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Air and space vehicle production: indicators of innovative activity

Abstract. We analyze the problems of increasing the innovative activity of air and space vehicle manufacturing enterprises in Russia by the year 2021 and consider indicators reflecting the innovative activity of organizations, such as the implementation of innovations, the proportion of organizations engaged in technological innovation, cost of technological innovation by the source of funds, the dynamics of the innovative production output. Besides, correlation analysis of the relationship between the main indicators of innovation activity and the intensity of expenditures on technological innovations has been performed to identify dependencies describing air and space vehicle production's distinctive features.

Keywords: Indicators; Innovation Activity; Air and Space Crafts; Remotely-Piloted Aerial Vehicle (RPAV); Correlation Analysis; Innovation Development Factors
JEL Classifications: O31; O32; L69; L93; C59; H59

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Виробництво повітряних і космічних апаратів: показники інноваційної діяльності

Анотація. У статті проаналізовано проблеми збільшення інноваційної активності підприємств із виробництва повітряних і космічних апаратів у Росії до 2021 року та розглянуто показники, що відображають інноваційну активність організацій Російської Федерації, такі як впровадження інновацій, частка організацій, що займаються технологічними інноваціями, вартість технологічних інновацій за джерелом фінансування, динаміка випуску інноваційного виробництва.
Авторами здійснено кореляційний аналіз взаємозв'язку між основними показниками інноваційної діяльності та інтенсивністю витрат на технологічні інновації для виявлення залежностей, що описують відмінні риси виробництва повітряних і космічних апаратів.
Ключові слова: інноваційна діяльність; повітряно-космічні кораблі; космос; кореляційний аналіз; фактори інноваційного розвитку.

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**Производство летательных и космических аппаратов:
индикаторы инновационной деятельности**

Аннотация. В статье изучены проблемы повышения инновационной активности предприятий по производству летательных и космических аппаратов в России до 2021 г. Рассматриваются индикаторы, отражающие инновационную активность организаций в РФ, например, инновационная активность, удельный вес организаций, осуществлявших технологические инновации, затраты на технологические инновации по источникам финансирования, динамика объема инновационной продукции.
Авторами осуществлен корреляционный анализ связи основных показателей инновационной активности с интенсивностью затрат на технологические инновации для выявления зависимостей, которые описывают отличительные особенности производства летательных аппаратов.

Ключевые слова: инновационная активность; летательные аппараты; космические аппараты; космос; бизнес; производство; корреляционный анализ; факторы развития инноваций

1. Introduction

In the modern world, the role of innovation in the economy is rapidly increasing. The analysis of recent years' data shows the urgency of problems related to the economic category of innovation because innovation activity occupies an essential place in a contemporary industrial enterprise's performance. Innovations are a means of obtaining significant and long-term competitiveness of industrial enterprises while being the main tool for technological development for individual enterprises and the entire industry in general. Therefore, it is important to study the industry specifics of innovative activity in air and space vehicle production to identify promising changes in enterprises whose innovative activities can boost the economy to a new level of innovative development (Mady et al., 2020). Innovative activity is characteristic of air and space vehicle manufacturing enterprises in Russia. This is because without new technologies, improving the quality, and increasing the range of products produced, the enterprise will not be able to increase its significance in the market. Moreover, to maintain the enterprise's level in the market, innovation must become a continuous process rather than a one-time event (Brem and Nylund, 2021).

Research in this area is important because nowadays, the implementation of innovative management in priority areas of various kinds of industries, in particular the production of air and space vehicles, will create new opportunities and prospects for innovative progress of the country's economy in general. Innovations are the main tool for developing specific enterprises and industries in general; they also serve a means of obtaining competitive advantages of industrial enterprises in the domestic and world markets. This is why research in this area is particularly important when considering the basic indicators of innovation activity and identifying the most significant ones (Chekhlomin and Demyanova, 2019; Jin et al., 2021).

