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Russia: A New Innovation System for the New Economy

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1. *Introduction: Innovation Processes in the Knowledge-based Economy of the XXI Century*

Russia, with its long scientific tradition, has always been one of the major contributors to the world's knowledge. The extensive growth in R&D manpower and investment during the decades had allowed the development of an extremely large R&D base, greater, in absolute terms, than that of most of the industrially developed nations. The collapse of the Soviet Union, and the transition to a market economy, radically affected the national R&D system inherited from the ex-USSR. This system developed under the Soviet system had three special characteristics: it was very large; it was centrally directed, and it was government financed (Gokhberg, L., et al., 1997). These features were ill-suited to a market economy, so it was not surprising that the R&D sector underwent a crisis in the years of transition. One consequence has been a drastic downsizing of the R&D base during the last decade, but there have also been structural shifts and institutional rearrangements in attempting to respond to new challenges.

Initial expectations of the transition period were high that the powerful S&T, freed of the rigidities of central planning, would provide the basis for high-tech exports and economic growth. Like some other rosy hopes for transition, the prediction was incorrect. Many parts the innovation system still clung to the remnants of the centralised economy, while relevant and efficient policies were lacking.

At the beginning of the twenty-first century, Russian S&T is approaching a turning point in the long and arduous transformation from a centrally controlled and administered structure, to a national innovation system that is desired to operate effectively in conditions of the emerging new economy. But to make this journey, a country needs more than a world-class stock of scientific knowledge, but also a set of institutions and capabilities to transform this knowledge into commercial results.

The emergence of the new economy in leading industrial countries is largely governed by the changing economic role of innovation, its rate, direction and implementation mechanism. An empirical analysis of the trends and factors affecting economic growth in the OECD countries in the 1990s points to innovation becoming the "key driver of a more productive economic growth," as demonstrated by the sharp increase of multifactor labour productivity index reflecting efficient productive use of labour and capital; the increasing influence of technological progress implemented in investment products (including ICT) and knowledge implemented in skilled workforce. The new relationship between science, technology and economic growth is, in fact, one of the main characteristic features of the new economy (OECD, 2000).

This relationship consists mainly in the following:

1. **The rate and quality of growth is notable for greater dependence on innovation-based technological changes in economy.** It is manifested by the

rapid growth of investment in R&D and technological and organisational innovation and increasing returns (resulting not so much from direct initial investment, but mainly from broad diffusion and application of innovation products and services); by the higher growth rate of hi-tech industries and services, and greater science-intensity and innovativeness of all economy sectors, including more traditional ones; and by appearance of new types of economic activities.

2. **Technological progress is accelerating; the life cycle of products and services is shrinking, and the time used for research, development and implementation of innovation has dwindled to mere months.** The industrial structure and, consequently, the business-oriented R&D of advanced nations is clearly shifting, as the share of innovation-active and dynamic branches such as computers, with their short product life cycle, is growing, while the share of those with longer product cycles and research and innovation aimed mainly at technologies rather than products (such as metallurgy, chemistry, etc.) is declining.

Innovation activity has been spurred on by rapidly developing ICT that provided the means for resolving fundamentally new scientific problems (such as the high-speed calculations, the deciphering of the DNA code, etc.), faster diffusion of knowledge, disappearance of natural monopoly on communication services, emergence of new markets, etc.

3. **S&T is increasingly turning to the economy and undergoing radical changes,** especially in connection with the growing share of the business enterprise sector in performing and funding R&D, the concentration of research in hi-tech sectors, and a growing orientation of science, including basic research, toward innovation (greater share of search-oriented and applied university research and of basic corporate science, use of published results in patents, etc.). The closer relationship between research objectives and corporate strategies manifests itself in a transformation of the institutional patterns of R&D, with industrial research shifting from specialised to productive corporate divisions, helping to eliminate institutional barriers within companies, reduce transaction costs and ensure more efficient implementation of R&D results into products and services (Iansiti and West, 1997). Simultaneously, other aspects of science are undergoing similar changes, such as methodology (integration of different branches of knowledge, interdisciplinarity, mathematisation, etc.), instrumentation (microelectronics, miniaturisation of instruments, computerisation, use of the Internet), and organisation (networks, associative structures, temporary working teams, project financing, etc.)

4. **New economy is a network economy, with internal relationships assuming a system-building role.** It refers directly to innovation activities, because their efficiency, and, in fact, their actual existence is determined by a combination of direct links and feedbacks between various stages of the innovation cycle, between

generators and consumers of knowledge, and between firms, markets, governments, etc. both within national borders, and, increasingly, on a global scale. Successful implementation of innovation depends both on the availability of generally accessible knowledge generated, for instance, by public research centres and universities, and on research facilities and know-how owed by firms. Additionally, stable relationships between science and industry and technology transfer mechanisms, the quality of infrastructure, mechanisms of financing R&D and innovation, approved S&T policies all play their own significant role. In a knowledge-based economy, "the opportunity and capability to get and join access to knowledge- and learning-intensive relations determines the socio-economic position of individuals and firms" (David and Foray, 1995).

