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SCIENCE AND TECHNOLOGY

Problems of Planning Scientific and Technological Development at the National Level[1]

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Abstract—The article analyzes problems of planning research and technological development. We consider two lines of theoretical concepts of planning, i.e., economic and mathematical versus empirical and evolutionary. Problems of the statistical basis for constructing economic and mathematical models of scientific and technological development are studied in detail. The example of Russia is used to show that the weakness of the theoretical framework of planning leads to inconsistencies in government priorities of scientific and technological development.

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Main directions and results of state innovation policy in russia in the 2000s. Over the past decade, Russia has pursued an active government policy in the field of scientific, technological and innovation development. However, the economic effects of these policies are thus far barely visible. This result is largely due to the weakness of the theoretical concepts that form the basis for the state planning of scientific and technological development.[2]

Since the late 1990s and early 2000s, Russia has consistently developed its national innovation system (NIS).[3] At the stage of especially energetic efforts in this field, i.e., in pre-crisis 2006–2007, such relevant structures were established as a Russian venture company (fund) (RVC), Rosnano, Rosatom, special economic zones (SEZs), a program for supporting technoparks was launched and on the federal level the government determined priority directions for technological development and compiled a list of critically important technologies. The Government Commission on High Technology and Innovation began its work at the same time.

During the crisis and postcrisis periods, the activity of the Government of the Russian Federation aimed at the development of the innovation system has increased (it includes NRC Kurchatov Institute, Skolkovo Innovation City, seven federal universities (FUs) and 29 national research universities (NRUs), technological platforms). In 2012–2013, innovation clusters were identified and selected and the law on reforming the Russian Academy of Sciences was adopted (Fig. 1).

In general, we can say that almost all of the major elements of NIS represented in the world practice have now been formulated in Russia.

The formation of the NIS has also been supported by a significant increase in state funding (from 2000 to 2012, federal budget spending on civil science in constant 1991 prices have generally increased by almost four times and its share in the GDP grew three times.

However, the overall level of domestic expenditure on research and development since the mid-2000s has remained relatively stable at 1.1% of GDP (Fig. 2).

With regard to the share of R&D, state funding in Russia's GDP has almost caught up with the developed countries such as France, Germany, Sweden, and the United States. At the same time, the existing gap in the overall level of domestic expenditure on research and development between Russia and developed countries is primarily due to the low level of business financing of research and development (Fig. 3).

However, innovation policy pursued by the state in the last decade has not yet caused any significant (compared with the growth in funding) changes in indicators of scientific and technological activity (the number of patent applications in the RF, the balance

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[3] In this paper, the national innovation system is understood in Lundvall's narrow interpretation, according to which the core of the NIS includes firms that interact with each other and with external infrastructure generating knowledge [1]. Thus understood, state innovation policy includes both policy aimed at the creation of development institutions and, partially, scientific, technological, and industrial policy.

