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Technological Development: Investment Structure Impact*

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Abstract. The study is aimed at determining the impact of a technology investment structure on changes in technological effectiveness of the economy that should be taken into account in the medium and long term. The research methodology includes structural and empirical analysis of the distribution of investment between new and old technologies, econometric models of technological level and investment in new and old technologies that have undergone a reasonable selection procedure according to the principle of best reliability; involves formulation of general principles and substantiation of technological development goals for the medium and long term. The technology structure determines potential of technological development and its dynamics. It is based on realized medium- and long-term goals and search for responses to competitive challenges. The work results in confirmation of the investments structure influence on the overall level of technological effectiveness of the economy, different sensitivity of investment in new and old technologies to changes in risk and interest rates. For Russian economy the analysis of two sectors, particularly manufacturing and transactional raw materials ones, shows that with interest rates gone up, we observe faster decrease in investment in new technologies than those in old technologies, the level of manufacturability goes down as well. Therefore, the task of Russian economy technological renewal can be solved with regard to risk reduction measures in the manufacturing sector and application of differentiated interest rates in a sectoral perspective, ensuring its overall reduction. Using the taxonomic analysis method, the author identifies key models of technological development (at a theoretical level) according to characteristics of the structure of investment in new and old technologies. This helps specify

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economic policy measures in terms of the impact of investments distribution on the technological level, as well as their dynamics, that is, evaluate contribution of investments in various types of technologies to the overall rate of economic growth.

Key words: technology, investment in new and old technologies, medium- and long-term goals of technological development, challenges and responses to the technology development, algorithm for elaborating development goals.

1. Introduction. Problem statement and research methodology

Technological development is characterized by considerable instability. Modern economic changes are associated with the deformation of previously adopted and established standards and rapid changes in institutions and technologies. Institutional instability increases sharply [1–10]. However, what are the reasons for such changes?

First, the expanding research and technological diversity, the rapid transfer of knowledge and experience over long distances with the training of a significant number of people, helps implement for a short period of time a particular solution, get ahead in the competitive race.

Second, knowledge and new technologies based on it, on the one hand, expand the opportunities; on the other hand, generate high uncertainty about the prospects of economic relations and development. This uncertainty increases business risks [11–15].

In the framework of the modern theory of economic growth and development, the aggregated models do not take into account the structural aspects of technology performance, especially the impact of macro-parameters of the economy on the change of the technological level [2–3, 8–10, 14–15]. Medium- and long-term technological development goals also require algorithms for harmonization within a single system of state planning; without such procedures it will be difficult to select priorities, especially if the state of the existing technological structure is not taken into account, measures to stimulate technological development may increase the imbalance in economic development.

In the medium term, safety and increase in efficient use of available technological reserve is important, while in the long term the purpose is to change the technological paradigm of life as a mode of reproduction based on a set of advanced technologies different from the previous class of technologies in higher efficiency.

The correlation between medium- and long-term technological development goals can be studied through analyzing the structure of "old-new" technologies[1] [2–3, 12–13], which can be achieved by solving the problem of investment distribution between these technologies, taking into account the impact of individual macro-parameters such as business risk[2] and interest rate. Next, we analyze the differences between the goals of technological development, with establishing possible algorithms for designing such goals in the framework of the general approach to planning, with further study of the impact of

[1] Investment in new technologies – the cost of technological innovation. Investment in old technologies – the difference fixed between capital investment and the cost of technological innovation. Source: calculated based on: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/ science/# and http://www.gks.ru /wps/wcm/connect/rosstat_main/ rosstat/ru/statistics/ enterprise/investment/nonfinancial /#.

[2] Risk is defined as standard deviation of profit based on: Rosstat collection *"Russia in Figures"* for 2006–2017, Section "Enterprise Financial Activity". The chosen research interval is 2005–2016, for which there is statistical information necessary for constructing models, for early periods there is no information.

investment in new and old technologies, as well as business risk in sectors and interest rate on the technological level. As applied research methods include comparative empirical analysis, econometric modeling (with selection of most significant statistical correlation of parameters)

2. Differences between goals of technological development over time

The overall purpose and meaning of technological development is to create a way to influence the resource, object, system, which would be more cost-effective than that which existed before. It is possible though either creating a method which until now was absent but necessary as it saves time and resources, or creating new types of goods, services, etc. [2–3, 14–17]. Thus, to create a new technology a method available at the moment is required – an old technology. Its capabilities, as well as the acquisition of new knowledge, create the potential for a new technology as a means of influence. This new technology can modernize the old technology, completely or partially replacing it (the process goes through the technological core [11, pp. 282–283]), or replace only the technological periphery, improving and updating the old technology. Therefore, the opportunities of technological development, the achievability of goals of this development strongly depend on the available technological framework, as well as the needs of production, the state of demand, the market structure, as well as the ability of science to create new knowledge, provide applied development results for their further introduction to forming the framework for improving applied technologies and creating new ones [3].

The long-term prospect for technological development is not easy to assess. For example, it is difficult to assess the seventh or eighth technological paradigms today because the forecast of the predominance of certain technologies in 50 or 100 years is within the scope of futurology. Economic science, despite the great importance of the neo-Schumpeterian school developing the idea of technological and economic paradigms and technological structures, is currently unable to state exactly what types of technologies will dominate after a specified time.

It is possible to imagine long-term goals in technology as goals of civilization preservation, extension of life on Earth. If plans can influence the development, provoking the performance of a particular trajectory, it is important not to develop on a chreod trajectory[3]. However, in the long term the most chreod trajectory is the civilization's loss of life force and/or its death due to war, or exhaustion of biodiversity, resources, climate disasters, etc. Technologically, economy should be organized in such a way that this aspect is prevented in the long run.

In order to achieve medium-term development goals it is necessary to analyze the current economic and technological state, determine priorities, ideally not normative, but based on the resource opportunities and objectives of economic development determined by the system of challenges and threats.

In this case, challenges are to be precisely identified, as well as threats to development, by providing methods of eliminating threats, reducing possible damage and preparing challenge responses. Challenge responses represent a system of measures that anticipates threats and damage because if the challenge is eliminated and the answer is received, the threat will not take place and damage will not be done. Here we face a "technological paradox" when the development of technologies requires a perfect technology of decision-making

[3] The term "chreod trajectory" in institutional economic theory means "inefficient development trajectory" which can be difficult to refuse.

and implementation of the state research, technological and educational policies that would contribute to technological development, and not act as a challenge to it, which requires a reasonable answer.

To sum up, the medium-term goals of technological development imply responses to current challenges in technology and state security, which requires setting priorities, order priority and volume of investment in areas of technological development (priorities), sectoral areas; and the formation of a plan for economic modernization. Usually, in a short and medium time interval, the technological map and areas of improvement in the near future are clear, only certain combinations, positions, priorities need to be clarified. Thus, the sixth technological paradigm includes nanotechnology, biotechnology, robotics, artificial intelligence, etc. However, it is important to understand what nanotechnology, robotics, artificial intelligence well be and what technologies are able to generate at the next stage of development. Only then can something be said about the opportunities of the seventh, eighth and further paradigms. For example, from the engineering point of view, these technological systems – robots, artificial intelligence, computer programs – are auxiliary technologies. The seventh or eighth paradigms will, for example, be characterized by eco-technologies, or technologies to save wildlife and forests, or the cultivation of new species of plants and the reproduction of human clones (genetic engineering). Many types of old technologies that make up the framework and standard of metal processing will remain. They can be repeatedly improved due to nanotechnology. In the author's opinion, it is technologies of energy generation and, what is important – distribution, and transportation that can and should change for human society to enter the era of a new technological revolution.

Thus, the long-term goals of technological development is the search for new technologies based on a radically different principle, affecting the basic processes of creating benefits and transforming resources, as well as managing the society. The long-term goals of technological development may include:

– environmental technology;
– technologies for conserving or restoring exhaustible resources or replacing them with inexhaustible resources;
– transgenic technologies;
– biocommunication;
– technology for preserving intelligent life on the planet.

