VIRTUAL ECONOMICS

67

ISSN 2657-4047 *(online)*

2020 Volume 3 Number 3 (July)

# EVALUATING THE RELATIONSHIP BETWEEN INVESTMENT IN INNOVATION AND THE VOLUME OF SOLD INNOVATIVE PRODUCTS IN THE INDUSTRY OF UKRAINE

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**Abstract.** Applying the correlation and regression analysis, the study of the relationship between the volume and structure of innovation costs and the volume of sold innovative products (SIP) in industry was carried out on the example of Ukraine. The time lag of the costs-of-sales impact was also considered. It was hypothesized that the total volume of sold innovative products and their structure (the share of new products for the market, the share of products sold abroad) depend on different types of investment in innovation. The correlation and regression analysis showed that the components of investment in innovation influenced differently the volume and structure of SIP, which confirmed the hypothesis. The total amount of SIP largely depends on the level of costs to purchase machinery, equipment and software, as well as costs related to the component "Other". Positive dynamics of sold innovative products that are new to the market, as well as the products sold abroad, is largely determined by the volume of expenditures on external scientific research. Thus, by influencing the structure of investment in innovation, a company can significantly increase the level of its competitiveness.

***Keywords:*** innovations, costs of innovation activity, structure of innovation costs, industry, innovative products, level of competitiveness

***JEL Classification:*** D920, O310

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**Citation**: Kovchuha, L. (2020). Evaluating the Relationship between Investment in Innovation and the Volume of Sold Innovative Products in the Industry of Ukraine. *Virtual Economics, 3*(3), 67-79. https://doi.org/10.34021/ve.2020.03.03(4)

Received: December 27, 2019. Revised: March 24, 2020. Accepted: June 3, 2020.

## 1. Introduction

Investment in innovation is one of the important factors of enterprises' innovative development. Investment is a dominant factor in the stable development of the economy. Innovation and investment are two inextricably connected economic processes. Investments form financial resources needed to implement most innovations, especially technological ones. That is why most researchers consider investment and innovation processes as interdependent phenomena.

## 2. Literature Review

There is a considerable number of studies evaluating the relationship between innovation costs and company performance. For example, Morris (2018) empirically proved that innovatively active companies are much more productive in the manufacturing sector as well as in the sector of services. A positive impact of product innovations on the companies' efficiency in developing countries was revealed in the work by Ramadani et al. (2019). The results of this study showed that company performance is most positively influenced by such factors as personnel qualifications, modern technologies and cooperation with foreign companies. The econometric analysis, presented in the work by Ciocanel et al. (2015), was conducted to confirm the existence of a cause-and-effect relation between innovation and competitiveness on the example of then 28 countries of the European Union. The analysis of innovation impact on competitiveness has confirmed that an "innovation paradigm" is resilient to restoring the competitive advantages lost by the countries during the economic crisis.

However, a positive relationship between innovation and productivity is not always clear. The study presented by Haltiwanger et al. (2003) showed that the application of advanced technologies gave a larger work productivity increase in the United States than in Germany. In the work by Carvalho et al. (2016), the insignificant impact of innovations on the productivity of Brazilian enterprises was empirically proven. The Ukrainian scientists have found that in the industrial regions of Ukraine the factor of research and development and innovation does not play a meaningful role in forming a gross regional product (Soldak & Shamileva, 2018). The analysis of the literature shows a significant interest of scientists in the problem of the relationship between innovation costs, company performance and competitiveness of the national economies. However, there is still no consensus among the economists on the benefits of innovation as a determinant of the productivity increase (Alymov et al., 2014; Amosha et al., 2019; Amosha et al., 2018; Boiko et al., 2019; Czyżewski et al., 2019; Dementyev & Kwilinski, 2020; Dzwigol, 2020a; 2020b; Dzwigol et al., 2019a; 2019b; 2019c; 2020b; Dźwigoł & Wolniak, 2018; Golovatyuk et al., 2018; Jamel et al., 2020; Furmaniak et al., 2018; 2019a; 2019b; Kuzior et al., 2019; Kuzior & Kuzior, 2020; Kwilinski, 2019; Kwilinski & Kuzior, 2020; Kwilinski et al., 2019a; 2019b; 2019c; 2019d; 2020a; 2020b; 2020c; 2020d; 2020e; Miśkiewicz, 2018; Miśkiewicz, & Wolniak, 2020; Pająk et al., 2016; 2017; Savchenko et al., 2019; Tkachenko et al., 2019a; 2019b; 2019c; 2019d). The research results differ both in terms of types of innovation, and among countries.

