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Empirical Study of Convergent-Divergent Trends in Innovation EU Countries Development

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Abstract. The article is devoted to the problem of disproportionate innovation development in the European Union and the impact of these processes on economic growth. The aim of the work is an empirical study of the unevenness and asymmetry of innovation spending in the EU and analysis of convergent-divergent trends in this area. The results of recent research show a desire to strengthen cooperation in the field of innovation, which changes the situation in a positive direction and proves the signs of convergence of innovation, and they are most pronounced in the least developed regions of Europe. The urgency of solving this scientific problem is that the internal convergence of the European Union in the field of policy to support research, development and innovation is one of the strategic goals of the association. Models based on the concept of convergence have become a methodological tool for determining the asymmetry of development. The study was conducted on the basis of analysis of statistical data of 28 European Union countries for the period 2008-2019. The article presents the results of an empirical analysis of the asymmetry of innovative development of EU countries in terms of research and development. It is established that there is a shift towards increasing the share of R&D expenditures in GDP. Convergent tendencies in terms of development asymmetry, σ-convergence and β-convergence are revealed. The study empirically confirms and theoretically proves that the reduction of differentiation and convergence of countries is manifested in increased funding for innovation in countries lagging behind in these parameters. The practical significance of the results of the study lies in the possibility of their use to assess the effectiveness of innovation policy in the European Union

Keywords: innovation development, R&D expenditures, rapprochement, disproportion, asymmetry, European integration

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INTRODUCTION

Globalisation trends in the world economy determine the innovation processes taking to a whole new level. Globalisation covers all stages of the innovation process – from basic research to the commercialisation of innovation. Close interaction of national innovation potentials, joint research by scientific communities of different countries, implementation of international innovation programs allow to achieve more significant results of innovation activities and open new opportunities in R&D (research and development) field.

The current policy of the European Union economic development, taking into account these trends, provides for the countries unification into an innovation union in which the stimulation of innovation development processes gets to the supranational level. However, the strengthening of integration processes, including in the field of scientific and technical cooperation, often gives rise to the so-called dissociation paradox. The paradox of dissociation is a manifestation of two opposite tendencies coexistence: to the economic space unification, on the one hand, and to its heterogenisation, on the other [1; 2]. The reason for this process is that countries that are close in some parametres tend to unite with each other. However, further expansion of integration associations such as the EU (European Union), the inclusion of national economies with a significant gap in levels of economic development, the state of national innovation systems, the dominance of different technological systems in the economy lead to increased heterogeneity and disintegration. Uneven development of the EU countries in the field of innovation is primarily associated with different amounts of R&D expenditures and the difference in goals and directions of their application.

In order to converge parameters and reduce disparities in the innovation development of the EU member states in 2002, the Council of Europe announced a course to create a single European research area, taking into account the EU enlargement, increasing the share of R&D expenditures in the EU to 3% of GDP (Gross Domestic Product); increasing the financing rate of innovation activities at the expense of private sector; increasing the level of vertical and horizontal coordination of innovation policy [3]. In this context, it is important to study the asymmetry of certain aspects of innovation development of the European Union countries and identify trends in its dynamics (convergent or divergent).

Problems of innovation development of the EU are a topic to study by many scientists. A study of innovation effect on the economic dynamics of European countries, conducted by V. Medeiros, C. Marques, A.R. Galvao, and V. Braga [4] show that gross domestic expenditure on R&D per capita is positively related to economic development indicators. At the same time, the countries of Northern Europe (Finland, the Netherlands, Norway, and Sweden) show better results in terms of innovation and entrepreneurship than the countries of Southern Europe (Spain, Greece, Italy and Portugal). The study of the existence and effectiveness of regional innovation systems in European countries by A. Rodriguez-Poz and R. Crescenzi [5] is aimed at analysing the relationship between investment in research and development, patents, and economic growth. Scientists have obtained results on the existence of intercountry disparities in the creation of new knowledge which affects the rate of economic growth in some regions.

The purpose of the study is an empirical study of the inequality and asymmetry of innovation expenditures in the EU countries and analysis of convergent-divergent trends in this area.

