Measuring technological level of organisations: methodological approaches and assessment

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Abstract

Purpose – *The paper aims to present the results of the first Russian pilot study on technological level of organisations upon the answers of 2,500 respondents out of nine sectors of economy to a broad specialised questionnaire. The purpose of the study is to assess the technological level of organisations on the basis of qualitative information that comprehensively reflects its most important characteristics, as well as identify factors that affect the technological level of production.*

Design/methodology/approach – *It offers a look at which methodological approaches were developed and what the survey shows on characteristics of the application of technology (the scope and extent of the application, level of technology, the problems solved by applying specific types of technology) and the application of intellectual property rights.*

Findings – *The paper also highlights some interesting findings that suggest that the majority of national organisations tend to pursue technological self-sufficiency strategies and quite a large part of them are not active in either domestic or foreign Science & Tecnology markets.*

Originality/value – *An originality lies in the proposed methodological approaches of the study, in the selected indicators of progressivity and the scale of application of technology related to the level of production capacities of the surveyed medium and large enterprises and organisations. This identifies significant incentives for organisations to increase their technology level as well as competitive advantages for the respondents themselves and for their competitors.*

Keywords *Advanced production technology, Improving technology, Intellectual property assets, Introduction and use of technology*

Paper type *Research paper*

Introduction: "Anamnesis" of the problem

The emergence of a new "technological wave", increasing global technological challenges and related processes of technological modernisation based on development, adaptation and use of modern technology, including fundamentally new technological processes, operations, methods and techniques, determine the need for measurement and integrated assessment of technological level of organisations.

Integrated systems for measuring the level of innovation and technological development were designed in economically developed countries, comprising numerous statistical and expert-based techniques, which covered a sufficiently wide range of activities, from R&D to marketing of innovative technologies, products and services (Hall and Jaffe, 2012; Miles *et al.*, 2006; Perrin, 2002). Analysis of the technological level primarily implies the following objectives:

- understanding competitive strengths and weaknesses of the existing technological level in various sectors of the economy;

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- proposing various science, technology and innovation (STI) policies, for the whole economy, specific sectors and individual companies; and
- encouraging and attracting investments.

In this context, studying best practices of foreign companies, the experience of countries that are now global leaders and those that are making rapid progress, certainly seems to be relevant – together with standards and recommendations proposed by international organisations of particular interest are the following:

Recommendations, standards and analytical materials of international organisations

- statistical manuals for the STI sphere published by the Organisation for Economic Co-operation and Development (OECD) and Eurostat (including the Oslo Manual (OECD, 2005, 2015); Frascati Manual (OECD, 2015); Handbook on Economic Globalisation Indicators (Balcet, 2005); TBP Manual (OECD, 1990) and Patent Manual (Schmoch *et al.*, 1994); European Statistical System Committee, 2011), by the United Nations Institute of statistics (UNESCO, 1984, 2010) by the World Intellectual Property Organisation [Glossary on Industrial Property Statistics, (WIPO), 2012] and the European Commission, which serve as a methodological basis for calculating and analysing the Composite Innovation Index and the European Innovation Scoreboard (Hollanders and Tarantola, 2011; European Commission, 2014a, 2014b);
- reports and reviews of leading international economic organisations containing policy evaluation in the innovation and technology area, focusing in particular on the quantitative and qualitative tools (OECD, 1998; Warwick and Nolan, 2014; UNESCO, 2015);
- materials and reviews published by relevant industry-level international organisations and analytical centres concerned with assessment of current state and prospects of industry-specific markets (DePasquale and Bradford, 2013; Bryant *et al.*, 2016; Economist Intelligence Unit, 2015);
- methodologies developed by the United Nations Conference on Trade and Development (UNCTAD) for assessing and rating the largest transnational corporations/TNCs (UN, 2007);
- approaches to assessing companies' competitiveness suggested by the World Economic Forum/WEF (Schwab and Sala-i-Martin, 2016);
- methodologies for developing and assessing the impact of priority Science & Tecnology (S&T) development areas in the EU, in the scope of the 8th Research Framework Programme (FP8) "Horizon 2020" continues along the path charted by FP7 towards integration of European research. FP8 designed to promote overall economic growth, increase the competitiveness of European economies by encouraging investments in knowledge, innovation and human capital; FP8 was aimed at supporting joint EU member states' and associated countries' projects in 2008-2020 (see, for example, European Commission, 2014c; Grebenyuk *et al.*, 2016); the EU launches two enormous projects, so-called Future and Emerging Technologies (FET) Flagships in major S&T areas; the most important of them were ICT, health and biotechnology, transport and aerospace, nanoscience and nanotechnology, materials, new production technologies; and
- methodological approaches to and tools for statistical observation and expert studies of new/emerging technologies (ICT, bio- and nano-technology), advanced production

technologies, S&T priority areas on the national level (Gokhberg *et al.*, 2012; Galindo-Rueda, 2010; Marx, 2010; McNiven and Palmberg, 2008).

National studies, industries and companies' practices

- reports and analytical materials prepared by leading international companies active in specific sectors; industry-specific marketing and analytical reviews (for example, annual reports on the portal for sustainability reporting www.sustainability-reports.com/);
- national studies, practical experience, organisational and methodological approaches to measuring the technological level in terms of production, patent and innovation activities; technology audit and benchmarking techniques applied by leading international companies (Kogan *et al.*, 2017; Jorgenson and Stiroh, 2000; Kim, 2010; Archibugi and Planta, 1996; International Institute for Sustainable Development, Deloitte & Touche and Business Council for Sustainable Development, 1992; Scherer, 1983);
- international strategic management and planning standards and practices and performance criteria; methodological approaches applied in international practices, on the national and corporate levels, to select quantitative or qualitative performance measures: balanced scorecard (BSC) principles; key performance indicators (KPI); criteria for goals and objectives setting (SMART system); best practices and experience of the largest international companies in measuring efficiency of their strategic planning, using a balanced set of indicators (PricewaterhouseCoopers, 2007; Brunsson *et al.*, 2012; Gilbert *et al.*, 2011; Parmenter, 2015);
- techniques and approaches applied by various national agencies, such as the US National Science Foundation (NSF) and the UK Department for Business, Innovation and Skills (Wolfe, 2016; Conti *et al.*, 2016; BIS Economics Papers, 2012); and
- the European Manufacturing Survey (EMS) initiated by the Fraunhofer Institute (Germany). Since 2003, it has measured the qualitative level of innovators and application of advanced high technologies[1]. The survey provides compatible data on the technological modernisation of the manufacturing sector[2] in countries such as Austria, Croatia, Denmark, Finland, Germany, France, Greece, Italy, The Netherlands, Slovenia, Spain, Switzerland, Turkey and the UK. Russia (represented by the National Research University Higher School of Economics) has participated in the EMS project since 2009. More information is available on the sites of the Fraunhofer ISI's online benchmarking (for example, Fraunhofer ISI, 2015).

This publication accumulating previous listed above research and practices presents the results of a study that is the first step towards performing an integrated measurement of the existing technological level, together with an identification of factors affecting the growth and competitive advantages of Russian organisations.

The article was prepared within the framework of R&D project which was implemented in 2013 by the National Research University Higher School of Economics and was commissioned by the Russian Federation Ministry of Education and Science, with participation of Autonomous Non-profit Organisation (Information and Publishing Centre) "Russian Statistics" and regional offices of the Federal State Statistics Service. The customer put forward both "hard and soft" requirements for the survey, which were fully implemented. The first contained the need to survey medium and large organisations and companies and the inclusion in the questionnaire of aspects relating to the study of the application of key technology in the context of the national priority areas. The second determined the number of surveyed objects (not less than 1,000) and regions of the Russian Federation (not less than 15).

The results obtained will help to meet the information requirements of government agencies, organisations and individuals in charge of making management and political decisions in the science, technology and innovation sphere; they provide essential tools for shaping more efficient policies aimed at technological modernisation of the economy and increasing the technological level of production at large and medium Russian organisations and enterprises.

Methodological approaches

The main methodological issue that had to be solved at the first stage of the study was related to the definition of the technological level of organisation. Oh *et al.* (2016) provide some classical definitions of technological level: "the level of accumulation of technology relating to industrial production" (Schmookler, 1966); and "the capability to effectively utilize technological knowledge in investment, production and innovation" (Solow, 1957; Oh *et al.*, 2016, p. 520).

Cho (2015) provides the definition of technological level as "[...] the relative technological capacity to use technology knowledge efficiently and refers to the extent to which technological knowledge is accumulated, invested in, produced, and innovated" (Cho, 2015, p. 7).

As shown in Coccia (2005); Rosłanowska-Plinchcińska (1988) provides two approaches for defining technological level (TL): economic, where TL "[...] is intended to be measured by the economic effects of the introduction of new solutions, as, for example, a price increase"; and techno metric, where TL "[...] is defined by means of the combined assessment of the set of technical–technological–functional parameters that present the examined product or technology" (Coccia, 2005, p. 958).