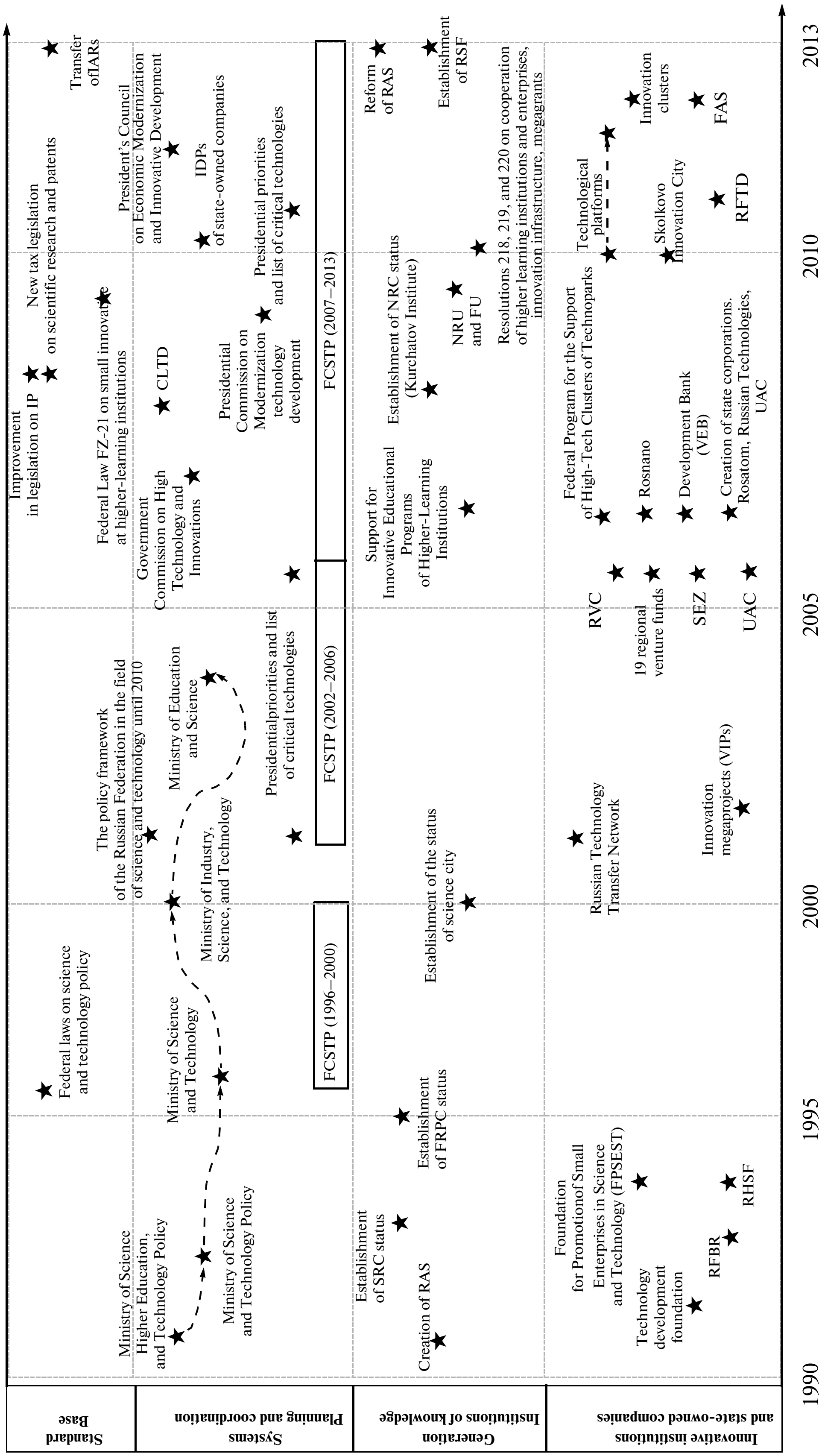

Fig. 1. Key elements of scientific, technological, and innovation policy in Russia in 1991–2013.

NOTATION

IP – Intellectual property;	IDPs – Innovation development programs;
SRC – State research center;	HLI – Higher learning institution;
FPSEST – Foundation for Promotion of Small Enterprises in Science and Technology (Bortnik Foundation);	CLTD – Concept of long-term development;
	NRU – National research university;
RFBR – Russian Foundation for Basic Research;	FU – Federal university;
RHSF – Russian Humanitarian Science Foundation;	VEB – Vnesheconombank;
RAS – Russian Academy of Sciences;	UAC – United Aircraft Corporation;
FRPC – Federal research and production center;	USBC – United ship-building corporation;
VIPs – Very important innovation projects;	FAS – Foundation for Advanced Studies;
NII – Scientific research institute;	IARS – Intellectual activity results;
RVC – Russian venture company;	RFTR – Russian Foundation for Technological Development;
SEZ – Special economic zones;	
NRC – National innovation center;	RSF – Russian Science Foundation.

of payments for the technology) or structural changes in the economy, e.g., the share of manufacturing in GDP and the share of high-tech and engineering products in exports (Table 1).

Discrepancies in the efforts and results of scientific, technological, and innovation policy in the last decade quite logically lead to a question about the quality of the planning of scientific and technological development (STD) on the state level.

Basic theoretical concepts and statistical problems of planning of scientific and technological development. *Basic theoretical concepts of std planning.* Two main directions of development of theoretical concepts of planning scientific and technological development can be distinguished at the state level, i.e., (1) an economic and mathematical model (models developed by K. Arrow [2] and P. Romer [3] and a model based on inpout–output balances [4]) and (2) evolutionary and

