DOI: 10.58423/2786-6742/2026-13-195-211
УДК 330.3:004.738.5

Viktoriia MAKAROVYCH
Doctor of Economic Sciences, Associate Professor,
Professor at the Department of Accounting and Auditing,
Ferenc Rakoczi II Transcarpathian Hungarian University
Berehove, Ukraine
ORCID ID: 0000-0002-0684-7072
Scopus Author ID: 57210844509
e-mail: makarovich.viktoria@kmf.org.ua
(Corresponding author)

Kateryna SOCHKA
Candidate of Economic Sciences, Associate professor,
Associate professor Department of Accountancy and Auditing
Ferenc Rakoczi II Transcarpathian Hungarian University
Berehove, Ukraine
ORCID ID: 0000-0002-6247-221X
Scopus Author ID: 57210756948
e-mail: szocska.katalin@kmf.org.ua

MULTIDIMENSIONAL ANALYSIS OF CLOUD TECHNOLOGY ADOPTION IN EUROPEAN UNION COUNTRIES

Анотація. *Цифровізація економіки та зростання ролі хмарних технологій як ключового інструменту обробки, зберігання та обміну даними зумовлюють необхідність комплексного аналізу їх використання. У статті досліджено особливості використання хмарних технологій у країнах Європейського Союзу з урахуванням міжкраїнних та галузевих відмінностей. Метою дослідження є виявлення закономірностей та особливостей використання хмарних технологій у країнах ЄС на основі багатовимірного аналізу та кластеризації відповідних показників. Методологія дослідження ґрунтується на застосуванні методів дескриптивної статистики, структурного аналізу та багатовимірного аналізу. Для оцінки динаміки використання хмарних технологій розраховано абсолютні зміни та темпи приросту показників, що дозволило визначити інтенсивність їх поширення у досліджуваному періоді. Галузевий аналіз забезпечив виявлення секторальних диспропорцій у рівнях використання хмарних технологій. Узагальнення міжкраїнних відмінностей здійснено із застосуванням кластерного аналізу, що дало змогу згрупувати країни за подібністю їх галузевих профілів. У результаті дослідження встановлено загальну тенденцію до зростання використання хмарних технологій у країнах ЄС, водночас виявлено значну диференціацію як за рівнем показників, так і за темпами їх зміни. Доведено, що найвищі рівні використання характерні для інформаційно-комунікаційної діяльності та професійних послуг, тоді як у традиційних секторах економіки показники є нижчими. За результатами кластеризації виділено три групи країн: "високий рівень інтеграції", для яких характерний високий та відносно однорідний рівень використання хмарних технологій;*

"перехідний рівень впровадження", що відображає середній рівень із помірною галузевою диференціацією; та "початковий рівень впровадження", для якого притаманний початковий рівень впровадження та фрагментарність використання. Встановлено, що зі зростанням загального рівня використання хмарних технологій зменшується галузева асиметрія. Отримані результати підтверджують наявність структурної неоднорідності цифрової трансформації в країнах ЄС та можуть бути використані для подальших досліджень ефективності впровадження хмарних технологій і оцінки їх впливу на економічний розвиток.

Ключові слова:. *хмарні технології; цифровізація; країни ЄС; багатовимірний аналіз; кластеризація; галузевий аналіз. відмінності між країнами.*

JEL Classification: L86; O14; O33; C38.