The increasing diversity of potential sources of S&T knowledge, the growing sophistication of modern technologies together with their broadening variety, which are required for implementing innovation, come on top of stronger competition and greater innovation risks. Even large companies are no longer capable of covering all existing disciplines as they could have done 20-30 years ago (remember, for instance, the past experience of IBM, AT&T and others), thus they go in for even greater specialisation of corporate research laboratories on the one hand, while on the other, step up all relevant types of co-operation (in the form of technological alliances, joint ventures, mergers and acquisitions, contracts with universities and research centres, use of specialised research, consulting, training and other services, acquisition of both embodied and disembodied technologies and so on). Studies of the new economy stress the intensive growth of local clusters and global alliances for creating, disseminating and implementing innovations, foreign direct investment, small company spin-offs, knowledge-intensive business services, mobility of qualified workforce acting as a vehicle for diffusing knowledge and increasing the efficiency of innovative activities.

A transition from a linear (science-production-consumption) to a systemic description of the innovation process signified a re-evaluation of economic growth factors, focusing attention on institutions and their relationships. Another fundamental characteristic feature of the national innovation system concept is the central role of companies in innovation. Science can generate knowledge and even stimulate demand for knowledge by proposing new, previously unknown technologies that may increase competitive position of firms, but it is firms that are engaged in practical implementation of innovations reaching consumers and creating feedbacks.

In our opinion, this approach should be used in evaluating Russia's R&D and innovation and elaborating systemic solutions for its moderinsation in directions meeting the new economy requirements. Only a comprehensive approach to restructuring the national innovation system along the triangle of "institutions –

mechanisms – policies" may help to overcome the disproportions and bottlenecks that have been hampering innovation-based economic growth. The negative experience of separating individual issues, such as funding or intellectual property, from the general context, as has been done in the Russian S&T policy repeatedly (and, for the most part, uselessly) is known well enough.

2. Russia's Innovation System: It Exists, But Does Not Work

Over the past decade Russian S&T existed in a qualitatively new economic, social and political environment, which has largely shaped its current state. The changing socio-political situation will continue to determine the sector's future growth trends and factors both in the short and long term. However, it is essential to note that the institutional structure of Russian S&T, with all of its internal relationships and mechanisms, mostly formed long before the onset of radical economic and political reforms, and were hardly suitable for facilitating its effective integration into a market environment. R&D organisations, and, indeed, scientists, had to face unaccustomed realities and attempted to adapt to the new conditions. But the adaptation proceeded in the absence of appropriate government response, such as proper strategic decisions providing for adequate transformation of the S&T sector and increasing its role in promoting positive social and economic changes in Russia. In the overall systemic crisis that affected the entire nation, it led to a sharp aggravation of the situation in the S&T sector.

As a result of a long development according to the so-called "Soviet model", that conformed to the administrative and command-based methods of governance, Russian S&T acquired three major characteristic features: it was large, centrally directed, and almost 100% government financed. Such was the status of Russian science when it first faced market reforms, and those major determinants have continued to exist until now.

1. **The institutional structure of Russian S&T remains archaic and ill-adjusted to market requirements.** No description of the current state of the country's S&T sector can fail to take into account the inertia in R&D organisation, the desire to preserve old institutional structures that conformed to the requirements of the former command and administration-based economy. The changes occurring over the recent decade have resulted in the emergence of new forms of ownership, elimination of almost all branch ministries and the building of new organisational structures, but they have failed to reach the fundamental grounds of the Soviet-era scientific institutional system which still underlies Russian S&T.

The total number of R&D organisations in Russia was 4,037 at the beginning of 2002; after falling by 13% over the period beginning in 1990, mainly due to the elimination of design organisations which used to carry out R&D. Unlike advanced industrial nations, however, research institutes separated from universities and firms remain the main organisational staple of Russian S&T, moreover, their number continues to grow. Despite the fact that R&D employment and expenditure dropped, respectively by half and two thirds over the period of 1990–2001, the number of research institutes increased by 1.5 times, growing from 1,800 to 2,700; they contribute with 70–80% of R&D personnel and expenditure. The only kind of institutional changes occur in the form of a splitting of existing organisations or creating new research institutes as legal entities rather than improving research capacities of firms and universities, although they form the backbone of innovation systems in countries with mature market economies.

Approximately 2,900 R&D organisations are state-owned in Russia (in contrast to several dozens in the US, UK, Germany, or Japan). Their funding comes mainly from the federal budget. Thus budget allocations, which have become considerably smaller in real terms, have to be stretched between a growing number of organisations. As the public R&D sector falls apart, a small number of more or less successful units do emerge, while many that retain the formal status of research institutions have practically discontinued research activities and have engaged in some kind of business operations instead: out of all those employed in the R&D sector, support personnel accounts for 44%, 40% have no university degrees. Furthermore, the funding of Russian R&D organisations remains insufficient: 1,200 rubles of domestic R&D expenditure per one research unit in 2001, compared to 2,300 rubles per unit in 1990 (expressed in 1989 prices, adjusted for denomination). While in itself, small R&D units can play a positive role, their further splitting can result in many of them becoming totally lifeless.

2. **Corporate R&D integrated into the real sector should play a key part in promoting innovation activities.** In leading industrial countries, it is firms that account for the bulk of R&D: 65% in the EU, 71% in Japan, and 75% in the United States[1]. Russia's "enterprise-based" R&D has meager resources (only 6% of total R&D expenditure) and an inclination to deal with narrow, short-term, technical problems of their own company, mainly adapting external research results to their internal production tasks.

