“Is increasing a share of R&D expenditure in GDP a factor in strengthening the level of innovation development in Ukraine compared with GII’s top countries?”

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IS INCREASING A SHARE OF R&D EXPENDITURE IN GDP A FACTOR IN STRENGTHENING THE LEVEL OF INNOVATION DEVELOPMENT IN UKRAINE COMPARED WITH GII'S TOP COUNTRIES?

Abstract

The study aims to test whether increasing a share of R&D expenditure in GDP strengthens the level of innovation development in Ukraine compared with top countries in the Global Innovation Index. It models the impact of changing a share of R&D expenditure in GDP on the level of innovation development based on 10 countries-leaders in GII 2022 and Ukraine. Correlation analysis proved the existence of a relationship between the levels of R&D expenditure (as percent of GDP) and innovation development (the overall score of GII); its strength and direction are characterized (for 2011–2020). The results show that in GII's top countries, the relationship between innovation development and R&D expenditure is direct in 70% of the sample's countries, mostly with high and very high relationship power without time lag or 1-2-year time lag. This relationship is inverse in Ukraine, with high relationship power and a 1-year time lag. The system dynamic linear panel-data model is built to determine and formalize the impact of changing a share of R&D expenditure in GDP on the level of innovation development for GII's top countries and the linear regression model – for Ukraine. For GII's top countries, it is confirmed that with an increase in R&D expenditures by 1%, innovation development potentially increases by an average of 2.71%, and in Ukraine – it decreases by an average of 4.8%. This discrepancy is explained by the need to improve state policy and regulatory framework in innovation development and its financing in Ukraine.

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INTRODUCTION

Today, the critical role of innovations in economic development is beyond doubt, especially in the digital transformation era (Pakhnenko & Kuan, 2023; Chen et al., 2023). Building innovative potential plays a central role in the growth dynamics of prosperous countries (OECD, n.d.). Innovation is a key driver of economic growth, accelerates economic recovery, and puts countries on the path to sustainable development. Innovation development is associated with new opportunities and advantages, increasing the efficiency of economic and other activities, optimizing costs, and increasing income (V. Raghupathi & W. Raghupathi, 2017; Melnyk et al., 2022). Therefore, one of the critical objectives of the EU over the past few decades has been to encourage increased investment in research to boost competitiveness (Eurostat, 2023).

Research and development (R&D) expenditure is one of the indicators of innovation development, especially in the context of indices of innovation investments and global science within the Global Innovation Index (GII) on a row with venture capital deals, international patent filings, scientific publications, etc. It is also a key indicator of government and private sector efforts to gain a competitive advantage in science and technology. It includes both capital and current expenditures in four sectors: government, business enterprise, higher education, and private non-profit organization, covering fundamental and applied research and experimental development.

In 2022, R&D expenditure relative to the GDP of the EU stood at 2.23 %, lower than in 2021 (2.27 %) (Eurostat, 2023). This indicator differs from country to country. In Ukraine, this indicator is at the level of 0.29% of GDP (2021), which is lower than the value of 2020, when R&D expenditures reached 0.4% of GDP (World Bank, n.d.d). At the same time, these indicators are available and were calculated by the World Bank in the pre-war period in Ukraine.

1. LITERATURE REVIEW

A significant amount of scientific work has been created on innovation development issues, but given the dynamism of innovation development, new challenges, and achievements in this field, this scientific direction of research is constantly relevant.

One of the important questions that scientists ask themselves is the effectiveness of innovations, their role, and their impact. Innovation efficiency is considered an optimal combination of contribution and result (Triyonowati et al., 2023).

Within the organized innovation space, the chances of strengthening sustainable development are increasing, which is especially important in countries with a transition economy to accelerate and complete socioeconomic transformations. The direction of developing industrial, technological, and scientific parks in Ukraine is determined using the five-fold spiral model in the "knowledge-innovation" plane (Petrushenko et al., 2021).

The formation and development of the organizational and economic mechanism for the activation of innovation development is the key to the development of the economy, the formation of competitive production, and the assurance of sustainable development (Berezhnytska et al., 2022).

Shkarupa et al. (2022) investigated innovation development in Ukraine compared to European countries and considered European development trends. The study emphasized that in countries with a developed economy, the acceleration of scientific and technological progress and the introduction of innovations differ and are related to the opportunities to develop the knowledge economy, commercialization of technologies, and innovation transfer networks.

In the context of R&D expenditures, the emphasis on innovation financing and financial regulation is made by Strielkowski et al. (2022), who examined innovation development's tax, monetary, budgetary, and investment instruments.

The issue of investing in innovation was considered by Iastremska et al. (2023), who studied the impact of investments in research and development as the basis of innovation development in modern conditions of economic development in real and virtual space.