Unlike the majority of the existing works, this article has the objective to evaluate the relationship not only between innovation costs and their results, but also to identify the dependence of the volume of sold innovative products (SIP) and their share, which is new to the market, as well as the volumes of products sold outside Ukraine, on the various types of innovation costs.

## 3. Methodology

To achieve the objective set, the methods of analysis and synthesis, comparative analysis and correlation-regression analysis were applied. The application package "Statistika" software was used. The industry of Ukraine was chosen as the object for observation. The specificity of the statistical information available determined 2017 as the time framework of the analysis. The research hypothesis is formulated as follows: the total volume of SIP and its share, which is new for the market, as well as SIP volume outside Ukraine, depend on different types of investments in innovation. Therefore, the following tasks were set:

- to study the interdependence between the volume and structure of costs for innovation activities and the volume of sold innovative products, taking into account the time lag of the impact of costs on sales volumes;
- to research the relationship between the costs of innovation and the volume of sold innovative products that were new to the market;
- to study the relationship between innovation costs and the volume of sold innovative products in the overseas markets.

The relationship between SIP volumes and total volumes of investment, including innovation, is stochastic. First of all, this is due to the fact that sales volumes, in addition to costs, are influenced by other factors, including market conditions in domestic and foreign markets, the level of knowledge-intensive economic activities and others. Under such conditions, determining the relationship between costs and results of innovation and its quantitative measurement is based on the econometric modelling, in particular, correlation-regression dependencies.

Regression models are based on the following initial hypothesis: the innovation costs affect the change in the volume of SIP both directly "year after year", and with one- or two-year time lag. A general view of regression models will be as follows:

$$Yx_{i,t} = F(x_{i,t}); or\ Yx_{i,t} = F(x_{i,t-1});\ Yx_{i,t} = F(x_{i,t-2}) \tag{1}$$

where $Yx_{i,t}$ is estimated sales of innovative products in the t year;
$x_{i,t}$ are expenditures for the t year;
$x_{i,t-1}$; $x_{i,t-2}$are the costs for (t-1) and (t-2) years respectively;
$i$ is the areas of innovation.

Expenditures in those areas of innovation which are presented in statistical books are: $x_1$ is total expenditures on innovation; $x_2$ is costs of internal scientific research and development (R&D); $x_3$ is costs of external scientific research and development; $x_4$ is the purchase of machinery, equipment and software; $x_5$ is acquisition of existing knowledge from other enterprises or organizations; $x_6$ is other types of costs. Regression models are built on the official statistics of Ukraine, presented in the State Statistics Service of Ukraine (2018, pp. 90, 103, 105).

The form of the regression model which most adequately corresponds to the developed dependences is chosen based on the combination of optimum approximation criteria : $min\,\Sigma\left(Y - Yx_{i,t}\right)^2$, a criterion of the least-squares method, max F-criterion (Fisher-Snedecor), $min\,E_{rel}$ (relative approximation error), and the regression model must be statistically significant by F-criterion $\left(F_p > F_\alpha\right)$. Under such conditions, the model parameters objectively reflect the dependence that was developed on the set of objects that act as observation points.

## 4. Results and Discussion

The 2017 identified pair dependences indicate that there was a fairly close relationship between the volume of SIP $(Y_1)$ and the total costs of innovation $(x_1)$ (See equations (2) and (3).

$$\begin{gathered} Y_1x_1 = 475{,}935 - 1{,}137x_1 + 0{,}003{x_1}^2; \\ Dy_1x_1 = 0{,}697;\ F_p = 11{,}5;\ F_\alpha\{\alpha = 0{,}05;\ \upsilon 1 = 2;\ \upsilon 2 = 7\} = 4{,}74; \end{gathered} \tag{2}$$

$$\begin{gathered} Y_1x_1 = 5{,}87{x_1}^{0{,}802}; \\ Dy_1x_1 = 0{,}616;\ F_p = 17{,}6;\ F_\alpha\{\alpha = 0{,}05;\ \upsilon 1 = 2;\ \upsilon 2 = 8\} = 5{,}32; \end{gathered} \tag{3}$$

