The object of the study is investment in R&D of enterprises. The problem of developing a mechanism for managing the level of R&D investment at industrial enterprises has been solved. The results are obtained:

– gradation of R&D investment levels at enterprises based on the application of the beta coefficient calculation methodology adapted to the R&D sphere;

– distribution of city-forming enterprises of the metallurgical industry by R&D investment levels: high level – 27 % of surveyed enterprises, average – 18 %, low – 55 %, critical – 0 %;

– development of a matrix based on the comparison of the level of R&D investment and the level of sales volumes of the enterprise's products calculated according to one algorithm. For each cell of the matrix, management decisions of strategic nature are proposed to increase the level of R&D investment.

The results obtained are explained by the assumption of a linear relationship between the size of R&D investment of a particular enterprise over time and aggregate industry R&D investment (as a benchmark). The tendency of R&D investment growth in the industry, regularity of R&D investments of the surveyed enterprises were confirmed, time series of R&D investment both at the evaluated enterprise and in the industry as a whole were processed using trend smoothing.

The features of the obtained results lie in the application of comparable coefficients (investments in R&D), as well as in the application of the developed assessment in the management of the enterprise.

The practical significance of this study results is the possibility of applying the obtained conclusions and recommendations to increase the level of R&D investment of large industrial enterprises in the volume, scope and conditions corresponding to the developing economy

Keywords: investment level, R&D, metallurgical industry, enterprise management

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DEVELOPMENT OF A MECHANISM FOR MANAGING THE LEVEL OF INVESTMENT IN R&D OF CITY-FORMING ENTERPRISES (BY THE EXAMPLE OF THE METALLURGICAL INDUSTRY)

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1. Introduction

Increasing globalization has created conditions for an innovative type of economic development, which has become a universally accepted strategy. Nowadays, economists unanimously recognize the key importance of innovation activity for enterprises that seek to maintain and develop their competitiveness. With the rapid development, technological innovation is becoming the foundation in various industrial production sectors. Among the leading countries in this direction are the United States, China and Japan. The World Intellectual Property Organization has calculated that the share of patents in these three countries is 65 % of the global total [1].

At the present stage, there are global trends to increase investments in research and development (hereinafter – R&D). The Lisbon Strategy [2] provides for EU countries to invest 3 % of GDP in R&D in order to create the most competitive and dynamic knowledge-based economy. This indicator has not yet been achieved by all European countries. Thus, while in Switzerland R&D expenditures amount to 3.4 % of GDP, Germany – 3.1 %, Belgium – 3.4 %, Denmark – 2.8 %, France – 2.2 %, Ireland – 1.1 %. Post-Soviet countries lag significantly behind in this indicator: Kazakhstan – 0.13 %, Moldova – 0.2 %, Ukraine – 0.3 % and others [3].

Decisions on participation in R&D investment are taken rather cautiously by national economies, especially in developing countries, due to the fact that innovation activities in general have a high degree of risk associated with uncertainty. Investment risk is the fact that the innovation may not have the expected demand, may not bring the planned profit, which will lead to loss of invested funds. On the other hand, companies that do not introduce innovative components into their production will quickly fall behind their competitors, which may lead to bankruptcy. In the case of R&D, the risk is even higher, since in their process new knowledge, innovative object (process, technology, product) will not necessarily be created. The competitive environment and scientific and technological progress lead to the need to invest in R&D.

Modern economic conditions are characterized by the intensification of competitive, and often unfair, politically biased struggle for the country's place in the world market. In this regard, the issue of investment support for R&D at a high level, which, if properly managed, will ensure the growth of competitiveness of enterprises and the national economy as a whole, is gaining relevance for the newly independent states.

2. Literature review and problem statement

Innovations do not spread chaotically in organizations. Innovative activity of companies is the result of thoughtful actions to implement investments and improve partnership relations between economic entities in the market.