In this regard, the relevance of the problem of forming a system of specialized innovation and investment banks, co-investment funds, etc., which would specialize in the field of investment support for innovation development, is not lost (Kozmenko & Vasylieva, 2008; Leonov et al., 2012).

Mallinguh et al. (2022) analyzed the factors affecting R&D spending in developing countries. The results show that exports, skilled labor availability, and informal competition are positively and significantly correlated with R&D expenditures. In contrast, innovation strategy, financial constraints, and technological incompatibility have little effect on the outcome variable.

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Ildırar et al. (2016) assessed the impact of R&D spending on economic growth, taking into account the impact of various types of R&D spending on economic growth for selected OECD countries for 2003–2014. All R&D expenditures were found to positively and significantly impact economic growth in individual OECD countries, but the magnitudes varied. Goel et al. (2008), however, using the example of the USA for the 48 years from 1953 to 2000, found a similar influence.

Bozkurt (2014) also identified a relationship between R&D expenditures and economic growth and its assessment. The author concluded that there is a long-run relationship between R&D spending and economic growth based on Johansen's cointegration and vector error correction models; specifically, the GDP growth rate will increase by 0.2630% if the share of R&D in GDP increases by 1%.

Another assessment of the impact of investment in R&D (in particular, the share of investment in research and development in the high-tech sector) on long-term economic growth is presented by Falk (2007) based on panel data for OECD countries from 1970 to 2004. A strong positive impact on GDP per capita was found.

Sokolov-Mladenović et al. (2016) examined the impact of R&D spending on economic growth in the EU for 28 countries over the period 2002–2012 based on a multiple regression model, which showed that a 1% increase in R&D spending (as a percentage of GDP) would lead to an increase in real GDP growth rates of 2.2 %.

Investments in research and development, technological innovation, and economic growth are mutually influencing and inseparable. Comparing data from China from 1995 to 2016, Liu and Xia (2018) constructed an index of R&D investment, technological innovation, and economic growth as study variables in a vector autoregression model. A long-term, stable, and dynamic relationship was revealed.

Pegkas et al. (2019) investigated the relationship between innovation and R&D spending in the EU countries for 1995–2014. The results of the empirical analysis showed a relationship between innovation and research and development and a positive and significant impact of business, state, and higher education research and development on innovation.

The question of the connection and impact of business expenditures on research and development on innovation activity in the EU countries was studied by Hunady and Pisar (2020), who focused on research and development in the business sector as the most important part of the innovation system. At the same time, the study emphasizes that although R&D spending can be considered the main prerequisite for successful innovation, successful transformation of investments in research and development into an invention or innovation cannot be guaranteed. In the long term, a positive cause-and-effect effect of business expenditures on R&D on patenting has been determined. Relationships between R&D expenditures, patent activity, and intellectual property were also at the center of attention of Samoilikova and Artyukhov (2023) and Soumadi (2023).

In addition to business expenditures on R&D, scholars separately study the impact of education sector expenditures on R&D (Yu et al., 2023) in the context of university-company competition (Nahla, 2023; Kaya et al., 2023). Artyukhov et al. (2021) developed a model of transfer of innovations from the field of education to ensure innovation development.

However, based on the above, it is worth noting that most scientists have studied the role of R&D spending in qualitative or quantitative terms, primarily on economic growth. The impact of R&D expenditures on strengthening innovation development was practically not assessed, especially for Ukraine compared to key countries, according to the Global Innovation Index.

The research purpose is to determine the impact of changing R&D expenditure in GDP on the level of innovation development based on 10 countries-leaders in GII 2022 and Ukraine.

The research hypothesis is formulated as follows:

H1: *Increasing a share of R&D expenditure in GDP strengthens the level of innovation development in Ukraine and top countries in the Global Innovation Index.*

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2. METHODS

The research methodology uses statistical, comparative, correlation, and regression analyses. Correlation analysis is used to confirm the relationship between the level of innovation development and R&D expenditure based on Pearson and Spearman methods of calculation of correlation coefficients (Pearson, 1896; Pearson & Filon, 1898; Spearman, 1904; Stata, n.d.b; Stata, n.d.d), checking Shapiro-Wilk test for normal data and taking into account possible time lags (Shapiro & Wilk, 1965; Shapiro & Francia, 1972; Stata, n.d.c).

Regression analysis is applied to formalize and estimate the influence of R&D expenditures on innovation development. For GII's top countries, a regression model for the assessment of panel data was built, especially a system dynamic linear panel-data model by Arellano-Bover/Blundell-Bond. For Ukraine, a linear regression model was used to assess time series data (Arellano & Bover, 1995; Blundell & Bond, 1998; Blundell et al., 2000; Stata, n.d.a). The comparative analysis compared obtained results in GII's top countries and Ukraine. All calculations and modeling are made in the STATA 18 software package.

