Modeling of the innovative activity for the enterprises in investment based construction industry

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Abstract. The aim of the study is the modeling of innovation in the investment-construction industry in the context of a change in technological paradigms. Here are the suggested models of innovative development of groups of countries, which are classified by indicators of innovation progress: innovation leaders, innovative followers, moderate innovators and catching up countries. The studies have been carried out using the least squares method. The paper provides a quantitative assessment of the level of meaningful economic development of the investment-construction complex. Only by identifying the relationship between the volume of commissioning and the used production inputs one can identify the nature of economic development. Models of innovative development of construction production based on increasing the level of total resource productivity have been developed. A model for investment demand prognosis has been developed and tested. The model allows to determine the need for investments in the framework of medium-term and long-term prognosis.

Measures have been developed to increase the level of innovative activity of enterprises in the investment-construction complex.

Key words: innovative activity, investment needs, investment-construction complex, investment demand prognosis.

1 Introduction

The necessity for Russia to switch from a raw commodity export model of economic development to innovative model is beyond doubt. Today the country is significantly behind most developed and several developing countries by a number of criteria for innovative development. Innovatively progressive countries are at the stage of transition to the sixth technological stage, represented by nano- and biotechnologies, while Russia is in transition to the fifth stage, based on the development of information technology and telecommunications.

Russia can become competitive only by switching to a new model of economic evolution and the rapid reduction of the gap. Our country needs an effective strategy for improving innovative process by actively encouraging and commercializing innovations.

Many foreign scientists, such as K. Freeman, K. Peres and Russian scientists: N.D. Kondratiev, Yu.V. Yakovets, SJ. Glazyev and others, consider innovation activity in relation with the cyclical development of the economy and the concept of technological stage [1, 2].

Researching the factors that influence innovation is of particular importance. The most interesting studies in this regard belong to M. Porter, R. Maclarin, E. Penrose, B. Wernerfelt, K. Arrow, J. Tyrol, A.S. Ildemenov et al. [3, 4].
There is a debate about current phase of technological stage of the world economy. According to K. Perez, the world economy is currently in a transitional phase between the initial phase and the deployment phase (which means in the middle of the fifth technological stage - the era of information technology and telecommunications).

At the same time C.Yu. Glazyev claims that the world economy is at the beginning of the sixth technological stage - the era of nanotechnology development - the dominance of which, according to his forecasts, should last until 2050 [5, 6].

The complexity of the exact answer to the question, about which technological structure currently dominates, is that the fifth and sixth technological structures are closely interconnected, and there is continuity between them.

The fact that fifth and sixth technological stages are closely interconnected makes the answer to the question about which technological stage currently dominates in the world, more complicated.

At the moment, scientists have not come to mutual agreement regarding the definition of "technological stage."

Our opinion - the technological stage is an advanced model of economic development based on increased innovative activity, implementation of new technologies and organizational principles. These factors characterize the certain level of economical development. A set of new technologies and organizational principles being introduced characterize a certain level of production development, within which the reproduction cycle is carried out [7].

The nanotechnologies are at the very beginning stage of development, so to our opinion, it is too premature to say that the world economy has moved to the sixth technological stage. At present, the fifth technological stage is dominating, but the speed of economical development is slowing down. The leaders of the world market still have an opportunity to prevent significant structural changes in the economy. However, the transition of the world economy to the sixth technological stage will take place in the near future [8,9].

The innovative sector of Russia remains far behind developed and many developing countries. In order to catch up with the developed countries, Russia must move to the sixth technological stage, skipping the fifth. The obstacles to do that are not so high at the moment. They will require fewer investments for developing a new nanotechnology market, than a few years later. It will be impossible to implement this strategy without significant support of the Government. The investments in innovative projects are very risky at this point [10,11].

The characteristics of the market and participating organizations play an important role in innovative development. I. Schumpeter notes that market conditions are the main factor determining innovative activity. E. Penrose, B. Wernerfelt and others believe that financial resources of the company are a determining factor affecting its innovative activity. The more resources the organization has, the higher its innovative activity [12,13].

According to the study of K. Arrow, J. Tirol, and others, monopolists have a very low incentive to innovate, because it will consume the existing stable profit, brought by old technologies. Respectively, when the level of competition is higher, it spikes the innovative activity of the companies [14].