Park *et al.* (2013) approves that "[...] Technological level is the measure used to evaluate current technological capabilities of the potential target companies, and the degree of technological level is measured by two indices: Technology quality and Technology quantity. [...] Technology quality can be represented by the number of citations the patents received. Patent citation is strongly related to economic value or importance of a patent, and thus an average citation frequency of all or parts of a target company's patents can evaluate its technology quality (Engelsman and van Raan, 1994; Hall, *et al.* 2000). Technology quantity measures the number of qualified technologies that the target company possesses" (Park *et al.*, 2013, p. 894).

Summarised the listed above definitions of the technological level, we developed our own as the level of application in industrial production processes of technology (key, improving, advanced manufactory) and intellectual property with the aim of increasing production efficiency, qualitative characteristics of products and achieving socially significant effects.

The important objective of the study was to develop a reliable information basis for shaping a more efficient economic policy, primarily in terms of increasing technological level at Russian organisations, accelerating the shift towards innovation-based development model and to monitor effects of this policy's implementation.

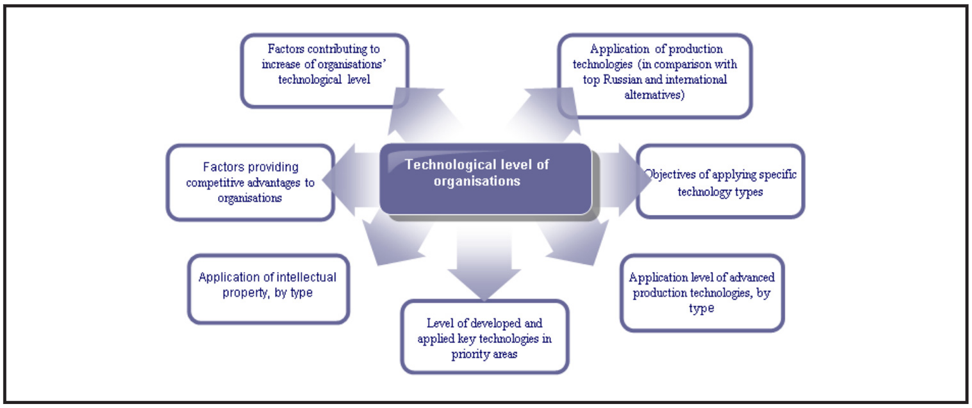
A one-time sample survey of 2,501 large and medium organisations from 25 Russian regions[3] out of ten types of economic activities was conducted (Table I).

The study comprised seven main areas which were concentrated on the application of various production and key technologies; application of intellectual property assets, by major asset types; factors contributing to the increase of production technological level at the surveyed large and medium organisations and their competitive advantages (Figure 1).

Table I Distribution of organisation sample by sector

Economic activity	*Sample*	*Rate (%)*
Total	2501	100.0
Mining	40	1.6
Manufacturing	1899	75.9
Production and distribution of electricity, gas and water	108	4.3
Construction	136	5.4
Communications	39	1.6
Activities involving application of computers and information technology	110	4.4
R&D	49	2.0
Provision of other services	31	1.2
Education	4	0.2
Sewage, waste disposal and similar activities	85	3.4

Figure 1 Analysis of organisations' technological level



While designing methodological approaches to study technological levels of organisations, particular attention was paid to various characteristics of the applied technologies (or technological processes, operations, techniques and methods), including how advanced they were, that were closely linked with the level of production potential of the surveyed large and medium organisations.

Organisations' strategies regarding sources of their technologies were analysed in the scope of the study, together with the scale of their application. This included the development and application of key technologies; utilisation of production technologies, including advanced ones; how these technologies compared with the best Russian and international alternatives; application of improving technologies; application of intellectual property assets; and factors of growth of the technological level of organisations and their competitiveness.

Production technologies were broken down according to whether their sources were developed in-house or acquired in Russia or abroad. Level of applied technologies that the respondents had to estimate was measured by comparing them to the best Russian and international alternatives: superior to alternatives, on a par with or inferior to them.

Levels of technologies' application, which the respondents had to determine, included active use, incomplete implementation and no application despite having a need to do so.

The study revealed objectives pursued by the surveyed large and medium organisations through application of each kind of improving technologies, such as increasing revenues, range of products and services, exports of products and services, labour productivity; improving business reputation, product quality; reducing costs, energy consumption or energy waste, production cycle, percentage of faulty products, environment pollution, use of hazardous/harmful (raw) materials; achieving a more efficient use of production facilities, a more flexible production; extending geographical market coverage; complying with technical standards, rules, specifications, etc.

For example, studies on the technologies improving production efficiency (further, TIPE) can be found for application in different sectors of economy (Alene and Hassan, 2003) (analysis of maize production sector); Dou, 2004 (TIPE for Aluminum Strip Cold Rolling Mill); Lin and Shao, 2006 (effect of information technologies); Burnell and Allan, 2009 (review of TIPE in agricultural sector); Liu and Chen, 2009 (RFID technology as TIPE for integrated-circuit packaging house).

A separate cluster of survey questions related to technologies, which classified as "improving" and comprised five different kinds: resource, energy-saving, ecological ("green"), those increasing productivity, as well as those improving product quality.

The survey also contained questions on the level of application of advanced production technologies[4], which included quickly developing practical knowledge areas with a significant application potential in various economic activities and transformed into general-purpose production technologies. The use of advanced technologies in the production process is an indicator of the firm's technological level (Beneito, 2001), as employees able to use them will be more receptive to technological changes. Advanced technologies also provide flexibility and efficiency and facilitate the development of innovations.

The study also analysed the level of key technologies, both those being developed and actually applied, which contributed most towards accelerating economic growth, advancing development of High-tech sectors and making use of the competitive advantages of the Russian economy. These key technologies are based on specific high-priority STI development areas, such as nanosystems industry, ICT, life sciences, efficient environmental management, transport and space systems, energy efficiency, energy saving and nuclear energy. As mentioned Aydogdu *et al.* (2017) "Technologies are constantly developed to address new demands and provide further opportunities" (Aydogdu *et al.*, 2017, p. 354). Moreover, "Macro-forecasts of the Technology Revolution suggest that the rise of e-commerce, green business, climate control, alternative energy, artificial intelligence, and other technological advances are likely to move the world to a more sophisticated level of development about 2020" (Halal, 2013, p. 392).

Since intellectual property, as a result of R&D, reflects the practical application of cutting-edge S&T achievements and facilitates the production of competitive products, the study also analysed the application of various intellectual property assets and the means of individualization[5]. Because a granted patent is generally accepted as a qualified technology that is protected as an intellectual property, the number of patents granted can reflect technology quantity (Geiger and Makri, 2006; Guellec and de la Potterie, 2000). Following them Di Guardo *et al.* (2016) approves, "The technological level is measured by the stock of patents computed as the sum of patent applications" (Di Guardo *et al.*, 2016).

Factors prompting organisations to increase their technological level included the high competition in the domestic market; demand by suppliers of (raw) materials, equipment, components, etc.; demand by customers and consumers; demand by business partners (participants of companies' production activities); availability of in-house R&D output; participation in government support programmes; requirements of technical regulations and standards; and need to match the industry's technological level.

The factors, which were considered as providing competitive advantages for the organisations, cover product prices, quality and novelty; products' matching consumer demand; level of technologies applied in production; timely provision of services and after-sale and/or additional services.

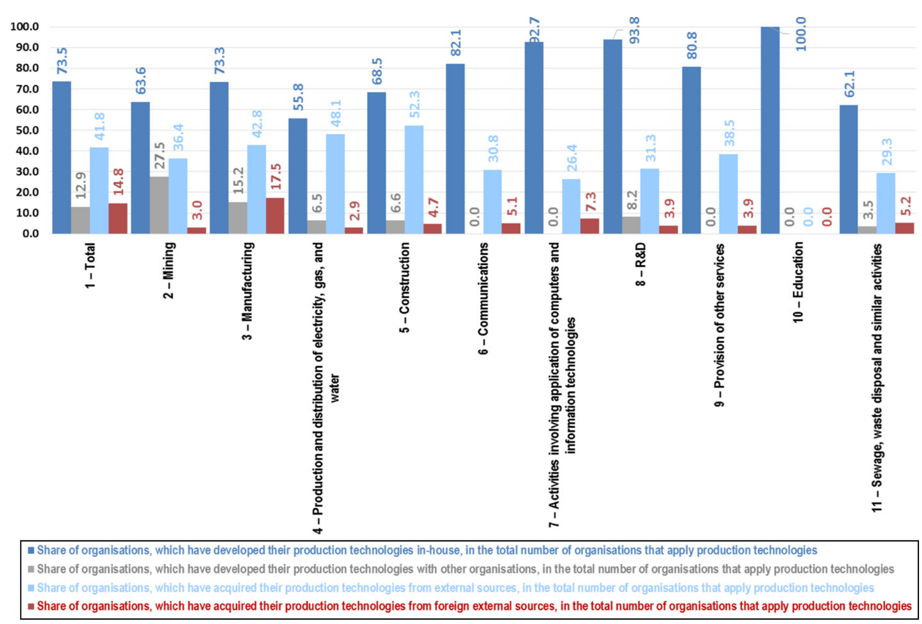
Application of production technologies

Technological modernisation based on implementing advanced S&T results creates the need to study and measure aspects of cutting-edge production technologies' application, including those increasing the productivity of machinery and equipment, efficiency of production processes, saving of floating assets, extending product range and markets and affecting organisations' technological level and competitiveness.