The information base involves statistical data from INSEAD, WIPO, and World Bank for a sample of 10 leading countries in GII-2022: Denmark, Finland, Germany, the Netherlands, the Republic of Korea, Singapore, Sweden, the United Kingdom, Switzerland, the United States of America (WIPO, 2022), and Ukraine for the period 2011–2020 according to the following indicators:

- the level of innovation development as a value of the general score of the Global Innovation Index (GII) (WIPO, 2022; WIPO, n.d.; INSEAD, 2011; INSEAD & WIPO, 2012);
- research and development expenditure as a percent of GDP, % (RD) (World Bank, n.d.d);
- net inflows of foreign direct investment, % of GDP (FDI) (World Bank, n.d.a);
- annual GDP per capita growth, % (GDP) (World Bank, n.d.b);
- labor force participation rate, total (% of total population ages 15-64) (L) (World Bank, n.d.c).

3. RESULTS AND DISCUSSION

Before applying correlation analysis, the data for the factor variable should be checked for submission to the law of normal data distribution using the Shapiro-Wilk test (Table 1), which will allow deciding on the appropriate correlation analysis method in the following research stage.

Table 1. Checking the normal distribution of the data for R&D expenditure based on the Shapiro-Wilk test

Country name	Obs	W	V	z	*Prob>z*
Switzerland	10	0.82912	2.633	1.843	0.03266 *
The United States of America	10	0.86152	2.134	1.408	0.07953
Sweden	10	0.97722	0.351	–1.631	0.94856
The United Kingdom	10	0.91056	1.378	0.568	0.28487
The Netherlands	10	0.80542	2.999	2.123	0.01687 *
The Republic of Korea	10	0.94820	0.798	–0.378	0.64723
Singapore	10	0.90105	1.525	0.755	0.22499
Germany	10	0.91859	1.255	0.398	0.34537
Finland	10	0.87190	1.974	1.252	0.10520
Denmark	10	0.90387	1.481	0.702	0.24147
Ukraine	10	0.86401	2.096	1.372	0.08508

Note: * – the data do not follow a normal distribution (Prob > z is less than 0.05).

The results of the Shapiro-Wilk test mean that data for the factor variable of R&D expenditure do not follow a normal distribution in Switzerland and the Netherlands (Prob > z is less than 0.05). The Spearman correlation method is used for these countries, and for other countries, the Pearson correlation method is applied. The results of correlation analysis, including the calculation of the correlation coefficient without time lag and 1-3-year time lag, are given in Table 2 to confirm the existence of the relationship and to determine when the investigated relationship is the most statistically significant.

The results of correlation analysis show that in GII's top countries, the relationship between the level of innovation development and R&D expenditure is confirmed; it is direct in 7 from 10 countries (70%

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Table 2. Confirmation of the relationship between the level of innovation development and R&D expenditure based on Pearson and Spearman correlation analysis

Country name	Correlation coefficient				Relationship power	Relationship direction
	Without time lag	1–year time lag	2–year time lag	3–year time lag		
Switzerland	0.4	0.1	0.5	0.3	high	direct
The United States of America	0.5	0.3	0.2	0.1	high	direct
Sweden	0.2	–0.1	0.1	–0.4	moderate	inverse
The United Kingdom	–0.1	–0.5	–0.8	–0.7	very high	inverse
The Netherlands	–0.3	0.1	–0.1	–0.1	moderate	inverse
The Republic of Korea	0.6	0.5	0.5	0.5	high	direct
Singapore	0.04	0.4	0.6	0.5	high	direct
Germany	0.8	0.5	0.3	0.04	very high	direct
Finland	0.02	0.7	0.5	0.6	high	direct
Denmark	0.1	0.3	0.2	0.3	moderate	direct
Ukraine	–0.6	–0.7	–0.6	–0.3	high	inverse

Note: 0 < |r| ≤ 0,19 – low correlation; 0,2 < |r| ≤ 0,49 – moderate correlation; 0,5 < |r| ≤ 0,79 – high correlation; 0,8< |r| ≤1 – very high correlation; a positive sign of the correlation coefficient characterizes a direct relationship, a negative one – an inverse relationship.

of the sample), mostly with high and very high relationship power without time lag or 1-2-year time lag. In the other 3 from 10 countries (30% of the sample), the relationship is inverse with moderate or very high relationship power without time lag or 2-3-year time lag.

In Ukraine, the relationship between the level of innovation development and R&D expenditure is confirmed as inverse with high relationship power and 1-year time lag.