Of course, these goals must be related to the technological problems of development of digital systems, electronics, nanotechnology, robotics, artificial intelligence, new machines, fully automated (autonomous) systems, genetics, etc.

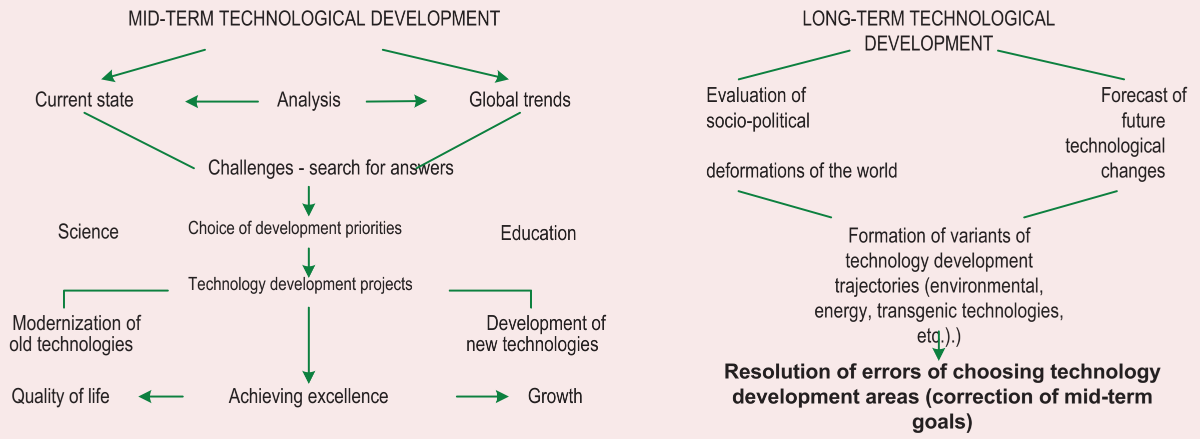
Thus, there is an initial technological framework and promising areas of development based on the already established technological and research capacity.

Conditions for functioning of markets and countries in the world system determine the possibility of technological renewal. We select three elements that determine the strength of these conditions:

1) the socio-political structure of countries and world system, dictating the predominating economic model for the politics, which requires superiority in technology;
2) superiority is determined by: resources, level of research and technology (including social organization), historically established status and level of country's development;
3) economic development, determined by the standard of living and the quality of life, which must be related to the level of technological development.

The first element cannot be changed on the medium-term time interval. For this reason, the second and third elements are the focus of both

Figure 1. Approximate algorithm for determining medium- and long-term goals of technological development



Source: compiled by the author.

medium- and long-term technological development goals.

The difference in the approach to identifying medium- and long-term technological development goals is demonstrated in *Figure 1*. It demonstrates the different content of the process of formulating medium- and long-term goals of technological development, and both algorithms are naturally constituent elements of the system of state planning.

Medium-term goals require an in-depth analysis of the current state and development opportunities (potential), taking into account global trends and performance, methodological tools for choice managing and replacement of priorities in technology and other areas of economic development, coordinated projects or modernization of current ones or creating fundamentally new technologies. This will require addressing the structural challenge of allocating investment between support for old and new technologies. By solving it, it will be possible to ensure economic growth and improve the quality of life within the "superiority" paradigm. Long-term technological development requires a scenario forecast of what will happen to technology and the socio-political structure of the world and countries.

Next, several possible development trajectories are to be assessed, with indicating the dominant role of both certain types of technologies and the structure of technological paradigms. On a long-term time interval it is very important to take into account the errors when choosing options and the trajectory itself, providing methods for trajectory correction in technology development. This approach will help shift towards the algorithm of medium-term technological development and adjust the medium-term goals.

The pursuit of technological excellence is directly linked to the benefits that economy derives from it. In the medium term, challenges in specific areas provoke responses in the form of improvements in existing or new technologies. *Table 1* provides examples.

Table 1 demonstrates that some technological responses are new, some are modifications of the previously used technologies, but the search for an answer makes us develop and adapt to the changing conditions.

The superior response to the existing technological challenge refers to the development of technologies that would cover the advantages of the technological capacity available and used by the competing party

Table 1. Challenges and provoked responses in the form of development of new equipment and technologies

№	Challenge	Technical and technological development as a response
I) Military technology		
1.	Withdrawal from the Anti-Ballistic Missile (ABM) Treaty	Hypersonic air-launched ballistic missiles (“Kinzhal” (Dagger)), communication jamming, S-400 and S-500 S-400 missile systems, a new nuclear engine with unlimited missile range
2.	UAVs	Laser weapons
II) Food production technology		
3.	Prohibition on the supply of agricultural equipment, products (sanctions)	Development of breeding and seed production, GMO-free production
4.	Sanctions to supply of electronic components, dual-use technologies, and software.	Development of domestic technologies, import substitution, creation and development of electronic centers such as Zelenograd, etc. Development of own programs, work for domestic programmers
III) Financial technology		
5.	Blocking of Swift payment system, Visa and Mastercard cards, e-servers, bank accounts – dollar transactions.	Domestic payment system, Mir card, creating domestic financial platforms, transfer of payments to national currencies*.

* Some of these technologies are not new, it is a modification of the already used technologies, which is subject to a challenge response to preserve sustainable economic development and, most importantly, the country’s economic and financial sovereignty.
Source: compiled by the author.

[18–22]. Based on the above, technologies, as well as responses to the challenges, can be “superior”, “neutralizing” and “adaptive”.

A) “Superior” technologies – leading advanced technologies, including impeding the efforts of a competitor (devaluing their efforts) to achieve excellence in this field. They tend to be less costly to implement, but ensure better results. Moreover, the competitor cannot find a superior solution on a fairly long time interval, that is, such technologies are long-acting, they block the competitor’s prospects in this area. This type of technology embodies the highest novelty in technological development – advanced newly created, previously unused technologies.

B) “Neutralizing” technologies – technologies that nullify all competitors’ measures at this stage of competition, but allow them to choose a different set of tools and methods on a different technological basis. Therefore, neutralizing technologies, which are cheaper than “superior”, however, will not provide technological and other independence of development for a long time. However, it can be successfully applied as a quick response to buy time for strategic decision-making, especially if superior technology is not yet available. The costs of neutralization should not be large, then this option is acceptable and ready for use. Before the opposite side’s introduction of technologies, the other side need to have a “neutralizing response” (technology). This type of technology symbolizes technological modernization.

C) “Adaptive” technologies – reduce the lag behind the leaders in technological development without creating development imbalances, and do not require high costs. Usually, they do not give complete neutralization and do not deprive the competitor of the opportunity to return the leading positions for some time. At the same time, the economy finds new opportunities to adapt to the dynamically changing technological landscape. These technologies and responses make it possible to agree on medium-term development goals and long-term targets. It is necessary to decide whether to respond to the challenges and in what way. The responses should lead to economic growth and improve the quality of life. [12, 18–20]

No matter which types of technologies and responses are considered, the problem of technological performance will be reduced to a technological structure where new and old technologies are present in economy and investment is distributed among these groups of technologies, setting the mode of their replacement and displacement [20, 22–24].

The assessment and implementation of the medium-term technology development goals involves:

– determining the actual state of economy, technological framework, global trends in technology and science development;

– analysis of military, political, financial, economic, social, demographic, environmental and other development challenges;

– analysis of the growth model and potential to improve the quality of life;

– the choice of development priorities be stage – period of stage realization;

– identifying necessary resources – investment to change the technological paradigm;

– analysis of the macroeconomic policy which either helps or does not implement development priorities; creating conditions for effective investment distribution between new and old technologies;

– implementation of medium-term planning of economic development projects and programs with a focus on technological renewal and creation of economic, institutional and social incentives for this;

– activation of the system of science and education – full focus on the development of new technologies and intellectual potential;

– modernization of existing technologies based on new principles – introduction of adaptive neutralizing technologies;

– solving the problem of advancing – creating new technologies based on fundamental research (scientific research), building schemes for their implementation in production.