Analysis shows that industry sectors possessing better R&D facilities at enterprises demonstrate greater activity in contracting external R&D. This positive correlation between in-house and outsourced research proves that these two forms of R&D are supplementary, rather than mutually exclusive. A firm that carries out its own R&D is apt to show more interest in innovation and have more R&D contracts with external organisations, while its own R&D units process S&T information and serve as an important source of knowledge for modifying the competitive strategy of

[1] Here and below, source of date for the OECD countries: OECD MSTI.

a company. As for Russia's manufacturing sector as a whole, the weak in-house R&D together with a lack of positive change toward integrating branch research institutes with companies and a continued presence of institutional barriers, all have a negative impact on the prospects of raising competitiveness of products.

Universities performing R&D still have a much too low share of Russia's overall R&D effort (approximately 5% of total R&D expenditure vs. 21% in the EU and 14–15% in Japan and the United States). The number of such universities dropped from 453 to 388 over the period of 1990–2001, and since newly established private universities carry out practically no research, only 40% of all Russian universities can be said to be involved in R&D. If this trend continues, the consequences can become irreversible, both for science and for education standards. Still, there is a new model of the university system that has been formulated in the course of reforms, that allows involvement of various integrated structures (educational and research centres, research and innovation centres, etc.) into the S&T enterprise in many regions of the country.

3. **Russian S&T has been notable for a weak innovation orientation.** The market gaps in the innovation sphere result not so much from the overall production decline brought about by the crisis of the 1990s, as from a lack of correlation between research subjects, institutional structures and the mechanisms of the R&D sector on the one hand, and needs of the national economy on the other. Even the investment growth at the turn of the century has failed to provide a noticeable flow of company financing into the R&D sector.

The organisational separation and institutional barriers between applied R&D and firms have resulted in a gap between R&D and innovation. The old economic system that used to provide for the operation of research institutes and design bureaus was intended primarily for stimulating research rather than innovation. The lack of balance between the two activities has resulted in low research efficiency and quality and poor technological standards in manufacturing and in other sectors, in a generally poor state of the manufacturing capacity and ultimately, on the poor competitive status of domestic products. This gap between science and innovation has not been closed: statistics show that research organisations, especially those related to the Academy of Sciences, as well as universities have a very low rating as information sources for technological innovation (Gokhberg and Kuznetsova, 2001).

This low demand for research results (less than 5% of all registered inventions and prototypes became the subject of commercial transactions in 1992–2001) can be to a great deal explained by their poor adaptation for practical implementation. The greater part of transactions made on the domestic technological market refer to design projects. The negative aspects of such deals are first, high implementation costs resulting in substantial risks for companies, and second, an absence of guarantees ensuring that the technical parameters set initially can be achieved at the implementation stage.

Over 70% of all inventions are hardly more than just minor improvements for existing and, for the greater part, obsolete equipment and technologies. Such inventions are easy to implement, as they do not require lengthy modification of the production capacities or radical technological changes, however, their economic effect peters out after no more than two or three years. New types of machines have, for the most part, poor technological characteristics and fall short of modern quality standards. No more than one third have documents protecting industrial property rights, 75% have no quality or safety certificates, 64% lack service and maintenance support structures or waste disposal technologies. As a result, many innovative companies prefer to purchase ready-made, primarily imported equipment rather than incomplete domestic technologies.

Innovation diffusion remains the weakest spot of the transition economy, just as it used to be under central planning. As a rule, innovation is introduced in no more than one or two enterprises. Even in the areas where Russia enjoyed leading positions in creating major innovations, it fell behind for their diffusion rate, as it happened, for instance, in steel smelting and processing. The other side of the coin was the frequently unnecessary borrowing of foreign technologies where there existed efficient domestic equivalents. As a result, instead of integrating into the global innovation chains, Russian S&T has kept lagging behind and having to catch up. Given the low prices on domestic technologies compared to those imported from abroad, more favourable conditions for co-operation at domestic rather than international level and the severe competition on the global market, a lack of funds and experience necessary to promote and patent Russian developments abroad, the comparatively closed nature of the Russian technological market can hardly surprise anyone.

The insufficient scale and rate of innovation diffusion and introduction continue to dominate Russian S&T policies. This issue should doubtlessly be broadened and formulated in terms of innovative orientation of the national economy, with government policies and businesses directed at developing high-tech production facilities.

4. **Russia's national innovation system is poorly balanced**, its main elements, such as R&D units, enterprises, and innovation infrastructures, are isolated from each other. Because of the indefinite economic situation, the industrial sector's strategy is not oriented toward innovation development and implementation of domestic R&D results. Even against the background of investment growth in 1999-2002, the innovation activity rate did not raise above 10%, compared to 51% for the EU. However the autarky of S&T and industry cannot last long as the present S&T base is fast becoming obsolete. Science in its present state is incapable of achieving

effective interaction with the manufacturing sector and meeting the requirements of the national economy. The unresolved issues of intellectual property rights distribution and underdeveloped technology and information services markets also hamper the introduction of research results into the economy.

At the same time, the current market reforms have failed to stimulate more active innovation. The newly-emerging economic mechanism has inherent inertial structures unfavourable for S&T progress and innovation. Even with the growing problems of restoring the productive potential (highly outdated capital assets, poor competitiveness of many industrial products, obsolete and resource-intensive technologies, etc.), there is little demand for research achievements. The main reasons are a lack of corporate investment resources, changes in the demand structure due to intensive S&T competition under the onslaught of advanced industrial nations, strong motivation to preserve employment and compensation levels, and a managerial culture that is not conductive to innovation.

