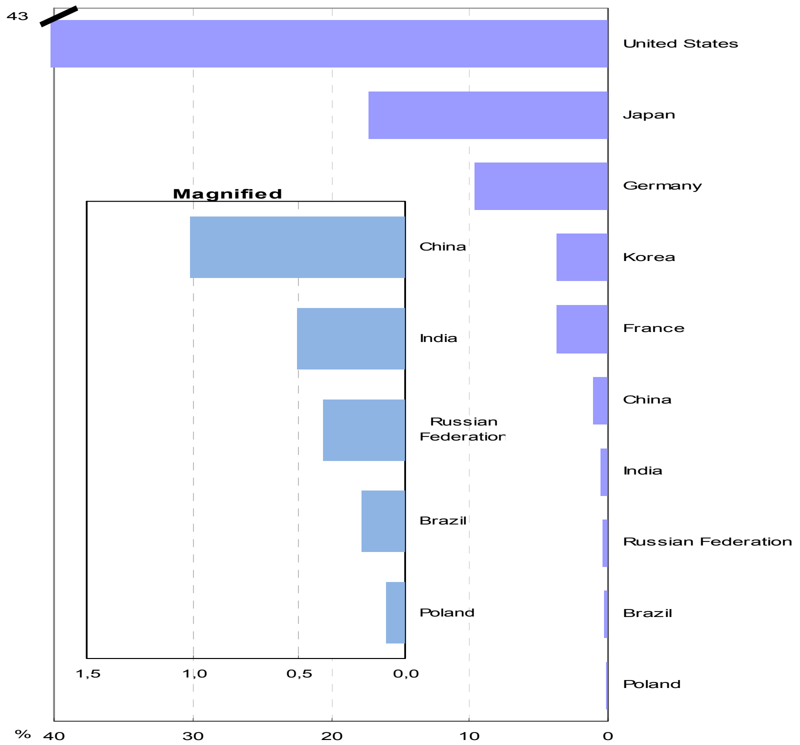


Source: OECD Science, Technology and Industry Scoreboard 2009, p. 71. Data available at http://dx.doi.org/10.1787/743854706424.
Note: Patent applications filed under the Patent Cooperation Treaty, international phase, designating the European Patent Office. Article counts are based on priority date.

5.3.1 Nanotechnology patenting

When it comes to the share of different countries in nanotechnology patents, the 2009 OECD report showed the USA in a comfortable lead with a 43 percent share of total PCT filings in the period 2004–2006. Together with Japan, at 17 percent, and Germany, at nearly 10 percent, the top three nations accounted for more than two-thirds of the total number of nanotechnology patent filings (see Figure 5.6.). South Korea and France followed with 3.7 percent each.

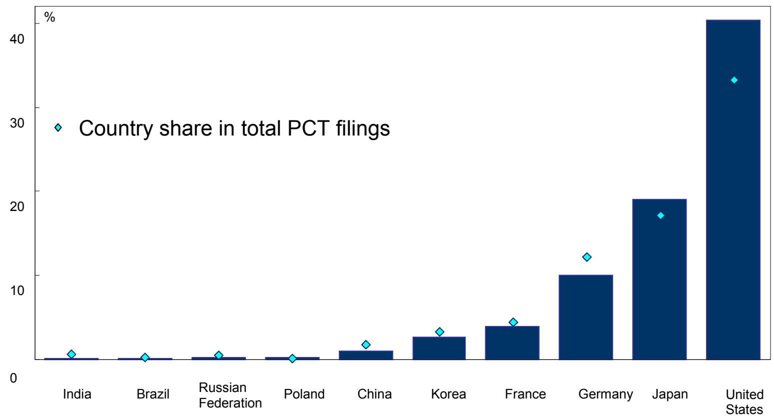
Figure 5.6. Share of nanotechnology patents filed under PCT, 2004–06 (selected countries)



Source: OECD Science, Technology and Industry Scoreboard 2009, p. 71. Data available at http://dx.doi.org/10.1787/743710614871.
Note: Patent applications filed under the Patent Cooperation Treaty, international phase, designating the European Patent Office. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

The USA had strengthened its position in comparison with the figures in the 2007 OECD report. In the 2007 report, the USA had a 40 percent share of PCT nanotechnology filings for the year 2004, and Japan came second with 19 percent of the total (see Figure 5.7). In another nanotechnology study, US dominance was even more overwhelming: 6801 of the total of 10 105 patents in 2006 were filed by the USA, nearly nine times as many as Germany's total of 773 patents.[181]

Figure 5.7. Share of nanotechnology patents and total PCT filings 2004, selected countries



Source: OECD Science, Technology and Industry Scoreboard 2007, p. 155. Data available at http://dx.doi.org/10.1787/118541047655 .
Note: Patent applications filed under the Patent Cooperation Treaty, international phase, designating the European Patent Office. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

The shares of the so-called BRIC countries[182] and of Poland are barely visible in Figure 5.7, but the magnified picture in Figure 5.8

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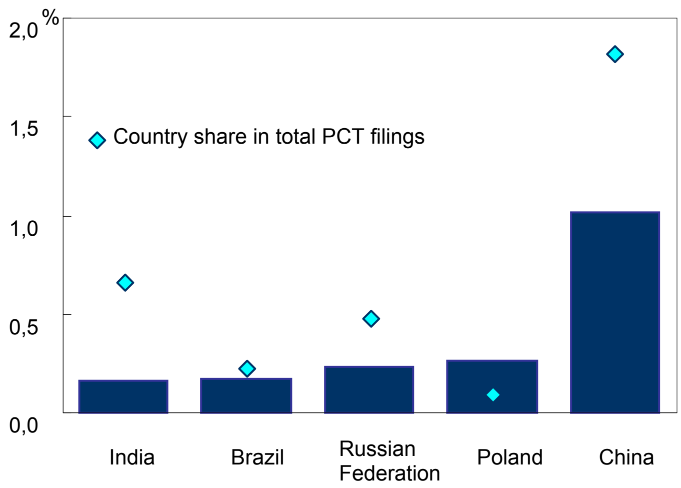
[181] Business Wire 'Top Nations in Nanotech See Their Lead Erode'
[182] The emerging economies of Brazil, Russia, India and China are sometimes referred to as a group with the acronym BRIC.

reveals that China was clearly ahead of the others, albeit with a mere one percent of the total nanotechnology patent filings in 2004. Russia contributed only 0.23 percent of the total nanotechnology patents, which is an almost negligible share. Russia was, however, in good company with India and Brazil in 2004.

Figure 5.8. Share in nanotechnology patents and total PCT filings 2004, magnified



Source: OECD Science, Technology and Industry Scoreboard 2007, p. 155. Data available at http://dx.doi.org/10.1787/118541047655 .
Note: Patent applications filed under the Patent Cooperation Treaty, international phase, designating the European Patent Office. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

Comparing the magnified pictures in figures 5.6 and 5.8, it seems that Russia increased its share of nanotechnology patents. In 2004–06 it nearly doubled its share to 0.39 percent, which is still a very small share. China kept its share while Poland fell back, but Russia did not advance in the rankings as India increased its share from 0.2 percent to 0.51 percent. In relation to the total shares of PTC filings, the USA, Japan and Poland each had a larger share of nanotechnology patents in 2004, according to the 2007 OECD study. This study indicated larger relative efforts in nanotechnology patenting in these countries, and this impression was further strengthened by figures for nanotechnology patents as a percentage of national total PCT filings in 2002–2004. Japan, the USA and Poland all performed better than the total for all the countries in the OECD statistics in this respect.[183]

Data for 2007 from the European Patenting Office[184] give a somewhat different picture (see Figure 5.9). The EPO classified close to 12 000 patents worldwide reported as nanotechnology patents in 2005. The US share of these was lower than its share in the OECD figures, at about 30 percent. Japan's share was two-thirds of its OECD 2009 share and Germany's was almost half. Furthermore, the French share in the EPO dataset on nanotechnology patents was less than one-fifth of that in the 2009 OECD figures.

On the other hand, the patent filings of China and South Korea were several times larger than those in the OECD statistics, representing well over 7 percent of the total nanotechnology patents and pushing Germany down to fifth place. The Brazilian share was almost three times larger than in the EPO data, although still just 0.62 percent of the total. Unfortunately, there were no data on Poland or India for 2007.

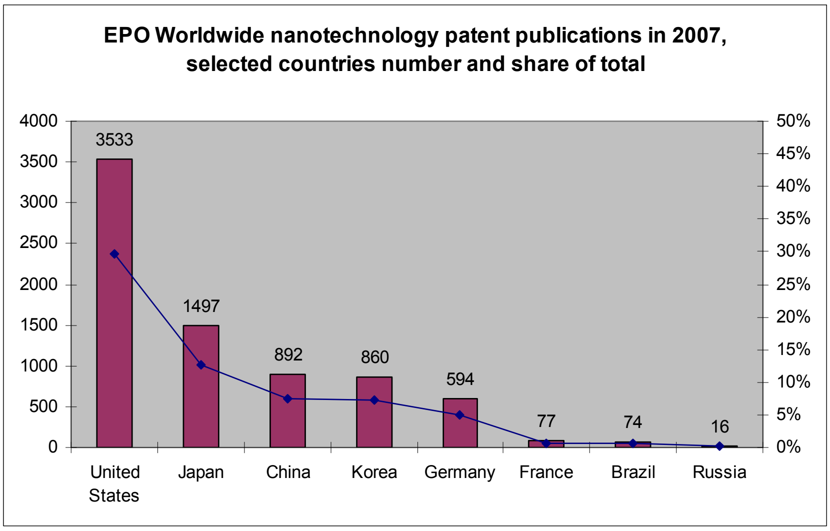
According to the EPO statistics for 2007, Russia had registered only 16 nanotechnology patents, accounting for 0.13 percent of the total number of patents. The shares of Russian patents in 2006 and 2008

[183] OECD *OECD Science, Technology and Industry Scoreboard 2007*, p. 155. See also In the 2009 OECD report, half the countries in this study showed a decline in their nanotechnology patent share of total national patent filings in the period 2004–06 compared with the period 1999–2001. Russia accounted for the largest decrease in both absolute and relative terms (see Figure 5.11.).
Figure 5.10 below.

[184] In 2010, 2007 was the most recent year with near complete statistics in the database. However, Polish and Indian data for 2007 were still missing in September 2010.

were 0.35 and 0.32 percent, respectively,[185] indicating that the figures for 2007 may have been an aberration. A share in vicinity of 0.3 percent corresponds quite well with the OECD data for Russian nanotechnology patenting.

Figure 5.9. EPO nanotechnology patents, 2007



Source: The EPO Worldwide database (esp@cenet) as of 7 September 2010.
Comment: India and Poland have been left out of the diagram, since there were no data for 2007 in the database at that time. This is probably due to the national patent offices not having reported yet.
Note: Patent applications in the Worldwide database with ECLA classification Y01N. Patent counts are based on the publication date and the country of filing.

The EPO figures indicate that Russia might be further behind China and Korea than the OECD data suggest. Ultimately, it is not the relative position as much as the actual number of patents published that is of interest, and the very small number of Russian nanotechnology patents in both the OECD and the EPO datasets

[185] For a longer series on Russian EPO nanotechnology patenting data, see Figure 5.12 below.

indicates that nanotechnology patenting activity has been weak in Russia.