In order to set and achieve long-term goals of technological development, a special type of forecast is required (the theory of technological paradigms is limited, as well as a technical and economic paradigm, since it is not clear what paradigm will prevail after a significant period of time). However, this inherent limitation should not discourage the researcher from making proposals for an indicative assessment of such goals, for example, based on short- and medium-term technological development goals.

The approximate algorithm for assessing the long-term goals of technological development, in the author's opinion, may imply:

– analysis of estimates and studies of futurologists and economists;

– analysis of trends in science development – fundamental disciplines – physics, chemistry, biology, electronics, etc.

– defining the possible "technological combinatorics" based on the properties of technological development for two medium-term prospects, as well as on what will be required to be solved by human society where restrictions are fatal (this will be the subject of search and creation of new technologies – according to the principle of threat overcoming, or refusal to use and reproduce other opportunities);

– assessment of imbalances created by new technologies in the medium term that will ensure future challenges and the technologies to address them.

This is not the whole possible list of long-term technological development goals. In this case, the combination effect in technology has a great potential even if the frequency of fundamental discoveries will decrease and there will be a period of stagnation of scientific discoveries. The combination effect helps solve many development problems, increase the impact, create new activities for people, etc. In this regard, it is likely that new technological structures – the basis for economic development – will be formed according to the combination principle[4], the predominance of some types of technologies will not be a prerequisite and characteristic of technological performance [16–17].

However, such a possible outcome would still keep the competition between new and old technologies, with the growth based on old technologies being in some cases preferable to that based on new technologies, which is less stable. Therefore, the investment composition in old and new technologies determines modern technological development; it is determined by the amount of risk and return on old and new technologies, the state of sectors where different types of technologies are used. Let us consider this structure in relation to the Russian economy where the problem of technological renewal is acute. We use Rosstat data and econometric estimates, calculate the statistical significance of applied models, select the most appropriate models, study the sensitivity of investment in old and new technologies, as well as the level of technological effectiveness to risk and changes in interest rate in the manufacturing and transactional primary sectors[5].

[4] Combination principle – explains the combination of technologies with the emergence of new opportunities or technologies, or the improvement of old technologies; this process does not often require a lot of resources and investment.

[5] The manufacturing sector includes activities (under OKVED – Russian Standard Industrial Classification of Economic Activitiesc): section D – manufacturing; section F – construction. The transaction primary sector includes activities (under OKVED): section A – agriculture, hunting and forestry; section B – fishing, fish farming; section C – mining; section E – production and distribution of electricity, gas and water; section G – wholesale and retail trade; repair of motor vehicles, motorcycles, household goods and personal items; section H – hotels and restaurants; section I – transport and communications; section J – financial activity; section K – real estate, renting and business services; section L – public administration and military security; social security; section M – education; section N – healthcare and social services; section O – other community, social and personal services.

3. Changes in investment composition and technology: the impact of risk and interest rate

In economy, constant changes in both investment amount and investment composition in new and old technologies take place. There are different possible variants – the model of technological development depending on changes in investment and its compositionb (summarized in *Table 2*). It is important to assess the contribution that investment in new and old technologies makes to the product dynamics. On order to identify this contribution additional calculations are needed within the framework of the structural formula [18, pp. 23–26] for GDP growth rate:

$$g = g_c\, c + g_I\, n + g_G\, a + g_{NX}\, b,$$

where: $g = (1/Y)\, dY/dt$; $g_c = (1/C)\, dC/dt$; $g_I = (1/I)\, dI/dt$; $g_G = (1/G)\, dG/dt$; $g_{NX} = (1/NX)\, d\,NX/dt$, $c = C/Y$, $n = I/Y$, $a = G/Y$, $b = NX/Y$ – structural GDP parameters by expenditure $Y = C + I + G + NX$, C – gross consumption, I – gross investment, G – government expenditure, NX – net exports.

If we take into account the structure of "new-old" technology, the structural formula will be the following:

$$\frac{dI}{dt} = Is\frac{d\gamma}{dt} + \frac{dIs}{dt}(1+\gamma)$$

$$\gamma = \frac{In}{Is}$$

$$\frac{d\gamma}{dt} = \gamma(g_{In} - g_{Is})$$

$$d_{is} = \frac{Is}{I}$$

$$i_s = \frac{Is}{Y}$$

$$I = Is + In = (1+\gamma)Is$$

Hence:

$$g = g_{In}(1+\gamma)\,\gamma\, i_s\, d_{is} + g_{Is}\,(1+\gamma)\, i_s\, d_{is} + g_c\, c + g_G\, a + g_{NX}\, b.$$

Table 2. Investment composition (In/Is) and models of technological development

Total investment - I	Composition of investment in "new–old" technologies	Technological development mode
I – increases (industrialization)	In –increases Is – increases	Innovation model. (technological industrialization). Development of high-tech industries (emergence of new) with the development of the initial technological basis, there are two modes in the ratio of growth rate of In and Is. $dIn/dt > dIs/dt$ – innovative development driven by new technologies (stronger effect of displacement of old technologies by new ones) or $dIn/dt < dIs/dt$ – innovative development with an emphasis on improving the existing technological framework (stronger effect of displacement of new technologies by old ones)
	In – increases Is – decreases	Model of technological breakthrough in which new technologies displace old ones (technological industrialization through technology substitution)
	In – decreases Is – increases	Model of strengthening the existing technological framework without new technologies (technological deindustrialization)
I – does not change (mixed models)	In – does not change Is – does not change	Preservation of technological development. Technological stagnation. Increased wear of the existing technological framework. (maintaining the industrial level)
	In – increases Is – decreases	The model of "creative destruction" in technology. For the given technological and industrial level there is resource distribution in favor of separate new technologies at the expense of old – the principle of "creative destruction"
	In – decreases Is – increases	Model of technological deindustrialization, with the growing influence of old technologies.
I – decreases (deindustrialization)	In – decreases Is – decreases	Model of absolute technological deindustrialization (technological degradation)
	In – increases Is – decreases	Model of "local innovation" amid general deindustrialization of a system
	In – decreases Is – increases	A model of conservation for technological backwardness

Source: compiled by the author.

This type of structural formula indicates the contribution of new technologies to the overall growth rate of economy – by rate of growth investment; and old technologies – by investment rate in old technologies.

Based on Table 2, different models of technological development of economy are possible, depending on the emerging composition of investment in new and old technologies. Depending on the established model certain measures of economic policy that stimulate technological development and the transition from one model to another become natural. Such options are:

– increase in total investment if they are currently not increasing or decreasing; in the latter case it is required to have measures to counteract their reduction;

– increased investment in new technologies;