The first thing to consider is the investment theory of creativity, according to which creativity is the process of making managerial decisions [4]. The failure of business owners to use the achievements of financial management in relation to innovation processes at the enterprise does not allow timely implementation of innovation projects, which is the main reason for the backwardness of economic entities. Because of this, the main obstacle to business development is not external constraints, but its own backwardness and internal obstacles. This problem remains unresolved.

The new growth theory [5] offers the concept that investing in innovations brings more return than investing in the expansion of traditional products. In this case, the most important goals of investment support creation can be capital growth, high capitalization rate, increase in the return on investment, transformation of the structure of capital investment, reduction of investment activity risks, etc. Developing the provisions of this concept, we summarize that the strategic goal of the system of investment support of innovation processes is to ensure the economic growth of companies.

The start of innovative development is set by R&D, which predominantly has no possibility of self-financing and depends on investments. The U.S. National Science Foundation gives a comprehensive definition of R&D, which is a planned, creative activity aimed at discovering new knowledge or creating new or significantly improved goods or services [6]. This study presents a classification scheme for companies investing in R&D, but does not present the levels of their investments suitable for management.

The OECD methodological document "Frascati Manual" [7] notes that uncertainty is one of the distinguishing characteristics of R&D. At the first stage of the project, the result and costs, including time, cannot be accurately calculated in relation to the objectives. With regard to basic research aimed at mastering new knowledge, the probability of not achieving the expected results is quite high. For example, when implementing a research project, there is a possibility of rejecting some competing hypotheses, but not all of them. The way to overcome this problem may be to look for opportunities to estimate such costs not only in relation to results.

When considering the problem of innovation activation through R&D investments, it is important to emphasize two debated approaches on this issue:

1. Representatives of the traditional approach emphasize the need for unconditional investment in R&D. Thus, [8] emphasizes that investment in R&D is crucial for companies seeking to expand their capabilities in today's dynamic marketplace. Another study [9] argues that the scale of R&D funding enables multinational corporations to compete in the global market. In the case of small and medium-sized enterprises, it is also R&D expenditures that increase the efficiency of production [10]. An interesting study [11] shows that investing in R&D of enterprises can produce not only direct but also indirect effects, which, one way or another, always affects the firm's income by increasing organizational potential. This suggests that it is advisable to carry out the development of a mechanism for managing the level of R&D investment with a link to the result of production.

2. The alternative (second) group of economists question the direct link between investment in R&D and economic development of the enterprise or emphasize the need to invest in the subsequent stages of mastering innovations of the production sector rather than the initial (R&D) stages. Thus, the study [12] notes that even within the framework of the developed managerial regional program, investments in R&D do not affect the intensity of innovative development of enterprises. The authors of the paper [13] believe that the main goal of any innovation is to obtain a better result with the same amount of resources, rather than investment and innovation itself. In the paper [14], the feasibility of increasing investment in enterprises is justified only with respect to applied research.

A critical review of studies under the alternative approach has led us to formulate the following objections:

1. Summarizing, we can note that R&D in general is characterized by uncertainty in the triad "cost-time-result", which in its critical form reflects uncertainty as to whether it is possible to achieve the set result to some extent. But in this regard, it is also advisable to expand R&D within the framework of existing production, i.e. in the format "R&D-innovation-production", so that they are not detached from production. Our position is based on the theory of production. The proof of the positive correlation between R&D expenditures and production volumes of industrial products is given in the study of a group of economists [15].

2. Increased R&D promotes the active creation of innovative developments, which makes R&D investment a profitable investment in case of successful implementation (e. g. Silicon Valley). In addition, the share of investment in R&D reflects the attractiveness to potential investors of manufacturing in general.

3. It is also important to note the macroeconomic argument. An economy specializing in commodities of primary industries has relatively low investments in R&D and product innovation, while at the same time such an economy is characterized by active investments in process innovation, purchase of equipment, often foreign. An increase in research in such a country may lead to an increase in innovation not within the country, but in other countries where there is a larger number of industries involved in the purchase of R&D.

All of this suggests that it is appropriate to conduct the study within the traditional R&D investment approach.