Surveyed large and medium organisations and enterprises applied more than 1 million production technologies, the vast majority of which (92.8 per cent) were in-house, developed by 73.5 per cent of the respondents. Only 4.1 per cent of applied technologies were acquired from external organisations. Note that the share of imported technologies was much lower still under 1 per cent. Less than half of the surveyed organisations did apply acquired technologies and about 15 per cent used imported ones.

Summary data show that overall, large and medium Russian companies pursue technological self-sufficiency strategies, referring to develop the necessary for them new technical solutions and technologies in their own S4T divisions and demonstrate an insignificant level of activity in the domestic and, in particular, foreign technology markets, as a rule buying not intellectual property but finished equipment. This trend is more common for the education and economic activity types, which involve computers and information technologies applications, conducting R&D and providing various services (see Figure 2). These sectors have the largest shares of organisations that apply in-house developed technologies.

Figure 2 Distribution of large and medium organisations and enterprises, which apply production technologies by source of technology and economic activity type (%)



Note: The total number of organisations is not equal to 100 per cent, as one organisation can apply several types of production technologies

Technological self-sufficiency strategies are less prominent in construction, production and the distribution of electricity, water and gas; in these industries, the shares of companies relying on in-house developed technologies were lower than the average Russian level (by 4 and 17.7 percentage points respectively), while shares of acquired technologies were higher (by 10.5 and 6.3 percentage points respectively).

As to the manufacturing sector, the overall share of enterprises which rely on in-house developed technologies is close to the Russian average, but in many activity types (high-, medium- and low-tech alike), there is a significant share of companies which apply in-house developed technologies. The main application areas are metallurgy (75.4 per cent), chemical (75.6 per cent) and textile industries (83.3 per cent), leather tanning, leather goods and footwear production (76.3 per cent), shipbuilding, aircraft, spacecraft and other vehicle construction (80 per cent), electrical engineering (82.9 per cent), furniture and related products (87 per cent), machinery and equipment (90 per cent), office equipment and computers (90.9 per cent), medical equipment, instruments, optical instrumentation and equipment, watches (93.8 per cent), radio, tv and communication equipment (96.9 per cent). At the same time, manufacturing industries display the highest shares of companies that apply technologies acquired from external sources, including imported ones (42.8 and 17.5 per cent). In mining, relevant indicators were much lower than the Russian average values (by 9.9, 5.4 and 11.8 percentage points).

The survey revealed insufficient cooperation in developing production technologies: only about 13 per cent of respondents said they cooperated with various kinds of partners. This may be primarily because of a low level of trust between organisations and to the risks of losing intellectual property. Large and medium mining and industrial organisations demonstrated closer cooperation. For instance, 27.5 per cent and 15.2 per cent respectively of such companies cooperated with other organisations in applying technological innovations. This figure is much higher (by more than 10 percentage points) than the relevant value for other organisations surveyed.

The cooperation of companies with R&D organisations is of utmost importance for increasing the quality and the novelty of technologies a. More than any other potential partners, R&D organisations have skilled personnel, necessary equipment and infrastructure. The survey revealed that companies engage slightly more than 8 per cent of R&D organisations to help them with developing and applying technologies.

For partners like R&D divisions of other companies, consulting and engineering firms, industrial parks, business incubators, technology transfer centres and other innovation infrastructure organisations, the relevant figures were modest.

Overall, ongoing cooperation was noted frequently. The surveyed organisations were oriented towards contract-based cooperation projects: more than three quarters of them preferred sporadic format.

However, if we consider specific indicators describing technology application, in particular economic activities (Figure 3), the picture is quite different. This is equally true for communication and mining companies whose shares of acquired applied technologies were much higher than the shares of in-house developed ones. A “softer” ratio of specific indicators was discovered for construction companies, organisations providing various services and operating in sewage, waste disposal and similar areas. It is only in economic activities, which directly involve the production of goods and the development of new technologies that the share of in-house developed technologies was much higher than those acquired from external organisations. This is especially relevant for the manufacturing industries; production and distribution of electricity, gas and water; computers and information technologies; and R&D.

The technological development level of large and medium organisations engaged in various economic activities is also characterised by the number of technologies used per

Figure 3 Distribution of production technologies applied by large and medium organisations by origin and economic activity type (%)

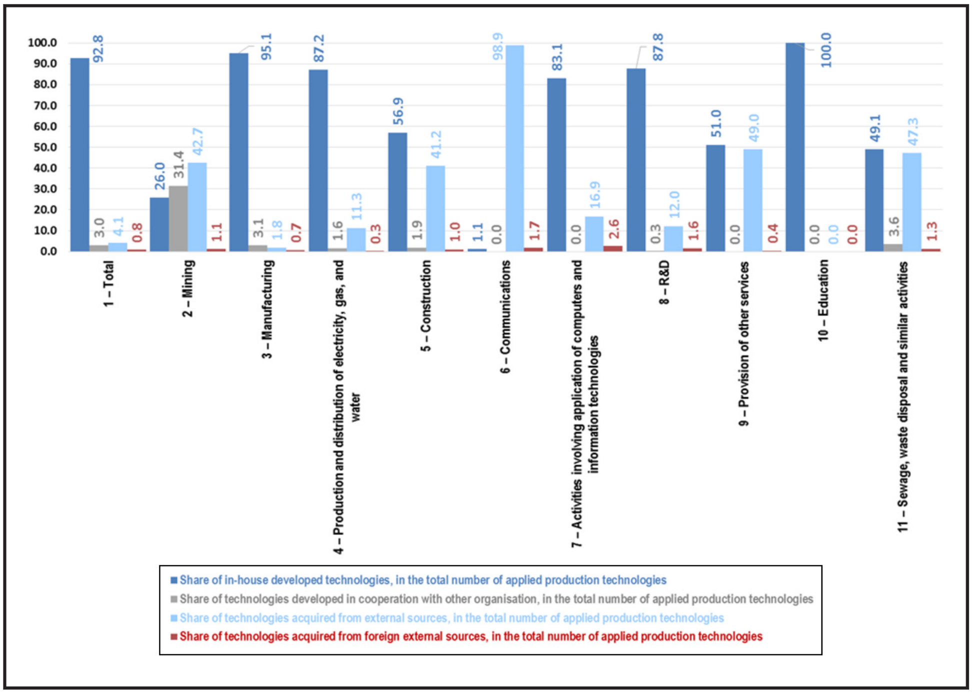


Table II Distribution of production technologies applied by an average organisation, by technology source and economic activity type

			Out of that		
			Acquired from external organisations		
				Out of that	
Economic activity	*Average number of applied production technologies*	*In-house developed*	*Total*	*In the RF*	*Outside the RF*
Total	42,311	39,284	1,740	1,421	319
Mining	1342	348	573	558	15
Manufacturing	52,836	50,221	956	579	377
Production and distribution of electricity, gas and water	1,988	1735	224	217	7
Construction	1165	663	480	468	12
Communications	53,490	577	52,913	51,987	926
Activities involving application of computers and information technologies	5,521	4,587	932	789	143
R&D	16,171	14,194	1,935	1,669	267
Provision of other services	950	485	465	462	4
Education	733	733	...	...	...
Sewage, waste disposal and similar activities	667	328	316	307	9

organisation. The most “technological” ones were communication and manufacturing companies: on average they applied 50,000+ technologies (Table II). However, if in the first case acquired technologies clearly dominated, in-house developed technologies led in the second. For all other economic activity types, the average number of applied production technologies was much lower than the Russian average. R&D organisations stand out in this group, together with companies whose activities involve application of computers and information technologies (16.2 and 5.5 thousand technologies per organisation, respectively); they mostly use in-house developed technologies. Further, each organisation engaged in these activity types on average applied the largest number of imported technologies.