It is important to be careful when comparing two different sets of data, but it is interesting that the developed Western countries in general, and those in Western Europe in particular, performed decidedly less well in the EPO statistics, while the emerging countries China, South Korea and Brazil did relatively better. As the OECD study was based on the country of origin of the inventors, while the EPO statistics reflect national patent filing, the emerging countries might be expected to do better in the OECD data, as many scientists from these countries are carrying out their research in the USA. However, as the statistics on India and Poland demonstrated, the EPO data for 2007 was still incomplete in late 2010, and it is therefore too soon to draw any definite conclusions on the basis of them.

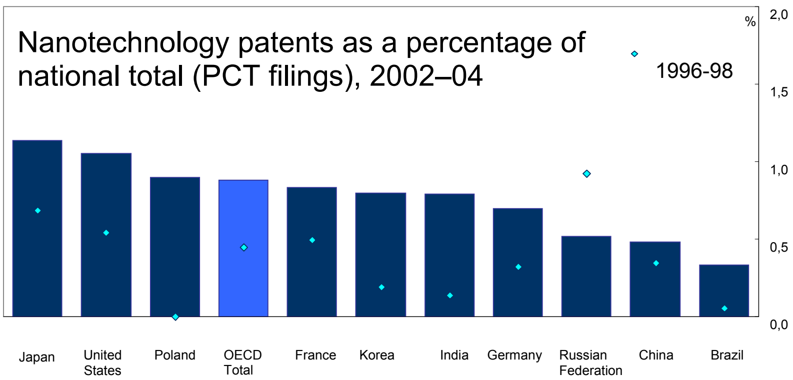
5.3.2 Nanotechnology patenting trends

Another way to assess the development of nanotechnology patenting is to compare the share of nano patents to the total share of patents filed by a country. Such a comparison reveals the strength of nanotechnology compared to other fields.

Looking at the share of nanotechnology patenting over time, all but one of the countries studied showed an increased share of nanotechnology patents in the national total in the 2007 OECD statistics compared to figures for the period 1996–98. Poland showed an exceptional increase, and in India, South Korea and Brazil the share of nanotechnology patents also increased markedly. The exception was Russia, where the share of nanotechnology patents had fallen from 0.9 percent in 1996–98, when Russia was in a clear lead, to just 0.5 percent of the national total of PCT filings in 2002–04 (see Figure 5.10).

In the 2009 OECD report, half the countries in this study showed a decline in their nanotechnology patent share of total national patent filings in the period 2004–06 compared with the period 1999–2001. Russia accounted for the largest decrease in both absolute and relative terms (see Figure 5.11.).

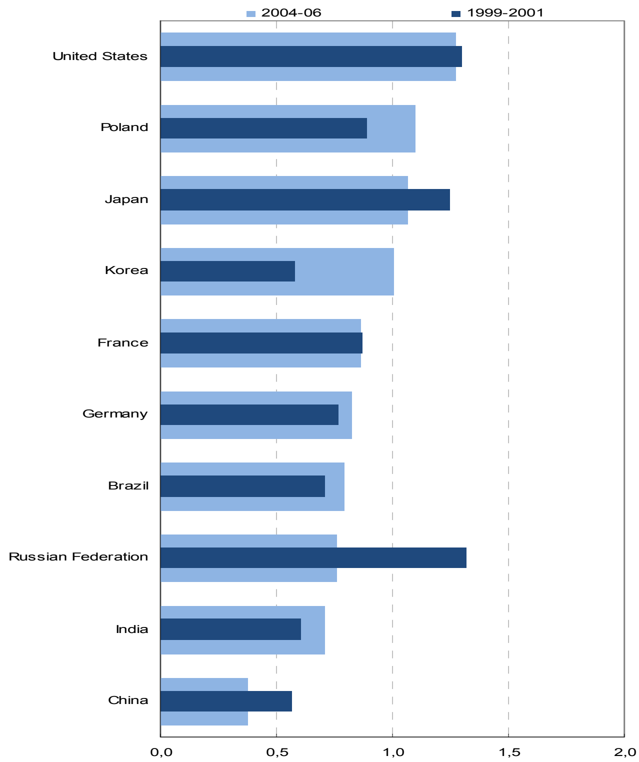
Figure 5.10. Nanotechnology patents compared to national total



Source: OECD Science, Technology and Industry Scoreboard 2007, p. 155. Data available at http://dx.doi.org/10.1787/118541047655 .
Note: Patent applications filed under the Patent Cooperation Treaty, at international phase, designating the European Patent Office. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

The decline in the share of nanotechnology patents in Russia's total international patent filings indicated that the field of nanotechnology had fallen behind other fields. At the same time, the nanotechnology patents of most other countries showed a positive trend. The share of nanotechnology patents was rather low, however, as over 99 percent of all international patent filings under the PCT concerned other areas than nanotechnology.

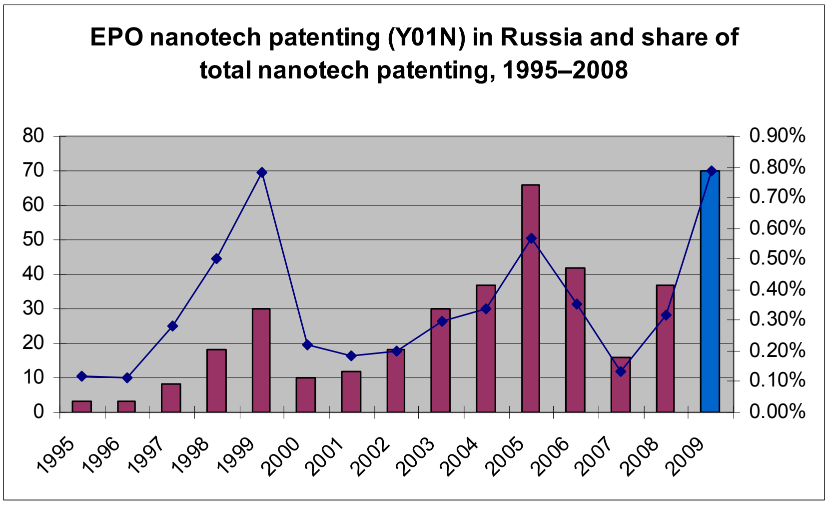
Figure 5.11. Nanotechnology patents in comparison to national total 2004–06, selected countries



Source: OECD Science, Technology and Industry Scoreboard 2009, p. 71. Data available at http://dx.doi.org/10.1787/743727147336.
Note: Data relate to patent applications filed under the PCT, international phase, designating the European Patent Office. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

Using the EPO dataset to study Russia in particular supports the conclusion made on the basis of the OECD results that the country had something of a decline in its share of nanotechnology patenting. According to the EPO data, the number of nanotechnology patent filings in Russia declined in actual numbers – and even more so in the share of total nanotechnology patenting – in the early years of the 21st century (see Figure 5.12). In the period 2004–2007, the number of Russian nanotechnology patents was higher than in the late 1990s, but Russia's share of total nanotechnology patents registered in the EPO database was consistently lower than its share in 1999.

Figure 5.12. EPO nanotechnology patenting in Russia, 1995–2008



Source: The EPO Worldwide database (esp@cenet) as of 7 September 2010.
Note: Patent applications in the Worldwide database with ECLA classification Y01N. Patent counts are based on the publication date and country of filing.

The year 2009 was a record year for Russian nanotechnology patenting in the EPO database. By September 2010, 70 Russian patents had been registered. The year had probably not been reported in full by all the national patenting offices, and there are likely to have been additional Russian patents for that year too. As reporting from the national patent offices to the EPO often lags behind and the patents are reclassified by the EPO, it was thus too early to draw any definite conclusions on 2009 in September 2010.

After a steep fall in 2000, Russian nanotechnology patenting seemed to be in a positive trend, albeit from a very modest level. Looked at from an even longer time frame, Russia's share of nanotechnology patent applications to the EPO in the period 1978 to 2005 amounted to 0.4 percent,[186] strengthening the impression of its modest share in nanotechnology patenting.

5.3.3 Russian nanotechnology subfield patenting

A brief look at the composition of Russian nanotechnology patent publications in 2005[187] in the EPO Worldwide patent database reveals that almost 40 percent of the Russian patent publications for that year were linked to nanotechnology for materials and surface science (nanomaterials). That was nearly twice as many as the runner-up, nanobiotechnology, which had one-fifth of the total (see Figure 5.13). A comparison with PCT filings by field of publication in 2004–06 (see Figure 5.5.) indicates that Russia was relatively strong in the subfield of nanobiotechnology compared to the world total, and possibly also in nanomaterials.

Data from 2003 on EPO classes Y01N2–12[188] reinforce the impression gained from the comparison with the OECD data. The share of nanobiotechnology patent filings was almost twice as high in Russia (20 percent, compared to 11 percent in the 2003 EPO data), and 38 percent of the patents related to nanomaterials in Russia, compared with 25 percent in the 2003 EPO data. A strong position in the field of nanobiotechnology would be consistent with Russia's traditional proficiency in biotechnology.

Russia also seems to be on a par with other countries in nanoelectronics and optoelectronics in the OECD statistics. Y01N4 and Y01N10 taken together are not far off the PCT data for electronic devices and optoelectronics. The PCT and the EPO data

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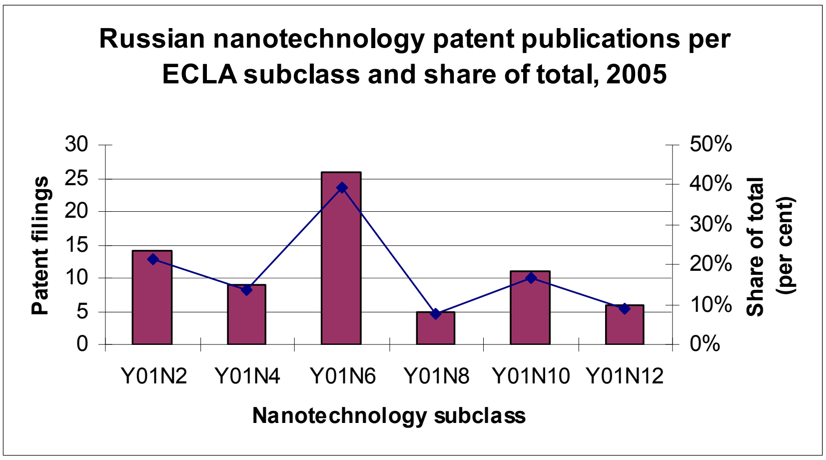
[186] Igami and Okazaki *Capturing Nanotechnology's Current State of Development via Analysis of Patents*, p. 14. Patent counts were based on the earliest priority date, the inventor's country of residence, and fractional counts.

[187] This year was chosen as it is the year with the largest number of registered patents in the most recent and probably most fully reported year.

[188] Hullmann *The economic development of nanotechnology*, p. 22.

concern similar, but not identical, subfields, which means that decisive conclusions cannot be drawn from these data sets.