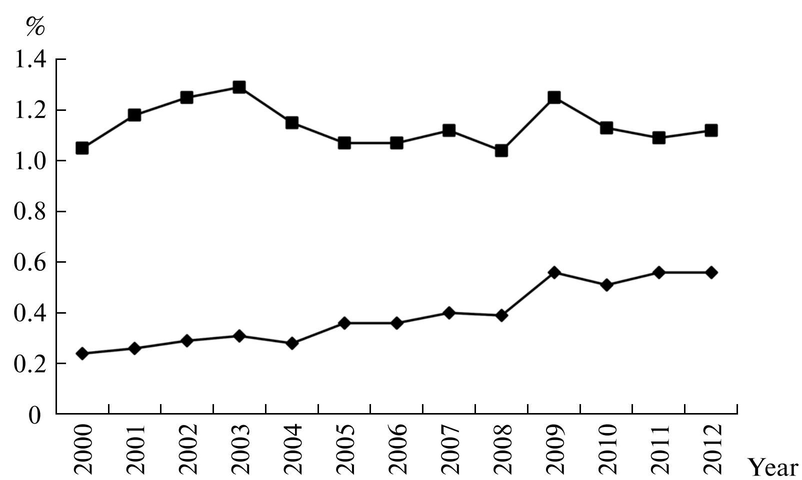

Fig. 2. Share of spending on civil science in the federal budget (–◆–) and the share of domestic expenditure on research and development (–■–) in the Russian GDP.

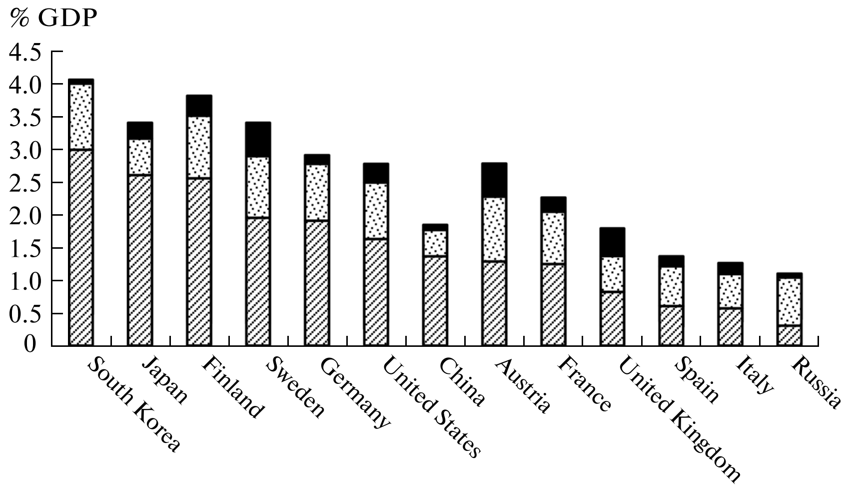

Fig. 3. Structure of domestic spending on research and development in Russia and other countries of the world in 2011 including ▨ business; ⚃ state; ■ others.

empirical concepts[4] (the concept of national innovation systems [5] and triple helix concept [6]).

While the first line theoretically enables ex-ante analysis, i.e., it represents a kind of programming for developing the scientific and technological complex, the second direction is more descriptive, since it offers *ex-post* analysis [1].

Despite the descriptiveness of the evolutionary and empirical models, since the 1990s, they have gained the greatest popularity in the academic and political environments. This can be attributed to the fact that these concepts propose concrete measures for the innovation policy based on a comparison with the policies implemented in other countries.

The question of the suitability some general institutional innovation systems for a particular country in a particular historical period is still open. Moreover, evolutionary and empirical concepts do not offer solutions on the choice of scientific and sectoral priorities on which limited available resources should be concentrated.

Accordingly, the practical application of the evolutionary and empirical concepts of STD planning involves problems associated with programming the economic effects of scientific and technological development and adapting the foreign experience of state innovation policies to the particular country's specifics.

However, attempts to solve these problems using instruments of economic and mathematical models have serious difficulties associated with the statistical basis for investigating scientific and technological development; some of the key issues here include the assessment of STD effectiveness and the disaggregation of STD indicators on the level of an individual industry.

Problems of assessing the STD effectiveness. While the statistics of resources allocated to STD is sufficiently developed (R&D spending, the number of researchers, the capital funds of science) and problems connected with the statistics of STD resources largely coincide with general statistical problems[5], the statistics of the STD performance is still a problem area.

The systematic investigations into the performance of scientific and technological sector began after the Second World War. In the 1970s, the focus of scientific and technological policy of the state shifted to improving the efficiency of research activities [7], which created an urgent need for instruments for measuring the impact of this policy.

In 1981, the OEDC issued guidance for measuring the R&D output with a special section devoted to indicators of the impact produced by scientific and technological activity [8]. The guidance included three main groups of indicators, i.e.,

– patent statistics;

– technological balance of payments, and

– high technology trade.