The majority of the respondents engaged in practically all types of economic activities believed the level of production technologies they applied was on par with top-level Russian alternatives (between 59.2 per cent in R&D and 89.6 per cent in construction) and even international ones (between 57.7 per cent in manufacturing and 92.3 per cent in communications companies). Most critical about their production technologies were organisations engaged in the production and distribution of electricity, water, gas and sewage, waste disposal and similar activities. Specifically, 45.3 and 27.3 per cent respondents in these spheres believed the technologies that their companies applied were on par with top international analogues, while 50 and 64.9 per cent thought their technologies were inferior (Figure 4). Overall, more than a third of the respondents assessed the level of their production technologies below top international achievements. In education, the relevant figure was exactly one third, in manufacturing it was 36.8 per cent. The lowest share of sceptical respondents was noted in activities involving the application of computers and information technologies, R&D and communications. And only 16.5 per cent of all organisations applied technologies superior to top-level Russian alternatives. The comparison with best international technologies looks much more modest: the overall figure for all surveyed large and medium organisations and enterprises equals 3 per cent. Above-average values for applying technologies superior to top-level Russian alternatives were noted in mining, manufacturing, provision of various services, education and R&D, for applying best international technologies, the figures for manufacturing were 3.1 per cent of respondents, 5.1 per cent for communications and 8.2 per cent for R&D.

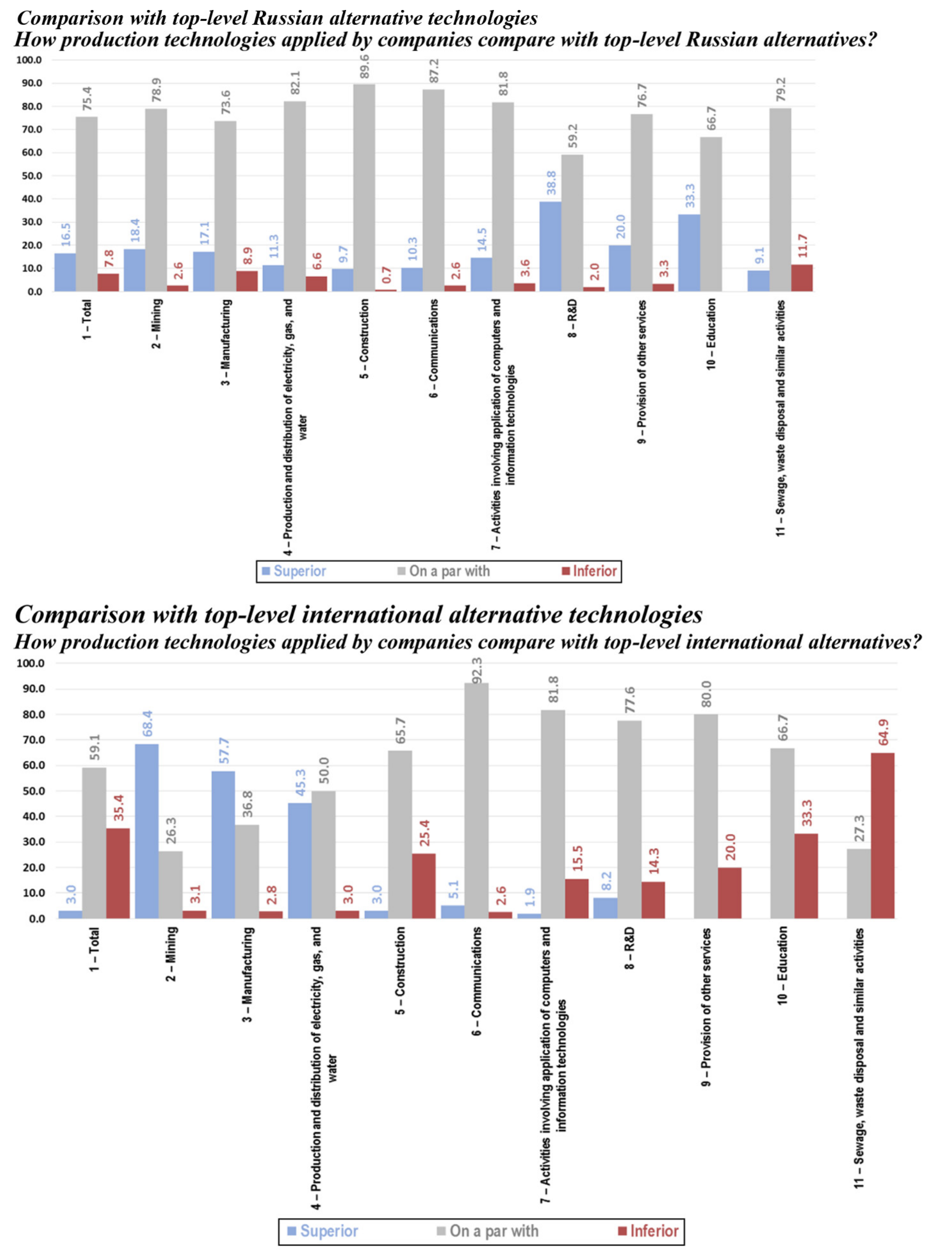
Objectives organisations pursue by applying technologies

When it comes to the application of specific improving technologies – in particular resource- and energy-saving and "green" ones and those increasing productivity and product quality – only little more than half of the companies actively apply such technologies in the production processes. In total, 44.4 per cent were in the process of implementing such technologies, and 81.2 per cent of large and medium organisations and enterprises felt a need to apply new technological processes (Figure 5).

Technologies, which help to improve the efficiency of production processes, were used most actively by 51.1 per cent of organisations, while those that aim to increase product quality by 61.7 per cent of organisations. Wherein most of the organisations reported some of their shipped products being made with the help of improved technologies and assessed the share of such products as significant.

For the whole sample, 43 per cent of the surveyed organisations reported that the share of their products manufactured with the help of improved technologies was 90 per cent or more. In most of the economic activity types, the share of companies that reported the highest shares of such products were between 46 per cent (R&D organisations) and 79 per cent (communication companies). Exceptions included construction and manufacturing companies and organisations providing various services. In the two latter industries, the shares of organisations, most of whose products used improved technologies, were only slightly below the average value for the sample (42.7 and 42.1 per cent, respectively); construction companies the value of this indicator by 29 percentage points lower (just 14 per cent). Less than 6 per cent of the respondents noted that shares of their shipped products using improved technologies were insignificant (under 10 per cent of total sales).

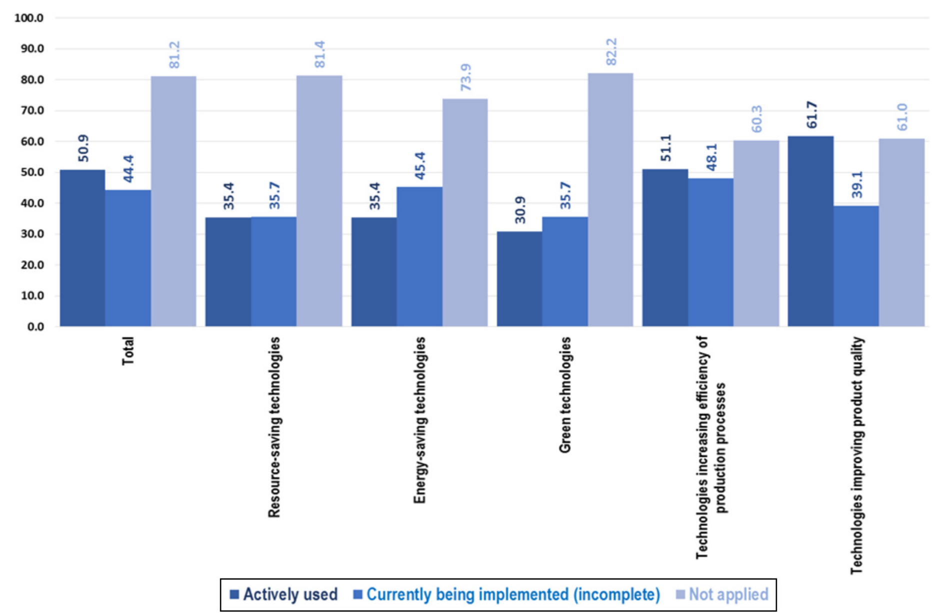
Figure 4 Distribution of large and medium organisations and enterprises which apply production technologies by how they compare with top-level Russian and international alternatives and by economic activity type: 2011 (%)



Note: The total number of organisations may not equal to 100 per cent, as one organisation can apply production technologies with different tech level

Least actively applied were green technologies (by 30.9 per cent of organisations) and resource- and energy-saving ones (35.4 per cent of organisations). At the same time, respondents noted the strongest need to apply these three technology groups (82.2, 81.4 and 73.9 per cent of organisations, respectively).

Figure 5 Distribution of organisations by application of specific improving technology type (%)



Note: The total number of organisations is not equal to 100 per cent, as one organisation can apply several types of specific improving technologies

It should be noted that all of the above improving technologies were implemented by companies, specifically those technologies that increased efficiency of production processes and improved product quality; green technologies, resource- and energy-saving technologies.