Figure 5.13. Nanotechnology patents per subclass in Russia



Y01N	**Nanotechnology**
Y01N2	Nanobiotechnology
Y01N4	Nanotechnology for information processing, storage and transmission
Y01N6	Nanotechnology for materials and surface science
Y01N8	Nanotechnology for interacting, sensing or actuating
Y01N10	Nanooptics
Y01N12	Nanomagnetics

Source: The EPO Worldwide database (esp@cenet) as of 13 March 2008.
Note: Patent applications in the Worldwide database, with ECLA classification Y01N2-12. Patent counts are based on the publication date, the country of filing ECLA classification. Some patents have been classified as belonging to more than one subclass, resulting in a larger number of Russian patents for 2005 if the subclasses are added together (71 patents) than the number of nanotechnology patents (66 patents). The percent share of total is calculated on the 66 registered nanotechnology patents. For EPO nanotechnology classification, see
http://v3.espacenet.com/eclasrch?ECLA=/espacenet/ecla/y01n/y01n.htm

Any comparison with the EPO data from 2003 suffers from the limits of comparing statistics from different years, but the subclasses are identical, as the same tagging system has been used. A comparison of the 2005 EPO data with the 2003 EPO data on the nanotechnology sub-classes strongly suggests that Russia was weaker in nanoelectronics (Y01N4, nanotechnology for information processing, storage and transmission). This field was the fourth largest for Russian patents in 2005 and made up only 14 percent of the total number of nanotechnology patent applications, while in the 2003 data this category was the largest with a 29 percent share of the total.[189]

A comparison between these data sets also highlights Russia's weak performance in nanomagnetics patenting, as this subclass only made up 9 percent of the total nanotechnology patent filings in Russia in 2005, down from a 14 percent share of the total in the 2003 EPO statistics. The shares for nano-optics and nanotools were roughly the same in both data sets, increasing by only a few percentage points. However, the statistical base is somewhat shaky, so the data must be considered with caution. Russia's EPO patent applications classified as nanotechnology patents in 2005 consisted of only 66 patents, which resulted in 71 sub-classifications as some patents were assigned to more than one subclass. The 2003 data set comprised more than 2500 patents belonging to the Y01N patent groups.

5.3.4 International knowledge flows demonstrated by patenting

As is the case with scientific publications, Russia has over time enjoyed a comparatively high level of international research collaboration in patenting. EPO data on international co-inventions in nanotechnology patent applications in the period of 1978–2005 show that Russia had the second largest share of international co-inventions, only slightly less than the world leader – China. The Russian share was equal to that of Germany, France, South Korea and the USA put together, and was a little over eight times the

[189] *Ibid*., p. 22.

world average share. Looking at the share of all international co-inventions in EPO patent applications, Russia came third in the world, not far behind Singapore and India. It is notable that Russia's overall share in international co-inventions was only slightly more than half its nanotechnology share.[190]

The EPO data suggest that Russian scientists have good access to global knowledge flows in the field of nanotechnology compared to other countries, and markedly better than in other fields of Russian patenting, in which Russia nonetheless had a large share. This indicates that Russian scientist in general, and nanotechnology scientists in particular, may be able to accelerate their learning curve by working together with foreign scientists on patenting. The low share of international co-inventions for the Western countries can be explained by the fact that scientifically leading countries tend to have a small proportion of international co-inventions.[191] Interestingly, the Asian countries – except for South Korea and Japan – showed a notably high ratio of co-invented patent applications, which is quite different from the above patterns of international scientific co-authorship.

5.3.5 Conclusions on patent activity

Russian nanotechnology patenting activity appears weak, both in absolute numbers and in its share of the world total. EPO and PCT data suggest that the Russian Federation accounted for only a small number of nanotechnology patents. The number is growing, but its share of the world total in this field has not increased at the same pace. Russia lags far behind the leading countries and also seems to be falling behind emerging nanotechnology nations such as China and South Korea. Furthermore, the field of nanotechnology seems to have fallen behind other technology fields in Russia in terms of

[190] Igami and Okazaki *Capturing Nanotechnology's Current State of Development via Analysis of Patents*, p. 42.
[191] *Ibid*., p. 42.

its share of international patent filings. Meanwhile, many other countries display positive trends in nanotechnology and international patenting.

According to statements in the Development Programme for the Nano-industry of the Russian Federation to the year 2015, Russia's share of international nanotechnology patents was less than 0.2 percent in 2007. The Development Programme envisaged an increase in the number of nanotechnology patents in Russia filed by domestic organisations and individuals from 35 patents in 2008 to 430 in 2015.[192] Even if this ambitious goal can be achieved, some 400 patents in 2015 would probably still only be a fraction of the world total. It would not place Russia among the leading countries in nanotechnology, but could prevent a further decline in its world ranking.

The patenting data suggest that the Russian Federation was relatively strong in the subfield of nanobiotechnology and possibly also in nanomaterials. The latter seems to be the largest subfield in Russian patenting – more than one-third of all patents filed in Russia in 2005 concerned nanomaterials. Nanobiotechnology and nanomaterials were two of the subfields singled out by Russian officials as priority areas for R&D. On the downside, EPO data suggest that Russia is relatively weak in nanoelectronics and possibly also in nanomagnetics. Nanoelectronics is a very important field for the electronic components industry.

Finally, Russia seemed to enjoy a privileged position when it came to its access to international knowledge as demonstrated by its co-invented patents. Russian nanotechnology scientists may be able to use their relatively good access to foreign know-how to accelerate their learning curve. The high degree of cross-border cooperation

[192] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 6; Appendix 2.

in patenting should facilitate the Russian government's efforts to increase the number of Russian nanotechnology patents.

5.4 Conclusions on nano research

At the end of the first decade of the new millennium, Russia seems to be losing ground in nanoscience and nanotechnology research. Although prolific in terms of the number of scientific publications, its poor performance regarding the quality of research publications and nanotechnology patenting should be a cause for concern. Russia has fallen behind the leading nations in the field and been overtaken by emerging Asian nanotechnology nations. In 2010, it remained doubtful whether the government initiatives introduced would be able to propel Russia to a place among the leading nanotechnology countries in the short to medium term – even if they were fully implemented.

Russia enjoyed a relatively strong position concerning international collaboration in both nanotechnology research and patenting. This could probably mitigate Russia's decline in the international rankings, if cross-border cooperation were to continue and be strengthened. Together with the government initiatives, intense international collaboration could make it possible for Russia to maintain its position as a second-tier contender.

A first priority should be to increase the quality of research and the number of nanotechnology patents. From a societal point of view, increased patenting is of the utmost importance. Scientific research is important for laying the basis for new patents, but would have more potential impact on society if it were successfully transformed into new products. Patenting and product development are also dependent on the climate for innovation and commercialisation, which is discussed in chapter 6.

6 Innovation, commercialisation and intelligence support

> Russia's rich educational, scientific and creative heritage gives our country clear advantages for creating a competitive economy based on knowledge and intellect, an economy driven not by the rate at which natural resources are exploited, but above all by the ability to come up with new ideas and inventions and introduce them more rapidly than others into everyday life.
>
> *President Vladimir Putin, April 2007*[193]

High quality scientific research and high levels of patenting are necessary prerequisites for R&D to have an impact on society. However vital these may be, they are not the only conditions that need to be in place. Innovation and commercialisation are of equal importance for achieving an impact on national economic, military and societal development. This chapter assesses Russian innovation and commercialisation and the potential impact of nanotechnology on Russia. For historical reasons, these areas may together be the weakest link in the chain.

In addition,[194] the chapter discusses obstacles to innovation and commercialisation, such as the legal framework and the business climate, which are found wanting in many ways, as well as the pros and cons of providing support to the nanotechnology effort through the intelligence services.

[193] President of Russia 'Poslanie Federalnomu Sobraniiu Rossiiskoi Federatsii [Address to the Federal Assembly]'.
[194] For an overview of the Russian innovation system in general, see Roffey *Biotechnology in Russia: Why is it not a success story?*, pp. 45–54 and 74–5.

6.1 Russian nanotechnology innovation

In February 2008, the minister for science and education, Andrei Fursenko, stated that the most important task concerning nanotechnology was to facilitate the necessary commercialisation of the scientific results achieved in the field. Fursenko enumerated five directions of such commercialisation to be supported by the government. The first promising direction for commercialisation was innovative construction materials, mainly new steel alloys, with an estimated market of RUB 150–200 billion per year. Second, was catalysts and catalytic membranes for the oil industry, with an estimated market of hundreds of billions of Roubles.

The third direction was so-called bio-chips for fast analysis of infectious deceases. The minister stated that there would be a need for millions of such analyses every year in Russia alone. Fourth, was new light sources, and the Russian market for light emitting diodes (LEDs) was estimated to exceed RUB 70 billion per year while the world market was estimated at USD 60 billion. According to Fursenko, Russian industry would definitely be able to compete in this area. The fifth and final direction for government support for the commercialisation of the results of nanotechnology research was instruments for diagnostics and measuring. Although the world market was estimated at only USD 1 billion, nanotechnology instrumentation was considered critical to the Russian nanotechnology industry as a whole.[195]

In November 2010, in his speech to the Third International Forum on Nanotechnology in Moscow, President Dmitrii Medvedev mentioned three main areas of Russian nanotechnology product development. Medvedev emphasized medical vaccines and batteries for vehicles, as well as the above-mentioned energy-saving LEDs. The most important tools for stimulating

[195] Obraztsov 'My gotovy k novoi revoliutsii. Nanotekhnologicheskoi' ['We are prepared for a new revolution. A nanotechnology revolution'].

nanotechnology innovation and commercialisation mentioned by the president were developing the National Nanotechnology Network and creating regional nano-centres to service small and medium-sized companies.[196]

The RUSNANO state corporation is an important state actor in innovation and commercialisation, and it was given responsibility for both the National Nanotechnology Network and the development of regional nano-centres. According to its Director General at the time, Leonid Melamed, one aim of RUSANO was to finance the development of nanotechnology products with a total turnover of RUB 4 trillion by 2015. In early 2008, it was projected that Russia could have some 4 percent of the world market for nanotechnology products by 2015, estimated at USD 1.2–2.9 trillion.[197] By November 2010, however, Russia's expected share of the world market had been adjusted downwards to 3 percent. Medvedev stated that the turnover in domestically manufactured nanotechnology products was forecasted to reach RUB 3 trillion by 2015.[198] It should be noted that many important applications for nanotechnology in Western society are in industries that are not strong sectors in Russia. This applies to the car, chemical and electronics industries, but also to cosmetics, and medical diagnostics and treatments as well as sports equipment and accessories.

According to a 2007 report by the business intelligence company Lux Research, cross-border nanotechnology activity was becoming

[196] President of Russia (2010) 'III Mezhdunarodnii forum po nanotechnologii [3rd International forum on nanotechnology]', RF Presidential Administration, on the Internet: http://news.kremlin.ru/news/9407 (published: 3 November 2010; retrieved: 4 November 2010).
[197] RBK 'Rosnanotekh ozhidaet vyruchki v 5 mlrd rub. [RUSNANO is expecting dividends of 5 bln Rubles]'.
[198] President of Russia 'III Mezhdunarodnii forum po nanotechnologii [3rd International forum on nanotechnology]'; C.f. Chubais 'RUSNANO: Results of three years and strategy up to year 2015', pp. 2–3.

more important. Taking advantage of international funding, innovation, manufacturing and markets for nano-enabled products was becoming vital for prosperous nanotechnology companies.[199] It is therefore important to note that Russia enjoyed a relatively strong position concerning international collaboration in both nanotechnology research and patenting (see chapter 5). In April 2009, Sergei Mazureko, the head of the Federal Agency for Russian science and innovation, stated that Russian nanotechnology organisations were involved in a number of R&D projects with foreign research institutions. According to Mazurenko, there were 28 cooperative projects with Germany, 16 with China, 15 with France and 10 each with the USA and Latin America.[200] Russia had also started cooperating on nanotechnology within the Commonwealth of Independent States (CIS).