LITERATURE REVIEW

Internal convergence of the European Union in the field of policy to support research, development and innovation is one of the strategic goals of the association. This question has been of concern to scientists for a long time. Moreover, the results of comparing the EU countries in terms of innovation due to external and internal factors are various in different periods of the study. The study of the processes of innovation convergence in European countries by analysing the relative changes in the innovation situation at the beginning of the 21st century [6] showed that there were no significant changes in the process of convergence in the innovation sector. This was due to progress in a number of countries with a high level of innovation while countries with relatively worse starting positions did not improve significantly. In particular, these are the countries that joined the European Union as a result of its enlargement. Further research [7] points to the convergence of the innovation potential of the EU member states in 2004-2008, but under the influence of the economic crisis of 2008, the differences intensified. Countries with lower levels of development have suffered more from the crisis, so the disparities in innovation opportunities have increased, which required the development of new innovation policies. It was assumed that the implementation of such a policy should contribute to convergence in the level of innovation development. However, the results of the analysis conducted [8] by the σ- and β-convergence method showed significant differences in the innovation potential between the highly innovative northern and less developed southern part of the European Union. According to researchers, this fact significantly limits economic growth. The study of the development asymmetry of certain aspects of innovation potential, in particular, R&D expenditure in terms of three sectors – government, business and higher education – has shown increased convergence in this area [9]. It was established that the main driver of convergence for the EU-15 was the business sector and for the EU-13 – government expenditure. However, these trends have worsened as a result of the financial and economic crisis.

The study of M. Voinarenko [10] shows a significant level of differentiation of factors and results of regional innovation in the countries of the European Union. Leaders of technological development at the regional level in almost all sectors of high technology are the most advanced economies (Germany, Britain, France, Sweden, the Netherlands). The revealed positive dynamics of convergence as a result of reducing the gap between peripheral regions and leaders of innovative development is characterised as unsatisfactory which requires further improvement of regional and scientific and technical policy of the EU.

Using the data of the Framework Program of the European Union, E. Erdil, I. Akçomak, U. Cetinkaya [11] found that the desire to strengthen cooperation in the innovation sphere changes the dynamics towards the positive direction and proved the signs of innovation convergence, and they are most pronounced in the least developed regions of Europe.

P. Bednář and M. Halásková [12] in their research conclude that, despite the fact that Western Europe is a world leader in innovation among OECD countries, the distribution of innovation development indicators is not uniform across regions. Scientists note the existence of a general spatial divergence in innovation efficiency and R&D expenditures along with local convergent trends at the level of several regions.

W. Baumol, R. Nelson, and E. Wolff concluded that some countries may form a kind of dynamic "convergence clubs" based on the implementation of common policies. According to them, such a "club" includes industrialised countries and countries with transformational economies only which have the necessary potential for convergence [13].

Analysis of the convergence of innovation activity in European countries in terms of regional R&D expenditure, conducted by C. Barrios, E. Flores, M. Martínez [14] in the period of 2002-2012, confirmed the hypothesis of convergence in the form of "innovation clubs" creation. Club convergence envisages that different economies do not have a common growth trajectory for all, but a common among the group (cluster) close in terms of entry level of development and other characteristics. Thus, cluster (club) convergence envisages the grouping of countries into homogeneous clusters within which the rate of convergence significantly exceeds the corresponding figure for the entire sample [15].

Asymmetry of European countries innovation development is also noted in the studies of K. Koschatzky, T. Stahlecker, H. Kroll, M. Graffenberger [16]. A. Biurrun [17] explains the growth of internal inequality by the world economy turbulence and the consequences of the crisis in developed countries. The scientist proves that the positive general evolution of reducing inequality and technological progress in Europe is not a linear process. As a result of this, the relevance of structural and institutional transformations in the European region is growing.

Complex and unresolved problem of disproportionate innovation development in the European Union and the impact of these processes on economic growth indicators require additional research in this area.

MATERIALS AND METHODS

The study of convergence of innovation activity in European countries in terms of regional R&D expenditure in the article is carried out in the following logical sequence: study of the dynamics and structure of R&D expenditure in the EU countries; analysis of asymmetry indicators of innovation development; σ- and β-convergence evaluation; formulation of conclusions on the existence of convergent-divergent relations between the EU countries. The asymmetry of economic systems development is considered as inequality and disproportion and its increase or decrease is explained by divergence and convergence of development, respectively. The founders of the convergence theory, American scientists R. Barro and X. Sala-i-Martin [18] formulated two convergence concepts:

1) the concept of σ-convergence is observed when the variance of development indicators tends to decrease, ie there is a convergence in time of the levels of development of economic entities;

2) the concept of β-convergence occurs when less developed territories have higher rates of economic growth than more developed ones as a result of which in the long run there is a level convergence of economic development of territories.