Among the advantages of new technologies and innovations, one can distinguish the following:

- modern innovations result in enhancing the quality of goods and services produced in the country;
- developing new technologies contributes to the partial abandonment of human labor, many processes become automated, which in turn cause increment in the accuracy of operations and the quality of the final product;
- developing contemporary human intelligence through innovation contributes to the emergence of new scientific discoveries and achievements;

The article considers two kinds of technological innovations, namely, product and process innovations. Product innovations contains the implementation and development of novel products. Implementing a novel products is expressed as an absolute product innovation if it considers the product, its functional characteristics, features, or utilized components and materials that sharply distinguish the innovative product from produced previously. Process innovations concern the progress of new or significantly enhanced production approaches (Veretyokhin et al., 2020). Such innovations aim to improve the efficiency of production or the existing products (Woldesilassie and Ivatury, 2020; Jin et al., 2021).

The analysis of innovation activity in the Russian Federation, presented in this article, is based on official statistics. National Research University Higher School of Economics (NRU HSE) publishes innovation activity indicators, which show the organization's role in the implementation

of innovations in general or their specific types. Based on these statistics, the authors analyze the air and space vehicle production for a specific period from 2011 to 2020.

2. Methods

In this article, a correlation method was used to obtain a statistical correlation of two or more random variables. This was done using Statistica software, which allowed calculating the Pearson's correlation coefficient, considered below. First, let's consider the concept of correlation analysis. It refers to a method for processing statistical data that measures the tightness of the relationship between two or more variables. A significant correlation between two random variables always evidences some statistical relationship in a given sample, but this relationship does not necessarily have to be observed for another sample and has a cause-and-effect nature.

To analyze the data and interpret the description of the correlation coefficient values, the data in Table 1 are used.

Table 1:
The correlation coefficient values and their interpretation

The values of the coefficient r	Correlation Interpretation
$0 < r < 0.2$	Very weak
$0.2 < r < 0.5$	Weak
$0.5 < r < 0.7$	Average
$0.7 < r < 0.9$	Strong
$0.9 < r < 1$	Very strong

Source: Compiled by the authors

Consider (x_1, y_1), (x_2, y_2), (x_n, y_n) be a sample of n observations of a pair of variables (X, Y). The sample correlation coefficient r is defined as:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \sum_{j=1}^{n}(Y_j - \bar{Y})^2}}, \quad (1)$$

where:
$\bar{X}$, $\bar{Y}$ are the sample averages defined as follows:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \; ; \; \bar{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i, \quad (2)$$

Further, based on the above methodology, a statistical investigation of the data collected by the NRU HSE is carried out. Methods such as induction, deduction, analysis, comparison, generalization, and concretization are also used.

3. Results and discussion

3.1. The influence of the intensity of expenditures on technological innovation

First, to further analyze changes in innovation activity, consider the intensity of expenditures allocated to technological innovations in the concerned area (Figure 1).

Based on the presented data, the maximum intensity of expenditures on technological innovations in the period from 2011 to 2020 was reached in 2016, amounting to 6%, while the minimum intensity was 3.9% in 2012 and 2020.

Technological innovation activity aims to obtain and apply new knowledge to solve technological and engineering problems, ensuring the production and operation of the enterprise as a single effective complex. It includes changes based on the application of scientific and technological progress, the latest technologies, and management tools.

Forming a system of indicators that show the level of technological innovation activity (in the context of product and process innovations) is a fairly relevant measure to evaluate an enterprise's innovative performance.

Product innovation activity involves manufacturing products or producing services that are new or have new characteristics or ways of using them. There are still opportunities to increase

product innovation levels since the proportion of organizations that have implemented innovations remains small.

Process innovation activity is aimed at implementing new technologies, improving the production method, or product delivery (Brem and Nylund, 2021). It may include improvements to the software's technical characteristics, components, and materials, their usability or other functional characteristics, changes in technology, production equipment, and the use of new materials and software (Chumarina et al., 2019; Jin et al., 2021). The proportion of organizations that implemented process innovations is also quite small.

3.2. Comparison of the proportion of organizations that implement product and process innovations, and the expenditures intensity on innovations in technology

An important indicator that characterizes innovation activity is the proportion of organizations that implement product and process innovations. The curves in Figures 2 and Figures 3 show these values for the period under review.

The line shows that the maximum percentage of organizations having implemented product innovations for the period under review is 66.7% which was reached in 2014 (National Research University Higher School of Economics, 2020).

Next, let consider the relationship between the percentage of organizations having implemented product innovations and the expenditures intensity on innovations in technology (Table 2).