In 2010, Medvedev stated that simplified immigration procedures were to be introduced for highly qualified foreign specialists.[201] It is doubtful whether collaboration with the CIS countries will significantly improve innovation and commercialisation in Russia, but cooperation with leading nanotechnology nations such as Germany, France and China may well do so. It should, however, be noted that the number of cooperation projects with leading nanotechnology countries such as Japan and South Korea is small. Few collaboration projects have been reported with the USA – the world leader in nanotechnology.

It is the quality, not the quantity, of international cooperation that is of paramount importance to the specific issues of innovation and commercialisation. Does comparatively strong research collaboration translate into an equally strong transfer of knowledge

[199] Business Wire 'Top Nations in Nanotech See Their Lead Erode'
[200] Shmeleva 'Nano-bio-technologii vytachshat mir iz ekonomicheskoi yamy [Nanobiotechnology saves the world from the economic crisis]'.
[201] President of Russia 'III Mezhdunarodnii forum po nanotechnologii [3rd International forum on nanotechnology]'.

in the areas of innovation and commercialisation? The available data do not support an affirmative answer to this question.

6.2 Obstacles to innovation and commercialisation

The effectiveness of the Russian government's efforts to stimulate innovation and commercialisation in high technology areas, such as nanotechnology, was mitigated by societal factors. The absence of a benevolent legal framework in combination with a high level of corruption resulted in a poor business climate. Altogether it threatened to severely reduce the potential for innovation and commercialisation in Russia, in particular for small and medium-size enterprises.

The lack of legal protection for property in general and intellectual property rights in particular reduced the propensity to develop new products and businesses. Russian civil law, mainly for historical reasons, has lagged behind in areas such as property rights, but the law was not the main problem. The lack of experience in the Russian courts with dealing with property rights was perhaps an even bigger problem, but the main factor was the weak rule of law in Russia. A high-profile Moscow investment banker stated at the Russia Investment Summit in September 2007 that the single biggest problem for business in Russia probably was the likelihood of receiving a proper court hearing.[202] It remains to be seen whether Medvedev will be able to turn the country from the path of 'legal nihilism', as he, as a former lawyer, has expressed his intention of doing.[203]

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[202] Reuters 'Political inference Hurting Russia Business', 12 September 2007 as referenced in Lucas (2008) *The New Cold War: The Future of Russia and the Threat to the West* (New York, Palgrave Macmillan), p. 72.

[203] Financial Times 'FT interview: Dmitry Medvedev'.

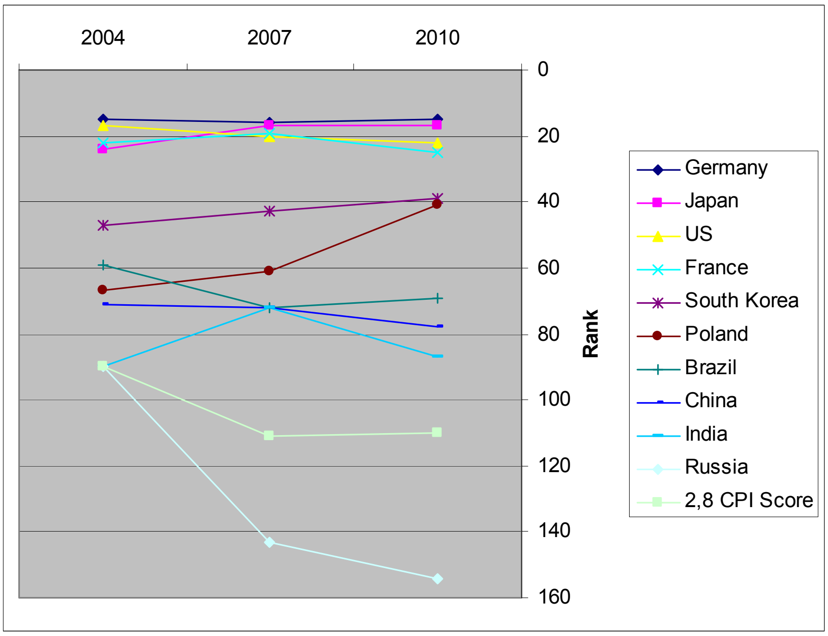
Another factor likely to seriously inhibit Russian innovation and commercialisation processes – as well as R&D on development – is widespread domestic corruption. Before he was elected, President Medvedev acknowledged the problem of corruption and the challenges in rooting it out.[204] By 2010, he had not presented a credible plan or policy on how to tackle corruption in Russia. The impact of corruption is difficult to assess, let alone compare between different countries. However, measuring the level of corruption gives an idea of the competitive advantages and disadvantages for different countries.

Transparency International's annual rating of perceptions of corruption ranks Russia 154 of the 178 countries and territories covered by the survey. It shares its place in the ranking with Cambodia, Congo-Brazzaville, Guinea-Bissau, Laos and Tajikistan, among others. More importantly, Russia is ranked the most corrupt country in Europe as well as among the G-20 nations.[205] In the period 2004–10, Russia fell in the rankings from 90 to 154 (see Figure 6.1).

Most of the comparable countries in the Corruption Perception Index (CPI) more or less maintained their position over the years. Poland gained several positions, from 67 in 2004 to 41 in 2010. Brazil and China fell slightly in the rankings, but the number of countries surveyed may have contributed to this. This, however, was not the case for Russia.

[204] *Ibid*.
[205] Transparency International (2010) *Corruption Perceptions Index 2010*, on the Internet: http://www.transparency.org/ (published: 26 October 2010; retrieved: 9 November 2010).

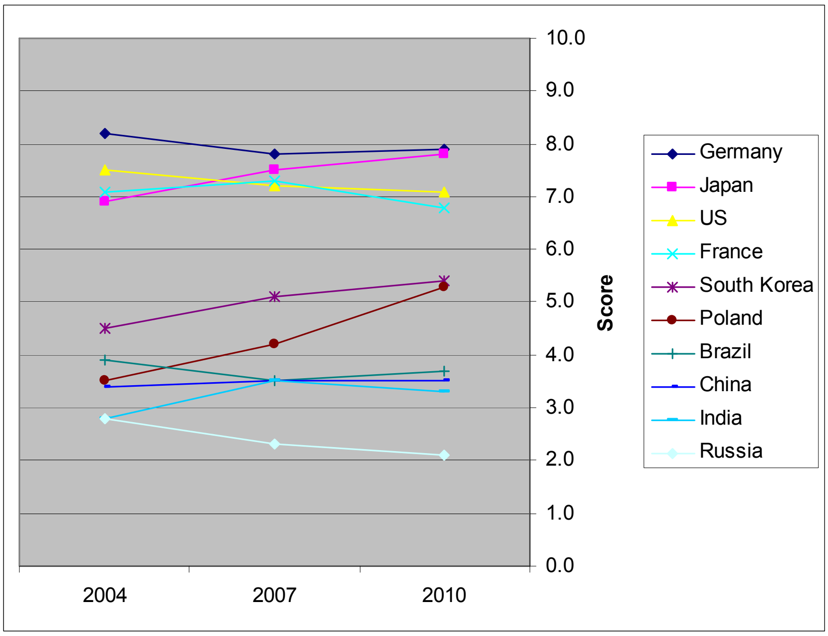
Figure 6.1. Transparency International Corruption Perceptions Index, Rankings for selected countries, 2004–10



Sources: Transparency International Corruption Perception Index for the years 2004, 2007 and 2010, available at www.transparency.org. The number of countries and territories surveyed increased from 146 in 2004 to 180 in 2007 and then fell slightly to 178 in 2010.
Note: The CPI ranks countries in terms of the degree to which corruption is perceived to exist among public officials and politicians. It is a composite index, drawing on corruption-related data in expert surveys carried out by a variety of organizations. It reflects the views of business people and analysts from around the world, including experts who reside in the countries evaluated.

As can be deduced from its ranking over the years, with a score similar to Russia's in 2004, that is a CPI score of 2.8, the increased number of countries and territories would have led to a fall to 110th position in the 2010 survey. From having shared the ranking of 90th with India in 2004, Russia dived in the rankings. The greater part of Russia's plunge was due to its score having decreased, as is shown in Figure 6.2. This was a serious cause for concern for Russia since the rankings are relative, while the scores are absolute. The Russian score went from 2.8 in 2004 to 2.1 in 2010, which is the biggest fall among the 10 comparator countries in absolute numbers (the USA comes second with a 0.4 fall).

Figure 6.2. Transparency International Corruption Perceptions Index scores for selected countries, 2004–10



Sources: Transparency International Corruption Perception Index for the years 2004, 2007 and 2010, available at www.transparency.org. The score is calculated on a scale where 10 is not corrupt and 0 is highly corrupt, *i.e.* countries with higher CPI scores are deemed less corrupt.

India, Japan, Poland and South Korea improved their scores over the years, indicating a reduced level of corruption in these countries. Russia, on the other hand, fared less well. The statistics presented by Transparency International suggest that corruption had risen in Russia and, moreover, that corruption had become a greater problem in Russia than in any of the nine other countries. This is bound to have a negative impact on Russian innovation and commercialisation processes unless Russia could radically reverse the trend.

A third important factor was the poor business climate for private companies, and in particular for small and medium-sized enterprises. During Vladimir Putin's two terms as president, Russian industrial policy was meddlesome and protectionist. The business climate was far from ideal for the growth of globally competitive companies. Putin's early reforms did not create a business climate beneficial for small and medium-sized enterprises. The aim of the reform legislation – apart from preserving the political weight of the central state apparatus – seemed to be to further the interests of companies dealing in natural resources. The harsh conditions for smaller businesses were already taking their toll – every fourth small and medium-sized enterprise in Russia was on the verge of bankruptcy or liquidation in 2001, according to the political analyst Lilia Shevtsova.[206] She further concluded that:

> Many small business people could not take the pressure from bureaucrats, demands for bribes, unreasonable requirements, and harassment by police and security services or the criminal underworld, so they chose to close their business and work for hire.[207]

In Western Europe, small and medium-sized enterprises generally account for the majority of the national GDP, but in Russia they account for a much smaller share. The business climate did not seem to have improved significantly half way into Medvedev's term as president. In 2010, the government was still mainly concerned with large companies, such as the state corporations and the major state joint stock companies. In 2008, then president-elect Medvedev acknowledged that state corporations accounted for about one-third of Russia's GDP.[208]

In a 2009 World Bank report on business climate world-wide, Russia ranked 120 out of 183 countries (see Table 6.1). Although

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206 Shevtsova (2005) *Putin's Russia* (Washington, Carnegie Endowment for International Peace), p. 190.
207 *Ibid*.
208 Financial Times 'FT interview: Dmitry Medvedev'.

ahead of India and Brazil, Russia was placed far behind the other countries in this study. The Russian Federation was far from having a competitive advantage regarding business climate, according to the World Bank report.

Table 6.1. World Bank Ease of doing business index, selected countries 2008–09

Country	2008	2009
United States	4	4
Japan	13	15
Rep. of Korea	23	19
Germany	27	25
France	31	31
Poland	72	72
China	86	89
Russian Federation	118	120
Brazil	127	129
India	132	133

Source: World Bank, Doing Business project (http://www.doingbusiness.org/).
Note: The ease of doing business index ranks economies from 1 to 183, with first place being the best. A high ranking means that the regulatory environment is conducive to business operation. The index ranks the simple average of the country's percentile rankings on 10 topics covered in the World Bank's Doing Business.