Absztrakt. *A gazdaság digitalizációja, valamint a felhőtechnológiák szerepének növekedése mint az adatfeldolgozás, az adattárolás és az adatcsere kulcsfontosságú eszköze szükségessé teszi alkalmazásuk átfogó elemzését. A tanulmány a felhőtechnológiák használatának sajátosságait vizsgálja az Európai Unió országaiban, figyelembe véve az országok közötti és az ágazati különbségeket. A kutatás célja a felhőtechnológiák alkalmazásában megfigyelhető törvényszerűségek és sajátosságok feltárása az EU tagállamaiban a releváns mutatók többdimenziós elemzése és klaszterezése alapján. A kutatás módszertana a leíró statisztika, a strukturális elemzés és a többdimenziós elemzés módszereinek alkalmazására épül. A felhőtechnológiák használatának dinamikáját az abszolút változások és a növekedési ütemek kiszámításával értékeli, ami lehetővé teszi elterjedésük intenzitásának meghatározását a vizsgált időszakban. Az ágazati elemzés feltárja a felhőtechnológiák alkalmazási szintjeiben meglévő szektorális aránytalanságokat. Az országok közötti különbségek összegzése klaszterelemzéssel történik, amely lehetővé teszi az országok csoportosítását ágazati profiljaik hasonlósága alapján. A kutatás eredményeként megállapítást nyert, hogy az EU országaiban általános növekedési tendencia figyelhető meg a felhőtechnológiák alkalmazásában, ugyanakkor jelentős differenciáltság mutatható ki mind a mutatók szintje, mind azok változási üteme tekintetében. A kutatás igazolja, hogy a legmagasabb alkalmazási szintek az információs és kommunikációs tevékenységek, valamint a szakmai szolgáltatások területére jellemzők, míg a hagyományos gazdasági ágazatokban a mutatók alacsonyabbak. A klaszterezés eredményeként három országcsoport különíthető el: a „magas integrációs szinttel" rendelkező országok csoportja, amelyet a felhőtechnológiák magas és viszonylag homogén alkalmazási szintje jellemez; az „átmeneti bevezetési szinttel" rendelkező országok csoportja, amely közepes szintet és mérsékelt ágazati differenciáltságot mutat; valamint a „kezdeti bevezetési szinttel" rendelkező országok csoportja, amelyre a felhőtechnológiák kezdeti szintű és fragmentált alkalmazása jellemző. Megállapítást nyert, hogy a felhőtechnológiák általános alkalmazási szintjének növekedésével csökken az ágazati aszimmetria. Az eredmények megerősítik a digitális transzformáció strukturális heterogenitását az EU országaiban, és felhasználhatók a felhőtechnológiák bevezetési hatékonyságának további vizsgálatához, valamint gazdasági fejlődésre gyakorolt hatásuk értékeléséhez.*

Kulcsszavak: *felhőtechnológiák; digitális transzformáció; EU-tagállamok; többváltozós elemzés; klaszteranalízis; ágazati elemzés; országok közötti eltérések*

Abstract. *The digitalisation of the economy and the growing importance of cloud technologies as key tools for data processing, storage, and exchange highlight the need for a comprehensive analysis of their adoption. This study examines patterns of cloud technology usage across European Union countries, taking into account both cross-country and sectoral differences. The research aims to identify the main characteristics and adoption patterns of cloud technologies in EU countries using multidimensional and cluster analysis. The methodological framework combines descriptive statistics, structural analysis, and multidimensional analysis. To evaluate the dynamics of cloud technology adoption, absolute changes and growth rates were calculated, allowing the intensity of adoption over*

the study period to be assessed. Sectoral analysis revealed significant disparities in cloud technology usage across economic activities. Cross-country differences were examined through cluster analysis, which enabled the grouping of countries according to similarities in their sectoral profiles. The findings indicate an overall upward trend in cloud technology adoption across EU countries, accompanied by substantial variation in adoption levels and growth rates. The highest adoption levels are observed in information and communication activities as well as professional and technical sectors, whereas more traditional sectors display lower levels of adoption. Cluster analysis identified three groups of countries: "Advanced Integration", characterised by high and relatively homogeneous adoption levels; "Transitional Adoption", reflecting moderate levels and moderate sectoral variation; and "Early-stage Adoption", associated with lower adoption levels and fragmented adoption patterns. The results also show that higher levels of cloud technology adoption are linked to lower sectoral asymmetry. The results confirm structural heterogeneity in the digital transformation of EU countries and provide a basis for further research on the efficiency of cloud technology adoption and its impact on economic development.

Keywords: *cloud technologies; digital transformation; EU countries; multidimensional analysis; cluster analysis; sectoral analysis; cross-country differences*

Problem description. The growing diffusion of cloud technologies across European Union enterprises is reshaping how information processes are organised. Cloud services enable access to computing resources and software without the need for in-house infrastructure, improving data processing efficiency and supporting more timely managerial decision-making. According to Eurostat, the share of EU enterprises using paid cloud services increased from 17.8% in 2014 to over 53% in 2025, reflecting a sustained upward trend in adoption [1].

Cloud technology use by enterprises occurs under increasing requirements for accuracy, consistency, and continuity in data processing. Information systems require stable operation and integrated information flows, which calls for careful consideration of organisational and technological design parameters. The specific features of cloud solution implementation depend on firm size and sectoral affiliation, shaping differences in usage practices. Cloud technologies are applied under diverse conditions, which are captured through a set of indicators reflecting their use across multiple dimensions. Taken together, these indicators provide a multidimensional perspective on the adoption process, where different factors interact to shape patterns of cloud service use in enterprises. Accordingly, analysing cloud technology usage requires an approach that considers the interplay between organisational, sectoral, and firm-level characteristics. Examining these dimensions within the European economic space makes it possible to identify both similarities and differences in cloud solution practices.

Literature review. The rapid development of cloud technologies has led to the formation of a substantial body of academic research on their use in enterprise activities.