These concepts are not equivalent as β-convergence indicates the existence of a long-term tendency to converge levels of economic development, while random shocks can lead to short-term growth of interregional differences and, consequently, σ-convergence [19].

The methodological approach to the study of interregional and intercountry disparities involves the use of appropriate mathematical tools. To determine the asymmetry of development in the study, a statistical apparatus using such indicators as the magnitude of variation, the coefficient of variation, the magnitude of regional disparities, standard deviation, oscillation, asymmetry and excess. The analysis of convergent-divergent dynamics (σ-convergence) was performed on the basis of variation index calculation.

The variation coefficient for determining σ-convergence (quantitative homogeneity of a set of objects) was determined by the formula:

$$K_{var} = \frac{\sigma}{\bar{y}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2}}{\bar{y}} \quad (1)$$

where y_i is the level of R&D expenditure in country i; $(\bar{y})$ – average level per capita; n – number of countries; σ – standard deviation of y values.

This indicator is considered both in statics to analyse the differences that occur at a particular time and in dynamics – to determine changes in the characteristics of a

set of objects. The increase in the indicator value in the dynamics indicates a general divergence trend among countries [15].

β-convergence characterises the situation when countries with a low level of the studied indicator have higher rates of economic growth than countries with its low level. Thus, in the long run there is an equalisation of levels of economic development [20].

To determine β-convergence, an econometric apparatus was used the application of which is based on the construction of regression models of expenditure and rate indicators. The study was conducted on the basis of analysis of statistical data analysis of 28 countries of the European Union for the period of 2008-2019.

RESULTS AND DISCUSSION

The European Union continues to develop a knowledge-based economy. The impetus to launch the innovation development strategy was the lag in the EU's economic growth from the United States which appeared in the 1990s. To a large extent, these trends were due to the insufficiently rapid technological development of the European Union, low rates of innovation, unsatisfactory level of funding in this area. As a result of the EU enlargement, the new members introduced negative characteristics of their own innovation systems, increased the disproportion of scientific and technological development. In view of this, overcoming differences and inequalities in the implementation of innovation processes and the realisation of scientific and technological potential of European countries has become one of the important tasks in the formation of integration cooperation.

The national innovation policy is most vividly characterised by the volume and financing directions of the scientific and technical sphere. Forms of research and development funding in the European Union differ depending on the nature of innovation: basic research and projects of national importance are funded entirely from the state budget, applied research – on a different basis. Research institutions conducting basic research receive basic financial support as institutions. Currently, 2.14% of GDP is spent on R&D in the EU, while in the US – 2.64%, Japan – 3.04%, with the share of the private sector in innovation financing in the US is 68.2%, in the EU – 66.4% [21].

Recently, there have been changes in the implementation of the innovation development strategy. Some countries have increased R&D expenditures or refused to reduce them which in general had a positive effect on the dynamics of innovation expenditures in the whole association (Fig. 1).

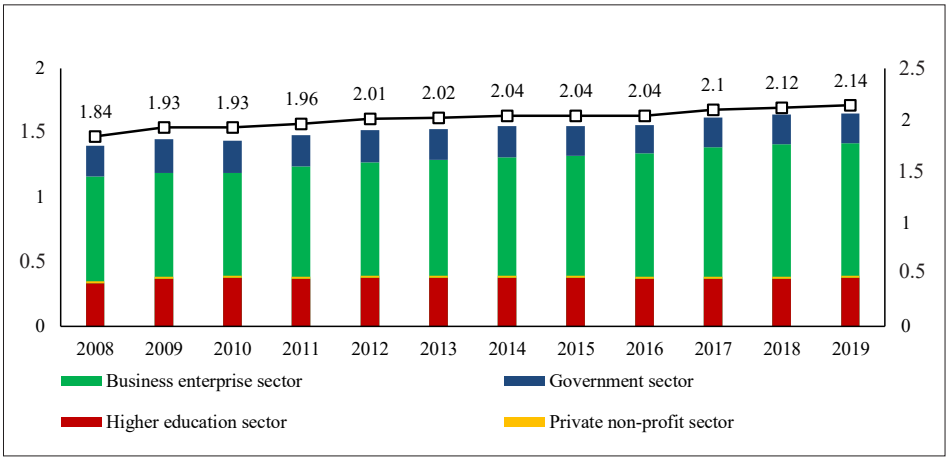

***Figure 1**. Dynamics and structure of R&D expenditures in the EU-28 countries in 2008-2019, % of GDP*
***Source**: developed by the authors based on Eurostat Database, 2020 [21]*