Membership of the World Trade Organisation (WTO) could stimulate the development of competitive and innovative companies in Russia, but it still seemed far away in 2010. Russian interest in joining the WTO is difficult to gauge as mixed signals have come from Moscow over the years. WTO membership – or rather, compliance with the WTO's rules – would be beneficial for importers of consumer goods and for many of Russia's manufacturers. It would also lead to a better business climate. However, it would not be as beneficial for the commodity industry, which has a very powerful lobby. It would also reduce the opportunities for using trade tariffs as a political tool aimed at other WTO countries.

The Russian Federation also performed less well in the Global Economic Forum report on competitiveness published in 2010. Russia was outranked by all the countries of reference in this study, coming far behind China, not to mention the top five (see Table 6.2). Regarding global competitiveness, Russia was at a disadvantage in comparison with the other nine comparator countries.

Table 6.2. Global Competitiveness Index, selected countries 2009–10

Country	**Rank**	**Score**
United States	2	5.59
Germany	7	5.37
Japan	8	5.37
France	16	5.13
Rep. of Korea	19	5.00
China	29	4.74
Poland	46	4.33
India	49	4.30
Brazil	56	4.23
Russian Federation	63	4.15

Source: The Global Competitiveness Report 2009–10, World Economic Forum. Available at http://gcr.weforum.org/gcr09/.
Note: The survey ranks 133 countries on a scale of 1 to 7, where 7 represents ultimate competitiveness.

A breakdown of the Russian ranking shows that institutions, goods market efficiency, the financial market and business sophistication accounted for its poor ranking. Infrastructure and technological readiness also contributed (see Table 6.3).

Table 6.3. Global Competitiveness Index, 2009–10, Russia

GCI 2009–10: Russia	**Subset**	**Rank**
Basic requirements		***64***
	Institutions	114
	Infrastructure	71
	Macroeconomic stability	36
	Health and primary education	51
Efficiency enhancers		***52***
	Higher education and training	51
	Goods market efficiency	108
	Labour market efficiency	43
	Financial market sophistication	119
	Technological readiness	74
	Market size	7
Innovation and sophistication factors		***73***
	Business sophistication	95
	Innovation	51

Source: World Economic Forum (2010) *The Global Competitiveness Report 2009–10*, available at http://gcr.weforum.org/gcr09/.
Description: The survey ranked the 133 countries individually both overall and in different categories.

Russia was more favourably evaluated , however, in terms of its macroeconomic stability and labour market efficiency, and particularly in market size terms. The World Economic Forum also considered Russia to have an advantage concerning nearly all aspects of innovation. Russia was ranked in the 40s for the quality of its research institutions, company spending on R&D, university-industry collaboration in R&D, and the availability of scientists and engineers as well as utility patents per million population. Only government procurement of advanced technology products, where

Russia ranked 69, pulled down the overall ranking for innovation.[209]

This positive picture of Russian innovation was countered, however, by a 2010 report on global innovation by INSEAD. Russia came eighth of the 10 countries compared in this study with a ranking of 64 (see Table 6.4). Only Brazil was ranked lower and again there was an obvious gap between Russia and the top five, and also between Russia and China.

Table 6.4. INSEAD Global Innovation Index, selected countries 2009–10

Country	Score	Rank
United States	4.57	11
Japan	4.50	13
Germany	4.32	16
Korea, Rep.	4.24	20
France	4.20	22
China	3.32	43
Poland	3.28	47
India	3.10	56
Russian Federation	3.03	64
Brazil	2.97	68

Source: INSEAD (2010) *Global Innovation Index 2009–10*, available at http://www.globalinnovationindex.org/gii/main/home.cfm.
Description: The survey ranked 132 countries, representing 96 percent of the world's Gross Domestic Product (GDP) and 91 percent of the global population.

According to the INSEAD report, Russia had been gradually falling back in the area of technology and innovation since the height of the Soviet era. The report noted that progress had been made with innovation but that Russia still faced many challenges:

209 World Economic Forum (2010) 'The Global Competitiveness Report 2009–10', *World Economic Forum*, on the Internet: http://gcr.weforum.org/gcr09/, Russia as selected country.

> Of late, the Russian Federation has taken multiple steps to boost Russian innovation but there is room for improvement. The Russian economy still lags behind other large OECD and middle-income economies in terms of R&D-based outputs. Russia has an educated work force, but yet it lacks the proper skills to compete in global markets. Russian firms' trade in parts and components for electrical machinery which is a standard measure of the integration in global production-sharing networks, is significantly lower relative to countries like Germany, Poland, China, India, South Africa, and Brazil. Interestingly, Russian scientists and inventors largely tend to apply only for Russian patents, avoiding patent registration abroad. Crucially, the Russian economy needs to work on increasing productivity levels and competitiveness in its manufacturing sector.[210]

As is mentioned above, there are a number of reasons why ideas are not patented in Russia. Intellectual property laws are weak and the courts are inexpert in handling such cases. This, in turn, explains why fewer intellectual property products have been developed in Russia.[211]

Widespread corruption, a lack of the rule of law and a business climate not conducive to small and medium-sized enterprises have thus negatively affected innovation and commercialisation in Russia. The political regime's inability to address these problems is likely to continue to negate government initiatives to stimulate innovation. The creation in 2010 of a state-sponsored special zone for innovation in the village of Skolkovo outside Moscow merely underscores the government's failure to create viable conditions in the country as a whole. With special laws and tax exemptions, the Silicon Valley-inspired Skolkovo centre is supposed to act as an incubator for new and innovative enterprises, but it remains to be seen whether the centre can nurture companies that will survive outside the special zone.

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[210] INSEAD (2010) 'Global Innovation Index 2009-2010', *INSEAD*, on the Internet: http://www.globalinnovationindex.org/gii/main/reports/2009-10/FullReport_09-10.pdf (retrieved: 11 November 2010), p. 28–9.

[211] Lucas *The New Cold War: The Future of Russia and the Threat to the West*, p. 89.

6.3 Intelligence service support: An alternative way forward?

There are many ways to boost national science and technology (S&T), and industry and each state tends to use a number of options in conjunction with each other. Increased spending on domestic R&D is one way to stimulate S&T. Intensifying and deepening international cooperation is another. The government can work with a multitude of instruments to create an environment conducive to innovation and research, such as making it economically rewarding through legislation that protects intellectual property, by eliminating corruption and bureaucracy that stifles entrepreneurship and by supporting creative research environments. An additional way could be to acquire foreign know-how and technology through espionage. This path is particularly tempting for countries with limited options in the areas mentioned above, or for those that believe they are too far behind the competition.

In 2010, there was little doubt that the intelligence services of the Russian Federation were active in S&T intelligence collection directed at foreign states. This conclusion is supported by official documents and historical precedents as well as assessments by scholars, former Russian intelligence officers and foreign intelligence services.[212] In 2007, the then-president, Vladimir Putin, was reported to have stated that 'the efforts of the intelligence [services] must be concentrated on strengthening the industrial […] potential of Russia'.[213] The impact of any intelligence gathered on the performance of Russian R&D and industry, however, is difficult

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[212] This section is to a large extent based on parts of the FOI Memo Westerlund (2010) *Russian Intelligence Gathering for Domestic R&D – Short Cut or Dead End for Modernisation?*, Stockholm, Swedish Defence Research Agency (FOI), April 2010, FOI Memo 3126.

[213] Fedorov (2007) 'SVR – odna iz samykh effektivnykh slyzhb [SVR – one of the most efficient services]', on the Internet: http://www.redstar.ru/2007/10/23_10/1_03.html (published: 23 October 2007; retrieved: 25 October 2007)..

to assess. Fully exploiting S&T intelligence demands significant domestic scientific and industrial resources.

It is, furthermore, not always obvious that intelligence support for domestic science and industry is easily compatible with the other avenues for stimulating research and development. This section explores the support provided by the Russian intelligence services to domestic nanotechnology research and industry, and examines its potential effects. Possible areas of support to the Russian nanotechnology effort, such as gathering intelligence and providing security and management, are discussed below as well as the obstacles to and risks associated with intelligence support.

6.3.1 Nanotechnology and Russia's intelligence services

The intelligence services can support the national science and industry in more than one way. They can provide access to foreign S&T or commercial secrets and help to protect domestic know-how from being stolen by other states and foreign companies. Intelligence agencies can also provide managerial and bureaucratic support to foster science and innovation. What, then, can the Russian intelligence services do to support the nanotechnology effort?

The Russian intelligence services have a proven capacity to collect and pass on information on foreign know-how, research and technologies to science and industry. For instance, the clandestine organisation created to collect intelligence for the Soviet biological weapons programme may still be functional and might be used to support R&D in the area of nano-biotechnology.[214] The Soviet nuclear weapons programme was dependent on a foreign intelligence–gathering organisation, the successor of which is the

[214] Kouzminov (2005) *Biological Espionage: Special Operations of the Soviet and Russian Foreign Intelligence Services in the West* (London, Greenhill Books), p. 32–8.

NRC Kurchatov Institute.[215] As is mentioned above, this institute still enjoys a central position in Russian nanotechnology. It is probable that the relationship between the Russian intelligence services and the Kurchatov Institute has remained close over the years, not least because nuclear science remains a closely guarded secret. It is possible that a leading role in Russian nanotechnology was given to the Kurchatov Institute for this reason, in combination with its scientific proficiency.

Gathering information for the use of domestic science and industry, however, is not risk-free. If the security services in other countries suspect that Russia is spying, the flow of knowledge into Russia could suffer. Foreign companies and research institutions will be alerted to the risk of espionage and access to state-of-the-art science could become restricted for Russian researchers and engineers.

Another way for the intelligence services to contribute to the development of domestic science and industry is by providing able managers. High-level officers in the intelligence services may be singled out to coordinate national efforts in science, as well as in other areas, because they are perceived as possessing the means for implementing grand plans. In 2010, a number of former intelligence officers were involved in the management of nanotechnology development in Russia at the senior executive level. As prime minister, Putin chaired the Government Commission on High Technology and Innovation which was, among other things, responsible for nanotechnology development. Other members of the Commission were the former foreign intelligence officer, Sergei Chemezov, director general of the defence-industrial state corporation Russian Technologies (Rostekhnologiia), and the head

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[215] The Kurchatov Institute is named after its original creator Igor Kurchatov, the scientific leader of the Soviet nuclear weapons programme headed by the NKVD director Lavrentii Beria; Holloway (1994) *Stalin and the Bomb* (New Haven, Yale University Press), p. 134 and 221. The People's Commissariat for Internal Affairs (Narodnyi Komissariat Vnutrennikh Del, NKVD) was the early Soviet era security service.

of Russian Railways, Vladimir Yakunin. Putin headed the Federal Security Service (FSB)[216] before becoming prime minister and both Chemezov and Yakunin are often alleged to have been officers serving in its predecessor – the KGB.[217]

Sergei Ivanov, the former Defence Minister, served in the KGB and later the Foreign Intelligence Service (SVR)[218] until 1998. In 2010 he was deputy chairman of the Government Commission on High Technology and Innovation, but he wielded even more influence over nanotechnology issues through his other prominent assignments. Ivanov was appointed first deputy prime minister in 2007 with responsibility for the defence industry, aerospace and nanotechnology. In the same year, he also became chairman of the Government Council for Nanotechnology. In 2008, Ivanov was entrusted with the supervision of the Development Programme for the Nano-industry of the Russian Federation to the year 2015.