In addition, the inclusion of another indicator, i.e., bibliometric, was specially discussed but due to the limitations of its application,[6] it was not included in the set of the most important indicators of scientific

[4] These concepts were developed under a strong influence of empirical studies, as well as evolutionary economics. It is the author's– A. F.

[5] For example, accounting for the depreciation of fixed assets, etc.
[6] Ibid.

Table 1. Performance indicators of scientific and technological development in Russia and separate indicators that characterize the dynamics of sectors of raw materials

Indicator	2000	2011	2011/2000,%
Number of patent applications filed in Russia, items:			
total	28688	41414	144
by domestic applicants	23377	26495	113
by foreign applicants	5311	14919	281
Balance of payments for the technologies, million USD:			
earnings from technology exports	203.5	584.7	287
payments for imports of technologies	182.9	1862.6	1018
balance of payments for technologies	20.6	−1277.9	
Share of the value added in the GDP, %:			
manufacturing industry	15.2*	12.9**	85
mining	5.9*	9.3**	158
Share in total exports, %:			
mineral products	53.8	70.3	131
metals, precious stones and articles thereof	21.7	11.1	51
engineering products	8.8	4.5	51
high-tech products	1.9	0.8	44

* Data for 2002
** Data for 2012
Source: Indicators of Science (2013) NRU HSE, Rosstat, OECD.

and technological activity (OECD Main Science and Technological Indicators).[7]

In addition to the above-mentioned indicators of the results of the scientific and technological process, an attempt was made to use the indicators related to innovation activities. These indicators were used in the United States as early as in the 1960s and were the responsibility of the National Scientific Foundation (NSF). In 1993, European countries held their first coordinated survey of innovation based on the Oslo manual issued in 1992[8].

However, attempts to study the scientific and technical activities using innovative indicators have been unsuccessful [9], since it was not the economic effect of innovation that they succeeded in measuring, but rather the results of the innovation process, i.e., the introduction of new technology, innovation, etc. In connection this, the emphasis in the use of innovative indicators gradually shifted to performance indicators.

The developed performance indicators of scientific and technological development failed to form a comprehensive evaluation system, which would allow one not only to trace the various stages of the chain of formation of the economic effect of using new scientific knowledge, but also to link[9] the results of previous and subsequent stages (publications → patents → implemented technologies → economic contribution of innovations at the enterprise level → economic contribution of innovation at the level of the economy). In other words, the resulting set of indicators only suggested a point measuring STD performance, which in many cases does not make it possible to adequately to assess the country's level of technological development.

Interesting results are obtained by comparing the estimated level of technological development for different countries based on formal statistical indicators (patents, balance of payments for the technology, high technology trade, etc.), and the results of surveys of international experts. Thus, if we compare the data shown in Figs. 4–8[10] and the results of a survey conducted by specialists of Battelle, the level of technological development of countries in the ten technological areas (Table 2), we can note the following differences:

[7] But then bibliometric indicators became fairly widespread; for example, they are part of the indicators published by the World Bank.
[8] Community Innovation Surveys for 1996, 2000, 2004, 2006, and 2008 can be found on the Eiristat website,
[9] The number of patents cannot be inferred from the number of articles, neither can the economic effect be derived from the number of patents as indicators reflected in the statistics are not able to grasp the "qualitative" characteristics of the observed values, which significantly differ in the case of articles, patents, terms of introduction of new technologies to production..
[10] OECD, World Bank, Science indicators (2013) NRU HSE.

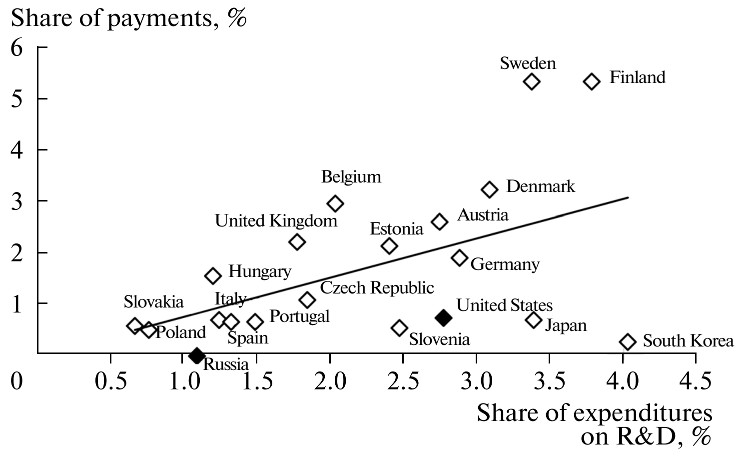

Fig. 4. Share of income payments for technology in GDP at PPP.