The conducted correlation analysis has shown that the percentage of organizations having implemented product innovations and the intensity of expenditures have an inverse average relationship, which indicates that high costs are spent on purchasing and installing new equipment. The inverse relationship is because at the beginning of implementation, production declines since at the time of purchase and installation of equipment and training of personnel, investments increase. Further investments are reduced, while the effect of innovation implementation increases because the equipment is installed and running.

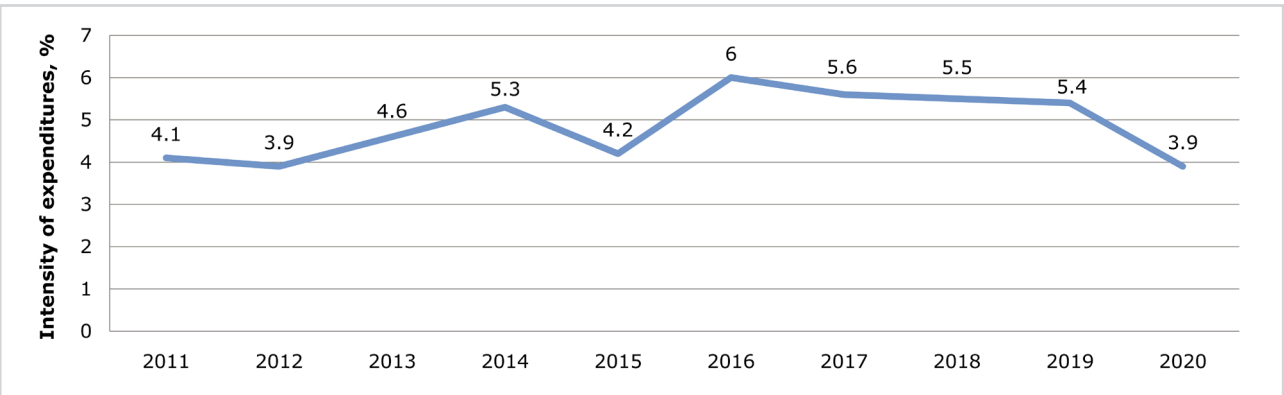

Figure 1:
The expenditures intensity on innovations in technology in 2011-2020
Source: Calculated by the authors

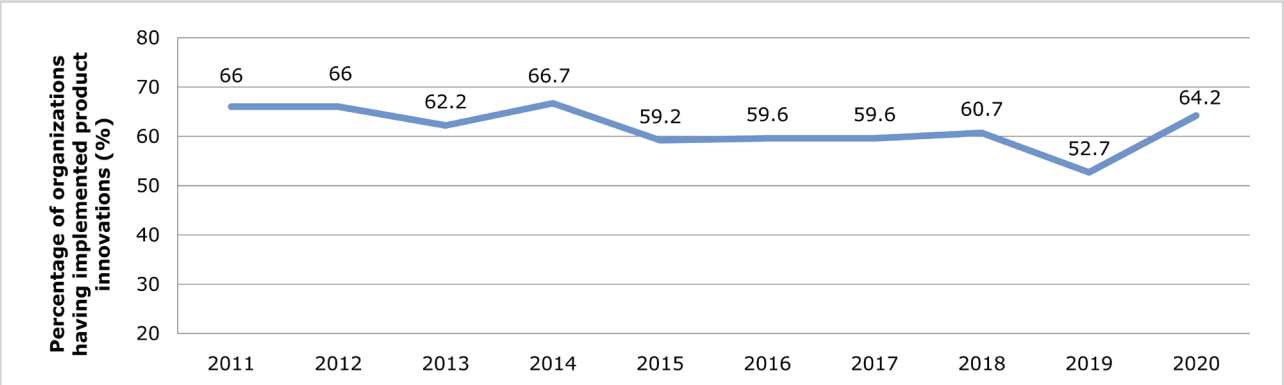

Figure 2:
Percentage of organizations having implemented product innovations (%)
Source: Calculated by the authors

The line below shows that the maximum percentage for the period under review was 69.1% reached in 2019.

Now let us look at the correlation between the proportion of organizations having implemented process innovations and the intensity of expenditures (Table 3).