It is probable that the professional backgrounds of these former intelligence officers has been less of a decisive factor in their appointments than their close friendship with Vladimir Putin.[219] Personal connections to Putin could also provide an alternative explanation for assigning a leading role in Russian nanotechnology

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[216] The Federal Security Service of the Russian Federation (Federalnaia Sluzhba Bezopasnosti Rossiiskoi Federatsii, FSB) is the main successor of the KGB. In 2003, the Border Troops and large parts of the disbanded signals intelligence agency FAPSI (Federalnoe agenstvo pravitelstvennoi sviazi i informatsii pri Prezidente RF, Federal Agency for the Protection of Government Communications) were incorporated in the FSB, making it the largest Russian intelligence service.

[217] Felshtinsky and Pribylovski (2008) *The Age of Assasins: The Rise and Rise of Vladimir Putin* (London, Gibson Square), p. 256. The Committee for State Security (Komitet Gosudarstvennoi Bezopasnosti, KBG) was the name of the all-union Soviet civilian intelligence service from March 1954 to the fall of the Soviet Union in the autumn of 1991.

[218] The Foreign (literally External) Intelligence Service (Sluzhba Vneshnei Razvedki, SVR) is the successor to the KGB First Main Directorate (Foreign Intelligence) and was created in 1991.

[219] However, such a friendship would perhaps not have developed without a shared professional background. C.f. Gomart (2008) *Russian Civil-Military Relations: Putin's Legacy* (Washington, D.C., Carnegie Endowment for International Peace), p. 62.

to the NRC Kurchatov Institute. The director of the institute since 2005 has been Michail Kovalchuk, the brother of Yurii Kovalchuk, who has been part of Vladimir Putin's entourage since the mid-1990s.[220] Yurii Kovalchuk started his career as a researcher at the Ioffe Institute, working with Vladimir Yakunin and Andrei Fursenko, serving as Minister for science and education in 2010. They were all major shareholders in the Bank Rossia and, with Putin, founding members of the *Ozero* summer house cooperative near the village of Solovevka outside St Petersburg.[221] Mikhail Kovalchuk was in 2010 also member of the Supervisory board of RUSNANO, which was headed by Andrei Fursenko.

In the light of the above, it seems probable that intelligence service skills were perhaps not the primary factor in assigning these former intelligence officers senior managerial positions, but rather the fact that they were trusted by Putin. The more critical question is whether these men have the managerial skills needed to foster innovation and a mindset conducive to expanding science and industry in the field of nanotechnology.

Russian intelligence services can also support Russian nanotechnology by providing security and protection. Safeguarding Russian science and technology from foreign intelligence services and corporations has been one of the tasks of the FSB since its creation in 1995. The FSB drew on the extensive experience of counterintelligence operations of its Soviet predecessor. It is a legitimate national interest to prevent foreign entities from stealing Russian know-how, but there is also a cost to security as it hampers the flow of information. The FSB has taken concrete steps to protect domestic nanotechnology research. In

[220] This claim has for instance been made by the former government ministers Boris Nemtsov and Vladimir Milov; Nemtsov and Milov (2008) *Nezavisimyi ekspertnyi doklad 'Putin. Itogi' [Independent expert report 'Putin. Results.']*, Moscow, Novaia Gazeta, p. 10–11.

[221] See for instance http://www.anticompromat.org/kovalch1/rossia_b.html

December 2008, the head of the FSB directorate for the Saratov region singled out Russian nanotechnology and electronics research projects as being of particular interest to foreign special services. The FSB regional chief also expressed concern that foreign intelligence services were trying to obtain classified information as part of international scientific exchange programmes.[222]

In 2007, there were several instances of charges of espionage being brought against Russian academics.[223] In January 2010 a director at one of the institutes of the Russian Academy of Sciences complained that the security services were paying close attention to Russian scientists and producing trumped-up charges of espionage.[224] Such activities by the domestic security services could result in scientists refusing to take part in international research projects or declining funding from abroad, which would be to the detriment of Russian science.

6.3.2 Intelligence support: a short-cut or a dead-end?

Industrial espionage and other types of intelligence service support could provide short cuts at a time when Russia feels that it is pressed to develop its nanotechnology science and industry rapidly in order to catch up with the West. Involving the intelligence

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[222] Interfax (2008) 'Foreigners Seeking High-tech Secrets in Saratov Region – Security Chief', *Interfax News Agency* (redistributed by BBC Monitoring Service) (originally published: 16 December 2008).

[223] Racheva (2007) 'Space as Evidence', *Novaya Gazeta*, on the Internet: http://en.novayagazeta.ru/data/2007/94/07.html (published: 17 December 2007; retrieved, 21 April 2010); Rich (2007) 'Scientist Scientists? Risk Prosecution', *Times Higher Education*, on the Internet: http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=207675 (published: 2 February 2007; retrieved 25 March 2010).

[224] Dziuba (2010) 'Sharashkina kontora [Sharashka's office]', *Novaya Gazeta*, on the Internet: http://www.novayagazeta.ru/data/2010/003/00.html (published: 15 January 2010; retrieved: 21 April 2010). The title of the article is an expression borrowed from Russian slang and alludes to the Soviet secret R&D laboratories set up within the Gulag labour camp system, often referred to as *sharashkas*.

services in scientific and industrial projects could, however, prove to be a dead end.

In 2010, Russia undoubtedly possessed the tools for extensive collection of S&T intelligence abroad. However, this does not automatically imply dividends for domestic science and industry. It could prove difficult to transfer foreign technology and know-how to Russian research institutions and industrial enterprises. A successful transfer of technology is dependent on the capacity of the recipients to make use of the information they receive. Even though Russian science has been internationally competitive in several areas in the post-Soviet era, large parts of domestic industry have found it difficult to convert scientific advances into competitive mass-produced products.

Tempting as it may be to cut corners by relying on the intelligence services to further national science and industry, there are several risks connected with such support. Reliance on intelligence may dull the edge of science by making it reactive and dependent on foreign findings. Even if it is possible to catch up with foreign competitors through espionage, it is hard to overtake them. Furthermore, the security mindset of intelligence services, with its emphasis on risk reduction, is in many ways the opposite of a climate conducive to research and innovation, that is, one that focuses on opportunities and encourages risk-taking. Too much security thinking becomes an obstacle to science.

Another important aspect of intelligence support to Russian nanotechnology well worth highlighting is its potentially negative impact on cross-border cooperation. In an era of technological globalisation, international cooperation is of the utmost importance for scientific and technological progress. As is concluded in chapter 5, Russia’s primary strength in nanotechnology research and patenting is its comparatively good position concerning international collaboration. Intelligence efforts may undermine Russia’s main advantage in the field of nanotechnology.

6.4 Conclusions

It is crucial to assess Russia's potential to make efforts in innovation and commercialisation in order to be able to draw conclusions about whether nanotechnology can fulfil the expectations that Medvedev and other politicians attach to this field and its ability to kick-start the economy. Without successes in these areas, good performance in scientific research and patenting will have only a limited impact on society.

Russia has big ambitions regarding the development of domestic innovation and commercialisation, not least in the field of nanotechnology. This is evident from the many state projects in this direction and the relatively large levels of funding envisaged. However, the road ahead is anything but free from obstacles. In fact, Russia could face greater problems in this area than many other countries. In 2010, Russia did not compare favourably with most other leading or emerging nanotechnology nations on important aspects such as business climate and perceptions of corruption in society.

The Russian government also acknowledged that there were problems regarding nanotechnology innovation and commercialisation. According to a statement in the Development Programme for the Nano-industry of the Russian Federation to 2015: '[t]he low susceptibility of the industry to product development in the field of nanotechnology under the conditions of transition to an innovation development road is the major restraining factor'.[225] Furthermore, Medvedev acknowledged in November 2010 the many legal and bureaucratic obstacles to nanotechnology research, innovation and commercialisation. The

[225] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 8.

main task for the state was to remove these obstacles by amending taxation, administrative and civil law.[226]

In 2010 the Russian Federation remained far from acquiring a competitive advantage regarding innovation and commercialisation that could boost domestic nanotechnology. This was partly due to its Soviet legacy, but Russia should have been able to take better care of the rich scientific inheritance it received from its predecessor.

Industrial espionage and counterespionage could be a way to catch up with Western R&D, but it could equally prove harmful by raising barriers both inside and outside Russia to cooperation with foreign scientists, engineers and businessmen. It could thus seriously undermine nanotechnology development. In other words, intelligence service support to nanotechnology science and to industry could do more harm than good.

[226] President of Russia 'III Mezhdunarodnii forum po nanotechnologii [3rd International forum on nanotechnology]'.

7 The feasibility and potential impact of Russian nanotechnology efforts

> Nanotechnology is capable of changing mankind, changing our lives. We have our unabashed task in this respect: we want to be among the leaders of this process – and we have the intellectual potential, the organisational requirements and the financial means to this end.
>
> *President Dmitrii Medvedev, October 2009*[227]

> We wanted [to do it] better, but it turned out like always.
>
> *Viktor Chernomyrdin*[228]

Are Russia's plans regarding nanotechnology feasible? The assessment in the previous chapters of Russian investment, research, innovation, commercialisation and intelligence service support in the nanotechnology sphere provides at least a tentative answer. There is also the question of the impact that nanotechnology could have on the Russian Federation from a security policy perspective.

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[227] President of Russia 'Vystupleniie na otkritii II Mezhdunarodnogo foruma po nanotekhnologiiam [Speech at the opening of the 2nd International Nanotechnology Forum]'.

[228] This quotation has, however with slightly different wording, been repeatedly attributed to Viktor Chernomyrdin as his comment on a botched monetary overhaul by the Russian Central Bank in 1993; Barry and Schwirtz (2010) 'Viktor Chernomyrdin, Russian Ex-premier, Dies at 72', *New York Times*, on the Internet: http://www.nytimes.com/2010/11/04/world/europe/04chernomyrdin.html?_r=2 (published: 4 November 2010; retrieved: 9 November 2010). Chernomyrdin, the Soviet oil and gas minister who became head of Gazprom and a long-serving prime minister under Boris Yeltsin, died on 3 November 2010. The quote in Russian, *Choteli kak luchshe, a poluchilos kak vsegda,* was reported by the Russian daily newspaper Gazeta in an obituary of Chernomyrdin; Gazeta (2010) 'Aforizmy Chernomyrdina [Chernomyrdin's aphorisms]', *Gazeta. Ru*, on the Internet: http://www.gazeta.ru/subjects/chernomyrdin.shtml?info_left1 (published: 3 November 2010; retrieved: 9 November 2010).

This concluding chapter analyses the likely success of the Russian nanotechnology effort based on its observed strengths and weaknesses. Thereafter, some tentative conclusions on the future impact of Russian nanotechnology on security policy are presented.