A considerable number of studies examine the factors influencing cloud technology adoption. In particular, A. Mujalli, M. J. G. Wani, A. Almgrashi, T. Khormi, and M. Qahtani conducted empirical research on enterprise readiness for adopting cloud solutions by integrating the Technology–Organisation–Environment

(TOE) framework with the Technology Acceptance Model (TAM), allowing both technical and organisational aspects of cloud technology use to be considered [2]. These findings indicate the transformation of business processes under the influence of cloud technologies and highlight the need to account for structural changes in their application. Similar conclusions were reported by A. Lutfi, who demonstrates the impact of the organisational environment on the use of cloud-based systems [3]. A. Khayer, M. S. Talukder, Y. Bao, and M. N. Hossain also emphasise that cloud technology adoption is associated with improved enterprise performance and depends on the complex interaction of internal and external factors [4].

Subsequent research further develops this research area by analysing the characteristics of cloud technology adoption. D. Ma, R. Fisher, and T. Nesbit examined the impact of cloud-based systems on firms providing accounting services and found that their implementation transforms the delivery of accounting services and facilitates the integration of accounting functions with clients' business processes [5]. D. Sastararuji, D. Hoonsopon, P. Pitchayadol, and P. Chiwamit show that cloud technology adoption depends on a combination of technological, organisational, and institutional factors [6]. H. Vo Van, M. Abu Afifa, N. Nguyen, and D. V. Bui synthesise previous research on cloud technologies and identify key research areas, including adoption drivers, benefits, risks, and the implications of implementing cloud-based accounting systems [7].

A. Rawashdeh and B. Rawashdeh provide evidence of the positive impact of cloud accounting on enterprise performance, assessed using a balanced scorecard approach [8]. S. Ahmad, E. Ghidan, and S. Yousef examine the adoption of cloud-based systems in the financial sector and demonstrate their contribution to improving the efficiency of information systems in enterprises [9]. These findings highlight the importance of sector-specific characteristics in the application of cloud solutions. The study by D. A. Pangastuti and F. Aligarh indicates that key determinants of cloud technology adoption include information security, managerial support, and resource availability [10].

Growing attention is also being paid to the impact of cloud technologies on the quality of financial information and enterprise management. F. B. Limba, S. G. Sapulette, and A. Talla emphasise that the use of cloud-based systems enhances the relevance and timeliness of financial data and supports more effective managerial decision-making [11]. W. Andayani, N. Adib, M. E. Arif, S. Indrayani, S. Wahyuni, S. L. Murdianingrum, and R. Widiastutik highlight the role of cloud technologies in improving transparency and efficiency in financial management [12].

M. Zaharia, A. Bălăcescu, and C. M. Ene highlight significant differences among European Union countries in the level of cloud technology usage, thereby confirming the heterogeneity of this process [13]. P. Pisar, J. Hunady, S. Khawaja, and F. H. Qureshi analyse key indicators of enterprise digitalisation, which allows them to identify cross-country differences in the level of digital technology adoption [14]. Their findings confirm structural heterogeneity among EU countries and make it possible to identify groups of countries with similar characteristics of digital

development. C. Tudor, M. Florescu, P. Polychronidou, P. Stamatiou, V. Vlachos, and K. Kasabali analyse the determinants of cloud technology usage in EU countries using machine learning methods [15].

Overall, existing academic research covers a wide range of issues related to the use of cloud technologies in enterprise activities. The growing body of empirical evidence and the diversity of characteristics describing cloud technology usage highlight the need for further research in a cross-country context. This requires the synthesis of a set of indicators while accounting for their interrelationships, enabling the identification of structural similarities and differences in cloud technology usage practices across European Union countries.

Goals of the article. This study aims to identify cross-country and sectoral patterns in cloud technology adoption across European Union countries using multidimensional and cluster analysis.

Methods and methodology. The study employs applied statistical and multidimensional analysis to identify cross-country and sectoral differences in cloud technology usage across European Union countries. To analyse the dynamics of cloud technology usage, descriptive statistical methods are used, including the calculation of absolute changes, growth rates, and summary indicators, allowing for the assessment of both the intensity and nature of changes over the study period. Sectoral characteristics are examined using structural analysis to identify disparities in the levels of cloud technology usage. Cross-country differences are further analysed using multidimensional methods, in particular cluster analysis, which enables grouping countries according to similarities in their sectoral usage profiles. The clustering approach is based on a set of indicators reflecting both the level and structure of usage and allows for the identification of homogeneous groups of countries. The interpretation of results combines quantitative analysis with economic reasoning, enabling the identification of stable cross-country patterns and typological differences in cloud technology usage across European Union countries.