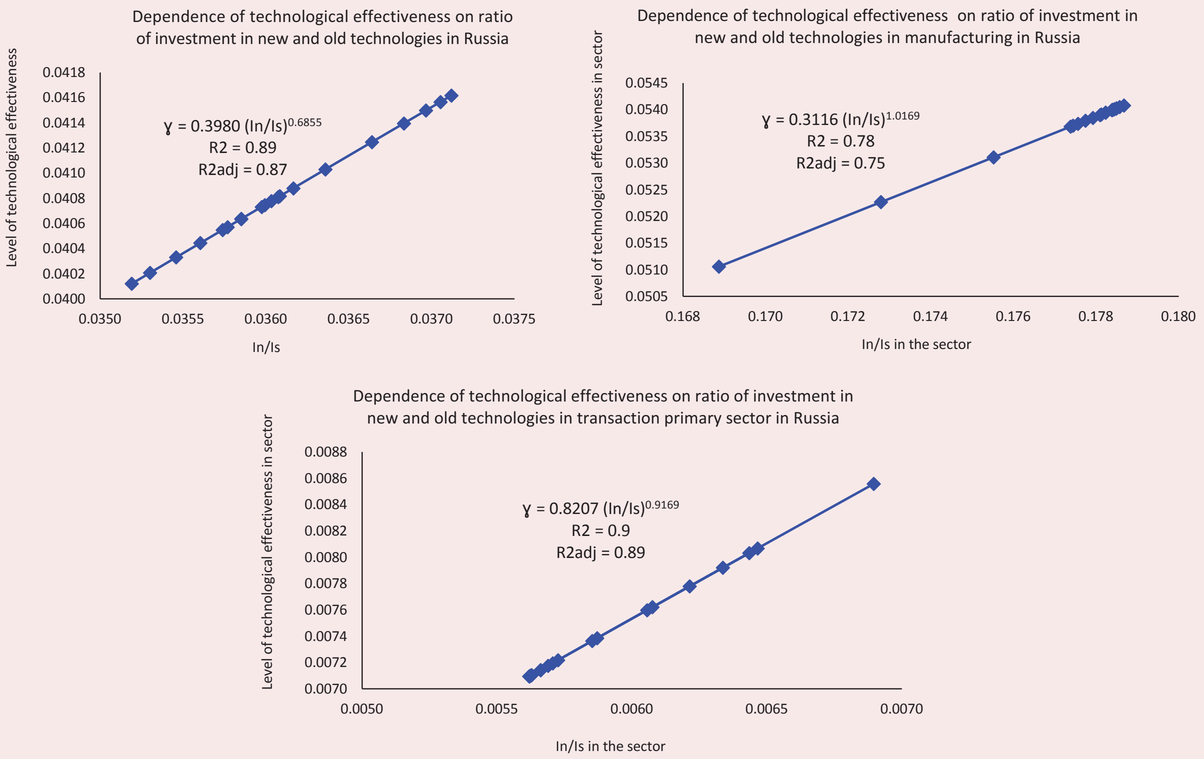
– increased investment to improve old technologies;

– change in rates ratio set in the general form of dIn/dt and dIs/dt with increased investment I and the growth of each component in investment composition in favor of investment in new technologies.

The selection of economic policy instruments taking into account industry specifics is a separate objective, but it will be associated with reducing business risks in economic sectors, since such an impact positively affects the amount of investment in old and new technologies.

It is natural to believe that a larger amount of investment corresponds to greater risks. The same dependence is typical for the Russian economy, including by sector – manufacturing and transaction primary sector. The level of technological effectiveness defined by

Figure 2. Level of technological effectiveness of the Russian economy*, manufacturing** and primary sector*** based on investment in new and old technologies (left to right)



* Statistics: F-criterion = 80.9; D-W criterion = 1.62 ∈ [1.33; 2.67]; White test: $\chi 2$ calculation. (0.08) < $\chi 2$ critical (3.8).
** Statistics: F-criterion = 36.9; D-W criterion = 1.63 ∈ [1.33; 2.67]; White test: $\chi 2$ calculation (0.13) < $\chi 2$ critical (3.8).
*** Statistics: F-criterion = 90.7; D-W criterion = 1,37 ∈ [1.33; 2.67]; White test: $\chi 2$ calculation (3.2) < $\chi 2$ critical (3.8).

Source: calculated based on: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/science/#; http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/enterprise/industrial/# and http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/enterprise/investment/ nonfinancial/#.

production ratio based on new technologies to production based on old technologies[6] depends on the ratio of investment in new and old technologies, respectively. With the growing profitability of sectors, the risks also grow. Increased costs of old technologies reduce the overall technological level; costs of new technologies increase the technological level in the Russian economy.

The level of technological effectiveness according to the above dependence parameters is demonstrated in *Figure 2*.

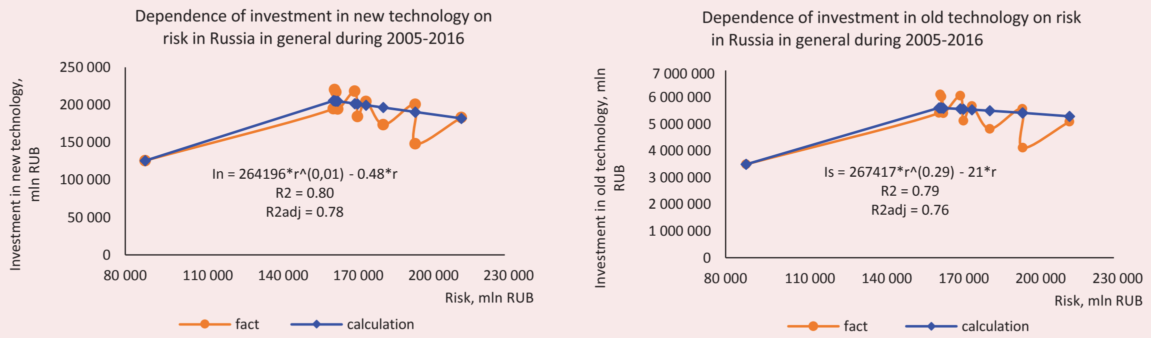
With the growing ratio of investment in new and old technologies, the level of technology increases. The level of technological effectiveness varies in a very narrow range. The narrowness of change range, of course, does not suggest that the technological level is very sensitive to risk and interest rate.

As you can see, investment in new technologies are more important for improving the technological level of manufacturing sector than transaction primary sector.

Investment in old technologies in Russia is much higher than investment in new technologies, setting the investment composition that does not contribute to a significant increase

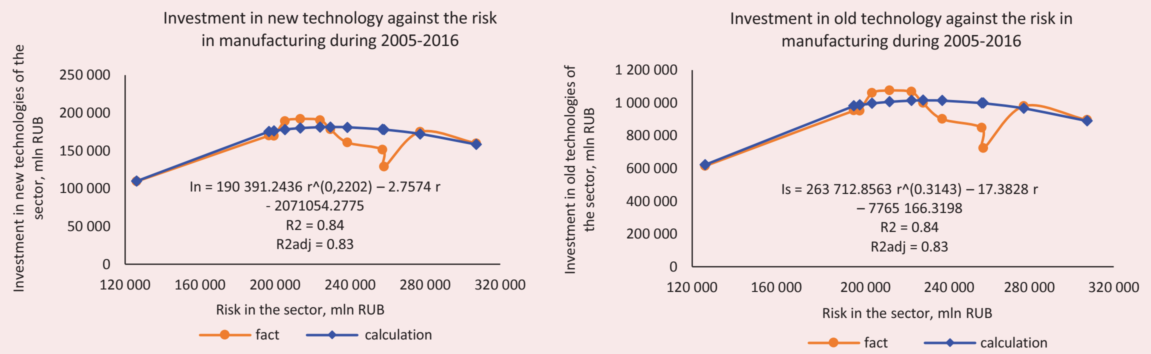
[6] Production volume based on new technologies – volume of shipped innovative goods, works and services. Volume of production based on old technologies – total volume of shipped products minus shipped innovative products.

Figure 3. Investment in new (left)* and old technologies (right)** and risk to the Russian economy, 2005–2016



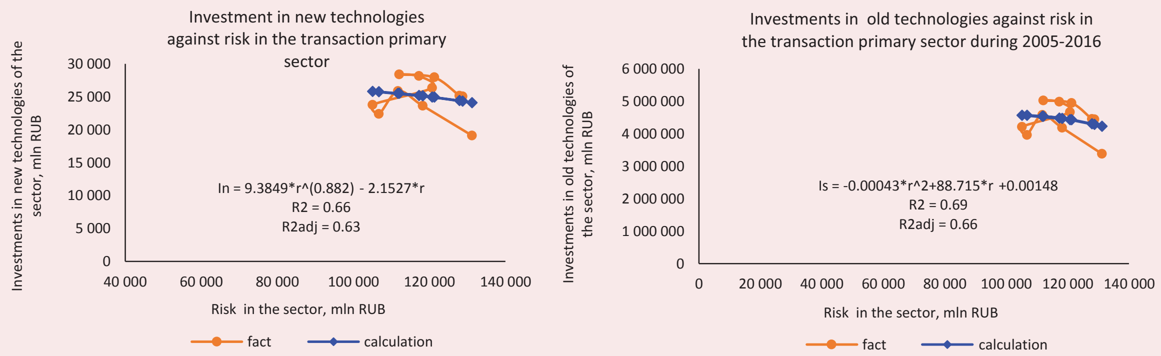
* Statistics: F-criterion= 31.5; D-W criterion= 1.69 ∊ [1.33; 2.67]; White test: χ2 calculation (1.35) < χ2 critical (3.8).
** Statistics: F-criterion= 26.8; D-W criterion= 1.45 ∊ [1.33; 2.67]; White test: χ2 calculation (2.76) < χ2 critical (3.8).

