R&D Investment Management as a Basis for Competitiveness: Methodological Support and Automotive Companies' Development Trends

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Abstract

The article examines the theoretical, methodological, and empirical issues of investment management in innovation. The competitiveness of enterprises in conditions of intense competition is based on innovations that require increasing amounts of investment. Investments in innovation should include investments in fixed assets, R&D investments, investments in personnel. Only such an integrated approach allows creating conditions for maintaining a high level of innovation activity. An improved analysis method is proposed to study investment in innovation, which identifies the following main stages: analysis of the dynamics of key indicators, the study of the impact of factors influencing R&D investment, analysis of the impact of investment in innovation on performance. Among the main methods used should be structural analysis, synthesis, correlation-regression analysis, and others. The processes of investing in innovation of automobile companies are characterized by complexity, high quantitative indicators, and are the basis of competitiveness.

Keywords: R&D investment; innovation activity; fixed assets; analysis; management; performance.

1. Introduction

The effective, innovative activity of the enterprise, which is the basis of its competitiveness in current conditions, depends on the action of many factors, but the main among of them is an investment in R&D. The ability of the enterprise to form or attract the investment necessary to ensure high activity and efficiency in the field of innovation, - these are the key tasks of modern management.

Industry leaders, especially in high-tech industries, are increasing their investment in innovation year after year and funding R&D at a higher level than in other companies and entire countries. The inability of other enterprises to provide investment in innovation at the level of major market players is a significant barrier to participation in the competition, which occurs based on "high" factors, and is the basis for further development of enterprises. Understanding the nature and quantitative and qualitative characteristics of investment in innovation at the corporate level determines the need for scientifically sound management of these processes, aimed at bridging the gap, which will allow companies to develop an economic capacity to invest in innovation. These issues are especially relevant for new enterprises and enterprises from developing countries, which lag behind the innovative characteristics of products due to the inability to ensure the development of innovation potential through its proper

financing. That is why the processes of formation of R&D investment and returns from them are relevant and require modern research, especially from the standpoint of integrated and systematic management.

2. The Purpose

The purpose of this manuscript is to conduct a comprehensive research of the processes of formation and using of innovation investment, as well as their impact on the results of the enterprise on the example of innovative companies. Based on this goal, it is advisable to outline the following main tasks:

- to systematize existing scientific papers that determine the understanding of the research subject;
- to improve the methodological procedures of a comprehensive study of R&D investment' processes;
- to investigate processes of R&D investment on the example of innovation-active companies;
- to identify the main elements (subsystems) of the innovation investment management system.

3. Theoretical Background

The processes of innovation investment by corporations have been studied by scientists and from different points of view. An important place in the study of innovation processes is determining the action of the most critical factors. The role of various factors of innovation is revealed in the works of Atkeson and Burstein (2010), Aghion, Bergeaud, Lequien and Melitz (2017), Gómez Vieites and Luis Calvo (2011), Smith, Busi, Ball and van der Meer (2008), Shukla and Singh (2015), Zennouche, Zhang and Bo (2014), others.

The external conditions of corporations are changing significantly: the world is being modernized (Vochozka, 2019; He, 2012), more and more business processes are being digitized (Hermann, Pentek and Otto, 2015; Yakovenko and Tarasenko, 2019; Kagermann, Lukas and Wahlster, 2011), there is a change in the social environment (Huybrechts and Nicholls, 2012; Kozhemiakina, Vochozka, Romanenko and Glukhova, 2019; Păunescu, Drăgan, Cantaragiu and Filculescu, 2013), several problems are solved through integration that changes competitive conditions (Sardak, Radziyevska and Prysiachniuk, 2019).

The target orientation of enterprises is complicated: if previously the goals of achieving financial results prevailed, now companies must increase efficiency in the field of technology and the field of environmental responsibility (Baumgartner and Ebner, 2010; Haessler, 2020; Strand, 2014). Companies can take a leading position in the market only by ensuring efficiency in innovation and increasing their investment.

The amount of finance in R&D is determined, first of all, by the size of the enterprise. The dependence of the amount of investment on the size of the enterprise is revealed in the works by Baldwin and Gellatly (2003), Başgoze and Cem Sayin (2013), Connolly and Hirschey (2005), Czarnitzki and Binz (2008).

For example, Stam and Wennberg (2009), Dushnitsky and Lenox (2005) investigate the role of R&D investment in the growth of new companies and concluded that they are significant in the early stages for high-tech companies' development. However, it is at this stage that companies have limited opportunities to form R&D investments.

On the example of German companies, Rammer and Schubert (2016) studied innovation activity depending on the size of enterprises and concluded that small firms often suspend innovation due to lack of funds, but over time even launch of innovation processes becomes more challenging. Refusal to innovate, for example, during the crisis, leads to a deterioration of the enterprise's market position in the long run.