Based on the identified relationship, to formalize the influence of the factor of R&D expenditures on the level of innovation development, a regression model was built for the assessment of panel data for GII's top countries (2011–2020) and time series data for Ukraine (2011–2020).

To increase the adequacy of the constructed models in addition to investigated indicators of the level of innovation development (as the value of general score of Global Innovation Index) (GII) and R&D expenditure (as a percent of GDP) (RD), the following additional indicators were added to the model:

- net inflows of foreign direct investment (% of GDP) (FDI);
- annual GDP per capita growth (%) (GDP);
- the rate of labor force participation (% of total population ages 15-64) (L).

For panel data of GII's top countries, system dynamic linear panel-data model by Arellano-Bover/Blundell-Bond was applied to estimate the impact of R&D expenditures on the level of innovation development.

This systemic dynamic linear model of panel data estimates assumes that panel-level unobserved effects correlate with the dependent variable's time lags. In addition, since this model is an extension of the Arellano-Bond estimator, which takes into account large parameters of autoregression and the ratio of the variance of the effect at the panel level to the variance of the idiosyncratic error, the influence of the values of the outcome variable of past periods is also taken into account. This method assumes no autocorrelation in the idiosyncratic errors and requires that the panel-level effects be uncorrelated with the first difference of the first observation of the dependent variable.

The following formula is used to construct the equation:

$$Y_{it} = \sum_{j=1}^{p} \alpha_j y_{i,t-j} + x_{it}\beta_1 + w_{it}\beta_2 + v_i + \varepsilon_{it}, \qquad (1)$$

$$i = 1, \ldots, N, t = 1, \ldots, T_i$$

where the α_j are p parameters to be estimated; x is a 1 × k_1 vector of strictly exogenous covariates; β_1 is a k_1 × 1 vector of parameters to be estimated; w_{it} is a 1 × k_2 vector of predetermined or endogenous covariates; β_2 is a k_2 × 1 vector of parameters to be estimated; v_i are the panel-level effects; ε_{it} are independent and identically distributed variables over the whole sample with variance σ^2.

In the case of this paper, the rate of labor force participation is a predefined exogenous variable. All other investigated variables are considered endogenous. The results of regression modeling are shown in Table 3.

The level of significance of the model (Prob > chi2 = 0.0000) and Wald test results (Wald chi2(14) = 170.88) means the adequacy of the built model. The coefficients for investigated indicators with a certain time lag are chosen based on the level of significance of z-statistics (P>|z| is not more than 0.05 – 95% – with 95% of probability, the hypothesis is confirmed, or 0.1 – 90% – with 90% of probability, the hypothesis is confirmed).

The resulting regression equation can be written as follows:

$$GII = 0.58GII_{t-1} + 2.71RD + \\ +0.05FDI_{t-2} + 0.13GDP + 0.2L + 9.86, \quad (2)$$

where *GII* – the level of innovation development as a value of the general score of the Global Innovation Index; *RD* – research and development expenditure as a percent of *GDP*; *FDI* – net inflows of foreign direct investment; *GDP* – annual GDP per capita growth; *L* – labor force participation rate.

So, for the panel of GII's top countries, R&D expenditures positively impact the level of innovation development: with an increase in R&D expenditures (as a percentage of GDP) by 1%, the level of innovation development (as the overall score of the Global Innovation Index) potentially increases by an average of 2.71% with 90.5% of probability.

The results of regression modeling for Ukraine are given in Table 4.

According to Fisher's test, the model's significance level does not exceed 0.05 (Prob > F = 0.05), which indicates the adequacy of the constructed model. The determination coefficient is not very high

Table 3. The results of the system dynamic linear panel-data model to formalize the influence of the factor of R&D expenditures on the level of innovation development in GII's top countries

GII	Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
GII						
L1.	.5826121	.1030207	5.66	0.000	.3806952	.7845291
RD						
L0.	2.718589	1.628147	1.67	0.095	–.4725212	5.909699
L1.	–3.367692	2.609632	–1.29	0.197	–8.482477	1.747093
L2.	2.03681	2.535079	0.80	0.422	–2.931855	7.005474
L3.	–1.371224	1.633861	–0.84	0.401	–4.573533	1.831085
FDI						
L0.	–.0294809	.0137518	–2.14	0.032	–.056434	–.0025278
L1.	.0110747	.01271	0.87	0.384	–.0138365	.0359858
L2.	.0548766	.0154424	3.55	0.000	.02461	.0851432
L3.	–.0678668	.0218512	–3.11	0.002	–.1106944	–.0250392
GDP						
L0.	.1322446	.0668045	1.98	0.048	.0013102	.263179
L1.	–.0700172	.2002193	–0.35	0.727	–.4624397	.3224053
L2.	–.1383543	.1519127	–0.91	0.362	–.4360978	.1593891
L3.	–.2167972	.1280184	–1.69	0.090	–.4677086	.0341143
L	.205064	.0884266	2.32	0.020	.031751	.3783769
_cons	9.868097	5.642228	1.75	0.080	–1.190468	20.92666