Figure 4. Investment in new (left)* and old technologies (right) ** and risk to manufacturing sector, 2005–2016



* Statistics: F-критерий = 58,1; D-W критерий = 1,64 ∊ [1,33; 2,67]; тест Уайта: χ2 расчет. (1,81) < χ2 крит. (3,8).
** Statistics: F-criterion= 56.1; D-W criterion= 1.46 ∊ [1.33; 2.67]; White test: χ2 calculation (1.93) < χ2 critical (3.8).

Figure 5. Investment in new (left)* and old technologies (right)** and risk to manufacturing sector, 2005–2016



* Statistics: F-criterion= 39.6; D-W criterion= 1.33 ∊ [1.33; 2.67]; White test: χ2 calculation (3.4) < χ2 critical (3.8).
** Statistics: F-criterion= 36.7; D-W criterion= 1.41 ∊ [1.33; 2.67]; White test: χ2 calculat ion (2.2) < χ2 critical (3.8).
Source: calculated based on: Rosstat collection “Russia in Figures” for 2006–2017, section “Enterprise financial activity” (Fig. 3–5).

in technological effectiveness (*Fig. 3–5*), with the risk increase significantly minimizing investment in new technologies and reducing investment in old technologies.

In manufacturing, the correlation between investment in new and old technologies and risk in the sector is similar to the graphs for the Russian economy (numerical values, of course, are different. For transaction primary sector, investment in new technologies is more than 100 times less than in old technologies, with higher investment corresponding to higher risks. With increased risks, there is still a decrease in investment in this sector in the period under consideration, both in new and old technologies (the results were obtained for the Russian economy during 2005–2016)).

Thus, the problem of technological renewal of the Russian economy is reduced to straightening the investment composition between new and old technologies and industries, increasing the overall technological level in economic sectors [2–3, 11–13, 22]. This requires a change in the institutional environment, in particular, a reduction in risks in manufacturing and increases risks in transaction primary sector. The objective of concentrating the development resource is addressed not only by attracting reserves, assets of the banking system, changes in the fiscal policy towards lending to manufacturing industries, but also by organizing the resource overflow from expanded transaction primary sector to manufacturing. This overflow will increase investment in new technologies and may improve the technological efficiency of manufacturing. We demonstrate the opportunities of such management as a way to achieve medium- and long-term goals of technological development by calculating the sensitivity of investment in new and old technologies to risk and interest rates as management parameters (specific tools of the economic policy).

We present the obtained dependence parameters obtained during the econometric study, linking risks and interest rates in manufacturing and transaction primary sectors and the Russian economy, as well as investment in new and old technologies on risk magnitude in each sector.

Correlation between risks and interest rates:

A) for the Russian economy: $r = 2096.3579\ i + 152\,724.7726$[7]

B) in manufacturing: $r = 12997\ i + 87\,224$[8]

C) in transaction primary sector: $r = 5430\ i + 56\,967$[9]

Correlation between investment in new (In) and old (Is) technologies and risks[10]:

A) for the Russian economy:

$In = 264195.6752\ r^{0.0056} – 0.4756\ r$

$Is = 267\,416.9011\ r^{0.2931} – 20.9689\ r$

B) in manufacturing:

$In = 190\,391.2436\ r^{0.2202} – 2.7574\ r – 2071054.2775$

$Is = 263\,712.8563\ r^{0.3143} – 17.3828\ r – 7765\,166.3198$

C) in transaction primary sector:

$In = 9.3849\ r^{0.882} - 2.1527\ r$

$Is = -0.00043\ r^2 + 88.71503\ r + 0.00148$

Now let us prent the models obtained for technological effectiveness (γ – ratio production volume based on new technologies to production volume based on old technologies in sectors under review and the economy of Russia) from the ratio of investment in new and old technologies:

A) for the Russian economy: $\gamma = 0.3980\ (In/Is)^{0.6855}$

B) in manufacturing: $\gamma = 0.3116\ (In/Is)^{1.0169}$

C) in transaction primary sector: $\gamma = 0.8207\ (In/Is)^{0.9169}$

Let us show the sensitivity of investment in new and old technologies to the tools of economic policy (risk and interest rate) and technological effectiveness.

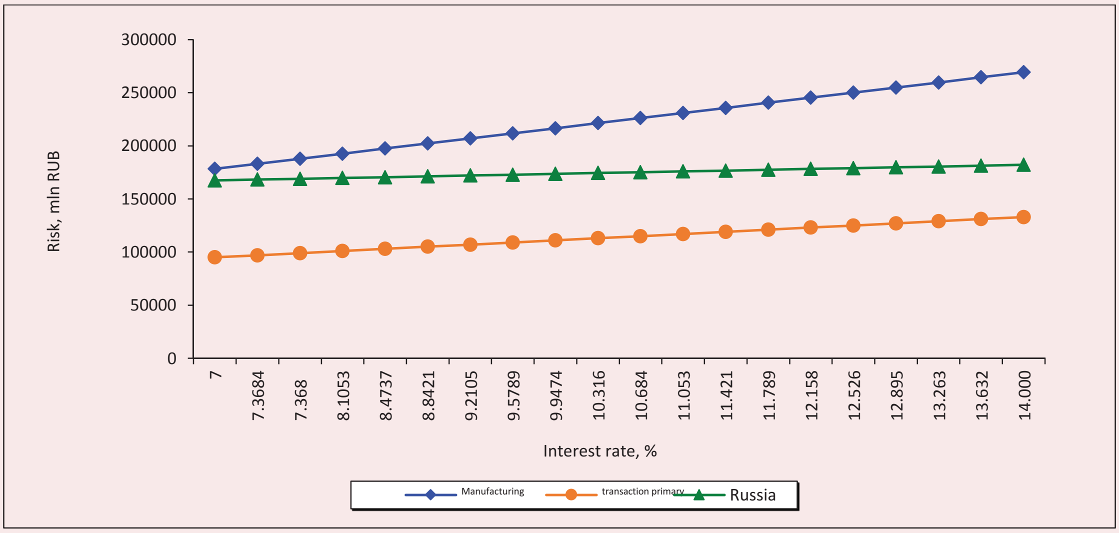
[7] Statistics: F-criterion = 5.4; D-W criterion = 1.34 ∈ [1.33; 2.67]; White test: χ2 calculation (1.31) < χ2 critical (3.8).

[8] Statistics: F-criterion = 4.98; D-W criterion = 1.84 ∈ [1.33; 2.67]; White test: χ2 calculation (1.43) < χ2 critical (3.8).

[9] Statistics: F-criterion = 22; D-W criterion = 1.47 ∈ [1.33; 2.67]; White test: χ2 calculation (2.04) < χ2 critical (3.8).

[10] For other dependencies, statistics are presented in Figures 3–5.

Figure 6. Risk and interest rate (manufacturing, transaction primary sector, TP, Russia's economy)



Source: calculated by: http://www.cbr.ru/statistics/?Prtid=int_rat&ch=PAR_222#CheckedItem.

Figure 6 shows changes in risk depending on interest rate for the Russian economy. Risks in the Russian economy increases slightly with an increased interest rate from 7 to 14%. However, in manufacturing and transaction primary sectors it grows faster, with the manufacturing sector significantly exceeding the risk in transaction primary sector.

If interest rate is reduced according to the obtained dependence parameters, risks in the sectors under review will decrease. Changes in the risk ratio, other than the interest rate, are influenced by internal conditions prevailing in each sector, as well as general economic changes.