Regarding the application of technologies by organisations engaged in different economic activity types (Table III), it should be noted that mining companies most

Table III Distribution of organisations actively applying specific production technologies by technology and economic activity type (%)

Economic activity	*Technology type* *Resource-saving*	*Energy-saving*	*Green*	*Increasing efficiency of production processes*	*Increasing product quality*
Total	35.4	35.4	30.9	53.1	61.7
Mining	28.6	33.3	57.1	47.6	61.9
Manufacturing	36.6	33.9	30.7	53.3	65.0
Production and distribution of electricity, gas and water	38.3	57.4	36.2	53.2	34.0
Construction	30.0	40.0	22.9	57.9	49.0
Communications	53.3	53.3	26.7	60.0	60.0
Activities involving application of computers and information technologies	24.0	32.0	24.0	58.0	42.0
R&D	24.3	32.4	32.4	56.8	70.3
Provision of other services	28.6	28.6	14.3	42.9	50.0
Education	–	100.0	50.0	–	50.0
Sewage, waste disposal and similar activities	31.6	47.4	42.1	26.3	36.8

actively use green and product quality improving technologies. Manufacturing companies concentrate on resource-saving technologies, technologies increasing production efficiency and product quality; companies engaged in production and distribution of electricity, gas and water, most actively use resource- and energy-saving technologies, green technologies and technologies increasing production efficiency. Construction companies focused on energy-saving technologies and technologies increasing production efficiency; communications organisations primarily applied resource- and energy-saving technologies and technologies increasing production efficiency. Sectors which involve the application of computers and information technologies demonstrated an active use of technologies increasing production efficiency; R&D organisations actively use green technologies and technologies increasing production efficiency and product quality.

According to data from Table IV, companies that actively apply green technologies do so to reduce environmental pollution, reduce use of hazardous (ecologically harmful), raw and other materials and comply with technological requirements, specifications, rules and standards.

Companies applying technologies, which increase the efficiency of production processes did so to increase their profit rates, reduce material costs and personnel costs, extend their range of products and services, improve product quality, more efficiently use their production facilities, increase flexibility of their production, shorten production cycle and increase productivity.

Companies which apply technologies to improve product quality succeed in increasing their profitability; improving their business reputation; extending product and service range and geographical market coverage; improving product quality; reducing percentage of faulty products; and meeting requirements of technical specifications, rules and standards.

It should be stressed that of the above objectives (expected to be accomplished by applying the advanced production technologies), only one (increase export of products/

Table IV Distribution of organisations by applied technology type and objectives that the technologies are expected to help accomplish (%)

	Technology type				
Objective	*Resource-saving*	*Energy-saving*	*Green*	*Increasing efficiency of production*	*Increasing product quality*
Increase profitability	55.7	44.6	11.1	50.0	36.6
Improve business reputation	10.6	13.0	23.7	22.2	51.4
Reduce material costs	70.7	46.7	9.0	38.8	10.8
Reduce energy consumption or waste	25.8	79.0	5.8	17.0	3.2
Reduce personnel costs	10.0	4.2	1.9	30.7	3.0
Extend product/service range	10.9	2.8	4.3	30.6	26.5
Extend geographical market coverage	6.7	2.7	2.4	15.7	33.0
Increase export of products/services	2.6	1.6	1.7	8.4	15.3
Improve product quality	13.6	5.2	10.0	33.6	73.3
Increase efficiency of production facilities	25.2	24.5	6.7	57.5	11.5
Increase flexibility of production	10.0	5.3	1.1	40.3	7.4
Shorten production cycle	10.5	7.7	2.4	40.2	7.0
Reduce percentage of faulty products	11.9	3.6	4.3	28.5	52.8
Increase productivity	13.7	5.7	3.6	54.5	11.7
Reduce environmental pollution	14.8	10.5	81.1	6.9	4.6
Reduce usage of hazardous/ecologically harmful (raw) materials	9.7	4.3	38.3	5.7	3.0
Meet requirements of technical specifications, rules and standards	15.5	13.1	27.3	27.3	45.0

Note: The total number of organisations is not equal to 100 (%), as one organisation can apply different types of technologies services) was selected by an insignificant number of large and medium organisations (between 1.6 and 15.3 per cent of them). This highlights a specific characteristic of Russian production companies, which are mostly oriented towards domestic product and technology markets.

A vast majority of the surveyed organisations were oriented towards the Russian market. The average share of companies, which shipped 90 per cent or more of their output domestically, was 83 per cent of the sample (Figure 6).

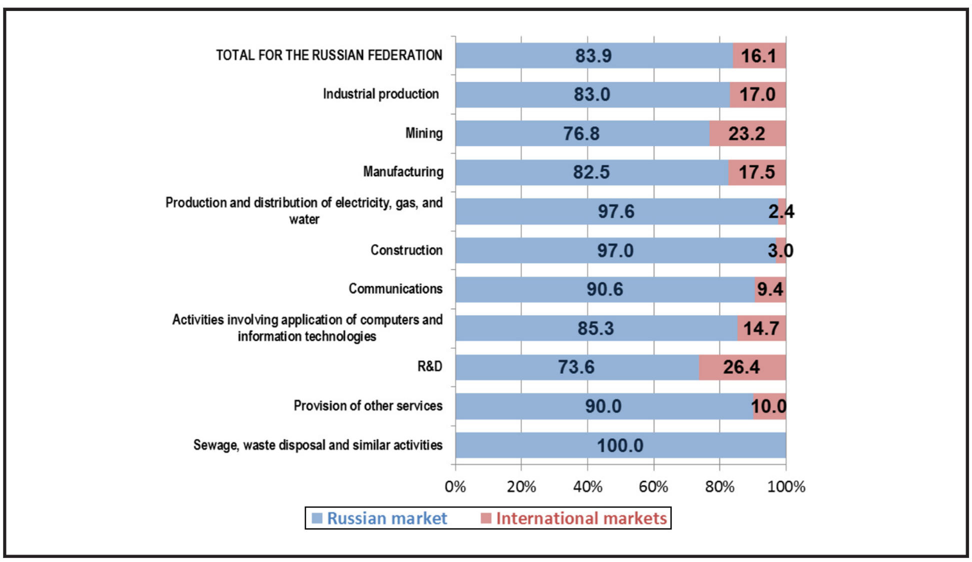
A more detailed analysis of product sales within the country, looking in turn at local, regional and national markets, revealed that for most of the companies the national market was the most important (66 per cent of the surveyed organisations). This trend can be seen as favourable since it indicates growing geographical coverage of organisational activities, and it is an indirect factor of increasing product competitiveness, including their qualitative (technological) characteristics. However, the shares of companies, which count local and regional markets as equally important as the Russian national market, were also sufficiently high (57 and 49.7 per cent, respectively).

More active export activities (measured by the share of products shipped to international markets) were noted mostly in the R&D sector and mining. In these industries, the share of companies that shipped products outside the Russian Federation, was higher than the sample average.

Level of production technologies' application

S&T progress – which is a critical condition of contemporary social development – results in transformation of rapidly developing areas of practical knowledge with a significant potential for application in various economic activity types, into advanced general-purpose production technologies. Having analysed the levels of these technologies' application in organisations, we note that only an insignificant share of large and medium organisations and enterprises actively apply them in their production processes. Companies were also rather passive regarding the implementation of such

Figure 6 Distribution of organisations by share of their products shipped to Russian (90% or more of their output) and international markets (10% or less of their output) and by economic activity type (%)



technologies. And between 59.3 and 97.3 per cent (depending on the technology type) of large and medium organisations did not apply advanced production technologies, despite feeling a need to do so (Table V).

It should be noted that so far Russian large and medium-size organisations have least actively used technology types such as intuitive multiple-mode programming techniques and devices. These would include:

- voice input, gesture and trajectory recognition (1.1 per cent of organisations);
- bio and genetic technologies applied in production processes (catalysts, bioreactors, etc.) (1.6 per cent); production technologies of micromechanical components (1.7 per cent);
- virtual reality, modelling and simulation technologies for product design and production (2.8 and 4.5 per cent of organisations respectively);
- integrated management and control systems (2.9 per cent);
- nanotechnologies and nanosystems (3.2 per cent);
- production and processing of new materials (composite, carbon fibre, renewable raw materials, etc.) (5.4 per cent of organisations); and
- production of construction materials based on metallic alloys (6.5 per cent).