7.1 The feasibility of Russia's nanotechnology efforts

Does Russia possess the intellectual potential, organisational requirements and infrastructure as well as the financial means needed to meet the targets envisaged in the government's plans to develop domestic nanotechnology? Has Russia the potential to become one of the leading nanotechnology nations in the world?[229]

Russia set out ambitious goals. For example, the short term goal of the Development Programme for the Nano-industry, launched in 2007, was to form a competitive sector for R&D in the field of nanotechnology by 2011. The intention was that new nanotechnology products would be developed and then industrially produced two to three years later, and that an efficient system for the commercialisation of nanotechnology products would be established. The ultimate goals of the Development Programme were to lay the foundations by 2015 for a large-scale increase in the production volumes of new types of products in the nano-industry and to establish Russian companies in the international high-technology market.[230]

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[229] See for instance the quote above by president Medvedev and statements by Vladimir Putin (Prime Minister Vladimir Putin 'V. V. Putin provel soveshanie po voprosy 'O realisatsii "Strategii razvitiia nanoindustrii"' [Putin held meeting on the issue of 'Realisation of the "Strategy of the development of the nano-industry"']'), minister for Education and Science Andrei Fursenko (World News Connection 'Russian Govt To Invest Over Rbl 4 Bln In Nanotechnologies In 2007').

[230] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 4.

Another grand target was set out in the RUSNANO long-term strategy. It specified that Russia's share in the world nanotechnology market should rise from 0.07 percent in 2008 to 3 percent in 2015.[231] A long-term goal, expressed in the RUSNANO strategy up to 2020, was the creation of a new technological base for the economy of the Russian Federation by 2025.[232]

For Russia to achieve these targets would mean overcoming a number of formidable challenges. In late 2007, the Russian government acknowledged that domestic demand for nanotechnology products in many socially important areas, such as medicine, energy production, ecology and housing, exceeded Russian industry production volumes tenfold.[233] In a speech at the opening of the Second International Nanotechnology Forum in October 2009, Medvedev claimed that Russia had the intellectual potential to become one of the world leaders in nanotechnology, but also acknowledged that the lack of qualified personnel was a serious obstacle to Russian nanotechnology development. Citing expert opinion, Medvedev stated that some 100 000–150 000 nanotechnology specialists were required.[234] However, the available data on Russian nanotechnology research performance, such as citations in publications and patents registered, does not support the statement that Russia had the intellectual potential required in 2009. Both the quantity and the quality of Russian research make it unlikely that Russia would become a leading nation within a single decade.

[231] Chubais 'RUSNANO: Results of three years and strategy up to year 2015', pp. 2–3.
[232] RUSNANO Supervisory Board 'Strategiia deiatelnosti gosudarstvennoi korporatsii "Rossiiskaia korporatsiia nanotekhnologii'" do 2020 goda [Strategy for the affairs of the state corporation 'Russian nanotechnology corporation' up to year 2020]', p. 11.
[233] RF Government *Programma razvitiia nanoindustrii v Rossiiskoi Federatsii do 2015 goda* [Development Programme for the nano-industry in the Russian Federation to the year 2015], p. 8.
[234] President of Russia 'Vystupleniie na otkritii II Mezhdunarodnogo foruma po nanotekhnologiiam [Speech at the opening of the 2nd International Nanotechnology Forum]'.

This conclusion is not surprising considering the hardships endured by the Russian science sector in the last few decades. In the early 1980s, Soviet science on microelectronics was some 15 years behind world standards.[235] Then, years of stagnation and efforts to reform (*perestroika)* followed, before the break-up of the Soviet Union left Soviet science in tatters. The turbulent 1990s, which ended in a financial meltdown, did not improve the situation for the remnants of Soviet science – or industry – inside Russia.

However, the main challenge regarding intellectual potential neither was or is primarily in the fields of science and engineering. Rather, it is questionable whether Russia possesses the necessary requirements and intellectual capital for innovation, entrepreneurship and business management. Improving these capacities is crucial to increasing Russia's share of the world market, which in turn is necessary to successfully restructure the Russian economy. As is concluded above in chapter 6, Russia did not have a competitive advantage in this respect in 2010. The cause was not necessarily weak intellectual potential. Instead, lack of infrastructure and institutional support, as well as insufficient funding, are likelier causes.

In the quote above, Medvedev asserts that Russia has the organisational requirements to become one of the leading country in nanotechnology. Did he have well-founded reasons for his optimism, or did it indicate that Russia would once again rely on the experience gained during the Soviet era by gearing the state apparatus to realise a large-scale project? The overview provided in chapter 3 shows that the state remained the dominant actor in the field of nanotechnology. Extensive government involvement in emerging fields of science and industry is not necessarily harmful.

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[235] Sagdeev (1994) *The Making of a Soviet Scientist* (New York, John Wiley & Sons), p. 298.

On the contrary, active state participation may be crucial for the development of new industrial sectors, especially in the early stages of the process. However, it is a very delicate matter to balance government interference so that it does not create suboptimal conditions or stifle initiatives.

It remains to be seen whether the solutions favoured by the political leadership and the skills of the bureaucracy are suitable for fostering the development of a high-tech industry in Russia. In 2010, its track-record of promoting growth outside the commodity and defence industry sectors was poor and did not provide grounds for optimism. Industrial policy was not suited to the growth of new small and medium-sized enterprises or to foster innovation and commercialisation. Furthermore, the level of incompetence and corruption in Russian state organisations risk undermining even sound government policies.

It was probably not a recipe for success to allow three state bodies, the RAN, the National Research Centre Kurchatov Institute and RUSNANO, to establish dominant positions in Russian nanotechnology. There were also obvious dangers involved in relying on the organisational strengths of the intelligence services. Intelligence support to science and industry could jeopardize Russia's comparative advantage: its close cooperation with other nanotechnology nations. Furthermore, the potential gains of any successful industrial espionage operations are likely to be small, because of the poor scientific and industrial infrastructure.

Russian infrastructure for nanotechnology R&D and industry was severely underdeveloped at the launch of the government nanotechnology strategy. This was reflected by the heavy emphasis on infrastructure investment in the different development programmes, as shown in chapter 3. The lack of infrastructure for nanotechnology research is also evident from the examination of the history of Soviet and Russian nanotechnology in chapter 5.

Despite the seriousness of the situation, the greatest challenge in 2010 and beyond is not R&D but the mass production of nanotechnology items. In 2007, the then Ministry for Industry and Energy stated that the capacity for micro-electronics component production in Russia had reached a critically low level. [236] Production facilities that allowed high volume serial production of quality micro-components were almost non-existent in Russia. Mass production of nanotechnology components is very demanding, and the outlook for rapid development seems bleak. Noting that Russia even in the traditional industries had proved unable to preserve production volumes, Academician Yurii Tretiakov considered an accelerated development of Russian nano-industry a utopian concept. He also expressed doubts that anybody would prefer investing in nanotechnology ”as long as the petroleum, gas and building businesses ensure superprofits in our country”.[237]

This leads on to the question of whether Russia possessed the financial means to become a leader in nanotechnology development when the strategy was launched. The statement in 2007 by the minister for Education and Science, Andrei Fursenko, that Russian investment in the development of nanoscience and nanotechnology infrastructure would allow Russia to become the world’s nanotechnology leader[238] does find some support in the data presented in chapter 4. Russia’s government expenditure on nanotechnology was arguably the highest in the world in 2009. However, industrial and scientific infrastructure development

[236] RF Ministry for Industry and Energy (2007) ’Elektronnaia strana [Electronical country]’, *Ministerstvo promyshlennosti i energetiki Rossiiskoi Federatsii*, on the Internet: http://www.minprom.gov.ru/activity/defence/news/57 (published: 11 September 2007; retrieved: 17 July 2008). A long term strategy for development of the domestic electronics industry up to 2025 was approved in 2007.
[237] Tretyakov ’Challenges of Nanotechnological Development in Russia and Abroad’, p. 20.
[238] World News Connection ‘Russian Govt To Invest Over Rbl 4 Bln In Nanotechnologies In 2007’.

needs seemed almost insatiable and there was little sign of substantial private investment in the sector.

In most other countries surveyed, private sector investment in nanotechnology surpassed government financing. This resulted in a less privileged position for Russia when its total funding for nanotechnology development was compared with that of other countries. In 2010, there were few private investors in Russia, and foreign capital had shown little interest in high-tech industries such as nanotechnology due to the poor climate for long-term investment. Investors from developed countries could have brought important capital to Russia, as well as ideas about corporate management, governance, and reporting and accounting standards – not to mention the fact that joint ventures are perhaps the most effective way of achieving technology transfer.

In conclusion, reaching the goals in the government's Development Programme and the RUSNANO strategy appeared unrealistic in early 2011. It does not seem likely that an efficient system for the commercialisation of nano-products will be in place by the end of 2011, given the challenges and lack of experience in this area. Nor is it likely, given the lack of an industrial infrastructure, that a significant number of new nanotechnology products would be developed by 2011 and industrially produced within two to three years.

The ultimate goal of the Development Programme also seems distant. With good will, Russia may be able to claim that it has laid the foundations for a large-scale increase in the production volume of new kinds of nano-industry products. However, Russian companies will not be established in the global high-technology market by 2015. In particular, it appears unlikely that the 3 percent share of the world market will be achieved on schedule.

The long term goal of the RUSNANO strategy of creating a new technological base for the economy by 2025 also appears difficult to attain in the light of Russia's industrial policy development up to

2010. A massive inflow of foreign direct investment and know-how, as well as a rapid growth in the competitiveness of companies due to a significantly improved business climate, could facilitate such a shift. There were, however, few signs that the political leadership might introduce the necessary changes in 2010. It therefore seems highly unlikely that the goals, short-term as well as long-term, for nanotechnology development in Russia will be reached.

These conclusions are valid for a number of technology sectors, and the government plans for these, in Russia. However, government plans and the targets set in them should not necessarily be interpreted literally. Perhaps they should be seen as a way of setting out the general direction in which to strive. Setting ambitions high may be a way, even the only way, of setting a large bureaucracy in motion. In the era of the Soviet planned economy, only a fraction of the targets in the plans were met.[239] For instance, not even one of Russia's state armaments programmes was fully realised. Instead, they were replaced by a new armaments programme, often several years before the end date of the existing programme. In other words, concluding that the plans will not be implemented in full or that the main goals will not be attained is perhaps not as important as simply establishing that the efforts are real, that money is being devoted to nanotechnology and that this is a genuine policy aspiration, albeit one that will take a long time to reach the end goal.

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[239] For instance, the former Russian academician Roald Sagdeev recounts that senior bureaucrats within the Soviet military-industrial complex acknowledged in the late 1970s that only 16 percent of the plans formally approved by the Commission on Military-Industrial Issues were implemented in full; Sagdeev *The Making of a Soviet Scientist* , p. 243.

7.2 The security policy impact of Russian nanotechnology

Will nanotechnology have a significant impact on Russian society? What are the security policy implications of Russia's nanotechnology efforts? This study does not provide ready answers to these questions and it is probably too early to say. While awaiting the advent of further research, it is possible to make some observations and draw some tentative conclusions.

In April 2007, the then President Putin, in his eighth address to the Federal Assembly, stated that nanotechnology was a key area of development. From a long-term perspective, it could increase the quality of life of the Russian people, improve national security and support strong economic growth.[240] In August 2010, Prime Minister Putin repeated that he considered the development of nano-industries directly connected to the modernisation of the Russian economy and to its future ability to innovate and develop.[241]

Russian nanotechnology could have an impact on the security policy of the Russian Federation, for example through its contribution to the strength, size and character of foreign trade, the national economy and military organisation, as well as to demographic developments and public health. Furthermore, the level of scientific proficiency in itself has an impact on the national self-image and how a country is perceived by other countries.