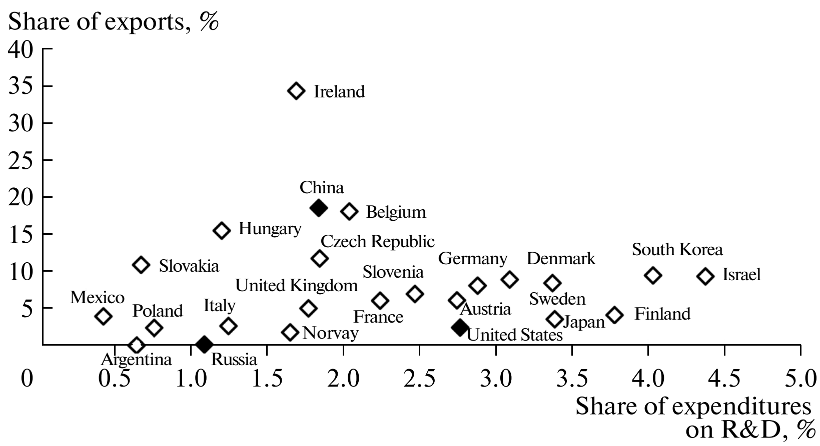

Fig. 5. Share of high-tech exports in the GDP at PPP.

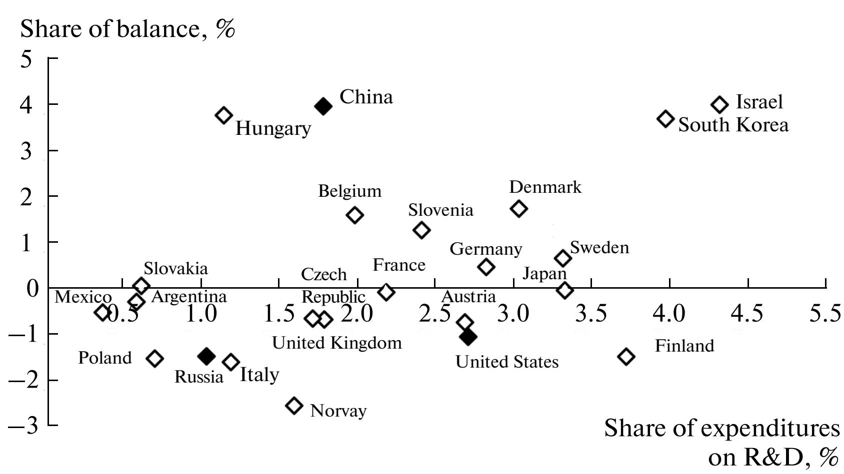

Fig. 6. Share of the balance (exports-imports) of foreign trade in high-tech products in the GDP at PPP.

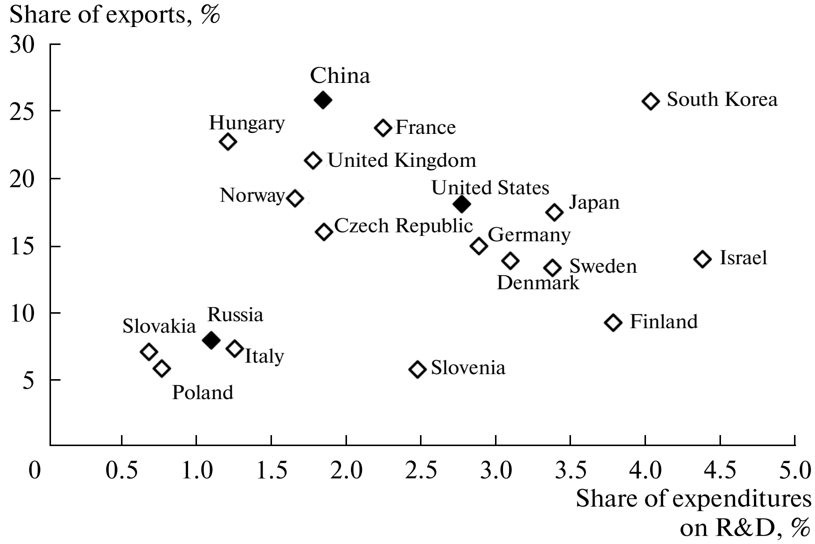

Fig. 7. Share of high-tech exports in the volume of industrial exports.