Another important factor is that only 14% of the overall R&D expenditure, or far less than the necessary amount, go to basic research. **Russia is not going to be able to retain its R&D potential without establishing its linkages with the national economy, while the economy cannot become competitive without relying on S&T.** To date, therefore, rather than the S&T sector pulling up the rest of the economy, what we have witnessed in post-Soviet Russia is the rest of the economy pulling down the S&T sector (Burger, 2002). If this trend continues, the S&T sector as well as high-tech industries can be expected to degrade, and that is why speedy modernisation of the national innovation system becomes a priority task in building the new economy.

3. S&T and Social Needs

What does society require from S&T and innovation? What kind of innovation system does Russia need? It is not easy to formulate answers to these questions, but answers are important for devising efficient R&D and innovation policies required to enhance the contribution of S&T and innovation to economic growth and public wealth. The current position is quite clear: according to public opinion surveys, 67% of those questioned believe that the role of science has declined in Russia; and 80% of respondents with a higher education hold the same opinion. Only 6% considered scientists as one of the most respected occupations in the country (Gokhberg and Shuvalova, 2003). Similarly, the business sector demand for R&D is not high by the standards of developed industrial nations: its share of R&D expenditure (20% in 2001) is three-fold lower than that for the OECD countries (64%). Even in former socialist countries, such as Romania, Slovakia and the Czech Republic the respective figure is higher, reaching 50–55%.

One should not place too much hope for an easy access to international technological markets. Russian S&T has a weak export promise, as highlighted by such indicators as the share of foreign funds in R&D expenditures (9%) and the size of technological exports ($240 million), which is 10-fold less than in Austria (2.4 billion) and far behind that of the United States (38 billion). Furthermore, contracts involving protected intellectual property rights accounted for just 1.3% of all technological exports in 2001. Consequently, the export of a greater part of high-tech developments, including those funded by the federal budget, provides poor return for the national economy. On the other hand, contracts to acquire low-standard, ecologically unsafe and unnecessarily high-cost technologies are made quite frequently, often giving the foreign counterparts advantages that violate even the national antimonopoly legislation.

Thus the national strategy with respect to S&T should be formulated based on present and future requirements of the national economy and society at large, as well as on the current state of S&T and innovation. It should be stressed, however, that we cannot agree with the frequently expressed opinion that the size of the R&D sector should be as large as the economy can "digest". In fact, it should be larger, with the surplus providing for the society's social demands and for long-term technological progress, which the business sector, especially in its contemporary Russian version, does not always perceive as necessary.

1. The strategy for S&T should be formulated on the basis of **a realistic assessment of the real size and capacities of Russian S&T and innovation: the former is medium-sized and the latter small compared to those in developed countries.**

In a assessment adjusted for the purchasing power parity, 2001 R&D expenditures amounted to $12.3 billion, or barely higher than in Sweden and the Netherlands ($8-8.5 billion) and considerably less than in Korea ($19.0 billion), UK ($27.1), France ($31.4), China ($50.3) and Germany (55.1 billion), to say nothing about Japan ($98.2 billion) and the United States (265.3 billion). R&D expenditures account for just 1.16% of Russia's GDP, which is less than for the Czech Republic (1.35%); for nations with middle-sized R&D base, such as Australia, Austria, Belgium, Norway and the Netherlands, the same indicator amounts to 1.5–2%, for Germany, Japan, Korea, Switzerland and the United States it is 2.5–3%.

Expenditure on technological innovation is not sufficient for fuelling a major innovation breakthrough in different sectors of the national economy. Their value is so small as to be patently inadequate to meeting the real requirements of technological modernisation of industry and expansion of the range of radically new domestic products. Innovation expenditure in manufacturing amounted to 1.3 billiard rubles in 2001, or just 1.4% of the total production volume, which is three-fold less than in the EU countries.

The only relative advantage of Russia's R&D sector is the high employment level (see Fig. 1), although its funding is far behind its employment potential (see Fig. 2). But even there the situation is far from rosy, as the outflow of active professionals of the most productive age groups continues, while the inflow of young specialists is minimal (approximately 10,000 persons annually). The age structure of R&D personnel is steadily deteriorating: approximately 48% of Russian researchers are above 50 years old, the average age of doctors of science is 53 years, while that of PhDs is 61 years. One out of five Russian scholars has reached retirement age. Due to low salaries and a shortage of modern research facilities, many of the researchers remain in their positions only nominally, while actually having jobs elsewhere.

While the government continues to act as the main sponsor of research (providing 56% of the R&D expenditure total), any further delay with reform and a continued efforts to stretch the meager resources between multiple R&D organisations and objectives may have the most damaging consequences. Unfortunately, the current practice of defining S&T priorities is directed at preserving the existing institutional structures. Public institutional funding of S&T exceeds project financing, meaning that instead of concentrating resources on developing prospective technologies, priority is given to the principle of "something for everyone". This approach scatters the limited resources and results in poor returns from S&T efforts.

The first step should consist in **recognising S&T as is a national priority to provide for public wealth and economic competitiveness; such recognition should be expressed materially in a radical increase of budget funding. Simultaneously, it is necessary to clearly limit government priorities for S&T.** It is high time to implement some of the approaches to defining priorities that are well-known and long-used in industrial countries (for instance, *Technology Foresight*) and to introduce the most efficient methods of their implementation. Primarily, they should cover health care, ecology, education and other key social issues, as well as national security. Another important priority is basic research, but just in case it is really fundamental, viable and adequate to international standards of excellence.