Main research results. Cloud technologies form the technological foundation of modern enterprise information systems, providing scalable access to software, computing resources, and data without reliance on local infrastructure. Their adoption reshapes data processing and information management, enhancing the responsiveness, flexibility, and coherence of business processes. This is consistent with the findings of D. Ma, R. Fisher, and T. Nesbit, who highlight the transformative impact of cloud solutions on business processes and service delivery [5].

In this context, it is useful to consider empirical data on the use of cloud technologies by enterprises in European Union countries over time. This approach allows for the simultaneous consideration of both levels of usage and their dynamics. M. Zaharia, A. Bălăcescu, and C. M. Ene highlight the heterogeneity of cloud technology usage across European Union countries [13].

The empirical basis of the study is formed by statistical indicators capturing the share of enterprises using cloud technologies across European Union countries for 2021, 2023, and 2025 [16]. To ensure consistency and comparability, the original data

were transformed into derived indicators reflecting both absolute and relative changes in cloud technology usage (Table 1).

The analysis is based on a set of indicators designed to provide a comprehensive assessment of cloud technology use across enterprises in EU countries. In particular, average values over the study period are calculated to reflect changes in the indicators over time.

The dynamics of cloud technology usage are further analysed using a generalised qualitative assessment (trend), based on a combination of absolute and relative changes in the indicator, enabling the identification of its main development trajectories.

Countries are ranked according to their level of cloud technology usage in 2025 in order to determine their relative positions within the sample. They are then grouped by usage levels to identify relatively homogeneous groups and reveal structural patterns in their distribution:

- ✓ High — >70%;
- ✓ Medium — 40–70%;
- ✓ Low — <40%.

The results of the calculations are summarised in Table 1.

The analysis of cross-country differences in cloud technology usage among enterprises in European Union countries indicates a high degree of differentiation both in terms of adoption levels and the nature of their dynamics over the study period. In 2025, the indicator ranges from 14.09% in Bulgaria to 77.79% in Sweden, highlighting a substantial gap between countries and the heterogeneity of digital development within the EU.

Absolute changes over the period 2021–2025 range from +0.99 percentage points in Cyprus and +1.38 percentage points in Sweden to +30.43 percentage points in Poland and +25.33 percentage points in Lithuania. Divergent trends are also observed across individual periods. In France, for example, the indicator declined from 26.91% in 2021 to 24.01% in 2023 (−2.90 percentage points), followed by an increase to 39.73% in 2025 (+15.72 percentage points). In Luxembourg, a decrease from 33.97% to 28.54% (−5.43 percentage points) was followed by a sharp rise to 51.25% (+22.71 percentage points). Similar fluctuations are observed in Estonia (57.98% → 56.15% → 63.66%) and Slovenia (41.17% → 39.64% → 46.62%), indicating shifts in development trajectories.

Growth rate analysis provides a clearer picture of the intensity of these changes. The highest growth rates over the period 2021–2025 are recorded in Poland (+109.6%), Romania (+101.5%), Hungary (+93.0%), and Lithuania (+71.9%), indicating a phase of rapid cloud technology adoption in countries with lower initial levels. This pattern of “catching-up development” is consistent with the findings of P. Pisar, J. Hunady, S. Khawaja, and F. H. Qureshi, who highlight cross-country variation in enterprise digitalisation. In contrast, countries with already high adoption levels show significantly lower growth rates, for example +1.8% in Sweden and +9.2% in Denmark, reflecting proximity to saturation.

Table 1

Dynamics of cloud technology adoption across European Union countries, 2021–2025.