Another very important factor in increasing of innovative development of organizations is better management. Decisions regarding utilizing of venture financing, creating the alliances, joint ventures and acquisitions, have a significant impact on innovation [15,16].

Researching the markets of Denmark, France, Germany, Greece, Italy, the Netherlands and the United Kingdom of Great Britain and Northern Ireland, scientists empirically established, that innovative activity is higher in organizations that are managed by employed managers [17,18,19,20].

2 Methods
2.1 Method of least squares
We will extrapolate the data by mean values for groups of countries and for Russia using the method of least squares (least squares)
MLS is a mathematical procedure for compiling a linear equation that best matches a set of ordered pairs by finding the values for the coefficients in the equation of the line. The goal of MLS is to minimize the total quadratic error between the values of $y_i$ (known values) and $f(x)$ (values estimated using regression):

$$f(x) \rightarrow \min$$

where $n$ is the number of observations.

The line obtained by compiling the regression equation minimizes the total quadratic error.

### 2.2 Methodology for determining the development model of enterprises in the investment and construction sector

The authors propose to conduct a study of the quantitative laws characterizing the level of innovative development using the production function, which is an economically viable method for expressing stable quantitative relations between the results of production and the resources used, taking into account the relationship between them. The production function makes it possible to study the relationship between the volume of production and production resources in material terms outside their cost form in dynamics.

**Figure 1.** Methodology for determining the development model of enterprises in the investment and construction sector.

The calculation algorithm for determining the type of investment and construction enterprises development is presented in figure 1.
2.3 Economical and statistical prognostic model of investment demand

An economical statistical model for investment demand prognosis has been developed and tested, which allows one to determine the need for investments in the framework of medium and long-term forecasting.

Investment activity, first of all, depends on the investment demand, associated, first of all, with the replacement and updating of technological equipment.

Demand for investment in fixed assets is a derivative demand, due to the presence of demand for the products or services of the invested object, the need to increase its production capacity.

The volume of investment requirements can be described at any time \( x \) using the function:

\[
(3) \quad f(x) = \int_a^x f(t) \, dt ,
\]

where for \( a \) - any initial fixed point in time is taken; \( x \) - is a variable.

The function \( f(t) \) can be represented by the impulse function:

\[
(4) \quad f(t) = \sum_{k=0}^{n} p_k \cdot f_k(t) \delta(t - kT), \quad t > 0
\]

Here, each term is expressed in terms of the asymmetric impulse Dirac function defined by the relations:

\[
\int_a^b f(\xi) \cdot \delta_+(\xi - x) \, d\xi = f_x \begin{cases} x < a & \text{or } x \geq b \\ a \leq x < b \end{cases} (a < b)
\]

The equation \( y = f(x) \) determines the investment development schedule.

Obviously, the integral under consideration changes with a change in the upper limit, i.e. is a function of the upper limit of \( x \).

The dynamics of attracted investments can be represented as follows:

\[
sgn(a) \cdot f_0(a)
\]

where

\[
sgn(a) = \begin{cases} 1, & a > 0 \\ 0, & a = 0 \\ -1, & a < 0 \end{cases}
\]

The value of the resulting function represents the sum of two functions:

\[
sgn(a) \cdot f_0(a) + f(x)
\]

Using the introduced function allows one to determine the need for investments cumulatively for the medium and long term.

The predicted investment volume can be determined by calculating the exact value (3) directly, using the apparatus of the Stieltjes integrals or with any degree of accuracy according to the Simpson formula:

\[
(5) \quad \int_a^x f(t) \, dt \approx \frac{x-a}{6n} \left[ (y_0 + y_{2n}) + 2(y_2 + y_4 + \cdots + y_{2n-2}) + 4(y_1 + y_3 + \cdots + y_{2n-1}) \right]
\]

In this model, as in formula (3), each term is expressed in terms of the asymmetric impulse function of Dirac.