Experts of the World Bank, having studied the indicators of seven developed countries, calculated an estimate of the increase in R&D investment by 0.1 %, due to which their factor productivity increased by 0.18 %. Those countries that adopt an intensive model of investment application receive a factor productivity of 0.02 % from the increase in R&D investment, while developing countries with an extensive model receive only 0.005 % [16]. Consequently, the former have a lower level of investment and innovation risks, while in developing countries such risk is 36 times higher. Thus, effective investment in R&D affects not only the activation of innovation potential, but also determines the overall economic growth.

Given that R&D investments reflect costs rather than their results, in practice, economic returns are possible only when correct and realistic objectives are set and project management tools, including management control, are applied. Thus, within the Management Control System theory, R&D control is described as a management system, the separate elements of which are classical financial tools of budgeting, accounting control, etc. [17]. A group of researchers in the paper [18] notes that investment support is a kind of mechanism for regulating the implementation of the innovation process, achievement of strategic goals, development objectives both at individual enterprises and in the economy as a whole. Consequently, the assessment of R&D investment level can be put into the mechanism of management of investment and innovation activity of the enterprise.

In general, when analyzing the scientific literature [10, 12, 13], a gap was found to find an answer to the question "How to manage the R&D investment level of an enterprise?", such studies have not been identified. Nevertheless, the need for a high level of R&D investment is proven within the framework of the traditional approach to the study of investment support for innovation and is consistent with the provisions of the theory of production. The conclusion that effective investment in R&D determines the overall economic growth led to the decision to use the combination of the R&D investment level and the resultant factor of economic growth of the enterprise in the methodological development.

3. The aim and objectives of the study

The aim of the study is to develop a mechanism for managing the level of investment in R&D of industrial enterprises, which will allow for the identification of sound strategies.

To achieve this aim, the following objectives are accomplished:

– to grade the levels of investment in R&D of enterprises in the evaluation process;

– to categorize enterprises by R&D investment levels;

– to apply the results of R&D investment level assessment to enterprise management.

4. Materials and methods of research

To quantitatively assess the level of R&D investment, it is important to take into account the nature of investment in a long period. The study was carried out by analyzing the time series of investment in R&D, the period of 10 years was chosen as the length of the time series. For the present study, the object is city-forming enterprises of metallurgical production in the Republic of Kazakhstan with a developing market economy. This industry is economically significant for the country, so regular investments in R&D are mandatory for city-forming enterprises.

In order to take into account the problem of significant dependence of enterprises of developing countries on external factors, a time series reflecting the investment in R&D of all organizations of the industry was used (additionally, the presence of a growth trend was assessed).

The hypothesis of the research: the mechanism of management of the R&D investment level of industrial enterprises can be developed on the basis of evaluation of R&D investment volumes and product sales volumes using the classical beta coefficient.

The R&D investment level was assessed on the basis of the beta coefficient calculation methodology, which is classically used for the stock market. The high level of R&D investment risk, as well as the importance of the dependence of developing economy enterprises on external environment factors, determines the validity of the methodology for the purposes of this study.

The weighted moving average method was used to equalize time series. Irwin's method was used to identify abnormal levels.

To apply the results of R&D investment level assessment in management at the enterprises, the matrix method was used. A similar beta coefficient methodology was used to analyze the volume of sales of the enterprises' products, which provides conditional "cleanliness" of intersections in the modeled matrix.

Data processing was performed using "Statistica 13" software.

5. Processes and results of R&D investment level assessment

5. 1. Gradation of R&D investment levels in the evaluation process

The basis of the coefficient β, which can be labeled as the R&D investment level (β_I), is the determination of a linear relationship between the amount of R&D investment of a particular enterprise over time and the aggregate industry R&D investment (as a benchmark). The level of R&D investment, in accordance with the methodology for calculating the classical beta coefficient, is determined by the following formula (1):

$$\beta_I = \frac{Cov(I_e, I_b)}{Var(I_b)}, \quad (1)$$

where:

β_I – R&D investment level;

Cov – covariance;

I_e – investments in R&D of enterprises;

I_b – R&D investments by industry;

Var – variance.