Country	2021	2023	2025	Absolute change 2023/2021	Absolute change, 2025/2023	Absolute change, 2025/2021	Growth rate, 2023/2021, %	Growth rate, 2025/2023, %	Growth rate, 2025/2021, %	Average value, 2025/2021	Trend	Rank 2025	Group, 2025
Austria	36,91	45,7	56,52	8.79	10.82	19.61	23.8%	23.7%	53.1%	46,4	↑↑	14	Medium
Belgium	51,72	51,79	67,72	0.07	15.93	16.00	0.1%	30.8%	30.9%	57,1	↑↑	10	Medium
Bulgaria	9,4	13,21	14,09	3.81	0.88	4.69	40.5%	6.7%	49.9%	12,2	↑	27	Low
Croatia	34,46	41,25	48,66	6.79	7.41	14.20	19.7%	18.0%	41.2%	41,5	↑↑	19	Medium
Cyprus	43,4	48,8	44,39	5.40	−4.41	0.99	12.4%	−9.0%	2.3%	45,5	↓	17	Medium
Czechia	39,18	45,67	55,72	6.49	10.05	16.54	16.6%	22.0%	42.2%	46,9	↑↑	15	Medium
Denmark	62,3	69,66	68,05	7.36	−1.61	5.75	11.8%	−2.3%	9.2%	66,7	↓	8	Medium
Estonia	57,98	56,15	63,66	−1.83	7.51	5.68	−3.2%	13.4%	9.8%	59,3	±	11	Medium
Finland	84,23	86,87	—	—	—	—	—	—	—	—	—	—	—
France	26,91	24,01	39,73	−2.90	15.72	12.82	−10.8%	65.5%	47.6%	30,2	±	23	Low
Germany	38,43	42,73	50,8	4.30	8.07	12.37	11.2%	18.9%	32.2%	44	↑↑	18	Medium
Greece	18,11	28,47	26,88	10.36	−1.59	8.77	57.2%	−5.6%	48.4%	24,5	↓	25	Low
Hungary	24,56	46,09	47,4	21.53	1.31	22.84	87.7%	2.8%	93.0%	39,4	↑↑↑	20	Medium
Ireland	67,01	70,46	77,2	3.45	6.74	10.19	5.1%	9.6%	15.2%	71,6	↑	2	High
Italy	61,95	61,21	75,84	−0.74	14.63	13.89	−1.2%	23.9%	22.4%	66,3	↑	3	High
Latvia	26,03	32,94	42,35	6.91	9.41	16.32	26.5%	28.6%	62.7%	33,8	↑↑	21	Medium
Lithuania	35,24	40,29	60,57	5.05	20.28	25.33	14.3%	50.3%	71.9%	45,4	↑↑↑	12	Medium
Luxembourg	33,97	28,54	51,25	−5.43	22.71	17.28	−16.0%	79.6%	50.9%	37,9	↑↑↑	16	Medium
Malta	52,75	66,92	74,48	14.17	7.56	21.73	26.9%	11.3%	41.2%	64,7	↑↑	4	High
Netherlands	62,07	61,2	69,58	−0.87	8.38	7.51	−1.4%	13.7%	12.1%	64,3	↑	5	Medium
Poland	27,74	58,22	58,17	30.48	−0.05	30.43	109.9%	−0.1%	109.6%	48	↑↑↑	13	Medium
Portugal	28,27	33,81	34,54	5.54	0.73	6.27	19.6%	2.2%	22.2%	32,2	↑	24	Low
Romania	10,52	16,1	21,2	5.58	5.10	10.68	53.1%	31.7%	101.5%	15,9	↑↑	26	Low
Slovakia	33,27	34,26	36,49	0.99	2.23	3.22	3.0%	6.5%	9.7%	34,7	↑	22	Low
Slovenia	41,17	39,64	46,62	−1.53	6.98	5.45	−3.7%	17.6%	13.2%	42,5	±	19	Medium
Spain	27,22	27,27	39,74	0.05	12.47	12.52	0.2%	45.7%	46.0%	31,4	↑↑	22	Low
Sweden	76,41	70,61	77,79	−5.80	7.18	1.38	−7.6%	10.2%	1.8%	74,9	±	1	High

Note: ↑ – growth; ↑↑ – steady growth; ↑↑↑ – sharp increase; ↓ – decline; ± – instability.
Source: authors' calculations based on Eurostat data [16].

ISSN 2786-6734; eISSN 2786-6742

Differences between sub-periods are also evident. In Poland, the growth rate for 2021–2023 reached +109.9%, whereas in 2023–2025 it stabilised at −0.1%, indicating a slowdown in growth dynamics. Cloud technology usage levels were summarised by calculating average values for the period 2021–2025, enabling the simultaneous analysis of both levels and their dynamics. The highest averages are observed in Sweden (74.9%), Ireland (71.6%), Italy (66.3%), and Denmark (66.7%), while the lowest occur in Bulgaria (12.2%) and Romania (15.9%). This suggests that certain countries maintain relatively stable positions within the overall structure of cloud technology usage.

The dynamics, assessed based on a combination of absolute changes and growth rates, make it possible to distinguish different development trajectories. A steady increase is observed in Austria (36.91% → 45.70% → 56.52%), Czechia (39.18% → 45.67% → 55.72%), and Latvia (26.03% → 32.94% → 42.35%). A sharp increase is characteristic of Poland, Lithuania, and Luxembourg, where growth is concentrated within specific periods. Unstable dynamics (±) are observed in France, Estonia, Slovenia, and Sweden, indicating alternating phases of increase and decline.