In 2010, the Russian population had been shrinking for many years and this demographic decline seemed set to continue for the

[240] President of Russia 'Poslanie Federalnomu Sobraniiu Rossiiskoi Federatsii [Address to the Federal Assembly]'.

[241] Prime Minister Vladimir Putin 'V. V. Putin provel soveshanie po voprosy "O realisatsii 'Strategii razvitiia nanoindustrii'" [Putin held meeting on the issue of 'Realisation of the "Strategy of the development of the nano-industry"']'.

foreseeable future. Nanotechnology would not appear to be a cure for the low birth rate, but it could have an impact on life expectancy by providing improved diagnostics and more effective medical treatments. Similarly, nanotechnology products could improve public health in Russia, allowing for a healthier workforce and improved physical wellbeing among potential military personnel.

However, this has not been among the top priority areas of nanotechnology research in Russia. It is also dependent on developments in the field of biotechnology, one of the five priorities in President Medvedev's modernisation plan. Despite ambitious plans, the chances of success were considered bleak in 2010.[242] Furthermore, a large proportion of the cases of early death and injury are the result of violence and accidents, which are often alcohol-related. Nanotechnology would not appear to provide any answers to this. On the whole, domestically manufactured nano-products will probably not have any significant positive impact on Russian demography and public health by 2020, and possibly not in the following decade either, although foreign nano-products may make a difference.

The potential impact of nanotechnology on the national economy has been touched on above. The chances of creating a new technological base for the economy by 2025 are slim, unless the government radically changes its industrial policies and manages to significantly improve the business climate in Russia. Nanotechnology will most likely contribute to Russian future exports, but in 2010 it did not seem destined to become a major source of export revenue over the following decade. Eventually, nanotechnology may, and probably will, become an important part of the Russian national economy and its foreign trade, but the

[242] Roffey *Biotechnology in Russia: Why is it not a success story?*.

impact of the domestic nano-industry will probably not surpass other indigenous high-technology industries.

The Russian Armed Forces will, like those of other nations, be interested in increasing their capabilities by employing nanotechnology, and there are a number of fields in which nano-products could lead to improvements. As is mentioned in chapter 1, firepower, protection, mobility, and command and control may be improved by the application of nanotechnology. However, developing such products domestically will take time and substantial resources. In 2010, it was doubtful whether the Russian military-industrial complex had the know-how and production facilities for the large-scale development of nano-enabled military materiel. In addition, the Russian military does not seem to be able to rely on significant spin-off effects from civilian product development, as Russia's nano-industry is still poorly developed. Further research is needed in order to accurately assess Russia's capacity to produce nano-enabled military materiel.

It is possible that the biggest impact of nanotechnology in the short term will be as a driver of the modernisation of the Armed Forces. "The use of new technology also calls for a rethinking of strategy in the way our Armed Forces are organised", the then-president Putin asserted in 2008. He also stated that new breakthroughs in bio-, nano- and information technology could lead to revolutionary changes in weapons and defence.[243] It could, however, be argued that the Russian military has not yet been able to adapt fully to the changes in military technology brought about by the development of micro-electronics.

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[243] President of Russia 'Vystupleniie Prezidenta Rossiiskoi Federatsii V. V. Putin na zasedanii Gosudarstvennogo soveta 'O strategii razvitiia Rossii do 2020 goda', Moskva, 8 Fevralia 2008 goda [Speech by the President of the Russian Federation at the meeting of the State Council on Russia's Development Strategy through to 2020 on 8 February 2008]'.

Even if the Russian defence industry could produce high-tech military materiel, many of the advances would yield little result as long as the Armed Forces were geared to 20th-century warfare. The organisational culture and the level of education among soldiers need to improve to enable new technologies to be used in their full capacity. A modernisation of the Armed Forces was initiated in 2008, but it will take many years to complete such an undertaking even with proper funds and the full backing of the political and military leadership.

As is discussed above, the effects of Russian nanotechnology on demography and public health will probably be negligible in the coming decade. The Armed Forces will not be able to benefit from any such effects for a long time. A steady decline in the number of potential recruits due to falling birth rates has been experienced since 2006, and it will not turn upwards until 2018.[244] On the whole, domestic nanotechnology will most probably not have a direct and visible impact on Russian military capabilities in the period to 2020, and possibly not even in the following decade.

The prospects for Russia becoming a leading nanotechnology nation, or a even a serious contender, in the coming decade appear bleak. This means that domestic nanotechnology developments probably will not have a strong positive impact on Russia's national self-image or how it is perceived by other countries. In fact, a large gap between the ambitious goals and the general perception of domestic nanotechnology developments may reinforce a national self-image of a country that lags behind. Nonetheless, Russian scientific proficiency in nanotechnology will probably allow some degree of cooperation with the world leaders as well as a pre-eminent position in the post-Soviet space.

[244] Leijonhielm and Westerlund (2007) *Russian Power Structures: Present and Future Roles in Russian Politics*, Stockholm, The Swedish Defence Research Agency (FOI), December 2007, p. 157 (Appendix I)

The tentative conclusion of this study is that Russian nano-science and the domestic nanotechnology industry will not have a significant impact on Russian security policy up to 2020, and possibly not in the following decade either. Judging from developments in domestic nanotechnology in 2010, the potential effects on demography, public health, the national economy, foreign trade, military capacity and Russia' standing as a scientific nation would appear to be negligible in the short to medium term from a security policy perspective.

Domestic nanotechnology will not be a panacea for Russia's ills, at least not in the coming decades. It will probably have an impact in the long run – together with biotechnology, ICT and other scientific advances. For the modernisation of Russia's economy and society, however, a revolution in politics seems more urgent than one in technology. Inevitably, the potential impact of the efforts in the field of nanotechnology – or any other scientific field – on Russia's security policy plays a secondary role to a more important issue. Russia's future position in the international arena rests on the development of its economic and industrial policies. Without a better business climate, Russia will continue to falter.

Appendix A. Using EPO statistics

EPO applications were chosen to study because: (a) the same legal rules apply for all applicants, avoiding statistical distortions from differing national rules; (b) the costs of an EPO application and examination are high, ensuring that EPO applications represent inventions of high technological and commercial value; and (c) all EPO applications are published strictly 18 months after the priority date, irrespective of when the patent is finally granted, a process that can take several years.

Furthermore, the EPO has devised a strategy for how to approach the interdisciplinary field of nanotechnology and the impacts this might have on the workload in each technical field, classification and search. The EPO has worked out a definition of nanotechnology and created a corresponding tagging system (Y01N), which enables the monitoring of the evolution of patenting trends in this area of technology. The tags overcome the intrinsic difficulty of retrieving relevant patent publications from the huge amount of information contained in the EPO's patent databases.[245]

In total, there were 429 patents classified as Y01N and filed in Russia in the EPO Worldwide database[246] as of 8 September 2010,[247] but when searching for 'nano'* in the title and/or abstract, 1 427 records were found pertaining to Russia.[248] The Y01N class has been used in this report, however, as patents are manually

[245] Scheu (2006) 'Mapping nanotechnology patents: The EPO approach', *World Patent Information*, Vol. 28, No. 3. For EPO nanotechnology classification codes, see http://v3.espacenet.com/eclasrch?ECLA=/espacenet/ecla/y01n/y01n.htm.

[246] The EPO Worldwide database is available at http://www.espacenet.com/access/index.en.htm.

[247] A significant increase from April 2008 when 279 Russian nanotechnology patents were found in the EPO database.

[248] This was almost double number of records sampled in April 2008, when 726 Russian nanotechnology patents were identified on the content in title/abstract.

classed according to a systems approach to the patents, and therefore more correctly reflect the content of the innovation than the title or abstract. The EPO classification system also makes the patents comparable between countries, since it is not the national patent offices that do the classification but the EPO.

The major bias with basing the analysis on EPO applications is the different strategic relevance of the European market for European countries and non-European countries. However, for high-end products – such as nano-enhanced products – the European market is important to Russia, due to the willingness of consumers to pay a higher price for additional features.

Taking all the above into consideration, analysing EPO applications provides valid information on the quality of Russian nanoscience and nanotechnology.

Appendix B. RUSNANO management

RUSNANO is controlled by a supervisory board and a Director General. A Science and Technology board consisting of experts in nanotechnology supports the former in a consultative role. The Supervisory Board consists of the Director General, who is appointed by the President of the Russian Federation, and 14 government-appointed members, of which five are nominated by the President, two each by the State Duma and the Federation Council, and five by the government.[249]

When RUSNANO was created, Leonid Melamed was appointed its Director General.[250] On the same day, the then-President Putin nominated five members of the RUSNANO Supervisory Board: the Director of the A. V. Shubnikov Institute of Crystallography (RAN) and the NRC Kurchatov Institute Mikhail Kovalchuk; the Deputy Secretary of the Russian Security Council Vladimir Nazarov; the First Vice President of the United Aircraft Manufacturing Corporation and General Director of Sukhoi Mikhail Pogosyan; the Deputy Head of the Presidential Experts' Directorate Vasilii Popik; and the Chairman of the Board of United Energy Systems of Russia Anatolii Chubais.[251]

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[249] Russian Federation *O Rossiiskoi korporatsii nanoteknologii* [On the Russian Nanotechnology Corporation].

[250] The Director General was appointed by Presidential Decree № 1152 on 7 September 2007; President of Russia (2007a) O generalnom direktore korporatsii ‘Rossiiskaia korporatsiia nanotekhnologii’ [On the director general of the 'Russian nanotechnology corporation'], Ukaz Presidenta Rossiiskoi Federatsii [Decree by the President of the Russian Federation] No. 1152, on the Internet: http://document.kremlin.ru/doc.asp?ID=041397 (published: 7 September 2007; retrieved 11 October 2007).

[251] President of Russia (2007d) ’Vladimir Putin proizvel kadrovye naznacheniia v gosudarstvennoi korporatsii ‘Rossiiskaia korporatsiia nanotekhnologii’ [Vladimir Putin appointed personnel to the state corporation ‘Russian Nanotechnology Corporation’]’, on the Internet: http://www.kremlin.ru/text/news/2007/09/143395.shtml (published: 7 September 2007; retrieved: 11 October 2007).

They were all appointed members of the Supervisory Board by the Government on the same day, together with, inter alia, the Minister of Industry and Energy, Viktor Khristenko; the chairman of the State Duma Committee on CIS and contacts with expatriates, Andrei Kokoshin; the chairman of the State Duma Committee on economic policy, trade and industry and tourism, Yevgenii Fedorov; and the Minister for Science and Education, Andrei Fursenko, who was appointed chairman of the Supervisory Board.[252]

In September 2008, Anatoli Chubais was appointed Director General of RUSNANO, after Leonid Melamed left the post.[253] Chubais continued to serve on the RUSNANO Supervisory Board after his appointment to the role of Director General.

[252] RF Government (2007c) 'Rasporiazhenie ot 7 sentiabria 2007 g. No. 1175-p [Directive of 7 September 2007 No 1175-r]', on the Internet: http://www.government.ru/government/governmentactivity/rfgovernmentdecisions/archive/2007/09/10/2616389.htm (published: 10 September 2007; retrieved: 24 October 2007). For the current and complete list of members of the Supervisory Board, see http://www.rusnano.com/Section.aspx/Show/14587.

[253] Leonid Melamed was released from his post by Presidential Decree 1400 on 22 September 2009 and Anatolii Chubais was appointed Director General by Presidential Decree 1401 of the same date.

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