Note: L0 – without time lag, L1, L2, L3 – 1-year, 2-year, and 3-year time lags; GII – the level of innovation development as a value of general score of Global Innovation Index; RD – research and development expenditure; FDI – net inflows of foreign direct investment; GDP – annual GDP per capita growth; L – labor force participation rate.

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Table 4. The results of the linear regression model to formalize the influence of R&D expenditures on the level of innovation development in Ukraine

GII	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
RD	–4.797271	2.187116	–2.19	0.060	–9.840769	.2462269
_const	39.24248	1.270601	30.88	0.000	36.31247	42.17249
Source	**SS**	**df**	**MS**			
Model	3.60733852	1	3.60733852	Number of obs = 10		
Residual	5.99835148	8	.749793934	Prob > F = 0.05		
Total	9.60569	9	1.06729889	R-squared = 0.3755		

Note: GII – the level of innovation development as a value of the general score of the Global Innovation Index; RD – research and development expenditure as a percent of GDP.

(R-squared = 0.3755), but it is at an average level, which does not indicate a low quality of the model.

The regression equation has the following form:

$$GII = -4.8RD + 39.24, \tag{3}$$

where *GII* – the level of innovation development as a value of the general score of the Global Innovation Index; *RD* – research and development expenditure as a percentage of GDP.

So, for Ukraine, with a 94% probability, R&D expenditures do not positively impact the level of innovation development: with an increase in R&D expenditures (as a percentage of GDP) by 1%, the level of innovation development (as the overall score of the Global Innovation Index) potentially decreases by an average of 4.8%.

That is why the hypothesis that increasing a share of R&D expenditure in GDP strengthens the level of innovation development in Ukraine and the top countries in GII was confirmed partly, only for GII's top countries.

Based on international ratings, Lymonova and Mahdich (2020) determined that Ukraine still needs a better regulatory environment and the development of a new legislative framework that would establish incentives for investing in priority areas of scientific and research work, which should be agreed with.

Some scholars have studied the relationship and impact of R&D expenditures on the overall evaluations of other global indices. In particular, Kiselakova et al. (2018) studied the impact of R&D spending on the assessment of the Global Competitiveness Index and its sub-indices using correlation analysis for the period 2007–2016. At the same time, the authors did not assess the impact on the Global Innovation Index, as in this study.

The determination of the share of R&D expenditures in GDP in the world as one of the key indicators of innovation development was also a research subject of Gavrilko and Pobochenko (2021). They found out the trend of R&D expenditures in the world for 2017–2021, emphasizing that during the COVID-19 companies' R&D spending fluctuated slightly, while global R&D spending increased. At the same time, these findings have not been formalized and validated with a quantitative assessment, as in this study.

Ivanová and Žárská (2023) had a similar purpose. They also confirmed the relationship between research and development expenditures and the aggregate innovation index based on correlation analysis but using the example of a sample of the Visegrad Group countries for a relatively shorter period from 2014 to 2021. Their results indicate a positive correlation between R&D expenditures and the aggregate innovation index in all V4 countries. However, the statistical significance of this relationship was confirmed only in the Czech Republic and Poland. Comparing the results of the present study with the above, further formalization and quantitative assessment of the impact based on the construction of regression models is the next step after the correlation analysis to be advantageous.

M. Dritsaki and C. Dritsaki (2023) ground the relationship between R&D spending and the Global Innovation Index, but for another sample and based on other methodology, in particular, in the EU countries for the period 2007–2020, using causal analysis and the PVAR model to determine the relationship between research spending and innovation growth in the EU countries. The results show a long-term positive significant relationship between R&D expenditure and the Global Innovation Index, while the relationship is negative in the short run. At the same time, the results obtained in this paper show that the relationship between studied indicators is not positive (direct) in all EU countries.