Table V Distribution of organisations by level of advanced production technologies' application (%)

Production technology type	*Actively used*	*Currently being implemented (incomplete)*	*Not applied*
Computer-assisted design (CAD) for engineering, production and supply activities	50.6	24.1	59.3
Integration of CAD systems with computer-assisted management systems (CAD/CAM)	17.9	20.4	80.4
Industrial robots/automated production and assembly lines	28.2	14.5	76.8
Automated Workload Management System (AWMS), automated materials and components transportation systems, loading/unloading	9.1	17.6	86.8
Technologies for safe human-equipment interaction (cooperative robots, "unprotected" automated work places, etc.)	11.1	16.9	85.7
Intuitive multiple-mode programming techniques and devices (voice input, gesture and trajectory recognition, etc.)	1.1	4.4	97.3
Virtual reality, modelling and simulation technologies for product design (digital prototyping systems including stereolithography, 3-D printing; finite elements method (FEM)	4.5	5.3	94.9
Automated monitoring and/or control systems (devices for monitoring incoming materials, process or end products control, vision systems)	24.5	21.0	76.0
Communication and control hardware and technologies (programmable logical controllers, local and intranet computer networks)	56.0	25.8	55.2
Production information and planning systems ((raw) materials and resources demand, etc.)	29.6	38.7	65.2
Manufacturing Execution Systems (MES) (integrating PPS/ERP and CAM systems)	6.0	23.1	86.1
Integrated management and control systems (integrating production processes, supervising, AI technologies and expert systems)	2.9	7.7	94.5
Electronic data exchange systems for operations/detail scheduling (ODS) with participants of value chain; supply chain management (SCM) systems	12.4	24.7	81.5
Virtual reality, modelling and simulation technologies for production (production flows and specific production stages)	2.8	6.4	95.2
Construction materials based on metallic alloys	6.5	3.0	94.2
Production and processing of new materials (composite, carbon fibre, renewable raw materials, etc.)	5.4	6.3	93.3
Bio- and genetic technologies applied in production processes (catalysts, bioreactors, etc.)	1.6	1.6	97.6
Micromechanical components production technologies (micromechanical processing, lithography, microinjection, etc.)	1.7	2.0	97.4
Nanotechnologies and nanosystems applied in production processes (to treat surfaces, etc.)	3.2	3.4	95.8

Note: The total number of organisations is not equal to 100 (), as one organisation can apply advanced production technologies of different levels

Meanwhile, more than 90 per cent of the surveyed companies noted a need to apply the above advanced production technologies.

More actively applied advanced production technologies included automated monitoring and/or control systems; production information and planning systems; computer-assisted design for engineering, production and supply activities; and communication and control hardware and technologies. The latter technologies were also most actively being implemented.

Level of key technologies developed and applied by organisations

Key technologies are a critically important mechanism for increasing the productivity of public R&D expenditures, which allows concentration of resources on applied technologies and contributes heavily to accelerating economic growth, stepping up development of high-tech economic sectors and implementing the competitive advantages of the Russian economy. About 16.7 per cent of the respondents (417 organisations) were developing such technologies (Figure 7).

In most of the organisations, the level of key technologies they developed, for practically all types of economic activities, was judged to be on par with top Russian and international alternatives (between 58.9-55.4 per cent in production processes and 87.6 per cent in communications). Organisations whose activities involved applications of computers and information technologies noted the unquestionable leadership in the Russian market of critical technologies they developed; half of the respondents, active in this sphere, believed the level of their technologies was higher than that of foreign ones.

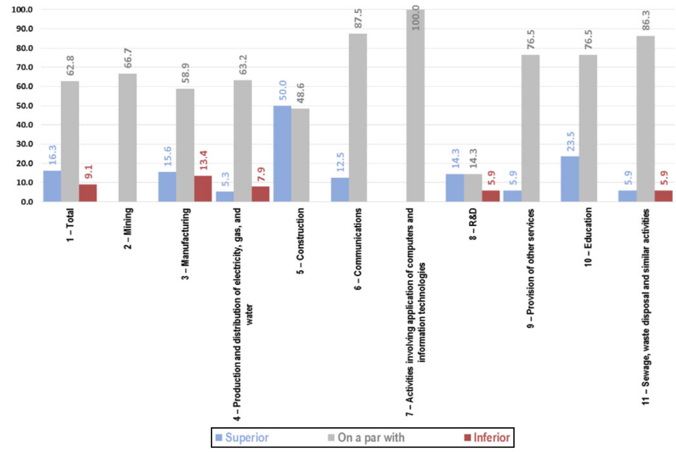
In a number of economic activities, key technologies developed by the surveyed organisations were assessed to be on par with or superior to, alternative solutions (specifically in mining, construction, communications and education). An exception was the R&D sphere: these organisations gave the lowest marks to key technologies they developed (only 14.3 per cent of respondents judged them to be on par with top Russian alternatives and nobody claimed their technologies were equal and much less superior, to either domestic or foreign technologies). On the whole, 9.1 per cent of respondents assessed the level of key technologies they developed as inferior to the best Russian alternatives, and 17.5 per cent believed they were inferior to top international solutions.

The scale of key technologies' application is also not large. More than four-fifths of the surveyed organisations did not use such technologies at all (Table VI). R&D and educational organisations applied key technologies more actively. The lowest shares of respondents who applied such technologies in production were in manufacturing and construction.

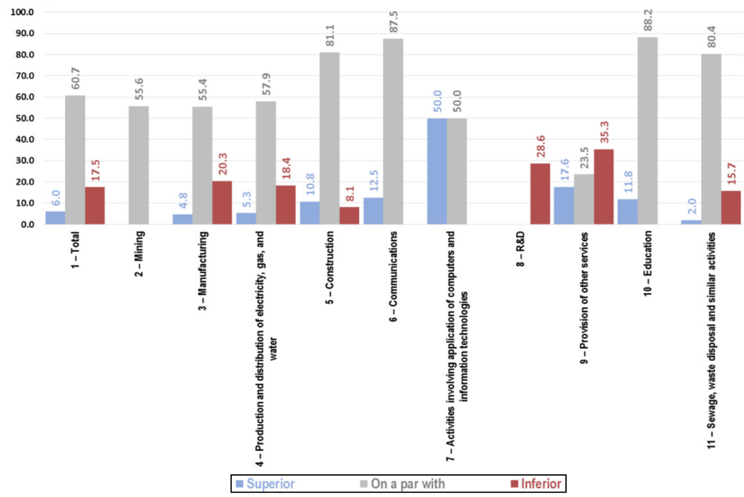
Technological processes were more actively applied in such priority areas as information and communication technologies and energy efficiency, energy saving and nuclear energy. This trend was also noted for large and medium organisations active in manufacturing, production and distribution of electricity, gas and water, construction and communications. Mining companies more actively used efficient environmental management technologies and biotechnology. Organisations engaged in sewage, waste disposal and similar activities actively used efficient environmental management technologies and ICT. R&D and education sectors have rather large shares of organisations that apply all of the above technologies. In total, 63.3 per cent and 50 per cent of educational organisations use nanosystems; 40.8 per cent of R&D and 25 per cent of educational organisations use ICT; 18.4 per cent and 50 per cent use transport and space systems; 24.5 and 25 per cent use life sciences; 20.4 and 50 per cent use efficient environmental management; and 28.6 per cent of R&D and 50 per cent of educational organisations use energy efficiency, energy saving and nuclear energy technologies.

Figure 7 Distribution of organisations – developers of key technologies by how they compare with top-level Russian and international alternatives and by economic activity type (%)

Comparison with Russian alternatives
How critical technologies developed by companies compare with top-level Russian alternatives?



Comparison with international alternatives
How critical technologies developed by companies compare with top-level international alternatives?



Note: The total number of organisations may not equal to 100 per cent, as one organisation can apply key technologies with different tech level

Ultimately, a large majority of the respondents from R&D and educational organisations assessed the level of key technologies they applied as being on par with, or superior to, top Russian and international alternatives (77.7 and 65.5 per cent, 14.9 and 4.6 per cent of organisations, respectively). Of particular note are:

- nanosystems technologies (especially technologies for making and processing functional and construction nanomaterials, computer modelling of nanomaterials, nanodevices and nanotechnologies, nano-, bio-, information and cognitive technologies);

Table VI Distribution of organisations applying key technologies by priority S&T area and economic activity type (%)

	Priority S&T area						
Priority S&T areas	*Nanosystems*	*ICT*	*Life sciences*	*Efficient environmental management*	*Transport and space systems*	*Energy efficiency, energy saving and nuclear energy*	*No critical technologies applied*
Total	3.4	13.9	1.2	4.4	1.8	10.1	81.4
Mining	–	15.0	25.0	20.0	–	7.5	75.0
Manufacturing	2.4	8.2	0.7	3.4	1.3	4.6	86.3
Production and distribution of electricity, gas and water	0.9	17.6	–	8.3	3.7	27.8	63.9
Construction	0.7	9.6	0.7	2.1	–	5.1	84.7
Communications	–	38.5	–	–	5.1	7.7	56.4
Activities involving application of computers and information technologies	2.7	42.7	1.8	3.6	0.9	3.6	52.7
R&D	63.3	40.8	24.5	20.4	18.4	28.6	24.5
Provision of other services	3.2	9.7	3.2	12.9	4.1	–	71.0
Education	50.0	25.0	25.0	50.0	50.0	50.0	50.0
Sewage, waste disposal and similar activities	–	5.9	–	7.1	1.2	2.4	80.0

Note: The total number of organisations is not equal to 100 per cent, as one organisation can apply key technologies of different priority S&T areas

- life sciences (in particular bioengineering technologies, cellular and biomedical technologies, bio-catalytic, bio-synthetic and bio-sensor technologies and technologies for reducing negative impact of socially significant diseases);
- transport and space systems (technologies for making next-generation space rockets and transport vehicles, high-speed transportation systems and intelligent control systems for new transport types); and
- energy efficiency, energy saving and nuclear energy technologies (high-power electrical engineering, technologies for making efficient energy transportation, distribution and usage systems, technologies based on new and renewable energy sources including hydrogen).

