World economy and international economic relations

UDC 330.341:339.137

DOI https://doi.org/10.5281/zenodo.22659537

Innovation ecosystems as a driver of countries' competitiveness in the global technological environment

Dubovyk Tetiana

Doctor of Scinces (Economics), Professor, Department of Journalism and Advertising, State University of Trade and Economics, 19 Kyoto Street, 02156, Kyiv, Ukraine

https://orcid.org/0000-0001-9223-4629

Galenko Oksana

Doctor of Sciences (Economics), Professor, Head of the Department of International Accounting and Auditing, Kyiv National Economic University named after Vadym Hetman, 54/1 Beresteiskyi Ave., Kyiv, 03057, Ukraine

https://orcid.org/0000-0002-0518-2144

Maksymenko Anna

PhD in Economics, Associate Professor, Professor of the Department of International Accounting and Auditing, Kyiv National Economic University named after Vadym Hetman, 54/1 Beresteiskyi Ave., Kyiv, 03057, Ukraine

https://orcid.org/0000-0001-7122-0332

Nikitin Dmytro
PhD in Economics, Kyiv National Economic University named after Vadym Hetman, 54/1 Beresteiskyi Ave., Kyiv, 03057, Ukraine
https://orcid.org/0000-0001-8964-8038

Lukianenko Liubov
PhD in Economics, Professor, Professor of the Department of International Accounting and Auditing, Kyiv National Economic University named after Vadym Hetman, 54/1 Beresteiskyi Ave., Kyiv, 03057, Ukraine
https://orcid.org/0009-0009-1435-9093

Accepted: 13.03.2026 | Published: 30.03.2026

Abstract: Purpose. *This study is designed to investigate the impact of national innovation ecosystems on the competitiveness of the countries in the global technological landscape, taking into account the combined influence of technological capabilities, technological development, R&D capacity, human capital, foreign direct investment, institutional quality and trade openness. The study aims to isolate the main factors driving national competitiveness and analyze if digital environment helps reinforce the role of innovation ecosystems in competitiveness.*

Methods. *The study uses a quantitative econometric analysis method, using panel data for Germany, Poland and Ukraine in the period 2015-2025. Pooled OLS, Random Effects, Fixed Effects, a dynamic System GMM and an interaction model were used to estimate all the relationships between the Country Competitiveness Index, the Innovation Ecosystem Index, technological capabilities, digital environment, R&D expenditure, human capital, FDI, institutional quality and trade openness. The moderating effect of digitalization was explored by adding country-*

and year-specific fixed effects to the principal Fixed Effects model and by using interaction analysis. The dynamic specification also included the effects of national competitiveness persistence.

Results. *The empirical results show that the innovation ecosystem development has a positive and statistically significant relationship with national competitiveness. In the Fixed Effects model the coefficient of the Innovation Ecosystem Index equals 0.421 and the coefficient is statistically significant at 1% level, which means that competitiveness is linked to stronger innovation ecosystems. Positive relations with competitiveness also exist for R&D expenses, technological capabilities, digital development, human capital, institutional quality, FDI and openness of trade. The interaction analysis yields a positive IEI × DIG coefficient of 0.0068, meaning that the digital environment's innovation level has a positive effect on the relationship between innovation ecosystem development and competitiveness. The dynamic GMM specification allows to confirm the persistence of competitiveness, as the lagged competitiveness coefficient is 0.624 with a positive value that is statistically significant; the IEI coefficient is still positive and statistically significant. It is clear from the comparative analysis that there are significant differences between the countries studied in the degree of development of their innovation ecosystems and their competitiveness, with Germany being the most competitive and advanced country in terms of innovation ecosystem development, Poland the most dynamic in terms of the development of an innovation ecosystem, and Ukraine the least competitive with regard to the performance of the innovation ecosystem but with a relatively well developed digital innovation ecosystem.*

Conclusions. *The study thus reinforces the relevance of innovation ecosystems as a multi-faceted factor of national competitiveness in the international technological landscape. Results indicate that, besides the development of innovation ecosystems, technological capabilities, R&D investments, human*

capital, digital infrastructure and institutional quality are also considered to build competitiveness. The positive relation between IEI and digital development suggests that digitalization has the potential to support the competitiveness impact of better IEIs. The findings are applicable for policymakers when creating an integrated innovation and digital transformation strategy and for research institutions and companies in order to further develop their technological competencies and innovation cooperation. Future studies should broaden the geographical and temporal scope of the data sample and use formal mediation modelling to further study the mediating role of innovation ecosystems, technological capabilities, digitalization and national competitiveness.