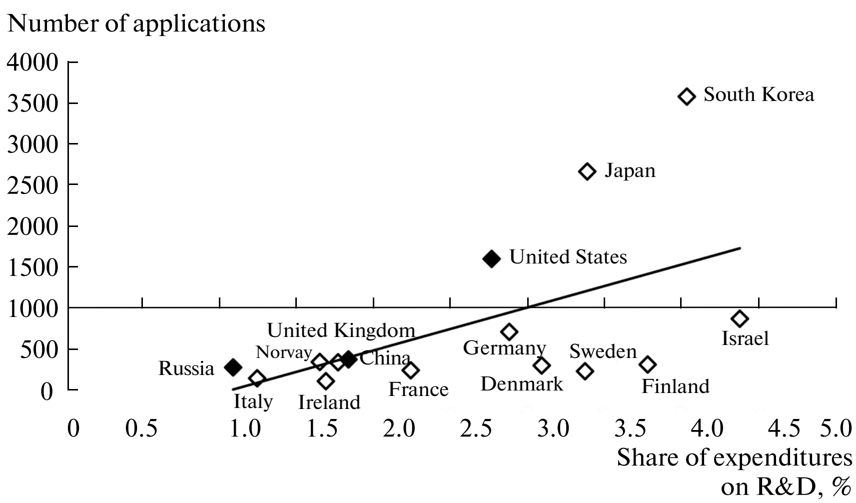

Fig. 8. Number of applications filed with the national patent office by national or foreign applicants per 1 million people.

—The surveys universally show the dominant position of the Unites States in eight technological areas, while, according to the formal statistical indicators, although being a stable member of the leading group, the United States is never recognized as the leader.

—According to the formal statistical indicators, the technological leaders include countries such as South Korea, Ireland, Denmark, Sweden, and Finland, while, according to the survey data, their position is considerably weaker.

—Estimates of the countries' level of technological development based on formal statistical indicators do not take into account the effects of globalization; for example, when a country with a comparatively low level of scientific development specialize in the assembly of imported components, then export the finished products all over the world.

Thus, comparisons of a country's level of technological development based on its meaningful assessment in poll surveys, as well as on formal statistical indicators, enable us to conclude that it would not be correct to use direct statistical indicators of scientific and technological development in economic and mathematical models.

Problems connected with the disaggregation of STD indicators to the level of an individual industry. When developing scientific, technological, and innovation policy, the focus is made not so much on the level of research-and-development spending as on the priority directions and policy instruments; an important role is

Table 2. Leading world countries in ten areas of technology

Place	Agriculture and food industry	Automotive industry	Civil aerospace engineering, rail and other nonmotorized transport	Military aerospace engineering defense industry and security	Chemistry, nanotechnology and other advanced material science	Power engineering (production and efficiency)	Environment and sustainable development	Healthcare, life sciences, biotechnology	Information and communication technology	Instruments and other non-ICT electronics
1	United States	Germany	United States	United States	United States	United States	Germany	United States	United States	United States
2	China	Japan	France	China	Japan	Germany	United States	United Kingdom	Japan	Germany
3	Germany	United States	Germany	Russia	Germany	Japan	Japan	Germany	China	Japan
4	Australia	Korea	China	United Kingdom	China	China	United Kingdom	Japan	Germany	China
5	Brazil	China	Japan	France	United Kingdom	United Kingdom	Sweden	Switzerland	Korea	Korea

Source: [10].

played by assessing effects at a lower aggregation level, in particular on the sectoral (branch) level.

The key instrument for modeling economic processes at the sectoral level is inpout–output balances. However, the application of inpout–output balances and their tools to the scientific and technological planning is also fraught with considerable difficulties.

Thus, Academician Glaz'ev as early as twenty years ago noted that "... the typical industry is not perpetuating integrity. Its component processes are included in different production and technological systems; they operate autonomously and, in their change, only weakly depend on one another" [11]. In terms of production and technological processes, the economic structure is significantly different from that given by official statistics.

The rapid development of the new economy based on advanced technologies (ICT, biotechnology) further complicates the task of analyzing technological ties for official statistics. According to V.A. Bessonov [12] "Russian statistics is more oriented to the economy at the industrial development stage.... It operates indicators in rubles at current prices, tons, cubic meters, pieces, kilowatt-hours, etc.... These units are hardly suitable for measuring the new economy. Will the transportation of microchips significantly affect the freight turnover measured in ton-kilometers?"