The density link is approximately the same, taking into account the one-year time lag. This is shown in equations (4), (5), (6). The calculated coefficients of determination $(Dy_1x_1)$ show that, on average, the change in the volume of sold innovative products by 60.0% - 70.0% is due to the change in the total costs for innovation.

$$\begin{gathered} Y_1x_1 = 5{,}16 + 1{,}87x_1 - 0{,}0001{x_1}^2;\ Dy_1x_1 = 0{,}703;\ F_p = 11{,}84 \\ Y_1x_1 = 5{,}16 + 1{,}87x_1 - 0{,}0001{x_1}^2;\ Dy_1x_1 = 0{,}703;\ F_p = 11{,}84 \end{gathered} \tag{4}$$

$$Y_1x_1 = 475{,}935 - 1{,}137x_1 + 0{,}003{x_1}^2;\ Dy_1x_1 = 0{,}697;\ F_p = 11{,}5 \tag{5}$$

$$Y_1x_1 = 40{,}0{x_1}^{0{,}553};\ Dy_1x_1 = 0{,}533;\ F_p = 12{,}54 \tag{6}$$

When analysing the impact of total costs in certain areas of innovation, it was determined that the greatest change in the volume of SIP entails the costs of purchasing machinery, equipment and software. The density link is about 0.93 (see equation (7). The most condensed link was formed when estimating the impact of costs on the volume of SIP in the same year (2017) (see equations (7) and (8). Therefore, we can conclude that the volume of sold innovative products depends on those investments in innovation that were made in the same period. The elasticity of change in equation (8) is 0.701, that is, each % of costs in this area is accompanied by an increase in SIP by 0.701 %.

$$Y_1x_4 = 413{,}44 - 0{,}752x_4 + 0{,}004{x_4}^2;\ Dy_1x_4 = 0{,}93;\ F_p = 65{,}5 \quad (7)$$

$$Y_1x_4 = 413{,}44 - 0{,}752x_4 + 0{,}004{x_4}^2;\ Dy_1x_4 = 0{,}93;\ F_p = 65{,}5$$

$$Y_1x_4 = 16{,}5{x_4}^{0{,}701};\ Dy_1x_4 = 0{,}628;\ F_p = 18{,}5 \quad (8)$$

The second most condensed factor $x_6$ includes the costs of other types of innovation (staff training, market adaptation of innovations, design development, etc.), which is proved by significant coefficients of determination (0.752 and 0.532). The dependence of SIP on the factor $x_6$ was calculated taking into account the one-year time lag – equations (9), (10) and two-year time lag – equation (11).

$$Y_1x_6 = 26{,}83 - 30{,}31x_6 - 0{,}057{x_6}^2;\ Dy_1x_6 = 0{,}752;\ F_p = 15{,}5 \quad (9)$$

$$Y_1x_6 = 26{,}83 - 30{,}31x_6 - 0{,}057{x_6}^2;\ Dy_1x_6 = 0{,}752;\ F_p = 15{,}5$$

$$Y_1x_6 = 126{,}2{x_6}^{0{,}55};\ Dy_1x_6 = 0{,}532;\ F_p = 12{,}5 \quad (10)$$

$$Y_1x_6 = 126{,}2{x_6}^{0{,}55};\ Dy_1x_6 = 0{,}532;\ F_p = 12{,}5$$

$$Y_1x_6 = 361{,}4{x_6}^{0{,}291};\ Dy_1x_6 = 0{,}233;\ F_p = 3{,}34 \quad (11)$$

$$Y_1x_6 = 361{,}4{x_6}^{0{,}291};\ Dy_1x_6 = 0{,}233;\ F_p = 3{,}34$$

The study showed a rather moderate link between the volume of SIP and the costs of external R&D $(x_3)$ with a one-year lag. They cause the change in SIP by 30.2% – equation (12); with a two-year lag , the link was rather weak. It is determined that the costs of other areas of innovation (internal research $(x_2)$, and acquisition of other external knowledge $(x_5)$ have a very little effect on the SIP dynamics.

$$Y_1x_3 = 1126{,}6 - 16{,}01x_3 + 0{,}26{x_3}^2;\ Dy_1x_3 = 0{,}302;\ F_p = 2{,}16 \quad (12)$$

$$Y_1x_3 = 1126{,}6 - 16{,}01x_3 + 0{,}26{x_3}^2;\ Dy_1x_3 = 0{,}302;\ F_p = 2{,}16$$