Increased risk in manufacturing is faster with growing interest rate than in transaction primary and significantly exceeds risks in the Russian economy, so that the difference in risk between sectors with an increased interest rate increases, with a decreased rate – it decreases. This affects the resource flow in the economic system because resource distribution (in particular, investment) is sensitive to risk.

Figures 7–8[11] demonstrate investment in new and old technologies in Russia based on risk and interest rate. With the growing interest rate and risk investment is reduced, and vice versa: with a decreasing – it is increased. Moreover, investment in old technologies is significantly higher than investment in new technologies and its sensitivity to changes in risks and interest rate is much higher.

Figure 9 demonstrates investment in new technologies from risk and interest rates for Russia's manufacturing sector.

Investment in new technologies in manufacturing is also not high, and with rising risks and interest rates it first slightly increases, then – decreases. This is due to the acceptance of risk in new results and technologies that are inherently risky, that is, investment increases, and this increase corresponds to the increasing risk. By increasing, the interest rate increases

[11] These and subsequent figures demonstrate empirical parameter values, according to actual data of specified parameters, the sources of which are listed above (see Fig. 2–6).

Figure 7. Investment in new technologies, risk (left) and interest rate (right), Russia

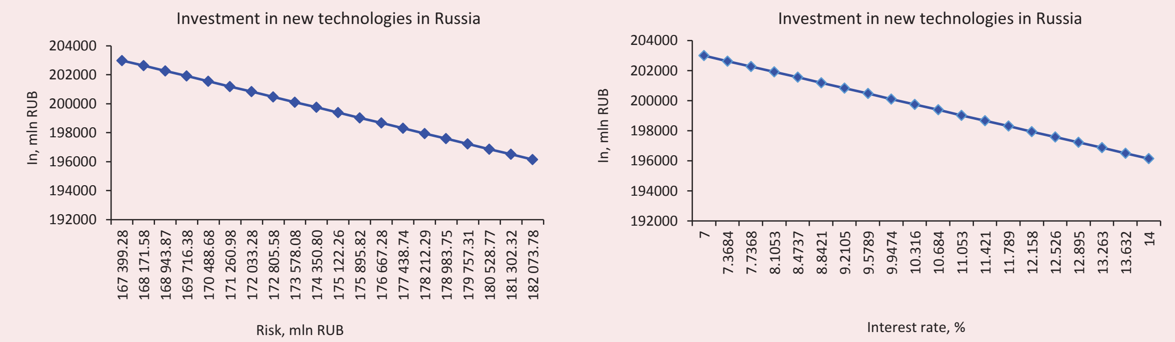


Figure 8. Investment in old technologies, risk (left) and interest rate (right), Russia

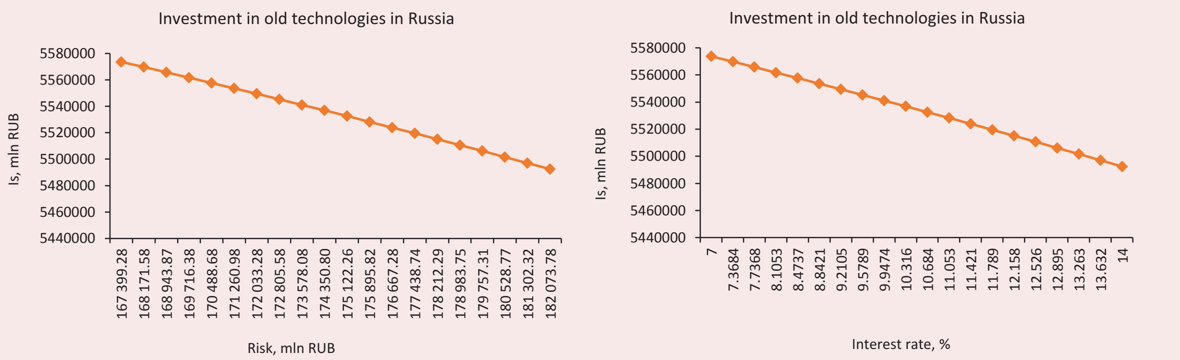
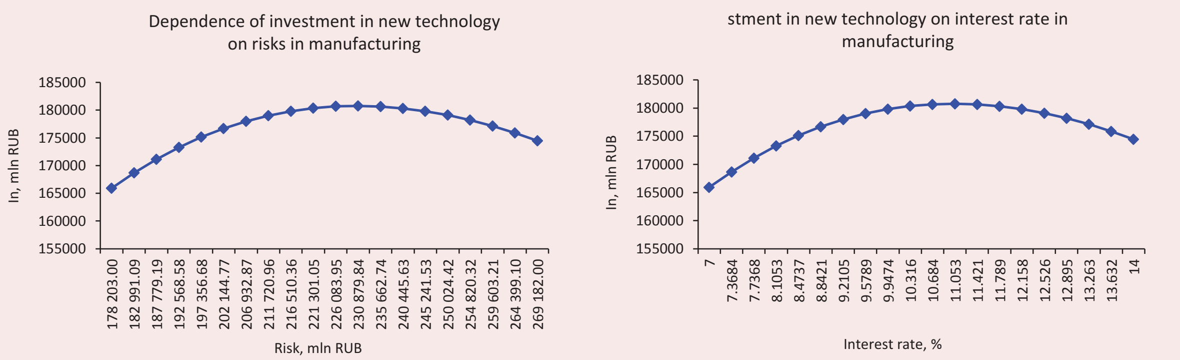


Figure 9. Investment in new technologies, risk (left) and interest rate (right), manufacturing



the risk. To some extent, investors take this risk (risk acceptance) but then, this investment is curtailed, new technologies are not introduced as the risk blocks this implementation.

Investment in old technologies in manufacturing is presented in *Figure 10*. The general nature of their changes is almost the same as investment in new technologies in manufacturing, but in old technologies investment is significantly higher.

In transaction primary sector, investment in new technologies changes from risk and interest rates in a different way than in manufacturing (*Fig. 11*). As interest rates and risk increase, investment decreases. The same is true for investment in old technologies in this sector.

Figure 10. Investment in old technologies, risk (left) and interest rate (right), manufacturing

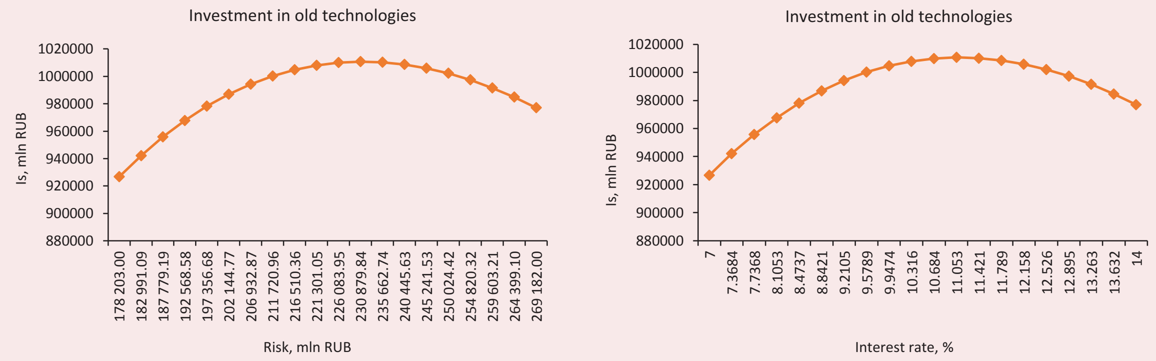


Figure 11. Investment in new technologies and risk (left), interest rate (right), transaction primary sector