Basically, this problem can be solved because industry experts usually have the necessary information in the technological breakdown and bringing it in line with the structure of OKVED would seem to be only a technical matter. However, usually, in practice, a concrete industry expert has only a sliver of the required information from the chain of technologically conjugated industries, and there is no general model of the comprehensive technological complex.[11]

In the absence of the developed technoeconomic models of chains of technologically conjugated industries, changes in the parameters of intersectoral relations in the mathematical models[12] have no solid calculation base, which seriously undermines the reliability of the estimated technological influence on socio-economic parameters. In this case, tentative parameters obtained in calculations make it possible to conditionally calculate the economic impact of new technologies while making investment decisions on technology projects requires a much more accurate assessment.[13] Because of this, the problem of accounting for the investment attractiveness of new technologies remains unsolved in macroeconomic models, including models of input–output balances.

[11]The only exception is the fuel and energy complex (FEC), in which various technoeconomic models are fairly common. In the world and in Russia in particular, we know quite a lot of long-term model predictions on FEC, which were calculated taking into account expected technological changes (see, e.g., [13–15]). However, there are almost no developed or well-known models in other sectors of the economy.

[12]The most common mechanism that takes into account technological impact on intersectoral linkages is the change in coefficients of direct expenditures in inpout--output balances.

[13]For example, ROI1 = 10% and ROI2 = 25%, i.e., it differs 2.5 times. These values characterize two substantially different situations from an investment point of view.

Problems in the russian practice of planning scientific and technological development. ***Problems of STD planning in russia at the level of strategic planning documents.*** Indicators of scientific, technological, and innovation development used in key strategic planning documents of Russia[14] can conditionally be subdivided into the following four main groups:

—development indicators of scientific and technological complex (number and average age of researchers, the number of domestic publications in international databases per 100 researchers, the number of NRU, NRC, etc.);

—indicators of innovative activity, i.e., the share of enterprises engaged in technological innovations, the volume of shipped innovative products, the number of patents per 10000 people, the number implemented technologies, etc.;

—indicators of technological development of business, i.e., the share of the innovation sector[15] in GDP, the share of domestic high-tech exports in international trade, energy intensity, labor intensity, etc.;

—resource indicators, i.e., the proportion and structure of the domestic research-and-development expenditures in GDP, the implementation cost of the state programs, etc.

The above-presented groups of indicators are rather weakly related. For example, the number of publications in international journals, the proportion of organizations engaged in technological innovation, and Russia's share in global high-tech markets are not directly connected in public documents[16] [16]. Neither do the planning documents present the rationale for the necessity and sufficiency of the funds allocated to the scientific and technological development resources for the achievement of the technical and economic objectives, i.e., the share of domestic producers in the global high-tech markets, reducing labor and energy intensity of sectors, etc.

Aggregate estimates of the impact of scientific and technological development on the Russian economy are given in only one document, i.e., the long-term forecast of socio-economic development of the Russian Federation until 2030[17]. However, its high level of aggregation does not suggest that the calculations were based on a specific set of innovation policies.

Thus, strategic-planning documents do not reflect a clear relationship between measures of the pursued innovation policy and quantitative socioeconomic effects.

Contradictions in state priorities of scientific and technological development in Russia. Over recent years, Russia's scientific, technological, and innovation policy has consisted of NIS development based on western principles as the policy was focused on creating new mechanisms for facilitating and supporting private business entry into innovation area. In recent years, we have also observed the increased influence of the triple helix concept, which involves shifting research and innovation functions to universities.

However, the large number of NIS elements created by the state has not stimulated any considerable growth in innovation activity, which many researchers attribute to the lack of stable relations between these elements [16]. This situation can partially result from contradictions in the state priorities of scientific and technological development. On one hand, one of the priorities of the state policy in the field of scientific and technological development is to involve the private sector in the process of modernizing the Russian economy[18]. In 2011–2012, the state already reached the funding level of the major developed countries (Fig. 3). Facing tight budget conditions in the coming years, the state will apparently not be able to continue to rapidly increase financing of the scientific and technological complex. At the same time, there is a considerable potential for increasing research-and-development funding from the private sector.[19] On the other hand, the lack of public resources for the further increase in the funding of scientific and technological development makes it necessary to concentrate resources on a limited number of priority areas, thus creating conditions for greater involvement of the business in the processes of technological modernization of the Russian economy.

In 2011, priorities in the development of science and technology were approved at the presidential level [17]. The priority areas included the following: new

[14]We analyzed the following set of documents: the concept of the long-term development of the Russian Federation; the long-term prognosis of the scientific and technological development of the Russian Federation; the long-term prognosis of socio-economic development of Russia until 2030; the strategy of innovative development of the Russian Federation; thematic government programs ("Science and Technology" and "Economic Development and Innovation Economy"); and sectoral government programs and concepts.