Ranking countries by cloud technology usage levels in 2025 helps clarify their relative positions within the overall structure. The leading countries are Sweden (77.79%), Ireland (77.20%), Italy (75.84%), and Malta (74.48%), while the lowest positions are occupied by Bulgaria (14.09%), Romania (21.20%), and Greece (26.88%). At the same time, most countries fall within the medium range, reflecting both disparities and a gradual convergence in cloud technology usage levels. The results are further summarised by grouping countries according to their level of cloud technology usage in 2025. The high-level group (above 70%) includes Sweden, Ireland, Italy, and Malta and is characterised by high values and relatively moderate growth rates. The largest group is the medium-level group (40–70%), which includes the majority of EU countries and shows significant variation in dynamics. The low-level group (below 40%) includes Bulgaria, Romania, Greece, Portugal, Slovakia, Spain, and France and is characterised by lower values but, in many cases, higher growth rates.Further analysis focuses on the sectoral characteristics of cloud technology usage over the period 2021–2025, enabling the identification of adoption patterns across different types of economic activity. The sectoral dimension is particularly important, as noted by S. Ahmad, E. Ghidan, and S. Yousef, who emphasise that both the nature and effectiveness of cloud solution adoption are influenced by sector-specific characteristics [9]. Given differences in indicator variability across countries and economic activities, sectors were grouped by cloud technology usage levels using adjusted threshold values. This is due to the generally lower levels of indicators in the sectoral dimension compared to cross-country data, which requires the use of relative intervals to ensure analytical relevance:

- ✓ High – >20%;
- ✓ Medium – 12–20%;
- ✓ Low – <12%.

The results of calculations are summarised in Table 2.

Table 2

Dynamics of cloud technology adoption across European Union countries by economic activity, 2021–2025.

Sector	2021	2023	2025	Absolute change 2023/2021	Absolute change, 2025/2023	Absolute change, 2025/2021	Growth rate, 2023/2021, %	Growth rate, 2025/2023, %	Growth rate, 2025/2021, %	Average value, 2025/2021	Trend	Rank 2025	Group, 2025
Manufacturing	9,46	13,55	19,26	4,09	5,71	9,8	43,2	42,1	103,6	14,09	↑↑	7	Medium
All activities (except agriculture, forestry and fishing, and mining and quarrying), without financial sector	9,72	14,16	17,95	4,44	3,79	8,23	45,7	26,8	84,7	13,94	↑↑	8	Medium
Electricity, gas, steam and air conditioning supply	19,48	19,91	25,22	0,43	5,31	5,74	2,2	26,7	29,5	21,54	↑	2	High
Water supply; sewerage, waste management and remediation activities	9,83	13,6	20,17	3,77	6,57	10,34	38,4	48,3	105,2	14,53	↑↑↑	5	Medium
Construction	4,14	9,22	10,09	5,08	0,87	5,95	122,7	9,4	143,7	7,82	↑↑↑	12	Low
Wholesale and retail trade; repair of motor vehicles and motorcycles	11,88	17,71	21,85	5,83	4,14	9,97	49,1	23,4	83,9	17,15	↑↑	3	High
Transportation and storage	8,84	9,61	12,55	0,77	2,94	3,71	8,7	30,6	42	10,33	↑	11	Low
Accommodation and food service activities	4,57	9,84	13,73	5,27	3,89	9,16	115,3	39,5	200,4	9,38	↑↑↑	10	Low
Information and communication	39,39	45,19	56,78	5,8	11,59	17,39	14,7	25,6	44,1	47,12	↑↑	1	High
Real estate activities	15,07	20,33	20,96	5,26	0,63	5,89	34,9	3,1	39,1	18,79	↑	4	Medium
Professional, scientific and technical activities	15,09	18,29	20,13	3,2	1,84	5,04	21,2	10,1	33,4	17,84	↑	6	Medium
Administrative and support service activities	9,24	10,63	14,74	1,39	4,11	5,5	15	38,7	59,5	11,54	↑	9	Low

Note: ↑ – growth; ↑↑ – steady growth; ↑↑↑ – sharp increase.
Source: authors' calculations based on Eurostat data [16].

The analysis of cloud technology usage across economic activities demonstrates substantial sectoral variation in both adoption levels and the intensity of changes over the study period. In 2025, values range from 10.09% in construction to 56.78% in the information and communication sector, highlighting a gap of more than 46 percentage points between the lowest and highest levels. Relatively high levels are also observed in electricity supply (25.22%), trade (21.85%), and real estate activities (20.96%), while most other sectors remain within the range of 12–20%.