Hence, β_I – is an indicator that shows the direction and level of correlation of R&D investment at a firm and its changes in general within the industry. The gradation of R&D investment levels of the enterprise according to this indicator is presented in Table 1.

According to Table 1, the enterprise with the result of β_I greater than one is characterized by a high level of R&D investment, uses its investment resources in this direction, outperforming the industry as a whole. In the range of $0<\beta_I<1$, the enterprise belongs to the average level of R&D investment, as the increase in R&D investment by the enterprise is slower than in the industry.

Table 1

Gradation of enterprise R&D investment levels

Level	β_I	Volatility	Dynamics
Critical	$\beta_I \leq -1$	The volatility of reduced investment in R&D of enterprises is greater than the volatility of growth in general industry investment in R&D	The dynamics of investments in R&D of the enterprise is opposite to the dynamics of general industry investments in R&D
Low	$-1<\beta_I<0$	The volatility of reduced investment in R&D of enterprises is less than the volatility of growth in general industry investment in R&D	
	$\beta_I=0$	–	The dynamics of investments in R&D of the enterprise does not correlate with the dynamics of industry-wide investments in R&D
Medium	$0<\beta_I<1$	The volatility of growth in R&D investment is less than the volatility of growth in general industry R&D investment	The dynamics of investments in R&D of the enterprise positively correlates with the dynamics of industry-wide investments in R&D
High	$\beta_I \geq 1$	The volatility of growth in R&D investment is higher than the volatility of growth in general industry R&D investment	

Source: Compiled by the author of the paper.

If the enterprise has a value of β_I less than –1, then against the background of increasing investments in R&D in the industry there is their reduction at the enterprise. This indicates the failure to utilize the opportunities provided by the trends of innovation processes in the industry, the innovation potential acquired during the period of activity is reduced. There is a resonance between the level of R&D investment of the enterprise and the general industry level, and, depending on the rate of reduction, this result is low ($-1<\beta_I<0$) or critical ($\beta_I \leq -1$).

5. 2. Distribution of enterprises by R&D investment levels

First, the industry trends of R&D investments are investigated. The results of trend assessment are presented graphically in Fig. 1 (R^2=0.94).

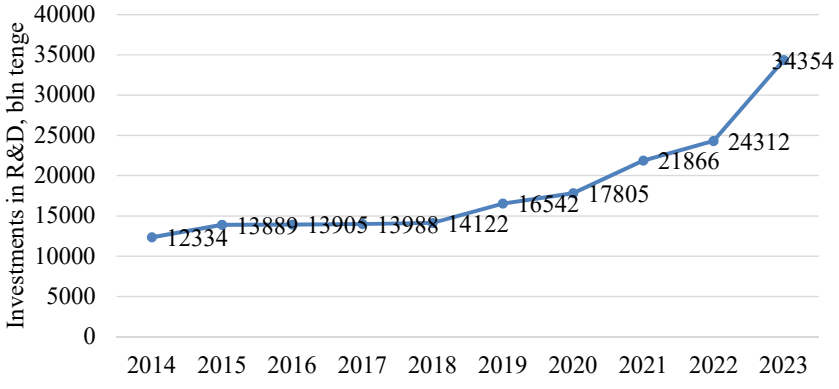

Fig. 1. Dynamics of investments in R&D of metallurgical enterprises of the Republic of Kazakhstan for 2014–2023

Note: 1 USD=444.5 tenge

Source: Compiled by the author according to [19]

The analysis of the dynamics of R&D investments in the enterprises of the metallurgical industry of the Republic of Kazakhstan for 2014–2023 confirmed the growth trend.

Further, the elimination of "emission points" was carried out, time series were smoothed. The identification of anomalous observations was carried out by Irwin's method [20] (2)–(4):

$$\lambda_t = \frac{|\gamma_t - \gamma_{t-1}|}{\sigma_y}, \quad (2)$$

$$\sigma_y = \sqrt{\frac{\sum_{t=1}^{n}(y_t - \bar{y})^2}{n-1}}, \quad (3)$$

$$\bar{y} = \frac{\sum_{t=1}^{n} y_t}{n}, \quad (4)$$

where λ_t – anomaly criterion;

σ_y – standard deviation of the sample;

y_t – the sample value under study;

n – sample size;

t – the observed time period.