The shift towards increasing the share of R&D expenditures in GDP was due to the consistent implementation of the European Economic Development Strategy "Europe 2020: a strategy for smart, sustainable and inclusive growth" which provided for high intellectual, sustainable and inclusive economic growth. This strategy contained a targeted initiative "Innovation Union" among the goals of which can be identified: increasing the innovation efficiency within the innovation association, as well as increasing the competitiveness and protection of the interests of innovation; integrating countries should implement a national innovation policy that is in line with the common innovation policy developed at the supranational level during integration [22]. The implementation of programs to stimulate innovation was also aimed at leveling the interregional characteristics of innovation development. The most common methods of regional development disparities evaluation involve the use of two methods: determining the discrepancy between the most prosperous and most problematic regions (scope of regional disparities) and estimate of the deviation range of regional indicators relative to their average value (using the variation coefficient) [23]. More detailed system of indicators is considered to be necessarily used for analysis. The dynamics study of these indicators will determine the type of innovation development:

asymmetric, harmonious and neutral. In this case, asymmetric (disharmonious) is a type of regional development for a certain period during which the regions that have a relative advantage of one or another indicator at the beginning of the period, then increase it, and regions that have a relative lag, increase it. In contrast, symmetrical (harmonious) is a type of regional development in which the gap in the level of regional indicators is reducing. With the neutral type of development, the ratio of regional indicators during the period remains unchanged [24].

An empirical study based on Eurostat data for 2008-2021 revealed the effectiveness of the policy to reduce asymmetry among the EU countries in terms of expenditures on research and development (Table 1).

***Table 1**. Indicator's dynamics of innovation development asymmetry in the EU countries in 2008-2019*

Time period (year)	Maximum	Minimum	Average value	Scope of variation	Coefficient of non-uniformity	Scope of regional disparities	Mean linear deviation	Mean square deviation	Dispersion	Coefficient of oscillation,%	Coefficient of variation,%	Coefficient of asymmetry	Excess
2008	3.54	0.39	1.43	3.15	9.08	2.2	0.69	0.88	0.77	219.79	61.22	0.95	0.26
2009	3.73	0.44	1.50	3.29	8.48	2.2	0.74	0.92	0.85	219.80	61.56	0.83	0.003
2010	3.71	0.44	1.51	3.27	8.43	2.17	0.71	0.89	0.79	216.71	58.91	0.79	-0.13
2011	3.62	0.45	1.58	3.17	8.04	2.01	0.75	0.89	0.8	201.18	56.71	0.61	-0.64
2012	3.40	0.44	1.60	2.96	7.73	1.85	0.76	0.89	0.79	184.59	55.39	0.57	-0.9
2013	3.27	0.39	1.61	2.88	8.38	1.79	0.75	0.88	0.77	178.80	54.49	0.52	-0.96
2014	3.15	0.38	1.60	2.77	8.29	1.73	0.73	0.85	0.72	173.05	53.14	0.55	-0.98
2015	3.22	0.48	1.61	2.74	6.71	1.7	0.72	0.83	0.69	170.11	51.58	0.62	-0.86
2016	3.25	0.44	1.55	2.81	7.39	1.82	0.74	0.86	0.75	181.71	55.89	0.68	-0.79
2017	3.36	0.50	1.58	2.86	6.72	1.81	0.72	0.85	0.73	181.26	54.13	0.68	-0.72
2018	3.32	0.50	1.62	2.82	6.64	1.74	0.72	0.85	0.72	173.81	52.16	0.66	-0.75
2019	3.40	0.48	1.65	2.92	7.08	1.77	0.73	0.87	0.75	176.51	52.49	0.62	-0.78
2019 to 2008, %	96.1	123.1	115.4	92.7	78.0	80.5	105.8	98.9	97.4	80.3	85.7	65.3	96.1

***Source**: developed by the authors based on Eurostat Database, 2020 [21]*

The obtained results of the spatial-dynamic estimate of the coefficients of uneven development confirm the disproportion presence. There is a tendency to reduce the asymmetry, though the differences remain significant. The value of variation coefficient – one of the most significant asymmetry indicators is quite high and exceeds 50% throughout the 12-year period. This indicates the presence of significant heterogeneity of the population and high variation level. The analysis of the asymmetry coefficient dynamics showed that the distribution of countries by the level of R&D expenditures is characterised by right-sided asymmetry (the indicator is positive), so most countries have a value of the studied parameter below average. Negative value of excess rate throughout the study period means that there is no so-called "core" which slightly varies, i.e., the countries concentration around the average value is insignificant.