There have been identified multifactor regression models, which determine the impact of all types of costs on the total amount of SIP in the areas of innovation: a linear model in kind – equations (13), (14):

$$Y_1 x_i = -149{,}61 + 2{,}641 x_2 - 29{,}607 x_3 + 0{,}001 x_4 + 149{,}1 x_5 + 21{,}76 x_6;$$

$$Y_1 x_i = -149{,}61 + 2{,}641 x_2 - 29{,}607 x_3 + 0{,}001 x_4 + 149{,}1 x_5 + 21{,}76 x_6;$$

$$Dy_1 x_i = 0{,}912;\ F_p = 4{,}5;\ F_\alpha\{\alpha = 0{,}05;\ \upsilon 1 = 5;\ \upsilon 2 = 7\} = 3{,}97; \quad (13)$$

Power model:

$$Y_1 x_i = 19{,}03 {x_2}^{0{,}367} {x_3}^{-0{,}251} {x_4}^{0{,}282} {x_5}^{0{,}128} {x_6}^{0{,}346} \quad (14)$$

$$Y_1 x_i = 19{,}03 {x_2}^{0{,}367} {x_3}^{-0{,}251} {x_4}^{0{,}282} {x_5}^{0{,}128} {x_6}^{0{,}346}$$

It is established that the set of factors of the multifactor regression model (13) causes the change in the volume of SIP in the set of industries by 91.2%. All factors, except $x_3$, directly affect the change in the volume of SIP. Partial coefficients of elasticity of the power function (14) show probable influence of factors: 1% of the costs of internal research provides an increase in SIP by 0.367%, an increase of 1% in other innovations increases the volumes of SIP by 0.346%, an increase of 1% in machine costs provides the increase in SIP by 0.282%.

A very important characteristic of the innovation effectiveness is the indicators of the volume of sold innovative products which were new to the market and which were sold outside Ukraine. The change in the volume of sold innovative products new to the market is only 30% due to the impact of the total costs of innovation (see equations (15), (16)). There is a direct dependence with a moderate density link.

$$Y_4 x_1 = -18{,}93 - 0{,}664 x_1 - 0{,}0001294 {x_1}^2;\ Dy_4 x_1 = 0{,}308;\ F_p = 2{,}22 \quad (15)$$

$$Y_4 x_1 = -18{,}93 - 0{,}664 x_1 - 0{,}0001294 {x_1}^2;\ Dy_4 x_1 = 0{,}308;\ F_p = 2{,}22$$

$$Y_4 x_1 = e^{-1{,}112} {x_1}^{0{,}952};\ Dy_4 x_1 = 0{,}294;\ F_p = 4{,}58 \quad (16)$$

$$Y_4 x_1 = e^{-1{,}112} {x_1}^{0{,}952};\ Dy_4 x_1 = 0{,}294;\ F_p = 4{,}58$$

The largest change in the volume of SIP which are new to the market is determined by the volume of costs for the purchase of machinery, equipment and software $(x_4)$ – equation (17). The theoretical coefficient of elasticity determined by equation (18) shows that each increase of percentage in costs in this area is accompanied by an increase in sales of innovative products new to the market by 79.5%.

$$Y_4 x_4 = -96{,}358 + 1{,}812 x_4 - 0{,}001 {x_4}^2;\ Dy_4 x_4 = 0{,}416;\ F_p = 3{,}57 \quad (17)$$

$$Y_4 x_4 = -96{,}358 + 1{,}812 x_4 - 0{,}001 {x_4}^2;\ Dy_4 x_4 = 0{,}416;\ F_p = 3{,}57$$

ISSN 2657-4047 (online)

$$Y_4x_4 = e^{0,31}{x_4}^{0,795};\ Dy_4x_4 = 0,274;\ F_p = 4,15 \tag{18}$$
$$Y_4x_4 = e^{0,31}{x_4}^{0,795};\ Dy_4x_4 = 0,274;\ F_p = 4,15$$