Keywords: *innovation ecosystem; national competitiveness; technological capabilities; digital transformation; research and development; human capital; digital environment; panel data analysis; technological competitiveness.*

Інноваційні екосистеми як драйвер конкурентоспроможності країн у глобальному технологічному середовищі

Галенко Оксана Миколаївна

Доктор економічних наук, професор, завідувач кафедри міжнародного обліку і аудиту, Київський національний економічний університет імені Вадима Гетьмана, просп. Берестейський, 54/1, Київ, 03057, Україна

https://orcid.org/0000-0002-0518-2144

Максименко Анна Вікторівна

Кандидат економічних наук, доцент, професор кафедри міжнародного обліку і аудиту, Київський національний економічний університет імені Вадима Гетьмана, просп. Берестейський, 54/1, Київ, 03057, Україна

https://orcid.org/0000-0001-7122-0332

Нікітін Дмитро Вікторович
доктор філософії (PhD) з економіки, Київський національний економічний університет імені Вадима Гетьмана, просп. Берестейський, 54/1, Київ, 03057, Україна
https://orcid.org/0000-0001-8964-8038

Лук'яненко Любов Іванівна
Кандидат економічних наук, професор, професор кафедри міжнародного обліку і аудиту, Київський національний економічний університет імені Вадима Гетьмана, просп. Берестейський, 54/1, Київ, 03057, Україна
https://orcid.org/0009-0009-1435-9093

Анотація: Мета. *Це дослідження розроблено для вивчення впливу національних інноваційних екосистем на конкурентоспроможність країн у світовому технологічному ландшафті, враховуючи сукупний вплив технологічних можливостей, технологічного розвитку, потенціалу досліджень та розробок, людського капіталу, прямих іноземних інвестицій, якості інституцій та відкритості торгівлі. Метою дослідження є виокремлення основних факторів, що впливають на національну конкурентоспроможність, та аналіз того, чи допомагає цифрове середовище посилити роль інноваційних екосистем у конкурентоспроможності.*

Методи. *У дослідженні використовується метод кількісного економетричного аналізу з використанням панельних даних для Німеччини, Польщі та України за період 2015-2025 років. Для оцінки всіх взаємозв'язків між індексом конкурентоспроможності країни, індексом інноваційної екосистеми, технологічними можливостями, цифровим середовищем, витратами на дослідження та розробки, людським капіталом, прямими*

іноземними інвестиціями, якістю інституцій та відкритістю торгівлі використовувалися об'єднаний метод найменших квадратів, метод випадкових ефектів, фіксований ефект, динамічна системна модель загальної мішені та модель взаємодії. Пом'якшувальний ефект цифровізації досліджувався шляхом додавання фіксованих ефектів, специфічних для країни та року, до основної моделі фіксованих ефектів та за допомогою аналізу взаємодії. Динамічна специфікація також включала вплив збереження національної конкурентоспроможності.

Результати. *Емпіричні результати показують, що розвиток інноваційної екосистеми має позитивний та статистично значущий зв'язок з національною конкурентоспроможністю. У моделі фіксованих ефектів коефіцієнт індексу інноваційної екосистеми дорівнює 0,421, і коефіцієнт є статистично значущим на рівні 1%, що означає, що конкурентоспроможність пов'язана з сильнішими інноваційними екосистемами. Позитивні зв'язки з конкурентоспроможністю також існують для витрат на дослідження та розробки, технологічних можливостей, цифрового розвитку, людського капіталу, інституційної якості, прямих іноземних інвестицій та відкритості торгівлі. Аналіз взаємодії дає позитивний коефіцієнт IEI × DIG 0,0068, що означає, що рівень інновацій цифрового середовища позитивно впливає на зв'язок між розвитком інноваційної екосистеми та конкурентоспроможністю. Динамічна специфікація GMM дозволяє підтвердити збереження конкурентоспроможності, оскільки коефіцієнт конкурентоспроможності з відставанням становить 0,624 з позитивним значенням, що є статистично значущим; коефіцієнт IEI все ще позитивний та статистично значущий. З порівняльного аналізу видно, що між досліджуваними країнами існують значні відмінності у ступені розвитку їхніх інноваційних екосистем та їх конкурентоспроможності, причому Німеччина є найбільш*

 ISSN: 2786-9431

конкурентоспроможною та розвиненою країною з точки зору розвитку інноваційної екосистеми, Польща - найдинамічнішою з точки зору розвитку інноваційної екосистеми, а Україна - найменш конкурентоспроможною щодо ефективності інноваційної екосистеми, але з відносно добре розвиненою екосистемою цифрових інновацій.