Dynamics of absolute variation indicators – average linear deviation, standard deviation, variation magnitude have a slight tendency to decrease. The conclusion to the significant degree of variation of the studied parameter during the whole period confirms the value of the oscillation coefficient which varied in the range of 219.79-176.51 but the amplitude of oscillations relative to the average value decreases.

The analysis results give grounds to hypothesise the existence of convergent trends in the studied characteristics of innovation development. To confirm this conclusion, σ-convergence which is defined as the decrease over time of the variation indicator (inequality, differentiation) of development of regions (countries), is going to be estimated. In addition to the variation indicator, such an indicator as the standard deviation is going to be used (Fig. 2).

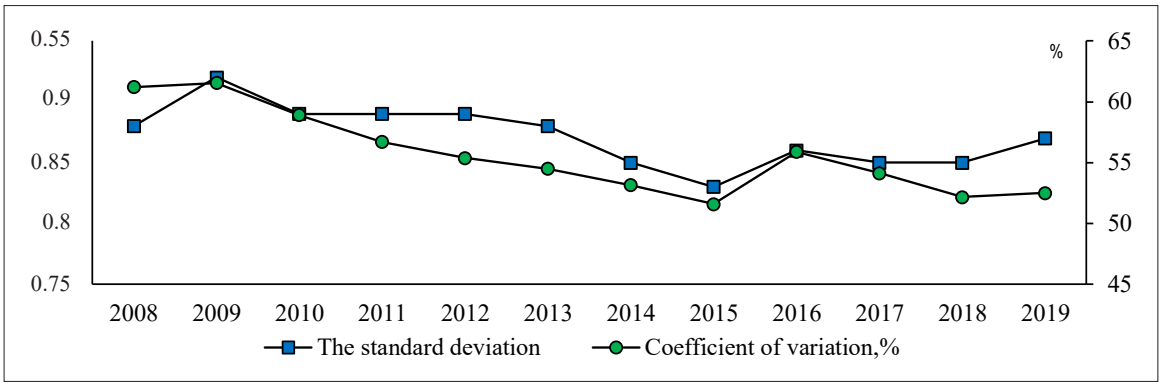

Figure 2. *Intercountry σ-convergence in terms of R&D expenditures in the EU countries in 2008-2019*
Source: *developed by the authors based on Eurostat Database, 2020 [21]*

The dynamics of both analysed indicators allows to draw conclusions about the tendency of gradual increase in convergence but the variation indicator is considered to be more informative because it does not depend on the dimension and scale of variables. The polarisation of the EU countries due to the implementation of a consistent innovation policy is declining as evidenced by the reduction of the variation coefficient by 8.73% points.

However, the reduction of regional development asymetry cannot be unambiguously interpreted as a positive shift. It may be caused by the deterioration of indicators in highly developed countries, thereby leading to approximation the indicators of countries with low levels of research parameters. Such smoothing is undesired for the development of the integration association as a whole. In order to formulate final conclusions, it is necessary to establish the presence of β-convergence for which the econometric apparatus was used and a regression model was built in which the dependent variable is the growth rate of innovation funding, and independent – entry level indicator. This will allow evaluating the dynamics of differentiation based on the pace of development of individual EU countries (study period – 12 years) (Fig. 3).

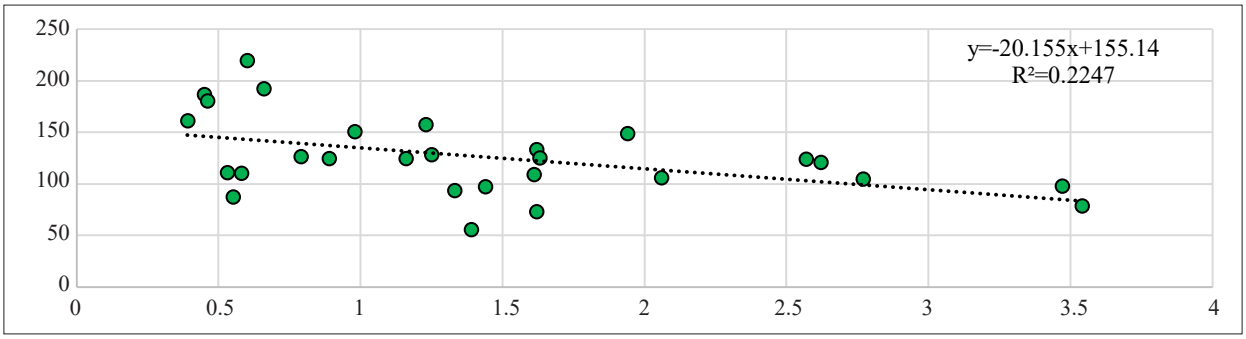

Figure 3. *Absolute β-convergence of R&D expenditures dynamics in the EU in 2008-2019*
Sources: *developed by the authors based on Eurostat Database, 2020 [21]*