Based on the generalization of the experience of Australian companies, analysts have concluded that there are significant differences between the size of firms and the content of innovation processes. Thus, innovations in small firms aim to increase productivity and solve current problems rather than create new products for consumers. This indicates that companies of different sizes choose the optimal form of R&D, which depends on their investment ability. Large firms conduct full-fledged research, and they provide the lion's share of R&D expenditures in Australia. (Australian Business Investment, 2020)

Another important factor of innovation is export activity, which encourages and promotes the intensification of innovation processes. For example, Atkeson and Burstein (2010), Aghion, Bergeaud, Lequien, and Melitz (2017), Maslak, Ishchenko, Grishko and Maslak (2019) consider models that reflect the relationship between trade and innovation. Scientists conclude that the basis of active export activity is the implementation of complex and systemic innovations.

In our opinion, it is expedient to consider these connections from another point of view and to consider the export

orientation of the enterprise as a driver of innovative processes in terms of their content, forms and volumes of necessary investments to meet the requirements of the world market.

To intensify export activities and increase the level of presence in the markets of all continents, companies are establishing their branches in different countries. Such sales and production activities are used to generate creative ideas and new technologies by creating international teams of inventors. Studies by Daiko T., Dernis H., Dosso M., Gkotsis P., Squicciarini M., Vezzani A. (2017) have demonstrated this feature of modern innovation-active companies.

The following important area of research of innovation processes is their complexity and systematization.

According to the OECD, Frascati Manual (2015), different innovation activities include Research and Experimental Development (basic research, applied research, experimental development) and Innovation (Product innovations and Business process innovations).

Complex and systemic innovation processes are the basis of enterprise competitiveness in the long run. This is fully confirmed by the experience of Chinese companies trying to move from the model of financing R&D, which helps to imitate, to the model of R&D of full-fledged innovators (König, Storesletten, Song and Zilibotti, 2020).

An important condition for ensuring systematic innovation management is the formation of a complete innovation chain of value creation, ie all stages of the process of transforming knowledge into business value, the modeling of which is presented in detail in (Roper, Du and Love, 2008).

For the formation of a complete chain of innovation processes in corporations, it is important to form elements of the ecosystem, particularly the formation of the innovation system (Kasych, 2013), the development of university education (Khovrak, 2019; Pochtovyuk, 2015), which generally affects the development of intellectual resources (Sardak and Sukhotepli, 2013; Sardak and Samoylenko, 2014; Prokopenko, Zięba and Olma, 2016).

Ortega-Argilés, Piva, Potters and Vivarelli (2009), Maslak, Grishko, Hlazonova and Vorobiova (2017) concluded that R&D investment is more efficient in high-tech sectors than low-tech sectors, where productivity growth is a more critical factor in productivity growth.

The key issue in R&D investments is their financial support, which is provided by various sources. Czarnitzki and Binz (2008), Kasych (2011) and Tkachenko (2011) concluded that domestic funds are more important for R&D investment. It is much more difficult to finance R&D from external resources, especially in small firms.

Aghion, Askenazy and Berman (2012) studied the nature of R&D investments, their cyclicity in accordance with credit constraints.

One of the biggest problems of R&D investment is the formation of the required amount of financial resources. Scientists Thakor and Lo (2017) developed a model of optimal capital structure for companies implementing long-term projects with a low probability of success.

Woerter (2014) investigated the impact of market competition on the sustainability of R&D persistence of R&D active firms and concluded that R&D expenditures in markets with a small number of competitors would be more sustainable.

The return on R&D investment is a key issue for their implementation, as they are quite expensive, even for powerful companies, and the effects can be probabilistic (Das, Kumar and Kumar, 2009; Guo, Wang and Wei, 2018; Jung and Kwak, 2018; Lantz and Sahut, 2005). The effectiveness of investment in R&D is considered differently from the standpoint of economists, politicians, accountants. The effect of R&D investment Hall, Mairesse, and Mohnen, 2010 was studied from the total factor productivity (TFP) point of view.

The impact of R&D investment on performance based on

the generalization of the Internet of Things Industry experience is presented in (Xu and Jin, 2016). The authors concluded that the total investment in R&D has a negative impact on the company's performance, while investment in labor and investment has a more significant positive effect.

Zang, Zhu and Mogorrón-Guerrero (2019) argue that the results of R&D investments should be considered in the long run, and therefore they are of strategic importance. Lantz and Sahut (2005) also call R&D investment strategic because they determine the strategic guidelines of the firm and have the most significant impact on the production cycle. The effects of investing in R&D are to strengthen market position, increase sales, but their effect on revenues and direct financial performance is questionable.

Conte and Vivarelli (2013) discusses the nature of the impact of R&D investment on the introduction of new products. The sustainability of innovations (outputs) is determined by the sustainability of investment in R&D (inputs) and previous experience – say Triguero and Córcoles (2013).

The innovative activity of the enterprise significantly affects its market value. This conclusion was reached by Başgoze and Cem Sayin (2013), who studied the power of R&D investment to explain the profitability of the company's shares.

Summarizing all the above, we can identify the following main areas of research:

- the role of investment in innovation in the development of enterprises, including at different stages of the life cycle, i.e., in conditions of varying size and industry affiliation of enterprises (Stam and Wennberg (2009), Roper, Du and Love (2008);

- determining the optimal amount of investment in R&D (Thakor and Lo, 2017);

- evaluation of the return on R&D investment (Hall, Mairesse and Mohnen (2010), Xu and Jin (2016);

- study of the impact on the value of the enterprise (Başgoze and Cem Sayin (2013), Horak, Krulicky, Rowland and Machova (2020).