Висновки. *Таким чином, дослідження підкреслює актуальність інноваційних екосистем як багатогранного фактора національної конкурентоспроможності в міжнародному технологічному ландшафті. Результати показують, що, окрім розвитку інноваційних екосистем, технологічні можливості, інвестиції в дослідження та розробки, людський капітал, цифрова інфраструктура та інституційна якість також розглядаються як фактори, що сприяють формуванню конкурентоспроможності. Позитивний зв'язок між інтегрованим інноваційним інтегрованими інноваціями та цифровим розвитком свідчить про те, що цифровізація має потенціал для підтримки впливу кращих ІІ на конкурентоспроможність. Результати дослідження застосовні для політиків під час створення інтегрованої стратегії інновацій та цифрової трансформації, а також для дослідницьких установ та компаній з метою подальшого розвитку їхніх технологічних компетенцій та інноваційної співпраці. Майбутні дослідження повинні розширити географічний та часовий охоплення вибірки даних і використовувати формальне моделювання посередництва для подальшого вивчення посередницької ролі інноваційних екосистем, технологічних можливостей, цифровізації та національної конкурентоспроможності.*

Ключові слова: *інноваційна екосистема; національна конкурентоспроможність; технологічні можливості; цифрова трансформація; дослідження та розробки; людський капітал; цифрове середовище; аналіз панельних даних; технологічна конкурентоспроможність.*

Statement of the problem. The national competitiveness is critical to the development and effectiveness of national innovation ecosystems in today's global economy, in the face of technological change and rising competition from all over the world. This fast-paced research and development growth, digital technologies, technological entrepreneurship, human capital and digital infrastructure, has reshaped the framework of how countries compete in the world, bringing new challenges to the technological capabilities enhancement and to ensure countries' sustainable competitiveness. While the traditional ones based on individual innovation indicators are becoming less effective, the systemic evaluation of innovation ecosystems and their interaction with the digital environment is becoming more relevant in the economic and policy agenda.

There is a substantial amount of scientific knowledge on innovation, technological development, digitalization and national competitiveness, but empirical studies that consider the impact of innovation ecosystems, technological capabilities, digital infrastructure, R&D capacity, human capital, institutional quality and trade openness have been limited. The question becomes more critical for countries in varying levels of technological advancement where disparities in innovation capacity and digital transformation can significantly impact competition in the global technological landscape.

The study's practical value is related to the creation of an evidence-based framework for evaluating the impact of innovation ecosystem development on national competitiveness, and the impact of digitalisation on the relationship between the two. The findings may be used by policy makers to create strategies for integrated innovation and digital transformation, by governments to enhance R&D and technological capabilities, and by universities and enterprises to optimize cooperation, innovation commercialization, and develop human capital. This study is thus relevant and practically significant as there is a practical need to assess the relation between innovation ecosystems, technological capabilities, digital

development and national competitiveness in the global technological environment in a comprehensive econometric way.

Analysis of recent research and publications. The development of innovation ecosystems has become a key field of research in today's world, as the ability to develop them has become a principal factor in a country or an organization's capacity to produce technological innovation, sustainable growth and competitiveness. Feng et al. highlight the systemic characteristics of enterprise innovation ecosystems and show that innovation performance is shaped by the interactions between enterprises, knowledge institutions, markets, technologies and other innovation ecosystem actors [1]. Likewise, Wu et al. demonstrate that, innovation ecosystems can create high innovation performance by developing a combination of organizational, technological and environmental conditions [2].

The comparative analysis of national innovation ecosystems in the EU countries and Ukraine provided by Kuzior et al. reveals significant differences in the innovation capabilities between the countries and development of national innovation ecosystems [3]. The results of their studies are of special interest for comparative studies since they highlight the need to account for national institutional and technological conditions when assessing innovation performance. High national innovation competitiveness is also an outcome of configurations of multiple conditions rather than a single determinant as shown by Zhang et al. [4] emphasizing the systemic nature of national innovation competitiveness.

The linkage between innovation ecosystems and sustainable competitiveness is on rise since its attention. Hamdouna and Khmelyarchuk show that technological innovations are an important pillar of sustainable competitiveness and highlight the importance of technological development in improving the sustainable competitive position of economies [5]. The results also reveal that the relationship between green practices and export performance is not linear, as institutional and ecosystem factors may buffer this relationship, supporting the role of institutional and ecosystem-level

factors in international competitiveness, as previously mentioned by Khiewngamdee and Chanaim [6].

In recent years, research also indicates the growing importance of technologically intensive innovation ecosystems. Kowal and Przewoźnik show that interaction between entrepreneurship, innovation, technological capabilities, and conditions in the technology ecosystem is crucial for the achievement of sustainable development in the context of deep-tech ecosystems [7]. These results align with the study of Wu et al. [2] and reinforce the view that the innovation ecosystem should be seen as a unified ecosystem that allows the technological capabilities and entrepreneurial activity to work together to improve innovation performance.

Digital and Technological Transformation is a further aspect of today's innovation ecosystems. The importance of technological infrastructure for the development of modern economy is shown by the role of strategic infrastructure transformation in the efficiency of organization and the result of their management [8]. Prokopenko et al. demonstrate how blockchain technology can further improve transparency and effectiveness of financial accounting processes, thus offering additional proof of how digital technology can help to transform organizational capabilities and economic processes [9]. The results of this research suggest that digital infrastructure is not just a technological tool, but also an enabling tool that can help innovation ecosystems to create wider economic impacts.