Direct government funding of applied technology-oriented research should be brought down to a justifiable minimum that would cover only areas that have great importance in the light of Russia's economic and social situation and geographical location. It should be supplemented with flexible mechanisms of co-financing R&D by the government and businesses, as well as with indirect incentives for research and innovation.

Figure 1. **R&D personnel per 10,000 labour force in Russia and OECD countries**

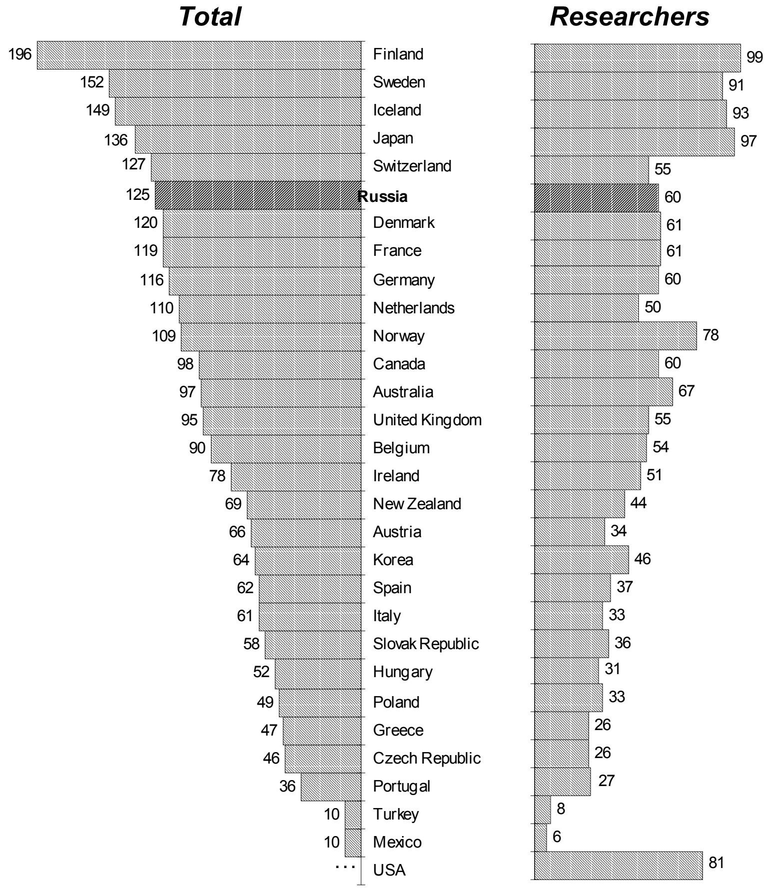
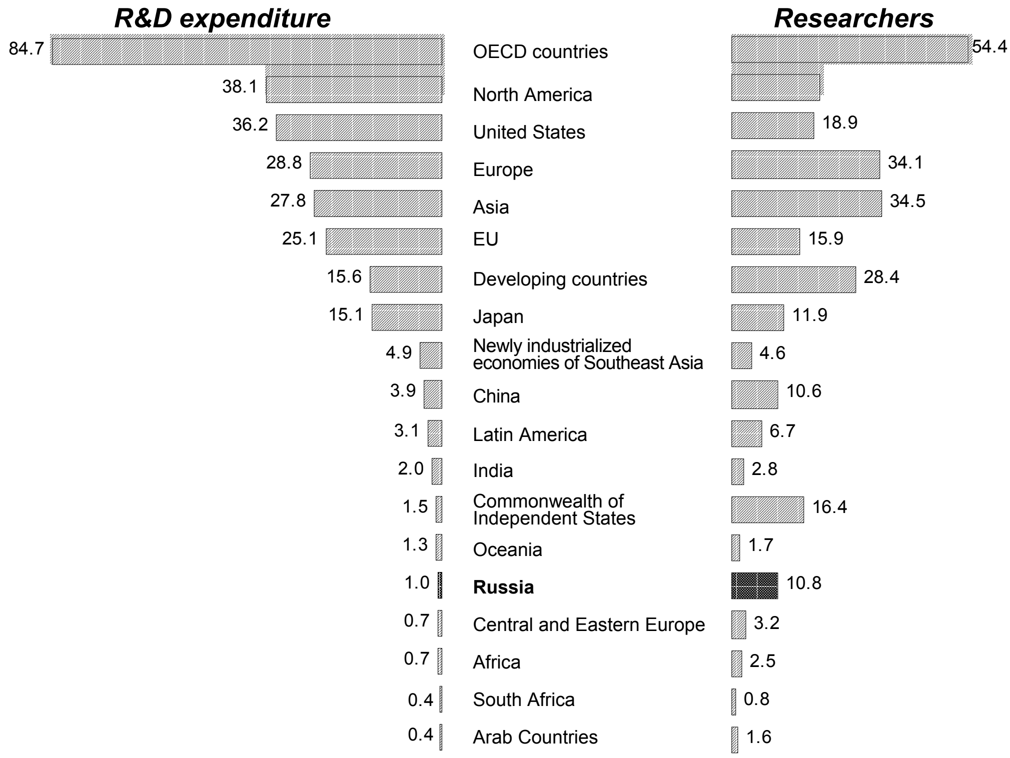


Figure 2. **Share of regions (countries) in world R&D totals**
(percent)



Source: UNESCO, 2001.