The diversity of the presented areas actualizes the study of R&D investment processes based on an integrated approach using modern methods and non-standard methods, as it will allow considering the processes depending on the action of certain factors and business results.

4. Results

4.1. Clarification of the concept of "investment in innovation".

Among the important research topics of the nature of investment in innovation is the clarification of the conceptual apparatus. In innovation management, two terms, "investment in R&D" and "R&D expenses," are used. The essence of the concept of "investment in R&D" is presented in the works of Ortega-Argilés, Piva, Potters and Vivarelli (2009), Czarnitzki and Binz (2008), Zang, Zhu and Mogorrón-Guerrero (2019), Jung and Kwak (2018). The term "R&D expenses" is used in the works of Damodaran (1999), VanderPal (2015), Apergis and Sorros (2014), Nissim and Thomas (2000).

There are many similarities between innovative investments and R&D expenditures, but at the same time, there are significant differences between them. The similarity is that these are resources invested in securing future income, and therefore it is advisable to use traditional methods of investment analysis to study them. In addition, the fact that investments in fixed assets and R&D investments are innovative should be taken into account. The differences between the studied concepts are more significant. Thus, capital investments are directed to assets that exist in tangible form. As a result of innovative investments, an intangible product is created, for example, knowledge, methods,

algorithms, etc. Innovative investments are directed to the salaries of researchers and engineering staff, which corresponds to the cost characteristics. As a result of innovative investments, the result obtained is embedded in the staff and their qualifications, i.e., it is necessary to retain scientists and engineers who would have the knowledge and promote their professional growth.

The second big difference between the two types of investments is the level of uncertainty in their profitability, which has several consequences. Investments in fixed assets have clear reproduction horizons through depreciation, according to the method chosen by the company. R&D investments, as a rule, have a low embodiment in the current revenue of the enterprise, and their role in future profits at the time of implementation is very difficult to measure.

Summarizing the above-mentioned, appropriate to state that innovative investments, compared to other alternative uses of financial resources of the enterprise, have the following characteristics:

- ❑ aimed at producing innovations;
- ❑ should be aimed at providing the company with highly qualified scientists and engineers;
- ❑ is strategically important for activities in all areas and determine the trajectory of enterprise development;
- ❑ generate profit for the company with a certain time lag;
- ❑ embody several risks that depend, among other things, on the dynamics of scientific and technological progress, and therefore enterprises do not manage them.

Innovation is a rather broad concept, respectively, investment in innovation is aimed at (Australian Business Investment, 2020, p.7):

first, financing activities to create new or improve existing products, as well as business processes that differ significantly from those produced/used (Research & experimental development (R&D) (basic research, applied research, experimental development, may be performed by the firm or acquired externally); non-R & D / other innovation (non-R&D design, planning & testing, IP acquisition, acquisition of innovation-related machinery, equipment & technology, innovation-related marketing, training, or business process changes);

secondly, financing activities to create conditions for the intensification of innovation processes, i.e., new opportunities for innovation. Thus, fixed assets form the material basis for production, and accordingly, the production of innovative products requires constant updating of fixed assets. The more dynamic the industry's scientific and technological progress to which the company belongs, the greater the dynamics of investment in the renewal of fixed assets. Some types of equipment need to be replaced every 5-7 years;

third, investment in staff development. In modern conditions, enterprises-innovators, understanding the decisive role in the innovation processes of engineering and technical personnel, not only create conditions for highly efficient activities but implement a comprehensive policy of professional development through which they contribute to staffing development and creativity;

fourth, investment in intangible assets. The modern world market of high-tech products makes clear quantitative and qualitative requirements for product characteristics. And, if the company implements a development strategy, then its products must meet these requirements. Companies that are unable to provide innovation activity at the required level independently, ensure the production of competitive products through the acquisition of intangible assets. Innovative enterprises through intangible assets reflect in value the intellectual property of the enterprise, in particular patents.

Therefore, to study the nature of investment in innovation, direct investment in R&D, investment in the renewal of fixed

assets, and the cost of development of scientific and technical staff.

Based on the approach of comparing inputs and outputs, costs and results, the nature of investing in innovation should be presented in the form of such a structural and logical scheme (Fig. 1).

Figure 1. Components of investment in innovation and the mechanism of their impact on financial results
Source: developed by the authors

Thus, innovative investments are investments aimed at creating complex conditions for the organization and implement innovative activities on a systemic basis. Accordingly, the management of innovative investments should be considered in the overall investment management system, and therefore ensure the coordination of investment and innovative development of the enterprise. The choice of priorities depends on strategic priorities, the state of fixed assets, the activity of innovation processes, and others. So, the company solves the problem of redistribution of financial resources between investment and innovation development goals.

A comprehensive study of investment in innovation is important for both the company and competitors, as it allows to assess the potential of the company to intensify these processes. Moreover, increasing investment in innovation is expected to increase the company's performance in the innovation sector and overall performance.

Based on these assumptions, we can formulate the following hypotheses of this study.