The identified "outlier points" are excluded from the time line and replaced by average values obtained by using calculations on neighboring observations.

The final stage is the smoothing of the series. From Fig. 2, we can conclude that the relationship between time series is non-linear.

If the process is non-linear, the weighted moving average method can be used to smooth the series (5):

$$\overline{y_t} = \frac{1}{4}(y_{t-1} + 2y_t + y_{t+1}). \quad (5)$$

The results are presented in Table 2.

Thus, the tendency of R&D investment growth in the industry, regularity of R&D investments of the surveyed enterprises were confirmed, time series of R&D investment both at

the assessed enterprise and in the industry as a whole were processed using trend smoothing. None of the surveyed enterprises showed a critical level of R&D investment. The distribution of enterprises by levels of high/medium/low was 3/4/4.

Table 2

Results of calculation of R&D investment level of surveyed enterprises

Enterprises	β_I	Level
Aktobe Ferroalloy Plant	1.873	High
Kazakhstan electrolysis plant	1.561	
Casogneupors	1.179	
Aksu Ferroalloy Plant	0.606	Medium
Zhairemsky mining and processing plant	0.512	
Ulba Metallurgical Plant	0.059	
Ust-Kamenogorsk Titanium-Magnesium Combine	0.055	
Balkhashtsvetmet	–0.011	Low
Taraz Metallurgical Plant	–0.311	
Temirtau Electrometallurgical Plant	–0.352	
Lisakovsky Mining and Processing Plant	–0.920	

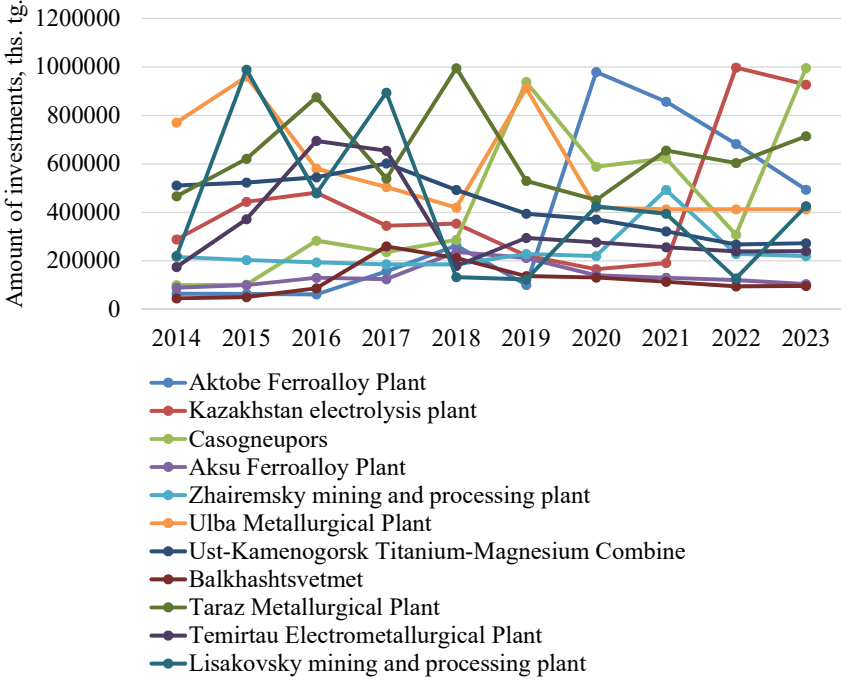

Fig. 2. Trends of enterprises' investments in R&D

Source: Compiled by the author of the paper on the basis of annual reports of enterprises

5. 3. Application of R&D investment level assessment results in enterprise management

In order to develop a matrix of managerial decisions related to the development of the level of investment in R&D at enterprises, we need another indicator related to investment and innovation activities and productive in relation to the economic growth of the enterprise. As such an indicator we propose to use the beta coefficient, but in relation to the volume of product sales (β_s).