[15]According to the definition given in the Forecast of Long-Term Socioeconomic Development of Russia until 2030, the innovative sector includes "spheres of science, communication and informatization, education and health service, forming human capital, and mechanical engineering."

[16]These documents do not contain any intermediate assumptions.

[17]The long-term forecast of socioeconomic development of Russia presents estimates of additional GDP growth spurred by investment in research and development and the development of technological applications. Besides it provides an assessment of the required amount of additional investment from the federal budget for the implementation of priority projects in areas of science and high-tech industries.

[18]The need to increase the participation of the private sector in scientific and technological development is mentioned in almost all strategic documents relating to innovative development.

[19]Thus, the share of R&D spending in Russian GDP covered by business is two times less than in Italy and Spain, three times lower than in France, and more than five times less than in the United States..

directions, including the nanosystem industry, information and telecommunications systems, and life sciences; traditional directions, such as transportation and space systems, energy efficiency, energy conservation, nuclear power engineering, and environmental management[20]; and defense and security, i.e., security and counter-terrorism, advanced weapons, and military and special equipment. As a result, these priorities (in the civil sector) were determined as directive guidelines for almost all elements of the national innovation system, including the following:

—RVC[21];

—Rosnano;

—national research universities[22];

—Academies of Sciences, Russian Foundation for Basic Research (RFBR), RHSF[23];

—technological platforms[24].

The traditional directions were financed through two main channels, i.e., federal target programs (FTPs) and funds of state-owned companies (United Aircraft Corporations Rosatom, Russian Railways, Gazprom, Rosneft, etc.). At the same time, through the initiative for creating innovative development programs for state-owned companies, which have has been implemented since 2010, the state has tried to significantly enhance the second channel of financing research and development. New directions were mostly funded through a special FTP[25] at the expense of development institutions and various research funds, as well as with funding from development institutions and various research foundations. In the field of ICT, private companies were also an important source of financing.

Despite individual units of government, priorities of scientific and technological development seem logical. Together, they lead to a contradiction that is largely responsible for the low efficiency of the Russian NIS. This contradiction can be formulated as follows:

—the acceleration of scientific and technological development requires the increase in the spending of private business on research and development;

—the scientific and technological priorities are oriented, first, to sectors dominated by state-owned companies (defense industrial complex, aviation, fuel and energy complex) and, second, to the new industries, which (with the exception of ICT[26]) are in their infancy and require injections of public funds for their development (pharmaceutical industry, new biotechnological production, companies engaged in the development of new materials);

—there are almost practically no instruments for supporting innovative development oriented to the industries that are dominated by private business, which funds development, i.e., railway and road freight machinery, equipment for oil and gas industry, low-tonnage chemistry, building materials industry, food industry, etc.

* * *

Therefore, planning scientific and technological development at the state level faces significant challenges. On one hand, formal indicators of scientific and technological development used in economic and mathematical models often contradict the results of the substantive assessment of scientific and technological level and do not form a comprehensive evaluation system of innovative development. On the other hand, there is a pressing issue of adapting foreign experience in planning of scientific and technological development, including the formation of scientific and technological priorities, to country-specific conditions.

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[20]The structure of the direction of "environmental management", in addition to environmental technologies, includes technologies of mining operations.

[21]Priority areas for investment identified according to the List of Critical Technologies (http://www.rusventure.ru/ru/company/brief/).

[22]Thus, the decree of the President of the Russian Federation as of October 7, 2008 "On the Implementation of a Pilot Project on the Creation of National Research Universities" stipulates that their creation is aimed at "implementing the priority directions of science, technology, provision of engineering, scientific, and human resources in order to meet the needs of industries and social sphere...."

[23]The State Program "The Development of Science and Technology" states that the subjects of the Unified Program of Basic Research of the Russian Federation will also take into consideration the "technological priorities of the state," which apparently refers to the list of "Priority Directions and Critical Technologies."

[24]Subjects of most technological platforms are directly or indirectly connected with the presidential priorities.

[25]Federal Target Program "Research and Development in Priority Areas of the Scientific and Technological Complex of Russia for 2007–2013".

[26]Information and telecommunications industry is an exception—there are a large number of private companies, including large ones. At the same time, in the area of ICT, there is an active process of innovation development and investment of private funds in technological development , while the rest of the "new industries" are not yet donors and recipients of resources for technological development.

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