- ❑ Hypothesis 1 (H1). R&D expenditures are the main form of investment in innovation.
- ❑ Hypothesis 2 (H2). R&D investment depend on the cyclical nature of economic processes and hence on the dynamics of revenues and production volumes.
- ❑ Hypothesis 3 (H3). The increase in R&D investment has a significant impact on the company's performance.

4.2. Methods of comprehensive research of R&D investment.

The investment in innovation is a complex process to ensure a comprehensive study of them, and we need to clarify the methodology.

The main directions of research of investments in innovations which are offered:

- ❑ comprehensive analysis of the amount of investment in innovation and its dynamics;
- ❑ study of the factors of investments in innovation;
- ❑ study of the impact of investment in innovation on performance.

The first stage of studying the nature of investment in innovation is to study their size and dynamics.

To understand the nature of investment in innovation, it is necessary to identify key characteristics of innovation processes. Among the key should be noted: stability and security.

Sustainability in (Rammer and Schubert, 2016) is called the main characteristic of innovation and R&D processes. Decreased innovation activity of firms, even in the short term, which saves financial resources, but to restart the innovation process may be a lack of not only financial resources but also competencies.

Security of innovation is ensured by implementing an intellectual property strategy through the use of patents, trademarks, and designs. Innovative branding strategies of the world's leading investors in R&D in the field of ICT have been studied in the paper of Daiko, Dermis, Dosso, Gkotsis, Squicciarini and Vezzani (2017). Researchers claim that industry leaders register 75% and 60% of global ICT-related patents and designs.

The main approaches to the analysis of the impact of investment in innovation on performance are disclosed in the works

Accordingly, to conduct a generalized analysis of investment in innovation, the following indicators should be used: total value of R&D investment, rate of dynamics, the share of R&D investment in income, structure of R&D investment, amount of R&D investment per employee, including one researcher – technical worker, the amount of investment in R&D per unit of output.

The second stage of the study of the nature of investment in innovation is the analysis of the dependence of their value on key factors that have quantitative characteristics and can be investigated by correlation-regression analysis. Of course, the mechanism of action of the main factors is determined by the scale of the enterprise, but understanding the dependence of R&D expenditures on quantifiable indicators can significantly increase the analytical support of management decisions in the field of innovation.

The process of innovations production is a complex process that depends on many factors. The key factors of influence are:

income from sales (x1) – the greater the scale of activity and income from sales, the greater the financial potential and, consequently, the ability of the enterprise to make investments. In modern conditions, at the stage of analysis and in the

process of management, leading enterprises began to use the indicator of the share of income as a key indicator of innovation and investment activity;

profit after income tax (x_2) is an important source of enterprise development, and therefore, at the discretion of shareholders, can be fully directed as an investment in innovation;

fixed assets investments (x_3) are by their nature investments in innovations, as they aim to acquire new fixed assets. Investments in fixed assets have a direct impact on the production process, and therefore their implementation is a priority for the company at any stage of development;

the number of staff engaged in research (x_4) – to ensure the productive work of NT staff requires large-scale investment in fixed assets and directly and R&D;

the value of intangible assets (x_5) in the form of patents, licenses, and other forms is the result of investment in innovation and needs support in the future;

the value of fixed assets (x_6) must be updated and increased, and therefore this indicator affects the amount of both investments in fixed assets and investment in R&D.

The general model reflects the relationship between these factors and the amount of investment in innovation (performance indicator):

$$Y = f(x_1, x_2, x_3, x_4, x_5, x_6).$$

Since these factors affect the performance of mathematical methods to use correlation-regression analysis, it is possible to establish the degree of dependence between the determinants and the performance.

The third stage of the study aims to investigate the impact of the level of innovation activity, an indicator of which is an investment in innovation, the effectiveness of the enterprise, which can be used as indicators of key financial results, the competitiveness of the enterprise, its market value and others.

Methodological approaches to analyzing the impact of innovation costs on enterprise value are disclosed in the works of Başgoze and Cem, 2013; Hall, Mairesse and Mohnen, 2010; Xu and Jin, 2016; Lantz and Sahut, 2005.

Most scholars conclude that R&D expenditures have a positive and significant effect on the market value of firms. The logic of these processes is quite clear: R&D expenditures create intangible assets that improve products' technical and technological characteristics and, therefore, generate additional cash flows.

To confirm such causal relationships in this study will be used:

a method of correlation analysis, which aims to establish the closeness of the relationship between R&D expenditures and several performance indicators;

analytical methods that involve the calculation of growth rates ahead of the growth rates of performance indicators selected for analysis compared to the growth rates of investment in innovation.

Among the performance indicators that should be considered, financial indicators - the amount of income, profit, assets; market indicators - the dynamics of the value of shares, the dynamics of the enterprise's market value.

4.3. Comprehensive study of investment processes in innovation.

1 stage. Analysis of the peculiarities of investment processes in R&D.