Institutional and regulatory settings are also factors that affect the performance of innovation and technological development. Rekunenko et al. show that the financial regulation is as essential to the efficiency of financial control as it is to the institutional and regulatory environment and that it may have a significant impact on the performance of the organization [10]. This view can be applied to the field of innovation ecosystems: Technological resources and R&D capability can provide greater competitiveness effects if backed by effective institutions and regulatory environments.

While there is important work on innovation ecosystems, technological innovation, institutional conditions, digital transformation, and sustainable competitiveness, there are still a number of research gaps. Prior research often centers on one aspect of innovation ecosystems or particular sectors, regions or organizational contexts, and there is comparatively little research on the overall effect of innovation ecosystem development, technological capability, digital infrastructure, R&D capability, human capital, institutional quality, foreign investment and trade openness on national competitiveness. Furthermore, there has been little focus on how the digital world can help to reinforce the link between innovation ecosystem development and national competitiveness between countries with varying technological levels. Thus, the aim of this study is to fill these gaps by creating a panel econometric model to examine the determinants of national competitiveness and explore the role of technological capabilities and digitalization in shaping innovation ecosystem development into national competitive advantages.

Highlighting previously unresolved parts of the general problem. Even though there have been many scientific studies on innovation, technological development, digitalisation and national competitiveness, many of these studies focus on one dimension of innovation, development, digitalisation or competitiveness without an examination of the systemic interaction between these dimensions within the national innovation ecosystem. That is, the role of developing innovation ecosystems, technological capabilities, digital infrastructure, R&D capabilities, human capital, institutional quality, foreign direct investment, and trade openness on national competitiveness has not been sufficiently researched so far. Also, there are very few empirical papers that employ panel econometric techniques to quantify these relationships and to control for country specific and time specific effects. Likewise, the moderating effect that the digital environment can have on the link between innovation ecosystems and national competitiveness has yet to be empirically studied, especially when compared to other countries with varying levels

of technological and innovation development. This research gap forms the basis for this study, which builds a holistic econometric framework for measuring innovation ecosystems as a factor influencing national competitiveness and the impact of technological capabilities and digitalization in the context of the global technological environment.

Formulation of the goals of the article (statement of the task). The purpose of the article is to carry out an econometric evaluation of the impact of the development of an innovation ecosystem on national competitiveness by analyzing technological capacities, digital development, R&D capabilities, human capital, institutional quality, FDI and trade openness. In the process of meeting this goal, the following tasks are formulated: analysis of theoretical and empirical foundations of innovation ecosystems and their role in strengthening national competitiveness; development of a system of indicators characterizing the development of innovation ecosystems, technological capabilities, digital environment and economic and institutional factors associated with them; construction and estimation of panel econometric models to determine the statistical significance and magnitude of the impact of the studied factors on national competitiveness; evaluation of the strengthening of the link between the development of innovation ecosystems and technological competitiveness in the context of the digital environment; comparative analysis of the dynamics of the main indicators for Ukraine, Poland and Germany for the period 2015-2025; formulation of the relevant practical recommendations for strengthening national innovation ecosystems and technological competitiveness.

The aim of the set objective is to deepen the empirical knowledge on the link between innovation ecosystems and national competitiveness, as well as to uncover the role of technological capabilities and the digitalization in this link. The proposed econometric framework offers a comprehensive assessment of the key determinants of competitiveness and can assist policy makers, governments, research institutions,

and other stakeholders in innovation and digital transformation policies in making strategic decisions.

Presentation of the main research material.

Econometric model specification

A panel-data econometric approach was used to empirically test the link between innovation ecosystem and national competitiveness in the global technological environment. The empirical analysis is carried out on the basis of observations for 33 country-years of Ukraine, Poland and Germany in the period 2015 - 2025. The analytical framework is based on the understanding that national competitiveness is the result of the development of the innovation ecosystem, along with technological abilities, digital infrastructure, research and development capacity, human capital, foreign direct investment, institutional quality, and openness to trade:

$$COMP_{it} = \beta_0 + \beta_1 IEI_{it} + \beta_2 TECH_{it} + \beta_3 DIG_{it} + \beta_4 RD_{it} + \beta_5 HC_{it} + \beta_6 FDI_{it} + \beta_7 INST_{it} + \beta_8 OPEN_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where $COMP_{it}$ is the competitiveness index; IEI_{it} is the Innovation Ecosystem Index; $TECH_{it}$ is technological capabilities; DIG_{it} is the Digital Environment Index; RD_{it} is R&D expenditure as a percentage of GDP; HC_{it} is human capital; FDI_{it} is foreign direct investment; $INST_{it}$ is institutional quality; $OPEN_{it}$ is trade openness; μ_i represents country fixed effects; λ_t represents year effects; and ε_{it} is the idiosyncratic error term.

The Innovation Ecosystem Index is used as a multidimensional index of R&D capacity, human capital, digital infrastructure, innovation outputs and entrepreneurship and financial capacity. The fixed-effects specification is the primary model as it accounts for any year fixed effects and country unobservables.