It is important to provide real incentives (not just lip service) to integrating research and production, to encourage a higher proportion of foreign investment in Russian S&T and to integrating Russian companies into international innovation and production chains that act as the drivers of post-industrial global economy. Russia's basic science potential could play an important part in all of the above measures.

The most important task is to do everything possible for Russian S&T to start responding to economic and social demands and getting more practice-oriented. There is no reason for the government to support research that is unlikely to have tangible returns for the economy, the public at large or the national defence in the foreseeable future. Conversely, funding that does go to applied research should be targeted at specific goals and distributed on competitive basis, with matching funding and peer review.

2. **Russia's present-day science holds particularly strong positions mainly in technological areas that were traditionally oriented toward supporting national defence capacity (such as space research, nuclear power, aviation), specific "intellectual" areas that do not require major capital investment, and studies of natural resources[2].** In this regard, the Russian S&T sector rests on a paradox. While the idea of the supremacy and huge potential of Russian science still prevails in the minds of the local official political and academic elite, in fact in the international market of high technology products (and in many cases even domestically) Russia comes far behind even formerly scientifically undeveloped nations of Southeast Asia. Russia's share of world high-technology exports is just 0.3 %, whereas that of Singapore, Korea or Taiwan is 4-8 %. In fact, the commercial success of any given technology comes as a result of its quality as compared to the best world analogues, the availability of state-of-the-art production facilities and demand on international markets. However, Russian S&T potential does not match much of global demand.

Although, despite a systematic lack of funding, Russian researchers have retained their advanced positions in many S&T fields, above all, aviation and space technologies, nuclear industry and nuclear waste disposal, certain information technologies, and lasers. A wide-ranging expert assessment of the current state and future prospects of critical technologies identified by the Russian Government as federal priorities for S&T, has shown that the following critical technologies can be considered as the most promising:

- aviation and space technologies involving new technical solutions, including non-conventional arrangement schemes;
- nuclear power generation;
- speech, text and image recognition and generation systems;

[2] This section was written with the contribution of Dr. Alexander Sokolov, Deputy Director, Institute for Statistical Studies and Economics of Knowledge, Higher School of Economics.

- nuclear fuel regeneration, waste treatment and disposal;
- parallel structure multiprocessor computers;
- mathematical modelling systems;
- recombined vaccines;
- transportation systems with alternative power sources;
- polymer compounds;
- laser technologies.

More detailed information is presented in Table 1.

Table1. **Critical technologies meeting standards of similar foreign analogues**

Critical technologies	Most promising directions of development
Speech, text and image recognition and generation systems	Mathematical models of image recognition, solution of non-conventional tasks in this area
Mathematical modelling systems	Non-linear processes and self-organisation of complex systems, mathematical experiment methods, algorithms for multiprocessor systems
Laser technologies	Technologies based on gas, solid and semiconductor lasers, thermal treatment
Electron, ion and plasma technologies	Bimetallic and metalloceramic layer formation using radial energy sources, surface treatment
Technologies for rapid evaluation and complex use of strategic ores and technogenic materials	Multifactor geological object models based on a morphological, qualitative and economic factors
Composite materials	Polymeric, metallic, ceramic and basalt composites, space construction materials, including carbon materials
Life support systems for extremely hostile environments	Life support systems for pilots, protection from harmful effects of mechanical and chemical components in water and in the atmosphere and from dangerous microbiological substances
Aircraft and spacecraft and systems based on novel technical solutions	Non-conventional structures such as the flying wing, EKIP-type craft, aerodynamic landing craft such as Fara and Shuttle, large-scale space constructions, etc.
Technologies for geological prospecting, forecasting, exploring and evaluating of various minerals including uranium	Identification of regularities in lithosphere development and processes resulting in accumulation of combustible substances, geotechnological equipment for prospecting and exploring mineral resources, space technologies for collecting data for geological, geophysical and geochemical research
Technologies for breaking down rock, tunnelling and drilling	Breaking down of hard and abrasive rock, oil and gas drilling based on new methods of new methods of breaking down rock
Technologies for treating oil and gas layers	Equipment for developing complex oil and gas deposits, electric and vibration methods of treating oil and gas layers
Non-conventional technologies for extracting and processing solid fuel minerals and uranium	Extraction of hard fuel minerals and uranium in open mines and tunnels, refinement, extraction of uranium from ores

Critical technologies	Most promising directions of development
Technologies for deep oil, gas and condensate refinement	Catalysts for cracking and catalytic reforming, adsorbents for sulphur refinement, cryogenic and membrane technologies for gas treatment and refinement, plasmochemical refinement of sulphurous gases, technologies for small-scale oil, gas and condensate refinement to obtain motor fuels
Nuclear power	Developing and manufacturing of fuel assemblies for new generation nuclear power plants, fuel cycle improvement , removal of fuel assemblies and other equipment and safety systems for currently operating nuclear power stations
Technologies for regenerating used nuclear fuel and for treatment and disposal of radioactive wastes	Closed nuclear fuel cycle, treatment of nuclear fuel and preparation for burial, separation of long-living particles for transmutation or burning-out in nuclear reactors
Electronic energy transfer technologies	Long-distance energy transfer, development of new-generation technologies, transformation and distribution facilities
Pipeline transportation of coal suspension	Preparation of highly concentrated coal suspension to be used for fuelling at power stations and communal boilers, long-distance pipeline transportation of coal suspension
Hydrogen power engineering	Hydrogen generation, storage, transportation and use in power engineering industry, and transport
Technologies for forecasting of climate, ecological, geological and resource-related changes	Global environment and climate changes, seismology, their impact on the biosphere

The most promising areas for penetrating new technology markets, however, are those with the highest rate of growth, i. e. ICT and biotechnologies. All technological forecasters assign them top priority status, but Russian developments in these areas are on the whole far behind the world state-of-the-art level. Thus Russia's prospects of entering international markets are limited to quite a small range of opportunities, further restricted by multiple trade barriers.