The dynamics of change across sectors vary considerably. Absolute growth over the period 2021–2025 ranges from +3.71 percentage points in transportation and storage to +17.39 percentage points in information and communication. Significant increases are also recorded in water supply (+10.34 percentage points), trade (+9.97 percentage points), manufacturing (+9.80 percentage points), and accommodation and food service activities (+9.16 percentage points). These results point to the expanding adoption of cloud technologies across a broad range of economic activities.

Growth rate analysis provides a clearer picture of the intensity of these changes. The highest growth rates over the period 2021–2025 are recorded in accommodation and food service activities (+200.4%), construction (+143.7%), water supply (+105.2%), and manufacturing (+103.6%). By contrast, sectors with already high levels of cloud technology adoption show significantly lower growth rates: +29.5% in electricity supply, +44.1% in information and communication, and +39.1% in real estate activities. This disparity suggests the emergence of a saturation effect in more digitally advanced sectors.

The dynamics across individual periods also reveal important differences. In construction, for instance, growth reached +5.08 percentage points in 2021–2023, but slowed to just +0.87 percentage points in 2023–2025. A similar trend is observed in real estate activities (+5.26 percentage points compared to +0.63 percentage points) and professional activities (+3.20 percentage points compared to +1.84 percentage points). Meanwhile, the information and communication sector continues to exhibit strong growth in both periods (+5.80 and +11.59 percentage points), confirming its sustained expansion.

The generalised assessment of cloud technology usage levels based on average values for 2021–2025 further confirms the persistence of sectoral differences. The highest average value is recorded in the information and communication sector (47.12%), exceeding the levels of most other sectors by more than twofold. Average values in trade (17.15%), professional activities (17.84%), and real estate (18.79%) form a group of sectors with relatively moderate levels of cloud technology usage. The lowest values are observed in construction (7.82%) and accommodation and food service activities (9.38%).

Ranking sectors by cloud technology usage in 2025 provides a clearer picture of their relative positions within the overall structure. The information and communication sector remains the clear leader (56.78%), followed by electricity supply (25.22%) and trade (21.85%), whereas the lowest levels are recorded in construction (10.09%) and transportation (12.55%). Most sectors (over 60%) fall

within the 12–22% range, indicating the gradual emergence of a medium level of cloud technology adoption. To summarise sectoral differences, sectors were grouped according to their level of cloud technology usage in 2025. Since sectoral indicator values are lower compared to cross-country data, adjusted threshold values were applied. The high-level group (above 20%) includes information and communication, electricity supply, and trade. The medium-level group (12–20%) comprises the majority of sectors, including manufacturing, water supply, professional activities, and real estate. The low-level group (below 12%) includes construction, transportation, and accommodation and food service activities, which show lower usage levels but, in several cases, relatively high growth rates.

Overall, the sectoral distribution of cloud technology usage reflects a combination of a highly concentrated group of digitally advanced activities and sectors undergoing rapid growth, creating a complex and multi-layered pattern of adoption.

The next stage of the analysis focuses on the structure of cloud technology usage across countries and sectors in 2025.

Figure 1 presents the sectoral structure of cloud technology usage across European Union countries in 2025, highlighting both cross-country and cross-sectoral variation. The visualisation reveals substantial differences in cloud technology adoption across economic activities, reflecting the uneven pace of digitalisation within the European economic space. The highest values are observed in the information and communication sector, where the indicator exceeds 80% in most countries, including Finland (97.31%), the Netherlands (91.01%), Sweden (92.60%), and Malta (92.67%). The extensive use of cloud technologies in this sector reflects its strong digital orientation and the integration of information processes. A similar pattern, although at slightly lower levels, is observed in professional, scientific, and technical activities, where the indicator also exceeds 80% in several countries (Finland – 93.92%, Sweden – 88.66%, Ireland – 87.98%).

Cloud technology usage is considerably more uneven across more traditional sectors of the economy. In manufacturing, levels range from 14.09% in Bulgaria to 77.79% in Sweden, while in construction they vary from 20.66% in Romania to 80.08% in Ireland. Transportation and storage also display pronounced cross-country variation, with values ranging from 17.95% in Romania to over 70% in Ireland and Croatia. The wholesale and retail trade sector stands out in particular, with usage levels exceeding 50% in most countries, including the Netherlands (67.24%), Italy (77.69%), and Malta (78.03%). This reflects the active integration of digital solutions in a sector heavily dependent on large-scale data processing and customer interaction.

Countries with high overall levels of digitalisation, such as Finland, Sweden, the Netherlands, and Ireland, consistently demonstrate high cloud technology usage across most sectors, reflecting a comprehensive approach to digital adoption. By contrast, countries with lower overall digitalisation levels, including Bulgaria, Romania, and Greece, display a more fragmented pattern, where relatively high values in some sectors coexist with substantially lower levels in others.