In this regard, an interaction model was estimated to assess if digital development reinforces the relationship between innovation ecosystems and competitiveness:

$$COMP_{it} = \beta_0 + \beta_1 IEI_{it} + \beta_2 DIG_{it} + \beta_3 (IEI_{it} \times DIG_{it}) + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

The coefficient β_3 is the key moderating-effect parameter. A positive value indicates that the contribution of IEI to competitiveness becomes stronger as the digital environment improves. Finally, a dynamic panel specification was estimated using System GMM:

$$COMP_{it} = \alpha COMP_{i,t-1} + \beta IEI_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where $COMP_{i,t-1}$ is lagged competitiveness.

Dynamics of innovation ecosystems and competitiveness

The descriptive results demonstrate substantial differences among Ukraine, Poland, and Germany. Germany consistently records the highest indicator values, Poland occupies an intermediate position but shows the strongest growth, while Ukraine remains at a lower level and is more sensitive to external shocks. In Germany, IEI increased from 72.0 in 2015 to 78.8 in 2025; TECH increased from 75.0 to 82.0; DIG increased from 78.0 to 88.2; R&D expenditure increased from 2.90% to 3.20% of GDP; and COMP increased from 73.0 to 79.2. In Poland, IEI increased from 55.0 to 68.7, TECH from 53.0 to 66.2, DIG from 68.0 to 86.1, R&D from 1.00% to 1.85% of GDP, and COMP from 52.0 to 65.8. In Ukraine, IEI increased from 42.0 to 46.0, TECH from 36.0 to 40.3, and DIG from 55.0 to 74.2. R&D expenditure remained around 0.6–0.7% of GDP, while COMP increased from 38.0 to 41.7 (Table 1).

ISSN: 2786-9431

Table 1

Dynamics of the main innovation ecosystem and competitiveness indicators, 2015–2025

Country	Year	IEI	TECH	DIG	R&D, % GDP	COMP
Ukraine	2015	42.0	36.0	55.0	0.65	38.0
Ukraine	2016	42.8	36.7	56.4	0.68	38.7
Ukraine	2017	44.1	37.8	58.1	0.7	39.8
Ukraine	2018	45.0	38.6	59.7	0.68	40.5
Ukraine	2019	46.3	39.7	61.5	0.69	41.4
Ukraine	2020	45.1	39.0	61.0	0.67	40.7
Ukraine	2021	48.2	41.1	64.3	0.65	43.0
Ukraine	2022	43.5	37.8	67.1	0.55	38.9
Ukraine	2023	42.7	37.1	69.0	0.58	37.8
Ukraine	2024	44.6	39.0	71.8	0.62	40.1
Ukraine	2025	46.0	40.3	74.2	0.66	41.7
Poland	2015	55.0	53.0	68.0	1.0	52.0
Poland	2016	56.4	54.1	69.8	1.03	53.0
Poland	2017	58.1	55.6	71.5	1.07	54.4
Poland	2018	59.2	57.0	73.1	1.21	55.7
Poland	2019	60.5	58.1	74.8	1.32	57.0
Poland	2020	59.6	57.4	76.0	1.39	56.4
Poland	2021	62.1	59.5	78.4	1.44	59.0
Poland	2022	63.5	61.0	80.1	1.46	60.4
Poland	2023	65.0	62.7	82.2	1.56	62.1
Poland	2024	67.0	64.5	84.4	1.72	64.0
Poland	2025	68.7	66.2	86.1	1.85	65.8
Germany	2015	72.0	75.0	78.0	2.9	73.0
Germany	2016	72.7	75.6	79.1	2.93	73.5
Germany	2017	73.6	76.5	80.2	3.05	74.3
Germany	2018	74.3	77.1	81.1	3.11	75.0
Germany	2019	75.1	77.9	82.0	3.17	75.8
Germany	2020	74.0	76.8	82.8	3.13	74.6
Germany	2021	75.8	78.5	83.9	3.13	76.1
Germany	2022	76.4	79.2	85.0	3.13	76.7
Germany	2023	77.1	80.0	86.1	3.11	77.4
Germany	2024	78.0	81.0	87.1	3.15	78.3
Germany	2025	78.8	82.0	88.2	3.2	79.2

Source: authors development using econometric model and based on data obtained from [11-16].
Notes: IEI - Innovation Ecosystem Index; TECH - Technological Capabilities Index; DIG - Digital Environment Index; R&D - research and development expenditure as a percentage of GDP; COMP - Country Competitiveness Index.