Each industry is characterized by its dynamics of scientific and technical transformations, which are determined by the

innovative activity of enterprises in the industry and the amount of investment in innovation. The basis of investment management in the innovation of any enterprise is an understanding of industry trends, i.e., the content and quantitative indicators of innovation and investment processes, which is important in terms of ensuring a response in the early stages. Accordingly, in the process of researching investments in innovations from the standpoint of testing the proposed algorithm and developing a set of management mechanisms, it is advisable to use the information base of industry, which is the carrier of scientific and technological transformations and driver of innovation, including other industries, including automotive.

To study innovation processes, it is advisable to use the example of global innovation leaders, which will help identify effective models of management of the studied processes, which can be the basis for use by other enterprises.

Every year, reputable agencies identify global leaders in innovation whose experience can serve as a shining example of successful development strategies. There are several approaches to evaluating innovation leaders. The first approach is based on the ability of investors to identify firms that are and will be active innovators in the future. The main criterion for classifying enterprises as leaders are their ability to "change and influence." For example, this is the rating of Forbes magazine (The World's most, 2020). Companies are valued at the innovation premium, i.e., the difference between their market capitalization and the net present cash flows from existing business. The second approach is based on the ability of companies to provide the appropriate level of financial support for innovation processes, as discussed above.

Innovative leaders in the world are companies operating in the field of information technology communications, e-commerce, and automotive. They represent a fairly large number of countries, but the leading position of US companies is undeniable. The United States supports the world's most active innovation culture. Its uniqueness lies in the fact that: risks and failures at the societal and individual levels are perceived as learning; research and discussion are actively encouraged; the role of government in business plays a less significant role than in other countries.

All this, in general, allows us to characterize "the United States not as a country but as a business." As a result, the United States grows "innovation winners" faster, even if the starting conditions for firms in the United States and other countries were similar.

This article is based on data from automotive companies, particularly Volkswagen Group, General Motors Company, Toyota, Nissan, Tesla, and Ford (Appendix A). We conducted a study of R&D investment in terms of absolute indicators their dynamics. In general, the following features can be noted.

1. In the planning and analysis processes, investments are tied to the amount of income and indicated as a percentage. Car companies ensuring the growth of revenues and their redistribution in the direction of investment in health and R&D investment fully carry out the innovation and investment model of development.

The relative rate of investment in R&D of the surveyed enterprises ranges from 3.5 to 6.5% of income (Fig. 2). Some reduction was observed only in 2009-2010 and was a manifestation of the global financial crisis. The average annual growth rate of R&D expenditures for the study period (from 2014 to 2019) was 99.5% at General Motors, 101% at Nissan, 102.2% at Ford, 104.8% at Toyota, 105.4% at Volkswagen Group, and 135.2% in Tesla.

Figure 2. Share of R&D investment in revenue, %

Source: compiled and calculated by the authors according the companies' information

It should be noted that the support of R&D investment at a consistently high level occurs against the background of maintaining and a certain increase in the share of investment in

fixed assets. After the crisis of 2007-2009, since 2010 there has been a gradual increase in this indicator (Fig. 3).

Figure 3. Share of investment in Fixed Assets in revenue, %

Source: compiled and calculated by the authors according the companies' information

2. Innovative companies, having a significant investment potential, determine the priorities of their use, as evidenced by the ratio of the two indicators of investment in health and R&D investment. According to the data, the Capital Expenditure is

equal in size (plus or minus) to the R&D investment. The ratio of R&D investment and investment in FA, if they are taken for the sum of 100, is presented in Fig 4.

Figure 4. The ratio of investment in R&D and fixed assets

Source: compiled and calculated by the authors according the companies' information

Thus, the basis of a high level of innovation activity is the ability of the enterprise to form a significant investment potential. Such activity characteristics in the coordinates of "investment-innovation" make it possible to maintain the status of global innovators for a long time.

Таким чином, основою високого рівня інноваційної активності є спроможність підприємства формувати значний інвестиційний потенціал. Саме такі характеристики діяльності в координатах «інвестиції-інновації» дають можливість зберігати статус глобальних інноваторів впродовж тривалого періоду часу.

3. Innovation is crucial for long-term competitiveness, but the real scale of funding for innovation varies considerably,

even among global innovation leaders companies. The presented data show that car companies, despite the high level of capital stock, continue to invest in fixed assets. Expenditures on R&D and investment in fixed assets differ in the studied enterprises: 35 thousand US dollars (Toyota) to 45 thousand US dollars (General Motors Company, Tesla). The economic basis of the ability of enterprises to send significant amounts to R&D is the achieved level of investment activity. It is because without solving the problem of ensuring the appropriate level of capital, the company cannot provide adequate funding for R&D. In general, the investment activity of the surveyed enterprises allows to ensure high investment rates of both types per employee (Fig. 5).

Figure 5. The amount of investment in R&D and investment in fixed assets per employee

Source: compiled and calculated by the authors according the companies' information

By drawing lessons from the world's leading companies in investment management in innovation allows us to identify the following main trends:

the volume of financing of the innovation sphere is constantly growing and exceeds the rates of investment in fixed assets and other areas of spending financial resources;

innovation leaders have reached a level where their performance is a challenge for followers, as in some cases, they exceed the costs of science and innovation of entire countries. Thus, the R&D costs of the top ten companies in The

50 Most Innovative Companies of 2020 are \$ 160 billion, while the last ten companies out of 50 are only 34.6 billion. \$ USA, i.e., exceed 4.6 times;

the growth of R&D expenditures is because companies are expanding the horizons of applied innovations: it is not only short-term innovations - new products, new technologies, it is more systemic transformations aimed at developing opportunities for innovation in the long run time;

the innovative direction of investment costs for most companies is, in fact, a "protected item", i.e., it is financed in

approximately planned amounts both in the period of short-term decline in profits and in the period of long-term crisis.