CONCLUSION

The purpose of the study was to determine the impact of changing a share of R&D expenditure in GDP on the level of innovation development in countries-leaders in GII-2022 and Ukraine. For the top 10 countries in GII rating and for Ukraine, correlation analysis allowed confirming that in GII's top countries, the relationship between the level of innovation development and R&D expenditure is direct in 7 from 10 countries (70%) mostly with high and very high relationship power without time lag or 1-2-year time lag. This relationship is inverse in Ukraine, with high relationship power and a 1-year time lag. A regression model was built to assess panel data for GII's top countries (system dynamic linear panel-data model by Arellano-Bover/Blundell-Bond) and time series data for Ukraine (linear regression model). In GII's top countries with an increase in R&D expenditures (as a percentage of GDP) by 1%, the level of innovation development (as the overall score of GII) potentially increases by an average of 2.71% with 90.5% probability. In Ukraine, with an increase in R&D expenditures (as a percentage of GDP) by 1%, the level of innovation development (as the overall score of the Global Innovation Index) potentially decreases by an average of 4.8% with a 94% probability.

The results show the different effectiveness of increasing R&D spending and their opposite effect in Ukraine and the top countries regarding the level of innovation development. In Ukraine, increasing a share of R&D expenditure in GDP is not a factor in strengthening the level of innovation development compared with GII's top countries. This discrepancy is explained by the need to improve state policy and regulatory framework in innovation development and its financing in Ukraine. At the same time, this study is limited by the sample of countries and time, which should be expanded in further studies to increase the quality of the obtained research results. Also, in further studies, it is advisable to analyze the structure of this indicator of R&D spending, distinguishing the components of financing by the state, business, education, etc.

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REFERENCES

1. Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics, 68*(1), 29-51. https://doi.org/10.1016/0304-4076(94)01642-D
2. Artyukhov, A., Volk, I., Vasylieva, T., & Lyeonov, S. (2021). The role of the university in achieving SDGs 4 and 7: A Ukrainian case. *E3S Web of Conferences, 250,* 04006. https://doi.org/10.1051/e3sconf/202125004006
3. Berezhnytska, U., Dobrovolska, O., Uniiat, L., Shevchenko, A., Horiashchenko, Y., & Halaz, L. (2022). Institutional principles of intensifying the innovative development of small and medium agribusiness. *Journal of Agriculture and Crops, 8*(4), 275-282. https://doi.org/10.32861/jac.84.275.282
4. Blundell, R. W., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87*(1), 115-143. https://doi.org/10.1016/S0304-4076(98)00009-8
5. Blundell, R. W., Bond, S., & Windmeijer, F. (2000). *Estimation in dynamic panel data models: Improving on the performance of the standard GMM estimator* (Working Paper No. W00/12). Institute for Fiscal Studies. Retrieved from https://econpapers.repec.org/paper/ifsifsewp/00_2f12.htm
6. Bozkurt, C. (2014). R&D expenditures and economic growth relationship in Turkey. *International Journal of Economics and Financial Issues, 5*(1), 188-198. Retrieved from https://www.econjournals.com/index.php/ijefi/article/view/1038
7. Chen, Y., Xu, S., Lyulyov, O., & Pimonenko, T. (2023). China's digital economy development: Incentives and challenges. *Technological and Economic Development of Economy, 29*(2), 518-538. https://doi.org/10.3846/tede.2022.18018
8. Dritsaki, M., & Dritsaki, C. (2023). R&D expenditures on innovation: A panel cointegration study of the E.U. countries. *Sustainability, 15*(8), 6637. https://doi.org/10.3390/su15086637
9. Eurostat. (2023, December). *R&D expenditure Highlights.* Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=R%26D_expenditure
10. Falk, M. (2007). R&D spending in the high-tech sector and economic growth. *Research in Economics, 61*(3), 140-147. https://doi.org/10.1016/j.rie.2007.05.002
11. Gavrilko, T., & Pobochenko, L. (2021). Research on transnationalisation of economic activity innovative component influenced by the Covid-19 pandemic. *Baltic Journal of Economic Studies, 7*(5), 59-66. https://doi.org/10.30525/2256-0742/2021-7-5-59-66
12. Goel, R. C., Payne, J. E., & Ram, R. (2008). R&D expenditures and U.S. economic growth: A disaggregated approach. *Journal of Policy Modeling, 30*(2), 237-250. https://doi.org/10.1016/j.jpolmod.2007.04.008
13. Hunady, J., & Pisar, P. (2020). Business spending on research and development and its relationship to invention and innovation. *Proceedings of the ENTRENOVA – ENTerprise REsearch InNOVAtion Conference, Virtual Conference* (pp. 542-552). Zagreb. Retrieved from https://www.econstor.eu/bitstream/10419/224720/1/51-ENT-2020-Hunady-542-552.pdf
14. Iastremska, O., Strokovych, H., & Gasimov, F. (2023). Relationship of investment in innovation and logistics activity in the conditions of the experience economy development. *Marketing and Management of Innovations, 1,* 12-23. https://doi.org/10.21272/mmi.2023.1-02
15. Ildırar, M., Özmen, M., & İşcan, E. (2016). The effect of research and development expenditures on economic growth: New evidences. *Proceeding of International Conference on Eurasian Economies* (pp. 36-43). https://www.avekon.org/papers/1776.pdf
16. INSEAD & WIPO. (2012). *The Global Innovation Index 2012. stronger innovation linkages for global growth* (464 p.). France, Fontainebleau. Retrieved from https://www.globalinnovationindex.org/userfiles/file/GII-2012-Report.pdf
17. INSEAD. (2011). *The Global Innovation Index 2011. Accelerating growth and development* (381 p.). France, Fontainebleau. Retrieved from https://www.wipo.int/edocs/pubdocs/en/economics/gii/gii_2011.pdf
18. Ivanová, E., & Žárská, V. (2023). R&D expenditure as a determinant of the aggregate innovation index in the V4 countries. *Innovative Marketing, 19*(2), 87-100. https://doi.org/10.21511/im.19(2).2023.08
19. Kaya, H., Kwok, J. S., & LaTurner, J. (2023). Experiential learning through the creation of an investment lab. *Financial Markets, Institutions and Risks, 7*(1), 16-25. https://doi.org/10.21272/fmir.7(1).16-25.2023
20. Kiselakova, D., Sofrankova, B., Cabinova, V., Onuferova, E., & Soltesova, J. (2018). The impact of R&D expenditure on the development of global competitiveness within the CEE EU countries. *Journal of Competitiveness, 10*(3), 34-50. https://doi.org/10.7441/joc.2018.03.03
21. Kozmenko, S., & Vasylieva, T. (2008). Specialized innovative investment banks in Ukraine. *Banks and Bank Systems, 3*(1), 48-56. Retrieved from https://www.businessperspectives.org/index.php/journals/banks-and-bank-systems/issue-159/specialized-innovative-investment-banks-in-ukraine
22. Leonov, S. V., Vasylieva, T. A., & Tsyganyuk, D. L. (2012). Formalization of functional limitations in functioning of co-investment funds basing on comparative analysis of financial markets