The maintenance and consolidation of Russia's market position requires great effort even in the areas where it has been traditionally considered strong. Thus, in the world space market, with its 30% annual growth rate, Russia can seriously compete only in putting paid load into orbit, especially using heavy carriers. But that accounts for less than one tenth of the international market, whereas communications satellites account for three quarters. In aircraft, Russian manufacturers have the best prospects in exporting fighters and certain types of freight aircraft, while the most promising area there are passenger airplanes and helicopters, moreover, it would hardly be possible to enter the global market without some co-operation with leading international companies. Even in the domestic market, Russian-made airplanes are only competitive because of the high cost of foreign-made aircraft. There is no international demand for many technologies considered "critical" in Russia because they either pose ecological danger, or have a very narrow sphere of application, or potentially small sales. One example of this is coal suspension pipeline technology.

In addition to providing opportunities to gain new niches in international markets, high technologies can serve as vehicles for achieving certain critical goals that may influence Russia's future, such as a greater efficiency of the national economy's basic sectors and a higher quality of life, increased defence capacity and improved ecology. Taking into account the real capabilities of Russian S&T and the situation in global and domestic markets, it would be advisable to concentrate on developing and implementing support measures for the following R&D areas:

- ***Information technologies and electronics***

Neuroinformatics, image recognition and analysis and mathematical modelling experiments have the best prospects for entering international markets due to the high quality and novelty of the developed technologies and low capital-intensity. These technologies are essential for applied computer modelling systems for nuclear power generation, environmental sciences, economics and social sciences, applied programmed intellectual systems for identifying and evaluating objects under conditions of poorly structured, non-formalised or imprecise data (potential foreign market – tens of thousands of systems annually). Another priority is the Russian-developed computer system capable of performing tens and hundreds of trillions of operations per second. It has applications for complex problem solving in the nuclear sector, aerodynamics, meteorology, etc. One more national priority is the development of integrated information and telecommunications systems based on domestic technologies and components.

- ***Manufacturing technologies***

The following manufacturing technologies have the best export potential: specialised laser equipment for medical purposes, space, machine building, defence, etc.; technologies for processing strategic minerals (such as uranium, precious metals, diamonds, etc.); electron-ion-plasma technologies for bimetallic and metalloceramic surface coating; revolving and linear mechatrone modules based on integrating methods derived from precision mechanics, electronics and electrical engineering.

- ***New materials and chemicals***

As far as new materials are concerned, Russia holds good positions in manufacturing polymers and composites (functional polymers possessing specific qualities and those used for construction purposes, such as superstrong and heat-resisting plastics, carbon-carbon space materials, etc.), superhard synthetic materials (primarily, the synthesis of fullerenes), durable heat-resisting powder alloys and intermetallic compounds, power- and material-saving heterogeneous, homogeneous and biological catalysts and certain types of membranes.

- ***Living system technologies***

Russian developments in medicine and agriculture are on the whole far behind those created by world leaders. The only exception is life support systems for extremal environment, used especially for space missions. A few technologies in other areas may also have some export prospects, such as precise identification of genes responsible for inherited and somatic disease in humans, bioprocessing, biosensorics, technologies for creating chimerical recombined proteins, live vaccines produced with the help of genetic engineering, split vaccines and some others. Additionally, immunocorrection technologies (diagnosing, therapy, prevention of diseases, and development of vaccines), chemical synthesis of medicinal substances and food supplements and biological methods of nurturing and protecting plants and animals have great importance for the nation's socioeconomic development.

- ***Transportation***

Most R&D products in the sphere of civil transportation have little hope of access to international markets. The major promise refers to aviation equipment based on new generation gas turbine engines, non-conventional arrangement systems and technical solutions, some types of ship-building and maritime technologies and navigation systems. In the short term, one of the main goals in this sphere should be attaining a good competitive status on the domestic market for Russian-made transportation systems such as high-speed railway transport, maritime and river transport, aircraft, and traffic control systems.

- ***Power and fuel***

The following technologies have a key role in exports in this field: designing and serial production of new generation nuclear power plants, improving the fuel cycle, dismantling plants at the end of their life cycle, safety and security systems for nuclear power stations, regeneration of used fuel rods, and treatment and disposal of nuclear wastes. There is hope for some export growth related to technologies of geological surveying (including space technologies), oil and gas drilling methods, development of complex oil and gas fields, vibration and electric layer treatment, and procession and refinement of solid fuels and uranium ores.

- ***Environment and ecology***

Russian technologies for monitoring the natural and industrial environment (outer space, atmosphere, hydrosphere and lithosphere) and its forecasting with respect to natural and mineral resources have good chances of being accepted in global markets. Russia's own environmental problems have somewhat receded from the public eye following the significant production decline, still, they have remained as serious as ever and even grown worse. The steady increase of the number of emergencies with ever more serious consequences calls for technologies that would reduce the risk of natural and industrial catastrophes.