In general, all of the above suggests that hypothesis H1 is proven.

Stage 2 analysis – analysis of the impact of factors on R&D investment. We will study the importance of the influence of the above factors on the example of the world's leading automotive companies in the BCG rating (Ringel, Baeza, Panandiker, and Harnoss, 2020). The researched enterprises are characterized by high innovative activity, so the study of the role of the most important factors of the studied processes allows, among other things, to determine specific industry patterns.

By the above justifications and symbols, we examine the

impact of such factors as income from sales (x1), profit after income tax (x2), investment in fixed assets (x3), the number of staff employed in research (x4), the value of intangible assets (x5), the value of fixed assets (x6).

Based on the calculations performed for each enterprise, a multiple regression equation was obtained, which expresses the correlations between several characteristics and the performance indicator. The weight of these relationships is confirmed by the obtained values of the R-square coefficient, which generally confirm a satisfactory approximation, i.e., the accuracy of the selection of regression equations is high. The results of the correlation analysis are presented in the table 1.

Companies	The equation of multiple regression	The most influential factors
Volkswagen Group	$Y = -3869 + 0,05X_1 - 0,11X_2 + 0,02X_3 + 0,05X_4 - 11,74X_5 + 64,32X_6$, R-квадрат = 0,98.	X3, X4, X6
General Motors Company	$Y = -2905 + 8,87X_1 - 0,05X_2 + 1,02X_3 + 50,86X_4 + 0,26X_5 - 0,04X_6$ R-квадрат = 0,66.	X1, X3,
Toyota	$Y = -356 + 0,003X_1 + 0,024X_2 + 0,21X_3 + 0,03X_4 - 0,74X_5 + 0,04X_6$ R-квадрат = 0,97.	X1, X3, X6
Nissan	$Y = -78,0 + 0,04X_1 - 0,13X_2 + 0,03X_3 + 0,1X_4 - 0,42X_5 + 0,01X_6$ R-квадрат = 0,98.	X1, X3, X6
Tesla	$Y = 286,8 - 0,11X_1 + 0,20X_2 - 0,12X_3 + 0,18X_4 - 1,44X_5 + 0,30X_6$ R-квадрат = 0,99.	X1, X4, X6
Ford	$Y = -630,6 + 0,04X_1 - 0,02X_2 + 0,23X_3 - 62,56X_4 + 0,09X_5 - 0,05X_6$, R-квадрат = 0,94.	X1, X3, X5

Table 1: Determining the importance of the impact of individual cost factors on R&D

Source: compiled and calculated by the authors according the companies' information

The presented data indicate that the most important factors in the cost of innovation are: income from sales, investment in fixed assets.

Undoubtedly, the economic basis for R&D expenditures is sales revenue. A significant number of enterprises in the process of analyzing innovation activity use such an indicator as to the share of R&D expenditures in sales revenues, emphasizing the latter's importance for innovation processes. To confirm this existing or non-existent dependence and for testing the hypothesis H2, it is advisable to analyze the stability and comparability of the dynamics of R&D expenditures and

sales revenues. For this purpose, it is expedient to calculate the coefficient of synchronization of dynamics of the specified indicators. The synchronization coefficient is equal to one if the dynamics of indicators are comparable in value and direction; the coefficient is more than one when the rate of dynamics of R&D expenditures exceeds the dynamics of revenues and vice versa. Perceiving as a general expected trend – a positive dynamics of income, we can expect a gradual increase with corresponding positive dynamics and R&D expenditures (Fig. 6).

Figure 6. The coefficient of synchronization of dynamics of the specified indicators

Source: compiled and calculated by the authors according the companies' information

A comparison of these indicator dynamics shows that the constant synchronicity of these indicators on the example of most companies is not observed. In most cases, the asynchrony of dynamics of the specified indicators at the investigated companies is traced.

The presented research shows that R&D investment do not fully correspond to the dynamics of other economic indicators that are the most "protected" item, and therefore hypothesis H2 is partially proved.

Stage 3 – the study of the impact of R&D investment on the results of enterprises.

Among the results that depend on the intensification of innovation processes, the company's profit, the size of assets, and market value should be noted.

Analysis of the dynamics of these indicators shows different trends against the background of a gradual increase in R&D investment (Appendix A).

The company's profit is an essential financial result, which largely determines and reflects the effectiveness of innovation in the long run. The profit of the surveyed enterprises is an unstable value, rather poorly correlated with the value of R&D investment. In some years, companies suffered losses. The performance of Tesla, which only made a profit in 2020, differs significantly.

The size of the assets of the surveyed enterprises differs in some way, reflecting the scale of production potential, but the common trend is gradual growth.