Regarding the impact of costs with a one-year lag , all types of costs in the areas of innovation were taken into account. It was found that the strength of the impact of 2016 total costs on the volume of SIP new to the market almost coincides with the results of 2017. There is a direct impact with moderate density link: each percentage increase in costs is accompanied by an increase in sales volumes of the new to the market innovative products by 0.65% (19). When estimating the impact of costs on separate areas of innovation, the highest density link was formed with $x_4(Dy_4x_4 = 0,3)$, $x_2(Dy_4x_2 = 0,286)$, $x_6\ (Dy_4x_6 = 0,216)$. There is a direct moderate dependence in these areas of costs. The growth of each factor is accompanied by an increase in the volume of new to the market SIP. Taken together, these three factors account for almost 50% of changes in sales of innovative products that are new to the market (20), and standardized ratios (21) show twice the impact of costs of domestic R&D than other areas of costs.

$$Y_4x_1 = e^{0,651}{x_1}^{0,65};\ Dy_4x_1 = 0,285;\ F_p = 4,38 \tag{19}$$
$$Y_4x_1 = e^{0,651}{x_1}^{0,65};\ Dy_4x_1 = 0,285;\ F_p = 4,38$$

$$tY_4x_1 = 0,52tx_2 + 0,283tx_4 + 0,288tx_6 \tag{20}$$
$$tY_4x_1 = 0,52tx_2 + 0,283tx_4 + 0,288tx_6$$

$$Y_6x_1 = e^{1,18}{x_1}^{0,672};\ Dy_6x_1 = 0,243;\ F_p = 3,2 \tag{21}$$
$$Y_6x_1 = e^{1,18}{x_1}^{0,672};\ Dy_6x_1 = 0,243;\ F_p = 3,2$$

Thus, the change in the volumes of sold innovative products which are new to the Ukrainian market is determined by a third of the previous-year costs of internal research and the purchase of machinery, equipment and software.

The dependence of the volume of sold innovative products outside Ukraine $(Y_6, Y_7)$ on the basis of regression models shows that there is a close link with the total costs of innovation $(x_1)$, which were made in the previous period, that is, with a one-year lag (22):

$$Y_6x_1 = 152,2 + 0,186x_1 - 0,0000014{x_1}^2;$$
$$Y_6x_1 = 152,2 + 0,186x_1 - 0,0000014{x_1}^2;$$
$$Dy_6x_1 = 0,932;\ F_p = 53,8;\ F_\alpha\{\alpha = 0,05;\ \upsilon1 = 2;\ \upsilon2 = 9\} = 4,26; \tag{22}$$

A differential analysis of the impact of expenditures on separate areas of innovation indicates virtually no link between the volume of SIP outside Ukraine and the costs of domestic research $(x_2)$ – equations (23), (24), (25), (26) – where the link density is very low. This indicates the lack of knowledge and skills at enterprises to implement research and development on their

 ISSN 2657-4047 *(online)*

own at the required level, sufficient to produce innovation and products competitive in the foreign markets.

$$Y_6x_2 = 662{,}43 - 2043{,}7\frac{1}{x_2}Dy_6x_2 = 0{,}047;\ F_p = 0{,}5 \tag{23}$$
$$Y_6x_2 = 662{,}43 - 2043{,}7\frac{1}{x_2}Dy_6x_2 = 0{,}047;\ F_p = 0{,}5$$

$$Y_6x_2 = e^{4{,}6}{x_2}^{1{,}162};\ Dy_6x_2 = 0{,}032;\ F_p = 0{,}33 \tag{24}$$
$$Y_6x_2 = e^{4{,}6}{x_2}^{1{,}162};\ Dy_6x_2 = 0{,}032;\ F_p = 0{,}33$$

$$Y_6x_2 = 574{,}42 - 1204{,}6\frac{1}{x_2}Dy_6x_2 = 0{,}081;\ F_p = 0{,}885 \tag{25}$$
$$Y_6x_2 = 574{,}42 - 1204{,}6\frac{1}{x_2}Dy_6x_2 = 0{,}081;\ F_p = 0{,}885$$

$$Y_6x_2 = e^{4{,}316}{x_2}^{1{,}264};\ Dy_6x_2 = 0{,}121;\ F_p = 1{,}4 \tag{26}$$
$$Y_6x_2 = e^{4{,}316}{x_2}^{1{,}264};\ Dy_6x_2 = 0{,}121;\ F_p = 1{,}4$$