4. What can be done?

The main theme of the ongoing discussion regarding government S&T policy remains the same, just as the substance of every complaint - the size of government support to science. It is quite obvious, however, that on the one hand, there are objective reasons preventing a significant increase of budget allocations while on the other, it is not obvious that even with greater public financing a radical improvement of the quality of basic research and practical returns to applied R&D could be guaranteed if institutional environment remains unchanged. Consequently, it would seem than in the short term, the only realistic solution consists in measures for more efficient use of available budget allocations together with institutional reform aimed at integrating the national innovation system.

It would be advisable to focus the discussion of measures to reform the sphere of R&D and innovation on the following major issues:

1. **Reform of the government R&D sector and support of institutional forms relevant for a market environment.**

- The government sector would have to be reduced, so as to decrease the number of recipients of direct budget allocations, get rid of the ballast and concentrate resources on supporting a limited number of viable organisations. The government sector must include only institutions that carry our basic research at international standards and a few of the most productive organisations that work directly for the government and government-supported sectors such as health, education, environment, defence and security, etc.
- Organisations that have lost their capacity for research, workforce and resources should be liquidated, their assets sold at auctions and the proceeds added to the government allocations for S&T.
- Those government organisations and R&D teams that have retained some potential for research should be either transferred to universities (thus creating research universities), or privatised (sold to investors) on condition that they should continue research in their sphere of expertise (thus strengthening, a corporate R&D sector).
- Centres for advanced research (centres of excellence) should be created as a specific form of promoting science and retaining the existing research potential. They should be organised on the basis of existing institutions or by putting together the most productive teams from different institutions, giving them a free choice of research areas and providing adequate financial and material resources.

2. **Restructuring budget allocations for S&T to make them more targeted and creating mechanisms of chain financing of the innovation cycle.** The most important principle would be a transition from subsidies to loans along the innovation

chain (basic science - applied research - development - introduction of innovation - consumption of the product).

- Government support of civil S&T must be increased by 30–40% per annum, the share of project funding and scientific foundations should grow, respectively, to 40% and 20% of the total (at present they are less than half of those). That part of public funds is to be distributed strictly on competitive basis, each allocation being sufficient for the entire duration of a specific research project. The number of government S&T programmes should be reduced, and restricted mainly to projects that have novelty and international relevance. Simultaneously, sizes of research contracts and grants should be increased.
- Government organisations should receive package funding instead of allocations broken down by detailed cost items, their operations should be regularly evaluated. This would lead to more trust in the competence of the research institute directors and their increased responsibility, hopefully leading to minimizing inefficient operational costs in order to cover certain expenses that failed to appear in official cost estimates and less "shadow scheming," helping to build "economy based on trust."
- Government programmes of S&T and innovation activities as well as public scientific foundations should concentrate their efforts on co-financing international projects, supporting small, science-intensive firms and technology transfer centres based in universities and public R&D centers, and providing substantial research grants for up to 5 years to young scientists.
- Budget funding of specific applied R&D projects in areas beyound government priorities should be carried out on competitive basis and only with matched funding provided by companies, up to 50% of total project funds.

3. **Promoting commercialization of R&D and developing technology markets.**

Given that venture capital is unlikely to appear in Russia in sufficient amounts soon enough, it is necessary to begin with providing legislative and institutional conditions conductive to its appearance.

- The present fuzzy system of intellectual property rights should be clarified as soon as possible, so that outcomes of government-supported R&D can be introduced into the economy, specifically:

a) R&D organisations should own the results of their research, even if it receives government funding, and they should have the right to license them to third parties (private companies) capable of effective introduction of research results to the market;

b) ensure that intellectual rights owners do the following: receive formal documentation protecting their R&D results obtained with government support, provide preference to small firms in licensing, organise production in Russia, share profits with the actual inventors, use profits from licensing to fund further R&D;

c) give an exclusive, irrevocable and free license to the government to use R&D results obtained with federal government support, withholding assignation rights;

d) give the government or authorised government agents exclusive rights to R&D results relevant to defence and national security, as well as those R&D results that the government intends to develop and introduce into production distributing and selling the products;

e) in addition to giving the government, or authorised government agents exclusive to third parties rights to R&D results relevant to defence and national security (including licensing the right to use and control R&D results), introduce accountability.

- The following measures for developing innovation activities must be implemented:

a) tax exemption of profits directed to introduction of new technologies and R&D funding;

b) using accelerated depreciation of tangible and intangible assets. This would lead to stepping up in-house and outsourced R&D, acquiring new industrial property objects, etc.;

c) providing private and government insurance (even with only partial coverage) of investment in innovation, support of insurance companies that insure risks involved in loans to developing innovative products.

- It is necessary to encourage the creation of start-up firms engaged in developing and transferring new technologies, including provision of seed capital (following the experience of the US SBIR programme), tax incentives as well as legal and information support. Also important is to encourage the creation of technology transfer centres in universities and research institutes, as mentioned above. A government programme to train managers for S&T and innovation could play an important part in this process.

- The government must provide legal and economic incentives for active participation of Russian R&D organisations and firms in global technological alliances and international programmes (not just research, but especially innovation programmes) on equal financial footing, removing all obstacles, such as tax and customs barriers, etc.

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