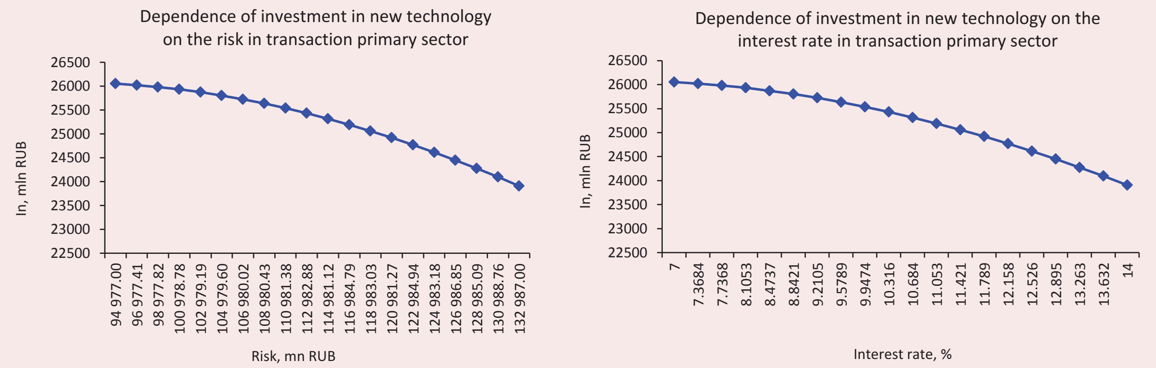
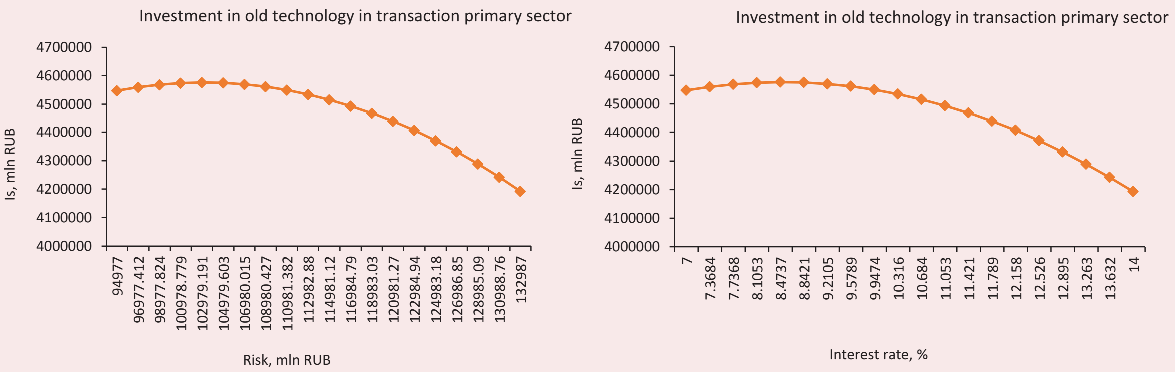


Figure 12. Investment in old technologies and risk (left), interest rate (right), transaction primary sector



And its reduction is quite fast, in the range from 7 to 14% (*Fig. 12*).

The total value of investment in the Russian economy decreases with the growing risk and interest rates, in manufacturing, investment performance repeats investment performance in new and old technologies. In transaction primary sector, total investment performance is similar to that in new and old technologies. There is a very small section of investment increase with the growing risk, then it is significantly reduced with the growing risk and interest rates.

With increasing risk and interest rates, the level of technological effectiveness decreases in manufacturing (*Fig. 13*), in transaction primary sector, with increasing risk and interest rate,

Figure 13. Technological effectiveness and risk (left), interest rate (right)

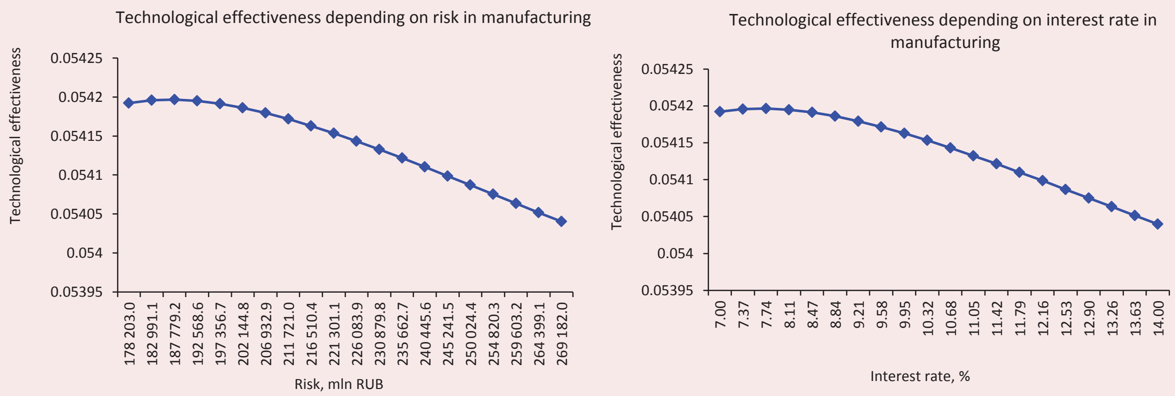


Figure 14. Technological effectiveness of transaction primary (TP) sector and risk (left), interest rate (right)

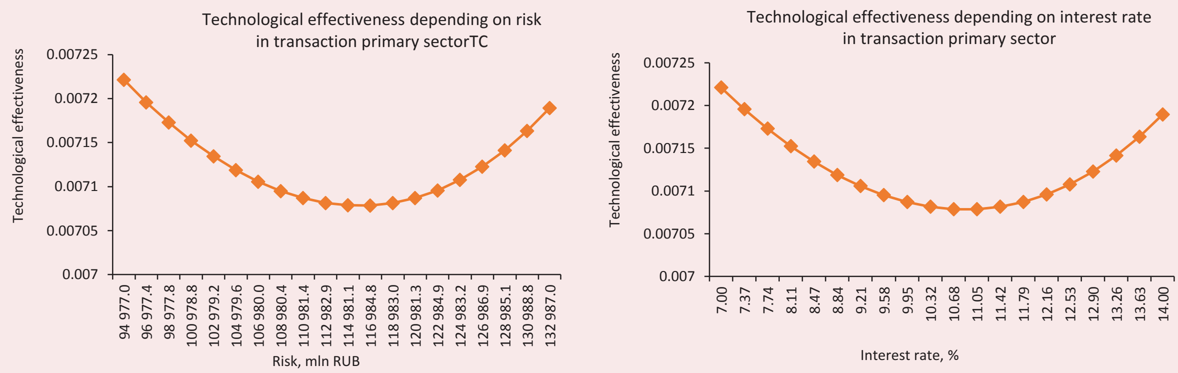
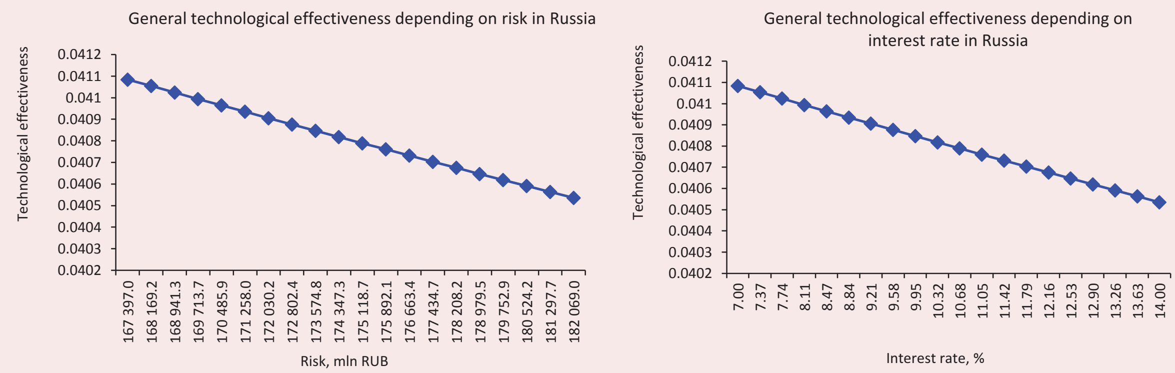


Figure 15. Technological effectiveness of the Russian economy and risk (left), interest rate (right)



technological effectiveness first decreases, then increases. For the Russian economy, an increase in risk and interest rate is accompanied by a decrease in the overall level of technological effectiveness (*Fig. 14–15*).

The level of technological effectiveness in manufacturing with a reduction in the interest rate below 7% practically equalizes the risk in manufacturing and transaction primary sectors (*Fig. 16*).