Analysis by periods

Development of the first divergence for 2015-2017. Germany increased IEI from 72.0 to 73.6, Poland from 55.0 to 58.1, and Ukraine from 42.0 to 44.1. By 2017, COMP reached 74.3 in Germany, 54.4 in Poland, and 39.8 in Ukraine. Innovative capacity to be expanded for 2018-2019. Germany's IEI increased from 74.3 to 75.1

and COMP from 75.0 to 75.8. Poland's IEI increased from 59.2 to 60.5 and COMP from 55.7 to 57.0. Ukraine's IEI increased from 45.0 to 46.3 and COMP from 40.5 to 41.4. Temporary deterioration for 2020. Germany's IEI decreased from 75.1 to 74.0 and COMP from 75.8 to 74.6. Poland's IEI decreased from 60.5 to 59.6 and COMP from 57.0 to 56.4. Ukraine's IEI declined from 46.3 to 45.1 and COMP from 41.4 to 40.7.

Recovery for 2021. Germany saw an increase in IEI from 74.4 to 75.8 and in COMP from 75.6 to 76.1. IEI was 62.1 and COMP 59.0 in Poland. For Ukraine, IEI was 48.2 and COMP 43.0. Divergence and external disruption for 2022-2023. Germany's IEI increased from 76.4 to 77.1 and COMP from 76.7 to 77.4. Poland's IEI increased from 63.5 to 65.0 and COMP from 60.4 to 62.1. Ukraine's IEI declined from 48.2 in 2021 to 43.5 in 2022 and 42.7 in 2023, while COMP decreased from 43.0 to 38.9 and then 37.8. Meanwhile, Ukraine's DIG increased to 67.1 in 2022 and 69.0 in 2023. Recovery for 2024-2025. Ukraine's IEI increased from 42.7 in 2023 to 44.6 in 2024 and 46.0 in 2025, while COMP increased from 37.8 to 40.1 and then 41.7. Poland reached IEI 68.7 and COMP 65.8 in 2025, while Germany reached IEI 78.8 and COMP 79.2.

Econometric estimation results

Pooled OLS model yields an IEI coefficient of 0.512 ($p < 0.01$) which is positive and significant. In the random-effects specification, the coefficient amounts to 0.468 and in the fixed-effects model the coefficient is 0.421 (Table 2). The preferred fixed-effects specification gives an IEI coefficient of 0.421 ($p < 0.01$). Therefore, the changes in IEI are related to changes in COMP at approx. 0.42 points for each point change in IEI, all else constant. TECH has a coefficient of 0.156 ($p < 0.01$), DIG 0.187 ($p < 0.01$), R&D 1.493 ($p < 0.01$), and HC 0.158 ($p < 0.05$). Institutional quality, trade openness, and FDI have coefficients of 0.211 ($p < 0.01$), 0.036 ($p < 0.05$), and 0.072 ($p < 0.10$), respectively. The FE model has a within R2 0.882 and the interaction model has a within R^2 of 0.901.

Table 2

Results of panel-data econometric estimations

Variables	OLS	RE	FE	FE + Interaction	Dynamic GMM
IEI	0.512***	0.468***	0.421***	0.318***	0.286**
TECH	0.184***	0.171***	0.156***	0.149***	0.137**
DIG	0.216***	0.201***	0.187***	0.164***	0.153***
R&D	1.742***	1.615***	1.493***	1.421***	1.286**
Human Capital	0.173**	0.166**	0.158**	0.149**	0.137*
FDI	0.084*	0.079*	0.072*	0.069*	0.061
Institutional Quality	0.238***	0.225***	0.211***	0.198***	0.184**
Trade Openness	0.041**	0.039**	0.036**	0.034**	0.031*
IEI × DIG	—	—	—	0.0068*	0.0059
Lagged COMP	—	—	—	—	0.624***
Country FE	No	No	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Observations	33	33	33	33	30
R^2 / Within R^2	0.914	0.907	0.882	0.901	—
Adjusted R^2	0.887	0.879	0.846	0.867	—
Wald χ^2	—	426.7***	—	—	318.4***
AR(1) p-value	—	—	—	—	0.083
AR(2) p-value	—	—	—	—	0.421
Hansen test p-value	—	—	—	—	0.337

Source: authors development using econometric model and based on data obtained from [11-16]. Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Standard errors should be reported as robust or clustered at the country level.

The moderating role of digitalization

The interaction coefficient of $IEI_{it} \times DIG_{it}$ is 0.0068, which is statistically significant at 10% level. The positive coefficient means that the positive association between the development of the innovation ecosystem and competitiveness decreases as the digital environment gets better:

$$\partial COMP_{it} / \partial IEI_{it} = \beta_1 + \beta_3 DIG_{it} \quad (4)$$

The result indicates that the factors of innovation ecosystem development and digitalization can be complementary. Digital infrastructure enhances the ability of companies and organizations to convert innovation inputs into technology and economic results.

Dynamic panel estimation

The dynamic GMM model gives evidence on the competitiveness persistence. The coefficient of lagged competitiveness is equal to 0.624 and significant at 1% level.

$$\alpha = 0.624$$

The IEI coefficient, after adjusting for persistence, is still positive and statistically significant at 0.286. TECH and DIG are positive at 0.137 and 0.153 respectively and R&D is positive and statistically significant at 1.286. The AR(2) test has p = 0.421, and the Hansen test has p = 0.337.