The basics of the β_s criterion construction methodology are similar to the calculation of the β_I coefficient. Accordingly, in the case when the rate of increase in sales at an enterprise becomes higher than the growth rate of the total volume of sales in the industry, then β_s is greater than 1. The opposite situation occurs when there is a steady decline in the sales volumes of products of a certain enterprise, while the industry as a whole shows an increase in the volume of sales ($\beta_s<-1$). It should be noted that in any enterprise there are periods of decline in sales volumes, but such declines are leveled by the smoothing method.

The proposed classification of enterprises is based on a matrix (Table 3).

Table 3

Types of enterprises by R&D investment levels and product sales volumes

R&D investment level	Sales volume level			
	High	Medium	Low	Critical
High	Leaders		Developing	
Medium				
Low	Inertial		Outsiders	
Critical				

Source: Compiled by the author of the paper on the basis of the proposed methodology.

It is possible to use more gradations on the basis of the 4 above-suggested levels of indicators, then the number of types will be 16. Since the purpose of the matrix is to develop management decisions for each type, due to the limited possibility of presenting this research within the framework of the paper, these types have been enlarged.

"Outsider" is an enterprise that does not increase investments in R&D, such an enterprise has a decline in sales volumes, which in general determines the decline in competitiveness (Lisakovskiy Mining and Processing Plant). The outsider needs a new catching-up development strategy (based on the study of investment and R&D organization experience of similar enterprises) to launch innovation activity. It is necessary to develop scenarios to attract strategic investors. At these enterprises, it is possible to observe the limitation of all types of resources, which makes it almost impossible to implement innovations independently. It is necessary to investigate the possibility of transferring the rights related to intellectual property, which can be done through the sale of patents or partial transfer of rights, using franchising or license sales.

Enterprises of the "inertial" type are organizations that have previously developed successful innovations and sell large volumes of products as if by inertia from previous efforts (Temirtau Electrometallurgical Plant, Taraz Metallurgical Plant, Balkhashtsvetmet). It is important to note that such an enterprise will not be able to remain in a state of inertia for a long time, it needs to take measures to increase the level of R&D investment in order to obtain new developments. One of such measures can be the organization of developments along the lines of sustainable and supporting innovations.

The "developing" type includes mature enterprises that have a high or average level of R&D investment, but their sales volumes are declining compared to the growth rate of the industry indicator (Kazakhstan Electrolysis Plant, Zhairemsky Mining and Processing Plant, Ulba Metallurgical Plant, Ust-Kamenogorsk Titanium and Magnesium Plant). The attention of "developing" type enterprises should be paid to critical success factors of R&D results application. It is recommended to use benchmarking as the basis of the strategy "Following the leader".

Sometimes such enterprises include those who only develop innovations for the benefit of the parent company and do not commercialize them. In order to increase the volume of sales, it is necessary to use the developments independently, as this option of commercialization provides not only the maximum level of income, but also the opportunity for the developers to observe the implementation of the innovation, which may lead to new ideas for improvement.

"Leader" is an enterprise-trendsetter, which is maximally successful in implementing a high level of R&D investment, which is also reflected in the high growth of product sales (Aksu Ferroalloy Plant, Aktobe Ferroalloy Plant, Kazogneupory). The strategy of position retention is recommended for this type.

Thus, the assessment of the R&D investment level of the enterprise can be used in combination with the performance indicators of the enterprise development to build a matrix on the basis of which it is convenient to make managerial decisions.

6. Discussion of the results of assessing the R&D investment level of enterprises

The application of the classical beta coefficient calculation methodology to the investment and innovation activity of an enterprise showed that it was easy to adapt and convenient to use. The gradation of R&D investment levels of the enterprise on the basis of the modified beta coefficient calculation methodology presented in Table 1 made it possible to evaluate and classify the enterprises.