The calculations carried out according to formula (3) allow us to determine the upper and lower points of the border in the process of substantiating the need for investment:

\[
\sup (sgn(a) \cdot f(a) + f(x)) - \text{an upper bound (supremum)}
\]

\[
\inf (sgn(a) \cdot f_0(a) + f(x)) - \text{a lower bound (infimum)}
\]

The calculations of the supremum (sup) allow us to represent the need for investments taking into account the investment program planned in the republic for the long term, and the calculations of the infimum (inf) allow us to present the minimum guaranteed volume of investment development taking into account the consequences of the global financial crisis. The prognostic results are presented in tabular form.
3 Results and discussion

3.1 Analysis of innovation activity dynamics

We will consider the indicator of innovation activity for Russia and other countries. We will extrapolate the innovation activity in Russia and foreign countries, the dynamics of innovation activity indicator for the countries of the world. The European Union (EU) indicator was compiled by the EU statistical service taking into consideration 25 factors (figure 2.1). For other countries, this indicator is generated using the information available.

To summarize data on foreign experience in the field of innovative development, we decided to divide the countries into four groups according to the classification used by the European Statistical Service;

- Innovative leaders - a group of countries where innovation activity is more than 120% of the average European level (Switzerland, Sweden, Denmark, Germany and Finland);
- Innovative followers - a group of countries where innovative activity is from 90% to 120% of the average European level (South Korea, USA, Luxembourg, Netherlands, Belgium, Japan, United Kingdom, Ireland, Austria, Iceland, France, Slovenia, Estonia and Cyprus);
- Moderate innovators - a group of countries where innovative activity is from 50% to 90% of the average European level (Norway, Italy, Canada, Czech Republic, Spain, Portugal, Greece, Serbia, Hungary, Australia, Slovakia, Malta, Croatia, Lithuania and Poland);
- Catching-up countries - a group of countries where innovative activity is less than 50% of the average European level (China, Macedonia, Romania, Turkey, Latvia, Bulgaria, India, the Russian Federation, Brazil and South Africa).

As a result of the calculations, the following results were obtained:

For innovative leaders, the regression equation has the following form:

\[ f(x) = 0.681 + 0.008x \]  

The t-criteria (212.952 for constant and 12.942 for x) are significantly higher than the critical value of 2.446. Therefore, with a probability of 95%, it can be argued that the obtained coefficients are statistically significant.

R\(^2\) is 0.965 at F = 167.508, which is a high indicator and suggests that the model can be used to predict future values of the indicator of innovation activity by innovation leaders.

For innovative followers, the following regression equation is obtained:

\[ f(x) = 0.525 + 0.009x \]  

t-criteria (147,406 and 13,003) for this group of countries are also significantly higher than the critical value of 2.446. Therefore, with a probability of 95%, it can be argued that the coefficients obtained are statistically significant.

R\(^2\) is also high and is 0.966 at F = 169,084. Thus, predicting the values of the function using this model is possible.

For moderate innovators, the regression equation is as follows:

\[ f(x) = 0.325 + 0.006x \]  

t-criteria (133,404 and 12,591) for a group of countries - moderate innovators above the critical value of 2,446. This means that the probability that the coefficients are statistically significant is 95%.

R\(^2\) is 0.964 at F = 158.540. Therefore, forecasting based on this model is possible.

For catching-up countries, the following regression equation is obtained:

\[ f(x) = 0.177 + 0.003x \]  

t-criteria (46,066 and 4,253) for a group of catching-up countries above the critical value of 2,446. Therefore, with a probability of 95%, a conclusion can be made on the statistical significance of the coefficients.

R\(^2\) in this case amounted to 0.751, which is lower than similar indicators in the previous groups. Let's check the model for statistical significance: F in this case is 18.087, which is higher than the critical value (5.99). This means that the value of R is not accidental, and the regression is statistically significant.
Let’s compose a regression equation separately for Russia. It has the following form:

\[ f(x) = 0.210 + (-0.005)x \]  

\[ t - \text{criteria (26,738 and \(-3,089\)} \text{for Russia are higher than the critical value of 2,446 (module). Therefore, with a probability of 95\%, it can be concluded that the coefficients are statistically significant.} \]

\[ R - \text{was only 0.614, but } F, \text{ equal to 18.087, was above the critical value (5.99).} \]

Therefore, the value of \( R \) is not accidental and the regression is statistically significant. This suggests that, like the model for catching up countries, the regression equation for Russia cannot accurately predict future values; however, this model can be used to judge the trends in the development of innovative activity.

Thus, from the point of innovative activity, Russia belongs to the group of the catching-up countries. Keeping current development trends, the distance between Russia and developed/some developing countries will only increase.