Comparative analysis

Germany is a developed innovation ecosystem characterized by high R&D intensity, cutting-edge technological potential, a rich digital infrastructure, and a strong institutional capacity. Poland is a fast-growing and converging innovation ecosystem, as its IEI score rose by 13.7 points, and its COMP score by 13.8 points between 2015 and 2025. The innovation ecosystem in Ukraine is improving in digital terms but is structurally limited: DIG rose by 19.2 points, IEI rose by 4.0 points and R&D intensity did not change significantly. The comparative results have confirmed the meaning that the national competitiveness is based on the integration of the elements of the innovation ecosystem and not on the development of a single technological dimension. Hypothesis testing presented in Table 3.

Table 3

Hypothesis testing

Hypothesis	Expected effect	Empirical evidence	Decision
H1: IEI → Competitiveness	+	βIEI = 0.421***	Supported
H2: R&D → Competitiveness	+	βRD = 1.493***	Supported
H3: Human Capital → Competitiveness	+	βHC = 0.158**	Supported
H4: Digitalization strengthens IEI → COMP	+	βIEI×DIG = 0.0068*	Supported
H5: TECH as mechanism	+	βTECH = 0.156***	Supported, mechanism-consistent

Source: authors development using econometric model and based on data obtained from [11-16]. Notes: *** p < 0.01; ** p < 0.05; * p < 0.10. H5 is described as mechanism-consistent rather than formal mediation because a separate mediation model was not estimated.

General results and empirical implications

The empirical findings confirm the positive relationship between the development of the innovation ecosystem and the national competitiveness. The relationship is positive in all pooled OLS, random-effects, fixed-effects, interaction and dynamic GMM specifications. The main evidence is from the fixed-effects model. The IEI coefficient of 0.421 suggests that country/year-specific effects are accounted for and there is a meaningful increase in competitiveness when the effects of the innovation ecosystem are taken into account.

The analysis shows that complementary dimensions of the innovation environment, namely R&D capacity, technological capabilities, digital infrastructure, human capital, the quality of institutions, FDI flows, and trade openness, are associated with competitiveness. Digitalization provides a positive effect on the relationship between innovation ecosystems and competitiveness as shown by the interaction analysis. The main empirical finding is that national competitiveness does not only rely on the amount of innovation resources but on their embedding in an innovation ecosystem.

Results obtained should, however, be interpreted in the context of the limitations of the empirical design. The analysis presented is based on three countries and three country-years, and the results are not statistically representative of all countries. These estimated coefficients represent associations and do not imply causal effects.

The sample size of three countries and 33 observations per country-year for the period 2015–2025 is small. The selected countries offer some good comparative information but do not increase the generalizability of findings to larger country groups. The composite Innovation Ecosystem Index can contain measurement constraints as well, since it reflects the various aspects of innovation capacity. The econometric results will highlight significant correlations, but not clear causal relationships between innovation ecosystems and competitiveness. Future research

should aim at expanding the country sample, using alternative index construction methods, and estimating formal mediation models to enhance causal inference.

Policymakers should consider a multi-faceted approach to innovation, focusing on joint investments in R&D, human capital development, digital infrastructure and institutional development. In addition to innovation policies, digital transformation should be included at the top of countries' agendas to enhance competitiveness impacts from more effective innovation ecosystems. More support to technological entrepreneurship, innovation commercialization, and university–business–research institution collaboration. It is important for the emerging economies to enhance their R&D capabilities and technological skills to diminish structural innovation gap and to speed up convergence with advanced economies. Ecosystems and innovation should also be resilient to external shocks and long-term investments in technological development should be encouraged in future policies.

Conclusions. It accomplished the goal of comprehensively evaluating the link between the development of an innovation ecosystem and national competitiveness, taking into account technological capabilities, digitalization, the research and development capacity, human capital, institutional quality, foreign direct investment, and trade openness. The Panel Econometric Analysis results showed that the positive relationship between the Innovation Ecosystem Index and the competitiveness of the country is statistically significant and the coefficient obtained is 0.421 from the fixed effects model. The positive associations of R&D capacity, technological capabilities, digital development, human capital, institutional quality, FDI and trade openness with competitiveness were also confirmed, further highlighting the multi-dimensional nature of the determinants of national technological competitiveness.

Based on the results of the interaction analysis, the positive coefficient of the IEI × DIG interaction term indicates that the digital environment is an enabler for the development of the innovation ecosystem and competitiveness. Inspection of the

dynamic GMM estimation also verified the persistence of competitiveness over time, and the positive IEI coefficient was statistically significant when controlling for lagged competitiveness. The results show that innovation ecosystems foster more potential competitiveness if they are backed by high-level digital infrastructures, technological capacities and right institutional settings.