The share prices of most of the surveyed companies fluctuate significantly. Tesla stock prices are characterized by a significant increase in 2020. According to the trends of stock prices, the market value of enterprises changes.

The generalized analysis of performance indicators testifies various tendencies and the necessity of definition of degree of linear dependence.

The study of the relationship between the influential factor

(R&D investment) and performance indicators (Net Income, Total Assets, Stoke Price, Market capitalization) will determine the importance of the impact of innovation activity, an indicator of which is R&D investment on the results of the enterprise. We use the correlation coefficient of Pearson and Spearman.

The calculation of Pearson's correlation coefficients (linear correlation coefficient) and Spearman's (rank correlation coefficient) is carried out using formulas 1, 2:

$$r_p = \frac{\sum(x_k - M_x)(y_k - M_y)}{\sqrt{\sum(x_k - M_x)^2 \sum(y_k - M_y)^2}}$$

$$p = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$$

where r_p , p – Pearson and Spearman correlation coefficients, respectively,

x_k , y_k – values of random variables;

$M_x = \frac{1}{n} \sum_{k=1}^n x_k$, $M_y = \frac{1}{n} \sum_{k=1}^n y_k$ – estimates of mathematical expectation of random variables x_k , y_k , n – sample size;

d – the rank difference.

Pearson's correlation coefficient indicates the correlation (linear dependence) between two variables x_k , y_k , which take values from (-1) to (+1) inclusive. A value of +1 means that the relationship between x_k and y_k is linear and reflects the growth of Y with increasing X . A value of (-1) – reflects the decrease in Y with increasing X . If the Pearson correlation coefficient is equal to 0, there is no linear correlation between the variables.

Spearman's rank correlation is a nonparametric measure of the statistical dependence between two variables, which is determined between ranks, i.e. a series of obtained quantitative values ranked in descending or ascending order. At 0 the relationship between the indicators is direct, and at 0 – inverse. If it is close to 1, there is a close (strong) relationship between the indicators, if 0.3 it is considered that the relationship is virtually absent.

The significance of the Pearson and Spearman correlation coefficients is checked by comparing the critical (tabular values of the Pearson and Spearman correlation coefficients), and if the value calculated modulo is less than theoretical, there is no relationship between the two variables x_k and y_k (Appendix B).

The results of the calculations are presented in the table 2.

Indicators	Volkswagen Group		General Motors		Ford		Tesla		Toyota	
	r_p	p	r_p	p	r_p	p	r_p	p	r_p	p
Net Income	0.087	0.839	0.064	0.466	-0.399	0.184	-0.862	-0.067	0.796	0.482
Total Assets	0.976	0.992	0.427	0.706	0.897	0.938	0.973	0.983	0.849	0.430
Stoke Price	0.335	0.815	0.166	0.480	-0.808	0.248	0.441	0.974	0.629	0.807
Market capitalization	-0.792	-0.27	-0.083	-0.012	-0.771	0.318	0.914	0.947	-0.763	-0.071

Table 2: Estimated statistical impact factors on R&D investment

Source: compiled and calculated by the authors according the companies' information

The calculated statistical results of the Pearson and Spearman correlation coefficients confirmed the importance of the impact of R&D investment on the value of assets and net income. Regarding the correlation coefficients of such indicators as R&D investment and share value, they are less significant. However, the least significant is the impact of R&D investment on the market value of the enterprise. Thus, the substantiated significance of R&D investment for individual results has partial empirical proof, and therefore, hypothesis H3 has a partial confirmation.

The conducted theoretical and analytical studies of innovation investment processes allow determining the management system's components, which aims to ensure sustainable development of the enterprise. The main patterns that should be taken into account, however, are:

R&D investment is the most active form of investment in innovation, but their effectiveness depends mainly on other forms of investment, including investment in human resources, investment in fixed assets;

monitoring of investment activity of the enterprise should be carried out regularly and taking into account trends in the industry, i.e., the main competitors;

systemic innovation activity, based on growing investments, depends on the strategic vision of their role in the development of the enterprise and requires implementation in the strategic management system.

As a result, the proposed innovation investment management system should include subsystems:

Information support subsystem – aims to study the external and internal environment to determine the requirements and opportunities for investment in innovation.

The functional support subsystem is aimed at balancing innovative investments by types in the context of ensuring their balancing and directing the cumulative action to ensure

integrated innovation development;

The financial support subsystem is focused on the formation of the necessary amount of financial resources to ensure financial support for all types of investments of the enterprise;

The subsystem of staffing is aimed at developing the intellectual capital of the enterprise, the level of which determines the ability of the enterprise to ensure the most effective use of innovative investments.

5. Conclusions

R&D is a functional area of activity of enterprises, which requires increasing investment to maintain efficiency. On the other hand, the increase in investment in R&D does not guarantee improved performance, as the level of scientific and technical development is determined by the characteristics of the intellectual resources of the enterprise, the state of fixed assets. Therefore, the company needs balanced management of all types of innovative investments. Even though sustainable and growing investments are not automatically accompanied by improved performance, car companies finance R&D at an unprecedented level of investment, despite ensuring the preservation of market positions and active participation in the competition.