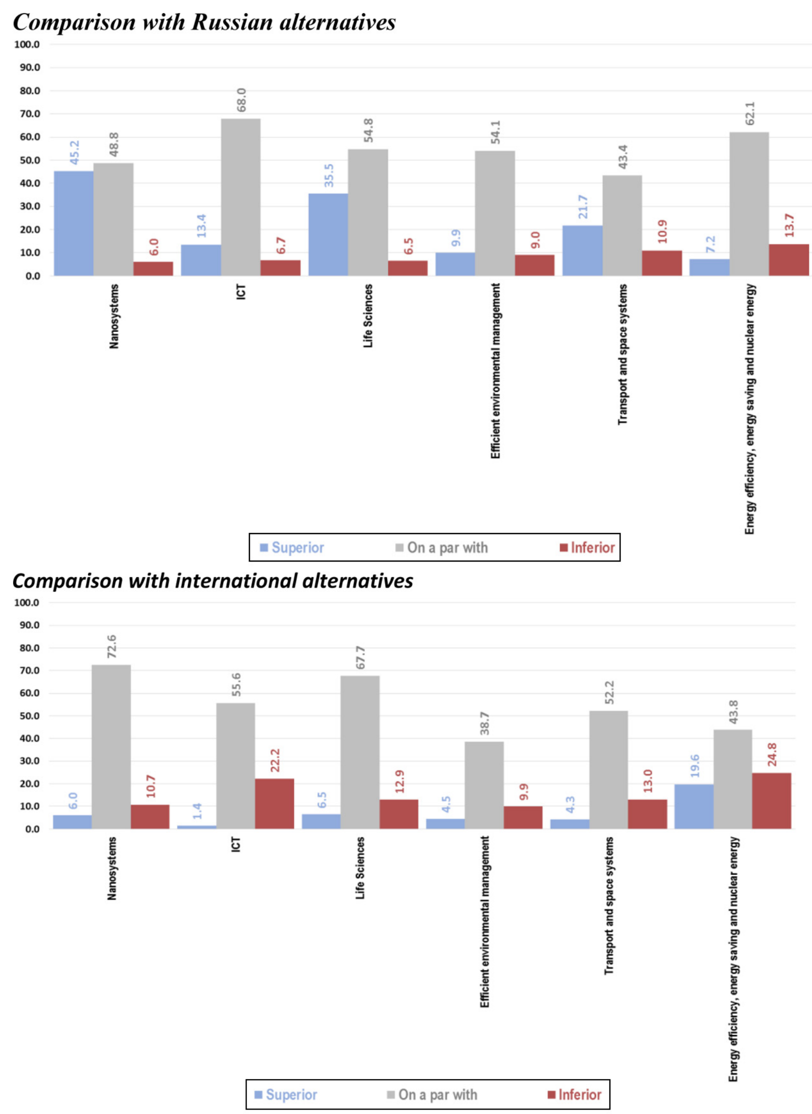
These technologies were mentioned by a significant proportion of organisations applying them (Figure 8) as being superior to top Russian alternatives (for the first three areas 45.2, 35.5 and 21.7 per cent of organisations, respectively) or to top international technologies (19.6 per cent of organisations for the latter area).

The shares of organisations, which assessed the level of their key technologies as inferior to international alternatives, were insignificant.

Application of intellectual property

Intellectual property being R&D output enables companies to manufacture competitive products, support their innovation activities and reflect the application of cutting-edge S&T results in production and organisations' technological level. As it turned out, not all respondents used various intellectual property assets and ascertainment methods in their production processes – only 1,600 large and medium organisations (64 per cent of the sample): 16.7 per cent of surveyed organisations used inventions, 14.5 per cent – utility models, 10.4 per cent – industrial designs, 46 per cent – trademarks, 1 per cent – microchip

Figure 8 Distribution of organisations applying key technologies according to how they compare with top-level Russian and international alternatives and by priority S&T area (%)



Note: The total number of organisations may not equal to 100 per cent, as one organisation can apply key technologies with different tech level

topologies, 49 per cent – computer software and 22.6 per cent of organisations used databases.

Only one-sixth of surveyed companies, both large and medium, made use of inventions and utility models whose application reflects the level of production technologies in companies (Table VII). These assets were more often applied by mining companies, manufacturing enterprises, R&D institutes and universities.

Most actively applied, in all types of economic activities without exception, were copyrighted information assets such as databases and computer software. Half of the surveyed manufacturing companies and all universities applied these kinds of intellectual property.

Table VII Distribution of organisations by applied intellectual property asset and economic activity type (%)

Economic activity	*Intellectual property asset*								
	Inventions	*Utility models*	*Industrial designs*	*Trademarks, appellations of origin*	*Know-how*	*Microchip topologies*	*Computer software*	*Databases*	*Other IP types*
Total	16.7	14.5	10.4	46.0	6.9	1.0	49.0	22.6	1.0
Mining	23.5	29.4	11.8	23.5	–	–	64.7	29.4	5.9
Manufacturing	17.0	14.8	12.1	48.9	6.5	0.6	45.5	18.9	1.0
Production and distribution of electricity, gas and water	8.2	4.1	6.1	12.2	–	–	79.6	38.8	4.1
Construction	5.7	6.5	10.8	41.9	3.2	1.1	60.2	38.7	–
Communications	5.6	2.8	–	61.1	–	–	52.8	19.4	–
Activities involving application of computers and information technologies	7.8	8.8	2.0	38.2	5.9	1.0	53.9	37.3	1.0
R&D	77.3	59.1	4.5	50.0	40.9	11.4	45.5	18.2	–
Provision of other services	8.3	4.2	8.3	41.7	8.3	–	45.8	37.5	–
Education	100.0	75.0	–	25.0	50.0	25.0	100.0	25.0	–
Sewage, waste disposal and similar activities	4.2	4.2	–	8.3	–	–	83.3	50.0	–

Note: The total number of organisations is not equal to 100 (%), as one organisation can apply different intellectual property assets

Trademarks and appellations of origin (methods usually applied to ascertain innovation products) were also used quite actively by companies. Areas such as mining, manufacturing, construction, communications, application of computers and information technologies, R&D and provision of various services using trademarks and appellations suggest the innovation-centric orientation of the above industries.

Factors providing competitive advantages

According to the survey, large and medium companies' competitive advantages were primarily provided by product and service quality and prices, their ability to match consumer demand and timely provision of services. Most of the respondents named these factors, both for the Russian economy generally and for specific sectors (Table VIII).

Product novelty and production technologies' level were seen as playing more modest roles: only one-fifth of the respondents noted these factors. It should be stressed that R&D and educational organisations considered the above competitive advantages to be much more important (57.4 and 50 per cent of organisations chose the first factor, compared to 36.7 and 25 per cent of organisations selecting the second, respectively).

The importance of product novelty and level of production technologies increased for companies engaged in all industries when they considered the advantages their competitors had. In addition to product prices, more than a quarter of large and medium organisations and enterprises noted them as the most important factors (Table IX).

Factors promoting the increase of organisations' technological level

The survey revealed that factors contributing to increased technological level of large and medium organisations included the need to meet demand by customers and consumers; high competition in the domestic market; and, the need to match the industry's technological level and requirements of technical regulations, rules and standards. These were noted by most of the respondents, both for the whole Russian economy and individual economic activity type (Table X).

Table VIII Distribution of organisations by factor providing competitive advantages and by economic activity type (%)							
Economic activity	*Product prices*	*Product quality*	*Product novelty*	*Ability to meet consumer demand*	*Level of production technologies*	*Timely provision of services*	*After-sale and/ or additional services*
Total	47.4	72.0	17.4	39.9	19.4	36.2	11.9
Mining	52.9	64.7	5.9	17.6	32.4	38.2	2.9
Manufacturing	49.6	74.9	17.6	44.0	19.2	35.7	11.5
Production and distribution of electricity, gas and water	26.0	51.9	2.9	27.9	19.2	31.7	15.4
Construction	46.6	71.8	11.5	21.4	23.7	47.3	11.5
Communications	53.8	69.2	23.1	25.6	15.4	25.6	25.6
Activities involving application of computers and information technologies	45.9	70.6	30.3	35.8	11.9	33.9	14.7
R&D	32.7	77.6	57.1	44.9	36.7	18.4	6.1
Provision of other services	31.0	55.2	6.9	20.7	31.0	37.9	17.2
Education	50.0	75.0	50.0	–	25.0	–	–
Sewage, waste disposal and similar activities	36.8	38.2	2.6	2.6	6.6	56.6	13.2

Note: The total number of organisations is not equal to 100 (%), as one organisation can name several factors providing competitive advantages