According to the convergence hypothesis, if a country (region) economy is initially away from the position of stable equilibrium, its growth rate will be higher than in the economy that is closer to it [16]. The hypothesis of β-convergence is confirmed by the negative regression coefficient, with a positive value a divergence is observed. The statistical significance of the regression coefficients of the constructed model is confirmed, Fisher's criterion is actually larger than the tabular criterion ($F\text{-criterion}_{factual}$ = 7.5348, $F\text{-criterion}_{tabular}$ (1.26) = 4.23). The negative value of the regression equation coefficient (-20,155) allows to conclude that countries lagging in terms of innovation financing have higher rates of increasing innovation expenditures which in the long run implies a convergence of the innovation development level of countries within the EU.

CONCLUSIONS

In summary, it should be noted that the unevenness and disproportion of regional parameters of innovation development has a significant impact on economy efficiency as differences lead to conflicts between regions (countries). The results of the conducted study of the innovation expenditures asymmetry and the study of convergent-divergent relations between the countries of the European Union to summarize that the countries are converging.

Convergent trends are observed in terms of development asymmetry and σ-convergence. The hypothesis of the existence of absolute β-convergence of the dynamics of R&D expenditures in the EU countries was confirmed by the results of building a regression model of the dependence of entry and tempo indicators. The

catching-up effect is manifested in the increase of innovation financing indicators in the countries lagging in these parameters. The tendency to reduce differentiation and rapprochement of countries in this context indicates the existence of a coherent innovation policy which proves its effectiveness in practice. In the long run, adherence to such a vector of development will allow the European Union to gain the status of a leader in research and innovation and ensure high rates of economic growth on an innovation basis.

Funding for R&D expenditure in the European Union will undoubtedly be affected by the UK's secession from the association. This, in turn, may change the trends identified as a result of the study. The nature analysis of this effect will determine the directions for further research.

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Емпіричне дослідження конвергентно-дивергентних тенденцій інноваційного розвитку країн ЄС

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Анотація. Стаття присвячена розгляду проблеми диспропорційності інноваційного розвитку в країнах Європейського Союзу та впливу даних процесів на показники економічного зростання. Метою роботи є емпіричне дослідження нерівномірності та асиметричності здійснення інноваційних витрат у країнах ЄС та аналіз конвергентно-дивергентних тенденцій у цій сфері. Результати останніх досліджень виявляють прагнення до посилення співпраці в інноваційній сфері, що змінює ситуацію в позитивному напрямку та доводять наявність ознак конвергенції інновацій, причому найбільше вони проявляються в найменш розвинених регіонах Європи. Актуальність вирішення даної наукової проблеми полягає в тому, що внутрішнє зближення країн Європейського Союзу у сфері політики підтримки досліджень, розробок та інновацій є однією зі стратегічних цілей асоціації. Методичним інструментарієм для визначення асиметричності розвитку стали моделі, які засновані на концепції конвергенції. Дослідження проводилось на основі аналізу статистичних даних 28 країн Європейського Союзу за часовий період 2008–2019 рр. У статті представлено результати емпіричного аналізу асиметричності інноваційного розвитку країн ЄС за показником витрат на дослідження та розробки. Встановлено, що відбувається зрушення в бік збільшення частки витрат на НДДКР у ВВП. Виявлено конвергентні тенденції за показниками асиметричності розвитку, σ-конвергенції та β-конвергенції. Дослідження емпірично підтверджує та теоретично доводить, що скорочення диференціації та зближення країн проявляється в підвищенні показників фінансування інновацій в країнах, що відстають за цими параметрами. Практичне значення результатів проведеного дослідження полягає у можливості їх використання для оцінки дієвості інноваційної політики в країнах Європейського Союзу

Ключові слова: інноваційний розвиток, витрати на НДДКР, зближення, диспропорційність, асиметрія, євроінтеграція