A high level of investment activity characterizes car companies. The main directions of investment are innovation, which occurs through the investment of fixed assets, investment in R&D, and increasing staff development costs. The enterprise's high level of investment activity is maintained for a long time because it is an investment in innovation that ensures a high level of efficiency in the field of innovation, hence the enterprise's competitiveness. Key accents in the

process of the innovation investment management: species composition, quantitative characteristics, priorities of innovative development of the company.

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GENERAL MANAGEMENT

Company	2014	2015	2016	2017	2018	2019	2020	Trends
R&D expenditure per employee, in US dollars								
Volkswag en Group	23193	26679	25857	24345	24437	24640	24879
General Motors	34259	34884	29333	40556	45087	41460	42330	
Ford	35829	33668	36318	39604	41206	38950	38170	
Tesla	45665	54909	46901	36705	29908	27970	21200	
Toyota	25630	27846	28863	27156	27502	25990	28400	
Nissan	32317	33289	34084	34048	35927	35890	34980	
Investments in fixed assets per employee, in US dollars								
Volkswag en Group	32996	25757	25071	24280	24364	24507	24600
General Motors	33046	36294	41777	46111	50289	45739	44500	
Ford	39572	35678	34328	34896	48713	40168	30870	
Tesla	95463	125211	71983	90962	43020	27740	44760	
Toyota	28169	32639	35340	31719	33666	36340	35740	
Nissan	29572	29978	32618	33333	35020	35120	34770	
Net Income								
Volkswag en Group	14712	-1755	5692	12833	13967	14947	9519
General Motors	2804	9687	9427	-3880	7916	6581	6247	
Ford	1231	7373	4589	7731	3677	47	-1279	
Tesla	-294	-888	-674	-1962	-976	-870	690	
Toyota	18231	19777	19195	17029	22445	16945	19100	
Nissan	4163	4347	6170	6722	2872	-6175	-4217	
Total Assets, in million US dollars								
Volkswag en Group	466862	423844	453409	477204	541082	546639	567853
General Motors	177501	194338	221690	212482	227339	228037	235194	
Ford	208615	224925	237951	258496	256540	258537	267261	
Tesla	5830	8067	22664	28655	29740	34309	52148	
Toyota	414374	434341	393649	453376	452774	467432	484660	
Nissan	147034	155115	144201	171315	168722	170571	156185	
Stoke Price, in US dollars								

GENERAL MANAGEMENT

Appendix A: Dynamics of the leading performance indicators of the studied corporations

Source: compiled and calculated by the authors according the companies' information

Volkswagen Group

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,96	1,00					
Столбец 3	0,09	0,34	1,00				
Столбец 4	0,97	0,96	0,12	1,00			
Столбец 5	0,97	0,95	0,15	0,94	1,00		
Столбец 6	0,92	0,97	0,31	0,96	0,89	1,00	
Столбец 7	0,98	0,98	0,21	0,97	0,98	0,95	1,00

General Motors Company

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,51	1,00					
Столбец 3	-0,29	-0,28	1,00				
Столбец 4	0,63	0,71	-0,10	1,00			
Столбец 5	0,05	0,21	0,19	0,03	1,00		
Столбец 6	-0,49	-0,69	0,16	-0,94	-0,06	1,00	
Столбец 7	-0,25	0,03	-0,54	-0,35	-0,18	0,36	1,00

Toyota

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,95	1,00					
Столбец 3	0,80	0,91	1,00				
Столбец 4	0,82	0,74	0,55	1,00			
Столбец 5	0,72	0,77	0,66	0,29	1,00		
Столбец 6	0,81	0,87	0,76	0,44	0,98	1,00	
Столбец 7	0,86	0,89	0,77	0,48	0,96	0,98	1,00

Nissan

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,89	1,00					
Столбец 3	0,49	0,81	1,00				
Столбец 4	0,81	0,83	0,55	1,00			
Столбец 5	-0,63	-0,68	-0,47	-0,74	1,00		
Столбец 6	-0,48	-0,46	-0,53	-0,36	0,18	1,00	
Столбец 7	0,82	0,79	0,45	0,59	-0,75	-0,19	1,00

Ford

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,90	1,00					
Столбец 3	-0,40	-0,21	1,00				
Столбец 4	0,86	0,75	-0,30	1,00			
Столбец 5	0,61	0,60	-0,66	0,35	1,00		
Столбец 6	0,91	0,86	-0,32	0,78	0,67	1,00	
Столбец 7	0,86	0,89	-0,18	0,78	0,57	0,94	1,00

Tesla

	Столбец 1	Столбец 2	Столбец 3	Столбец 4	Столбец 5	Столбец 6	Столбец 7
Столбец 1	1,00						
Столбец 2	0,90	1,00					
Столбец 3	-0,79	-0,48	1,00				
Столбец 4	0,64	0,31	-0,91	1,00			
Столбец 5	0,95	0,98	-0,62	0,48	1,00		
Столбец 6	0,82	0,68	-0,67	0,55	0,74	1,00	
Столбец 7	0,99	0,94	-0,72	0,57	0,98	0,85	1,00

Appendix B