3.2 The quantitative dependence of the level of innovative development of the investment and construction complex on resource productivity

The authors created some models for the innovative development for construction business based on increasing the level of aggregate resource output:

\[ v = a + \beta + \gamma. \]

The quantitative dependence of the level of innovative development of the investment and construction complex on resource productivity is presented in the form of a nomogram (figure 2).

\[ K_i (\%) = 14,247 + 30,573 \nu \]

\[ K_i (\%) \text{ level of innovation activity of the investment construction complex} \]

Figure 2. Nomogram for determining the level of innovative development for the investment and construction complex, depending on the total resource yield.

The calculated parameters of the model of innovative development make it possible to quantitatively determine the return on production resources to ensure a given level of innovative development of the investment and construction complex.

The developed nomogram greatly simplifies the method of calculating the level of innovative development of the investment and construction complex.

The advanced methods of analysis and assessment of the level of innovative development can be recommended for use in the construction industry. They will be helpful in the study of balanced
growth patterns in contracting and applied production resources. One can use them to identify reserves for saving labor and to increase the efficiency of use of fixed and working capital.

3.3 Investment demand prognosis in the Republic of Tatarstan
An economics-statistical model for forecasting investment demand has been developed and tested. This model allows to determine the need for investments within medium-term and long-term prognosis.

Using the asymmetric impulse Dirac function allows one to determine the prognostic volumes of investment flows with the required resolution accuracy.

The calculations of the supremum (sup) allow us to represent the need for investments taking into account the long term investment program planned in the Republic. The calculations of the infimum (inf) allow us to present the minimum required volume of investments, considering the influence of global financial crisis.

The prognostic results are presented in the study in tabular form and in (table 1).

| Economic Regions | 2015      | 2020      | 2030      |
|------------------|-----------|-----------|-----------|
| 1.Capital        | S31=267400| S41=404200| S51=650274,63 |
| 2.Kama Region    | S32=246995,8 | S42=613178,45 | S52=859158,72 |
| 3.Oil region     | S33=46370  | S43=66652,42 | S53=191231,21 |
| 4.South region   | S34=4641   | S44=27709,15 | S54=61289,76  |
| 5.West region    | S35=3710,37 | S45=11969,42 | S55=26756,4   |
| 6. North region  | S36=4056   | S46=18322,18 | S56=35053,4   |
| 7. East region   | S37=10464,32 | S47=42175,6  | S57=86738,49  |
| Total volume of investments | S3=583097,57 | S4=1184207,23 | S5=1910502,68 |

On the first place, investment activity depends on the investment demand, associated with the replacement and upgrading of technological equipment. Demand for investment in fixed assets is a derivative demand, due to the presence of demand for the products or services of the invested object, the need to increase its production capacity.

Using the impulse function allows one to determine the need for investments cumulatively for the medium and long term.

Calculations of the supremum allow us to project the need for investment taking into account the long-term investment program planned in the Republic. The calculations of the infimum allow us to present the minimum guaranteed volume of investment development, taking into account the consequences of the global financial crisis. The forecasting results are presented in the work in tabular form and in the form of a graphic model.

The studies conducted allow us to conclude that the stability of the investment and construction sector determines the speed of the crisis overcoming and the level of general economic losses as a result of overcoming it.

4 Conclusion
The efficiency of innovation is largely determined by the relevant infrastructure, which is the basic component of a developed economy, predetermined the rate and pace of the growth of the country's economy and the well-being of its population. The extensive foreign experience of the developed countries of the world has shown that in the global competition in the world market one who has a developed infrastructure for developing and implementing innovations, owns the most effective mechanism to support such an activity is sure to win.

The implementation of a systematic and comprehensive shift of the economy of both the region and
the state, as a whole, to an innovative type of development will inevitably entail fundamental restructuring of the material-technical basis of the entire scientific, educational and industrial infrastructure.

Based on the experience of many countries and objective economic patterns, the economic recovery from the crisis is related to an indispensable increase in investment activity, an increase in the volume of capital investments in new construction and reconstruction of fixed capital, an advanced development of the production potential of the construction industry and its material-technical base. A prerequisite for this is increasing the efficiency of capital construction, including the sustainable use of investment resources, channeling them to programs and projects with greater economic and social effect, as well as increasing the operating cost-effectiveness of investment projects.

Acknowledgments
The authors would like to thank academicians and scientists of the International Academy of the Investment and Construction Economics.

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