The conducted correlation analysis has shown that the proportion of organizations implementing process innovations and intensity of expenditures on technological innovations in 2011-2020 has an average relationship. The implementation of product innovations takes place within a shorter time frame, while the effect of implementation is manifested within a year.

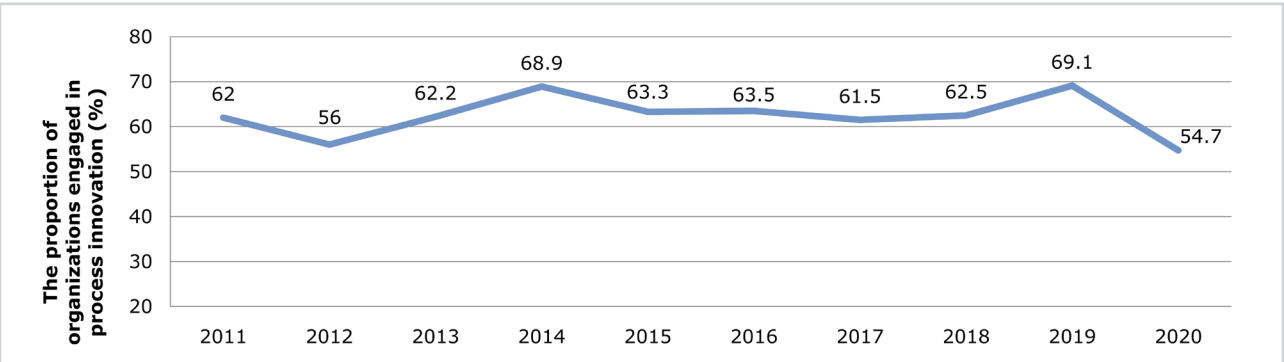

Figure 3:
The proportion of organizations having implemented process innovations (%)
Source: Calculated by the authors

Table 2:
Correlation analysis of the proportion between organizations having implemented product innovations and the expenditures intensity on innovations in technology in 2011-2020

Correlation analysis	
The percentage of organizations having implemented product innovations	**Intensity of expenditures on technological innovations**
66	4.1
66	3.9
62.2	4.6
66.7	5.3
59.2	4.2
59.6	6
59.6	5.6
60.7	5.5
52.7	5.4
64.2	3.9
Correlation analysis results	
1.00	-0.51
-0.51	1.00

Source: Calculated by the authors

Table 3:
Correlation analysis of the proportion between organizations having implemented process innovations, and the intensity of expenditures on technological innovations in 2011-2020

Correlation analysis	
The percentage of organizations having implemented process innovations	**Intensity of expenditures on technological innovations**
62	4.1
56	3.9
62.2	4.6
68.9	5.3
63.3	4.2
63.5	6
61.5	5.6
62.5	5.5
69.1	5.4
54.7	3.9
Correlation analysis results	
1.00	0.62
0.62	1.00

Source: Calculated by the authors

4. Conclusion

As a consequence of the conducted research, the following outcomes may be drawn. The analysis of the proportion between product and process innovations when implementing air and space vehicles into production at Russian enterprises shows that both innovations are given attention. The cost behavior analysis of technological innovations has shown that in the analyzed period, there were trends towards increasing the expenditures on process innovations that, in a long-term perspective, could bring significant changes in production (Trifilova, 2005). During the period under review, almost every year a large proportion of expenditures was accounted for by process innovations, except for 2019, when this proportion was 45.43%, while in other years, the share was more than 50%, and reached even maximal value of 77.99% in 2011. The implementation of innovations increases the determining factor of the company's performance, i.e., competitiveness in contemporary market relations.

Prospects for the development of air and space vehicles can be divided into certain categories. The space industry has received a new breath over the past five years. The number of space startups has increased dramatically as this industry sector was able to attract significant investments. It is quite difficult to assess the real prospects of the space vehicle production sector because they are based on forecasts about the relevance and return of the spent funds that have not yet been implemented. But this area is developing, and in the future, it may become of great importance for the state. The remotely-piloted aerial vehicle (RPAV) industry sector is very promising and many countries have been actively implementing new technologies in this area for a long time. The RPAVs can perform different tasks, and even now, with the implementation of advanced technologies, it is possible to replace traditional air and space vehicles with RPAVs completely.

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