To calculate the coefficient β_I, the trend of R&D investments in the metallurgical industry over the time period of 10 years was revealed. As shown in Fig. 1, the trend of industry R&D investment in the metallurgical industry is generally positive and reflects an upward trend. From 2015 to 2018, there is a slight increase, then the build-up of R&D investment in the metallurgical industry is at a faster pace. It should be noted that the growth rate does not drop even during the period of pandemic restrictions (2020–2021), which can be explained by the strategic importance of the industry for the country, as well as equalization through investment in applied research in the field of digital technologies to support the work of metallurgical enterprises. In general for the industry, the investment level has an even distribution, which allows us to conclude about the validity of the results obtained.

According to the results presented in Table 2, 27 % of surveyed enterprises have a high level of R&D investment, 18 % of enterprises show an average level, and 55 % have a low level. There are no enterprises with a critical level of R&D investment, the closest to it is Lisakovsky Mining and Processing Plant (β_I=−0.92).

Due to correlation of four gradations allocated on the basis of the ranges of two beta coefficients (Table 3), combinations of values corresponding to 4 types of enterprises ("Leaders", "Inertial", "Developing" and "Outsiders") appeared, which will allow managers to adjust the strategies of investment and innovation development of enterprises.

There is a similar study [20], in which it is proved that high investments in R&D cause a higher number of patents in the business environment (on the example of EU countries). At the end of the study, the authors emphasize that an analysis of this problem at the firm level could complement the results. Our study is conducted at the firm level and, in comparison with the study [21] has some advantages: it takes into account the industry factor; it takes into account the risk factor, which is reflected in the application of beta coefficient; it takes into account that patents are not the only indicator of the results of R&D expenditures, more informative are the sales volumes of products; it substantiates the application of the assessment results in enterprise management.

The limitations of the present study are due to the fact that the classical method of calculating the beta coefficient also has its limitations:

1) retrospective trends do not always determine trends for the future;

2) results depend on the period chosen;

3) the linear relationship between variables is in the nature of an assumption (theoretical construct).

The disadvantages of this study are related to the fact that not only R&D is involved in investment and innovation processes, and with the development (expansion) of this study it is possible to calculate an estimate of the level of investment in intangible assets in general, human capital and other factors affecting the efficiency of innovation activity of the enterprise related to its economic growth.

In addition, it is possible to introduce a benchmarking stage – to compare the results of β_I with the values of competitors' indicators. The obtained results reflect the peculiarities of only one country and one industry, as the sample includes Kazakh enterprises and metallurgical industry. High-tech industries, when applying this methodology, may give a different result, for example, taking into account the exponential growth of investment in the industry. To obtain more universal results, it is necessary to conduct a comparative analysis of different countries or at least countries of the same level of economic development.

7. Conclusions

1. It is proposed to assess R&D investment levels based on the calculation of the classical beta coefficient with adaptation to the R&D sphere of enterprises. Determination of the linear dependence between the size of R&D investment of a particular enterprise over time and the total industry R&D investment (as a benchmark) gives 4 ranges that allow grading the level of R&D investment into high, medium, low and critical.

2. The approbation on the example of 11 city-forming enterprises of the metallurgical industry showed the validity of the proposed tool for assessing the level of R&D investment. The distribution of city-forming enterprises of the metallurgical industry by R&D investment level showed that there is no critical level, but more than half of the enterprises (55 %) were at a low level of investment, while the industry as a whole shows a steady growth of investment in R&D.

3. Application of the results in enterprise management is proposed on the basis of the matrix formed at the intersection of the R&D investment level indicator with another significant indicator of economic growth – beta coefficient on the volume of sales of production output. The latter is de-

termined by the same algorithm based on the classical beta coefficient. The correlation of four gradations in enlarged blocks was carried out, resulting in combinations of results in the form of 4 types of enterprises: "Leaders", "Developing", "Inertial" and "Outsiders". Each type of enterprises corresponds to its own management decisions of strategic nature to increase the level of R&D investment.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors have used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

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