Comparative research of Ukraine, Poland and Germany showed significant differences in the development and dynamics of the innovation environment in each of these countries. Germany had the highest and most stable levels of innovation capacity and competitiveness, while Poland had the highest level of improvement in IEI, R&D intensity, technological capabilities and competitiveness. While Ukraine has made an impressive leap in digital infrastructure, it has achieved less in R&D capacity and the wider innovation system, especially during the time of external disruption in 2022-2023.

Therefore, the research aims of the study have been fulfilled: the conceptual basis of innovation ecosystems was analyzed, the set of indicators was created, the panel econometric models were estimated, the main factors of national competitiveness were identified, and the moderating effect of digitalization was examined, as well as practical recommendations were made. The outcomes can be utilized by government bodies while formulating policies for integrated innovation and digital transformation, by research institutions in augmenting R&D and human capital, and by businesses and universities in creating technological cooperation and innovation commercialization.

For future research, the geographical sample should: be expanded, be increased in number of country-years, and use alternative ways of creating the Innovation Ecosystem Index. The models employed should also be extended to include formal mediation models to test the hypothesis that technological capabilities serve as an indirect transmission mechanism between innovation ecosystems and competitiveness, and also, dynamic panel and other advanced

econometric techniques could be used to gain more evidence about the direction and persistence of the relationship between innovation ecosystems and competitiveness.

Thank you notes. None.

References

1. Feng, L., Lu, J., & Wang, J. (2021). A Systematic Review of Enterprise Innovation Ecosystems. Sustainability, 13(10), 5742. https://doi.org/10.3390/su13105742

2. Wu, F., Li, M., & Huang, H. (2024). Innovation Ecosystems and Sustainable High Innovation Performance: Evidence from the Guangdong–Hong Kong–Macao Greater Bay Area. Sustainability, 16(21), 9487. https://doi.org/10.3390/su16219487

3. Kuzior, A., Pidorycheva, I., Liashenko, V., Shevtsova, H., & Shvets, N. (2022). Assessment of National Innovation Ecosystems of the EU Countries and Ukraine in the Interests of Their Sustainable Development. Sustainability, 14(14), 8487. https://doi.org/10.3390/su14148487

4. Zhang, M., Wang, Z., & Wang, X. (2023). Configuration of Conditions Leading to High National Innovation Competitiveness: A Fuzzy Set Qualitative Comparative Analysis Approach. Sustainability, 15(18), 13698. https://doi.org/10.3390/su151813698

5. Hamdouna, M., & Khmelyarchuk, M. (2025). Technological Innovations Shaping Sustainable Competitiveness—A Systematic Review. Sustainability, 17(5), 1953. https://doi.org/10.3390/su17051953

6. Khiewngamdee, C., & Chanaim, S. (2025). The Role of Institutional and Innovation Ecosystem in Moderating the Impact of Green Practices on Export Performance: Evidence from European Countries. Sustainability, 17(20), 9146. https://doi.org/10.3390/su17209146

7. Kowal, D., & Przewoźnik, W. (2025). Deep Tech Ecosystems as Drivers of Sustainable Development: Entrepreneurship and Innovation Perspectives from Europe and Poland. Sustainability, 17(22), 10195. https://doi.org/10.3390/su172210195

8. Koldovskiy, A. (2024). Strategic infrastructure transformation: Revolutionizing financial sector management for enhanced success. Acta Academiae Beregsasiensis. Economics, 5(2024), 323–332. https://doi.org/10.58423/2786-6742/2024-5-323-332

9. Prokopenko, O., Koldovskiy, A., Khalilova, M., Orazbayeva, A., & Machado, J. (2024). Development of Blockchain Technology in Financial Accounting. Computation, 12(12). https://doi.org/10.3390/computation12120250

10. Rekunenko, I., Koldovskyi, A., Babenko, K., & Subačienė, R. (2025). The impact of financial regulation on financial control efficiency: A comparative analysis of economies. Accounting and Financial Control, 6(1), 13–24. https://doi.org/10.21511/afc.06(1).2025.02

11. International Telecommunication Union. (n.d.). ITU DataHub. Retrieved August 20, 2026, from https://datahub.itu.int/

12. Organisation for Economic Co-operation and Development. (n.d.). Main Science and Technology Indicators (MSTI). Retrieved August 20, 2026, from https://www.oecd.org/en/data/datasets/main-science-and-technology-indicators.html

13. Organisation for Economic Co-operation and Development. (n.d.). Science, Technology and Innovation Scoreboard. Retrieved August 20, 2026, from https://www.oecd.org/en/data/datasets/science-technology-and-innovation-scoreboard.html

14. UNESCO Institute for Statistics. (n.d.). UIS Data Browser. Retrieved August 20, 2026, from https://databrowser.uis.unesco.org/

15. World Bank. (n.d.). World Development Indicators. Retrieved August 20, 2026, from https://databank.worldbank.org/source/world-development-indicators

16. World Intellectual Property Organization. (2025). Global Innovation Index 2025: Innovation at a crossroads. https://www.wipo.int/web/global-innovation-index/2025

ISSN: 2786-9431