Expenditures on purchasing the machinery, equipment and software have a greater impact on the change in sales outside Ukraine, even coefficients of determination for all versions of the statement show that an increase of this type of costs by 25% - 28% determines the change in sales. However, the expenditures of the previous year have a more significant impact on the parameters of power regression (see equation (27)). Each increase of percentage in expenditures in this area causes an increase in SIP outside Ukraine by 0.533%. Expenditures on external R&D $(x_3)$ have even more significant impact on the dynamics of this indicator, taking into account the one-year lag – equation (28). Thus, the change in the volume of SIP outside Ukraine by 77.5% is due to the costs of external research, which were made in the previous year.

$$Y_6x_4 = e^{42{,}284}{x_4}^{0{,}533}Dy_6x_4 = 0{,}409;$$
$$Y_6x_4 = e^{42{,}284}{x_4}^{0{,}533}Dy_6x_4 = 0{,}409;$$
$$F_p = 6{,}92;\ F_\alpha\{\alpha = 0{,}05;\ \upsilon1 = 2;\ \upsilon2 = 10\} = 4{,}96; \tag{27}$$

$$Y_6x_3 = 278{,}23 - 14{,}4x_3 + 0{,}212{x_3}^2;$$
$$Y_6x_3 = 278{,}23 - 14{,}4x_3 + 0{,}212{x_3}^2;$$
$$Dy_6x_3 = 0{,}775;\ F_p = 15{,}54;\ F_\alpha\{\alpha = 0{,}05;\ \upsilon1 = 2;\ \upsilon2 = 9\} = 4{,}26; \tag{28}$$

The results of the study showed a significant link between investment in innovation and the production of innovative products. It is revealed that, on average, the change in the volumes of sold innovative products by 60.0% - 70.0% is due to the change in the total costs of innovation activities. A correlation-regression analysis also revealed a different impact of the components of innovations costs on the volume and structure of sold innovative products, which confirms the hypothesis. The total amount of SIP largely depends on the level of costs to purchase machinery, equipment and software. Each percentage of costs in this area is accompanied by an increase in SIP by 0.701%, as well as costs related to the component "Other". The growth of the costs by 1% leads to an increase in the volume of SIP by 0.55%. The positive dynamics of sold innovative products new to the market is mainly determined by the costs of internal research, machinery and equipment, as well as other costs. All together, these three factors cause changes in sales of almost 50%, but standardized ratios show twice as much impact of costs on domestic R&D than other areas of expenditure. Volumes of sold innovative products outside Ukraine are largely determined by the volume of expenditures on external research. Calculations have shown that the change in the volume of SIP outside Ukraine by 77.5% is due to the costs of external research, which incurred in the previous year. Thus, influencing the structure of innovation costs, a company can achieve maximum economic return from them and significantly increase the level of its competitiveness.

## 5. Conclusions

The results of the analysis confirmed the research hypothesis on the existence of the dependence of the total volume of sold innovative industrial products and its share that is new to the market, as well as the volume of products sold outside Ukraine, on different types of innovation costs. These results are consistent with the conclusions of most Ukrainian and foreign scientists on the existence of a close positive relationship between investment in innovations and company performance.

The study showed that, in general, the total costs of innovation is quite closely related to the amount of SIP both in the respective years and taking into account the one- and two-year lag of costs. It is determined that approximately 70% of the change in the volume of SIP is due to the direct dynamics of the total costs of innovation. Among the components of costs in the areas of innovation, the greatest impact, both in separate years and the lags, is observed in the costs of purchasing machinery, equipment and software. There is a high-density link between the volume of SIP and the costs in the direction of "Other".

The change in the volume of sold innovative products new to the market is only one third due to the impact of total expenditures on innovation in the current year. Expenditures for the previous year have a more significant impact. Each percentage of their growth causes an increase in sales in this area by 0.65%. Expenditures on external R&D, which were invested in the previous year, have the greatest impact on the change in the volume of new products sold in the market. The volume of SIP outside Ukraine mainly depends on the volume of total expenditures on innovation for the previous year. Each percentage of expenditures is accompanied by an increase in the volume of sold innovative products outside Ukraine in the following year by 0.62%. Expenditures on external R&D in the previous year have the most significant impact on the volume of SIP outside Ukraine.

Within the framework of further research, the development of proposals for optimizing the structure of innovation costs in the industry of Ukraine, taking into account the results of the evaluation, seems relevant.

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