Figure 16. Risk and interest rate in the Russian economy and its sectors

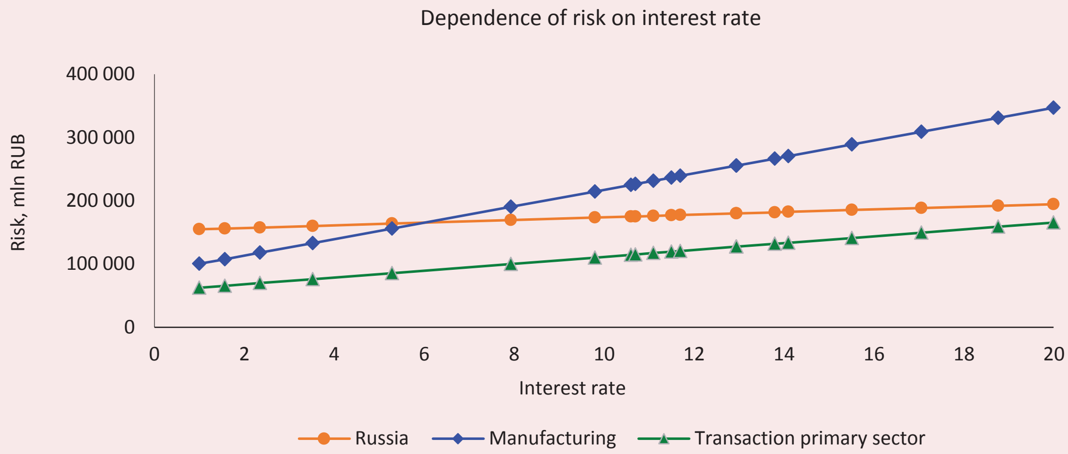
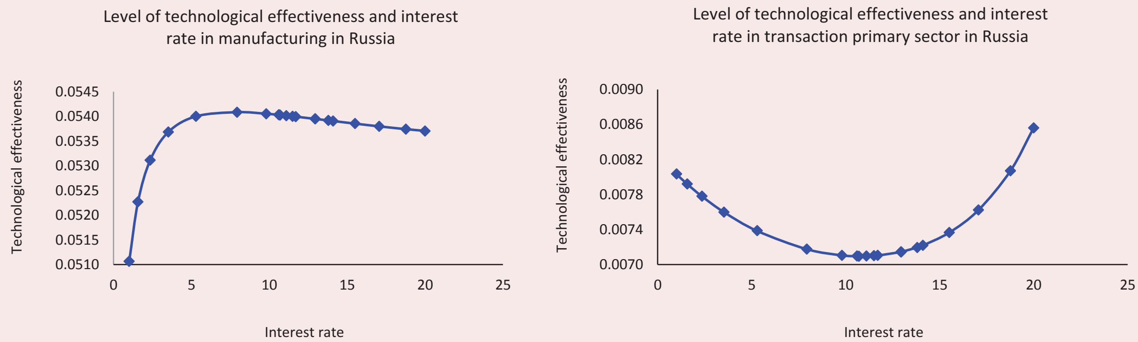


Figure 17. Technological effectiveness in manufacturing (left) and transaction primary sector (right) from interest rate



At a rate of interest above 5.5%, the risk in manufacturing becomes higher than the Russian level.

A decrease in the rate is accompanied by decreased risks. Of course, this model makes a significant assumption that risk depends on the interest rate, when it can be more determined by other factors. Therefore, for rigorous analysis it is necessary to reject factors according to their influence on risk. However, for the purpose of demonstrating the role of interest rate this model is enough.

In manufacturing and transaction primary sectors, the link between the level of technological effectiveness and interest rate is demonstrated in *Figure 17*.

As can be seen, at an interest rate of up to 8–10% in manufacturing with the growing interest the level of technological effectiveness increases. This sector corresponds to an increase in risk. Then, at a rate above 10% (risk above 200,000 million rubles) the level of technological effectiveness is reduced. It should be noted that the increase and decrease is extremely small, it occurs in a very narrow range of technological effectiveness.

This effect is probably due to the fact that having reached a certain level it is difficult to quickly reduce technological effectiveness by changing the interest rate. Moreover, the level of technological effectiveness is not high and varies by a small amount. In transaction primary sector, at an interest rate of up to 10% the level of technological effectiveness decreases with the increasing rate (at the same time, it is lower than in manufacturing), then it increases with the growing interest rate, although insignificantly. Perhaps this is due to the fact that transaction primary sector, having a high interest rate, has great opportunities due to the speculative component to replace the applied technologies. For the Russian economy as a whole, the prevailing ratio is that with the growing interest rate there is a decrease in technological effectiveness.

Thus, in manufacturing sector, a low-range growth in interest rate, leading to increased risks reflects the growth of the sector and its investment, which itself is associated with an increase in demand for capital, an increase in interest rates and risks. Such a reaction is natural. With a higher rate and its increase, risks are also increased; the level of technological effectiveness is reduced, but gradually and slowly, until the technological capacities are exhausted. With low risks and low interest rate, investment in new and old technologies in manufacturing are increased, with higher risks and lower interest rates – it is decreased. The qualitative dependence for transaction primary sector is similar. However, investment in manufacturing increase the technological effectiveness, in transaction primary – declines, which is associated with the function of technological effectiveness for both sectors (decreasing return in transaction primary sector, increasing return – in manufacturing).

4. Conclusion

To sum up the results of the study we make some significant conclusions.

First, establishing a new growth model for the Russian economy can be due to changes in its technological structure set by new and old technologies and investment in them. This will require a shift of resources between manufacturing and transaction primary sectors. Taking into account the effect of investment distribution between different technological capacities has not yet been fully implemented in investment models, which increases the usefulness of the approach used in the article not only for diagnosing the current economic situation, but also from the point of view of specifying the objectives of technological development, with consequent actions in the economic policy. Theoretically, the influence of risk and interest rate as macro-parameters on the process of technological renewal is demonstrated.

Second, quantitative assessment confirms that the sensitivity of investment in new and old technologies is different to changes in risk and interest rates, which are the control parameters determining the amount of investment flow, hence, the scale of technological innovation in economic sectors.

Third, within the framework of the state planning system, the correlation between medium- and long-term goals of technological development (with the algorithm of their analytical definition – setting) is identified, with the differentiation of these goals in terms of changing the structure of old and new technologies, when there is a natural (stimulated) displacement of some technologies by others. Based on the reviewed groups of technologies (in the author's classification [11]), we proved the need to stimulate the creation of "superior", "neutralizing" and "adaptive" technologies, commensurating the ability to ensure the implementation and interaction of each of these types of technologies in the emerging conditions. The proposed algorithms make it possible to clarify the setting of economic development priorities in technology and reduce the level of unjustified changes in priorities and development goals.

Fourth, it is found that the level of technological effectiveness of the Russian economy quite weakly responds to changes in interest rate and risk, especially in manufacturing and transaction primary sectors. But the changes that we have managed to impose show that the growth of interest rate and risk act towards reducing the technological effectiveness will at least not significantly increase it. Of course, the level of technological effectiveness depends on many factors, including risk, however, if we assume a linear correlation between interest rate and risk (statistically, this dependence is quite reasonable), the overall impact will imply an increased interest rate in its low values accompanied by an increase in technological effectiveness in manufacturing. With a high share, the technological efficiency of manufacturing decreases with the growth of the interest rate. Transaction primary sector operates under the opposite model, as its technological effectiveness increases at a high interest rate, as the speculative nature (with the dominance of transaction activities) of this sector at a high interest rate expands the possibility of replacing technologies that have significant specific features compared to production technologies (used in manufacturing). Thus, empirical analysis establishes (from the actual data) that different interest rates may correspond to different levels of technological effectiveness.

Further research prospects include an opportunity to compare the levels of technological development in different countries, determining the impact of different macroparameters of the system on its change, including the sectoral aspect of the problem, as well as the structure of investment distribution in technological innovation.

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