within FM CEEC. *Actual Problems of Economics, 134*(8), 75-85. Retrieved from https://eco-science.net/downloads/

23. Liu, C., & Xia, G. (2018). Research on the dynamic interrelationship among R&D investment, technological innovation, and economic growth in China. *Sustainability, 10*(11), 4260. https://doi.org/10.3390/su10114260
24. Lymonova, E. M., & Mahdich, A. S. (2020). Innovation development and investments in Ukraine. *Nobel Herald, 13*(1), 58-63. Retrieved from https://econforum.duan.edu.ua/images/PDF/2020/9.pdf
25. Mallinguh, E., Wasike, C., Bilan, Y., & Zoltan, Z. (2022). The impact of firm characteristics, business competitiveness, and technology upgrade hurdles on R&D costs. *Problems and Perspectives in Management, 20*(4), 264-277. https://doi.org/10.21511/ppm.20(4).2022.20
26. Melnyk, L., Matsenko, O., Kubatko, O., Korneyev, M., & Tulyakov, O. (2022). Additive economy and new horizons of innovative business development. *Problems and Perspectives in Management, 20*(2), 175-185. https://doi.org/10.21511/ppm.20(2).2022.15
27. Nahla, N. (2023). University-company collaboration: what are the obstacles in Algeria? *SocioEconomic Challenges, 7*(1), 59-64. https://doi.org/10.21272/sec.7(1).59-64.2023
28. OECD. (n.d.). *Innovation for development*. Retrieved from https://www.oecd.org/development/innovationfordevelopment.htm
29. Pakhnenko, O., & Kuan, Z. (2023). Ethics of digital innovation in public administration. *Business Ethics and Leadership, 7*(1), 113-121. https://doi.org/10.21272/bel.7(1).113-121.2023
30. Pearson, K. (1896). Mathematical contributions to the theory of evolution.–III. Regression, heredity, and panmixia. *Philosophical Transactions of the Royal Society of London, Series A, 187*, 253-318. https://doi.org/10.1098/rsta.1896.0007
31. Pearson, K., & Filon, L. N. G. (1898). Mathematical contributions to the theory of evolution.–IV. On the probable errors of frequency constants and on the influence of random selection on variation and correlation. *Philosophical Transactions of the Royal Society of London, Series A, 191*, 229-311. https://doi.org/10.1098/rsta.1898.0007
32. Pegkas, P., Staikouras, C., & Tsamadias, C. (2019). Does research and development expenditure impact innovation? Evidence from the European Union countries. *Journal of Policy Modeling, 41*(5), 1005-1025. https://doi.org/10.1016/j.jpolmod.2019.07.001
33. Petrushenko, M., Burkynskyi, B., Shevchenko, H., & Baranchenko, Y. (2021). Towards sustainable development in a transition economy: The case of eco-industrial parks in Ukraine. *Environmental Economics, 12*(1), 149-164. https://doi.org/10.21511/ee.12(1).2021.13
34. Raghupathi, V., & Raghupathi, W. (2017). Innovation at country-level: Association between economic development and patents. *Journal of Innovation and Entrepreneurship, 6*, 4. https://doi.org/10.1186/s13731-017-0065-0
35. Samoilikova, A., & Artyukhov, A. (2023). Analysis of the relationship between "business-science" coopetition and intellectual property receipts. *SocioEconomic Challenges, 7*(1), 149-157. https://doi.org/10.21272/sec.7(1).149-157.2023
36. Shapiro, S. S., & Francia, R. S. (1972). An approximate analysis of variance test for normality. *Journal of the American Statistical Association, 67*(337), 215-216. https://doi.org/10.1080/01621459.1972.10481232
37. Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3/4), 591-611. https://doi.org/10.2307/2333709
38. Shkarupa, O., Vlasenko, D., Makedon, H., Bilan, S., & Serafimova, D. (2022). Economy of knowledge and transfer of innovations: Ukraine's progress through the lens of European development trends. *Knowledge and Performance Management, 6*(1), 100-113. https://doi.org/10.21511/kpm.06(1).2022.09
39. Sokolov-Mladenović, S., Cvetanović, S., & Mladenović, I. (2016). R&D expenditure and economic growth: EU28 evidence for the period 2002–2012. *Economic Research-Ekonomska Istraživanja, 29*(1), 1005-1020. https://doi.org/10.1080/1331677X.2016.1211948
40. Soumadi, M. M. (2023). Intellectual property and patent rights protection for innovators in Jordan. *Business Ethics and Leadership, 7*(1), 12-24. https://doi.org/10.21272/bel.7(1).12-24.2023
41. Spearman, C. E. (1904). The proof and measurement of association between two things. *American Journal of Psychology, 15*(1), 72-101. https://doi.org/10.2307/1412159
42. Stata. (n.d.a). *Arellano-Bover/Blundell-Bond linear dynamic panel-data estimation*. Stata Manuals. Retrieved from https://www.stata.com/manuals/xtxtdpdsys.pdf
43. Stata. (n.d.b). *Correlations of variables*. Stata Manuals. Retrieved from https://www.stata.com/manuals/rcorrelate.pdf
44. Stata. (n.d.c). *Shapiro-Wilk and Shapiro-Francia tests for normality.* Stata Manuals. Retrieved from https://www.stata.com/manuals/rswilk.pdf
45. Stata. (n.d.d). *Spearman's and Kendall's correlations*. Stata Manuals. Retrieved from https://www.stata.com/manuals/rspearman.pdf
46. Strielkowski, W., Samoilikova, A., Smutka, L., Civín, L., & Lieonov, S. (2022). Dominant trends in intersectoral research on funding innovation in business companies: A bibliometric analysis approach. *Journal of Innovation & Knowledge, 7*(4), 100271. https://doi.org/10.1016/j.jik.2022.100271
47. Triyonowati, Elfita, R. A., Suwitho, & Mildawati, T. (2023). Does innovation efficiency affect financial performance? The role of ownership concentration. *Investment*

Management and Financial Innovations, 20(1), 58-67. https://doi.org/10.21511/imfi.20(1).2023.06

48. WIPO. (2022). *Global Innovation Index 2022. What is the future of innovation driven growth?* (15th ed.) (89 p.). Geneva, Switzerland: WIPO. Retrieved from https://www.globalinnovationindex.org/gii-2022-report
49. WIPO. (n.d.). *The interactive database of the GII 2013–2022 indicators.* Retrieved from https://www.globalinnovationindex.org/analysis-indicator
50. World Bank. (n.d.a). *Foreign direct investment, net inflows (% of GDP).* Retrieved from https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS
51. World Bank. (n.d.b). *GDP per capita growth (annual %).* Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG?view=chart
52. World Bank. (n.d.c). *Labor force participation rate, total (% of total population ages 15-64).* Retrieved from https://data.worldbank.org/indicator/SL.TLF.ACTI.ZS?view=chart
53. World Bank. (n.d.d). *Research and development expenditure (% of GDP).* Retrieved from https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS
54. Yu, Y., Xinxin, W., Ruoxi, L., & Tingting, Y. (2023). The mediating role of human capital in the relationship between education expenditure and science and technology innovation: Evidence from China. *SocioEconomic Challenges, 7*(1), 129-138. https://doi.org/10.21272/sec.7(1).129-138.2023