Table IX Distribution of organisations by factor providing competitive advantages to their competitors and by economic activity type (%)							
Economic activity	*Product prices*	*Product quality*	*Product novelty*	*Ability to meet consumer demand*	*Level of production technologies*	*Timely provision of services*	*After-sale and/ or additional services*
Total	51.9	19.7	26.3	11.2	28.6	14.8	14.2
Mining	60.0	36.0	12.0	4.0	40.0	8.0	8.0
Manufacturing	55.3	21.6	26.7	11.4	30.6	14.3	13.1
Production and distribution of electricity, gas and water	27.3	14.3	10.4	2.6	20.8	13.0	18.2
Construction	41.9	16.2	27.4	12.0	31.6	21.4	11.1
Communications	28.9	10.5	42.1	10.5	13.2	13.2	23.7
Activities involving application of computers and information technologies	34.5	9.1	35.5	23.6	17.3	12.7	30.0
R&D	46.7	9.5	26.2	9.5	28.6	16.7	7.1
Provision of other services	23.8	4.8	33.3	–	19.0	19.0	9.5
Education	50.0	–	50.0	–	–	25.0	25.0
Sewage, waste disposal and similar activities	52.2	13.0	4.3	–	6.5	23.9	15.2

Note: The total number of organisations is not equal to 100 (%), as one organisation can name several factors providing competitive advantages to their competitors

An exception was R&D and educational organisations: in addition to the first two factors, they consider the availability of in-house S&T results to be important and participation in government support programmes.

Conclusion

In this first pilot study on technological level for a large representative sample of Russian medium and large organisations, we have got not surprising results and more surprising ones, some of them satisfactory but others puzzling.

Among the expected but not entirely desirable results we found the following:

Table X Distribution of organisations by factor promoting an increase of their technological level and by economic activity type (%)

Economic activity	*High competition in domestic market*	*Requirements by suppliers of (raw) materials, equipment, components, etc.*	*Demand by customers and consumers*	*Requirements by companies – partners in production*	*Availability of in-house S&T results*	*Participation in government support programmes*	*Requirements of technical regulations and standards*	*Need to match sector's technological level*
Total	63.4	10.7	73.7	5.2	10.6	5.7	21.2	32.9
Mining	40.0	10.0	60.0	2.5	10.0	7.5	27.5	50.0
Manufacturing	68.6	11.0	75.7	5.5	9.8	4.4	21.6	36.4
Production and distribution of electricity, gas and water	24.1	8.3	70.4	4.6	3.7	5.6	35.2	61.1
Construction	63.2	13.2	67.6	5.1	4.4	9.6	18.4	44.2
Communications	79.5	10.3	56.4	–	12.8	–	25.6	33.3
Activities involving application of computers and information technologies	59.1	10.0	66.4	4.5	17.3	10.0	14.5	34.5
R&D	34.7	10.2	79.5	10.2	71.4	32.7	8.2	18.4
Provision of other services	38.7	12.9	61.3	3.2	16.1	12.9	25.8	19.4
Education	75.0	–	50.0	–	50.0	25.0	–	–
Sewage, waste disposal and similar activities	31.8	4.7	68.2	2.4	–	7.1	8.5	23.5

Note: The total number of organisations is not equal to 100 (%), as one organisation can name several factors promoting an increase of their technological level

- Russian, both large and medium, organisations tend to pursue technological self-sufficiency strategies, prefer sporadic cooperation with their partners in developing and applying technologies and are not active in foreign technology and product markets.
- The prevailing number of organisations mostly apply production technologies which appropriate to the top-level of Russian and even international alternatives; at the same time, a significant number of the respondents applied technologies which were inferior both to Russian and international alternative solutions (7.8 and 35.4 per cent of organisations, respectively).
- Most actively applied were technologies which improved production efficiency (a half of the surveyed organisations applied them) and product quality (61.7 per cent of organisations); least actively applied are environmental, resource- and energy-saving technologies (applied by a third of the surveyed organisations).

A rather predictable and undesirable was low level of intellectual property application () by both large and medium organisations in their production processes, including inventions, utility models, and know-how. It was not surprising that the most highly technologically developed economic activities were communications and manufacturing; such companies, on average, apply 50,000+ technologies (however, in the first case technologies acquired from external sources predominated, while in manufacturing most of the applied technologies were developed in-house). As the less obvious but satisfactory findings were major incentives for large and medium organisations to increase technological level of their production included demand from their customers and consumers, high competition in the domestic market, need to match technological level of the industry and requirements of technical specifications, regulations and standards.

Among the most undesirable and somewhat puzzling results it should be noted such as:

- *Low application level of necessary production technologies*: only a little more than a half of the surveyed organisations actively apply them, 44.4 per cent apply them occasionally, and 81.2 per cent of large and medium organisations and enterprises do not apply production technologies they need to apply.
- *Low application level of advanced production technologies*: insignificant number of organisations actively apply advanced production technologies – from 1.1 to 56.0 per cent depending on the technology type; between 1.6 and 38.7 per cent of organisations passively implement such technologies; and a sizeable proportion of large and medium organisations (between 59.3 to 97.3 per cent) do not apply advanced production technologies that, however, they would like to apply a rather insignificant number of surveyed organisations which develop and apply key technologies (less than one-fifths of respondents).

Also, rather puzzling for us was a significant divergence in the lists of competitive advantages that are significant for the surveyed organisations themselves and for their competitors. If major competitive advantages of large and medium-sized organisations based on product quality and prices, meeting consumer demand and timely provision of services, then for their competitors were selected prices, product novelty and high level of applied technologies.

The rapid S&T progress, which is one of the critical conditions of modern social development, requires the improvement of the monitoring system for the creation and use of modern technology in production processes. This survey made it possible to identify the level, scope and directions of technology development, the structure and characteristics of the technologies, the factors that provide competitive advantages and contribute to improving the technological level of organisations and companies, to obtain information that forms a collection of evidence-based policy data.

The major finding makes clear, above all, is the necessity to continue analysing different aspects of technological level of organisations, sectors and the economy as a whole. We must go on comparing sectors and regions. The results of this case study should be supplemented by qualitative and quantitative characteristics of the development of technology, the emergence of radically new one, in particular platform (converged) technology of interbranch usage (in some combinations of ICT, bio- and nano-, aerospace, chemical and other technology), basically are cross-cutting technology with a large-scale application that determines the ability to produce hi-tech products. Another line of future study must be development of framework that enables us to measure the effects from the introduction and application of technology.

Notes

1. Organisations are classified as leaders developing innovations at the cutting edge of technological development or adopters of a "catch-up" development strategy.
2. The EMS is unusual in that it allows analysis of resources and activities of companies connected with application of new technologies and organisational innovation in sufficient detail. The accent is placed on measuring such aspects of innovation activities as technological modernisation of production processes, which contributes to creating additional value: application of highly productive machines and equipment, distribution of advanced manufacturing processes, organisational principles and efficient management techniques and new business models supplementing the product range with additional (accompanying) services. Certain EMS indicators help to analyse specific features of development and application of particular technologies by companies – which provides additional data about the level and quality of their innovation activities. Other indicators provide data, which help in making clear conclusions about the scale of required modernisation for various sectors of the economy.
3. It should be noted that the regions were chosen based on the numbers of medium and large organisations they had with the highest potential to operate in high-priority STI development areas listed below.
4. Specifically, were selected such technologies, as: computer-assisted design (CAD) for engineering, production and supply activities; integration of CAD systems and computer-assisted management systems (CAD/CAM); industrial robots/automated production and assembly lines; automated workload management system (AWMS), automated materials and components transportation systems, loading/unloading; technologies for safe human-equipment interaction (cooperative robots, "unprotected" automated work places); intuitive multiple-mode programming techniques and devices (voice input, gesture and trajectory recognition); virtual reality, modelling and simulation technologies for product design (digital prototyping systems including stereolithography, 3-D printing; finite elements method or FEM); automated monitoring and/or control systems (devices for monitoring delivered materials, process or end product control, vision systems); communication and control hardware and technologies (programmable logical controllers, local and intranet computer networks); production information and planning systems (raw materials and resources demand); manufacturing execution systems (MES) (integrating PPS/ERP and CAM systems); integrated management and control systems (integrating production processes, supervising, AI technologies and expert systems); electronic data exchange systems for operations/detail scheduling (ODS) with participants of value chain; supply chain management (SCM) systems; virtual reality, modelling and simulation production technologies (for production flows and specific production stages); construction materials based on metallic alloys; production and processing of new materials (e.g. composite, carbon fibre, renewable raw materials); bio and genetic technologies applied in production processes (e.g. catalysts, bioreactors, DNA test systems for the food industry, machine-tool arrangement on the basis of the structure of DNA); micromechanical components production technologies (e.g. micromechanical processing, lithography, microinjection); nanotechnologies and nanosystems applied in production processes (e.g. to treat surfaces).
5. Including inventions, utility models, industrial designs, trademarks and appellations of origin, microchip topologies, computer software and databases.

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