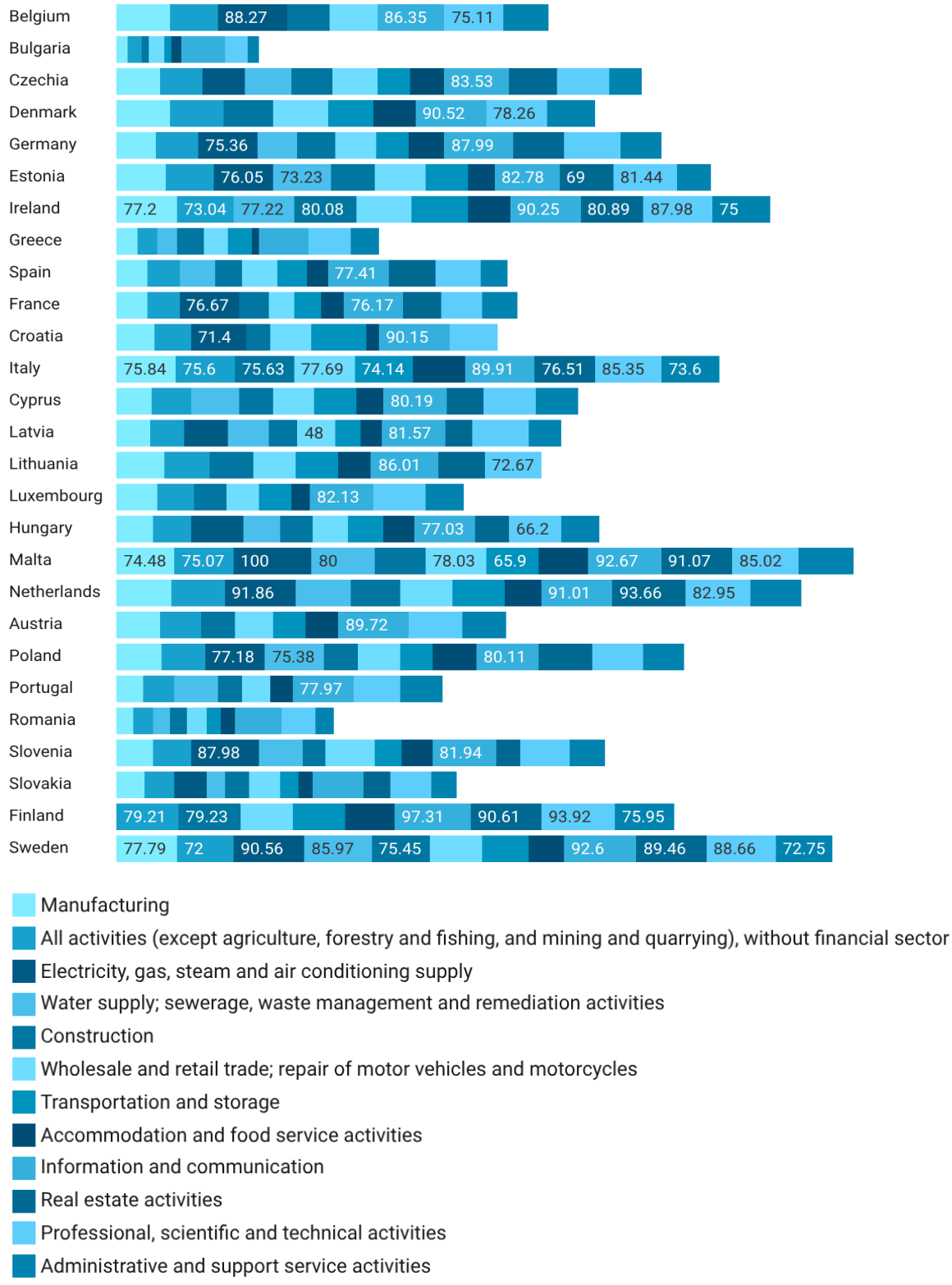

Figure 1. Structure of Cloud Technology Usage Across European Union Countries by Economic Activity, 2025 (%)

Source: authors' calculations based on Eurostat data [16].

The visualisation suggests that both cross-country and sectoral heterogeneity characterise cloud technology usage. This is reflected in the coexistence of consistently high adoption levels in digitally intensive sectors and a more uneven distribution across traditional economic activities.

To summarise cross-country differences in cloud technology usage among enterprises, a multidimensional analysis was conducted involving the clustering of European Union countries based on a set of indicators reflecting both usage levels and sectoral structure. The input variables include indicators of cloud technology usage across key economic activities in 2025, allowing structural characteristics of digital transformation to be taken into account.

The clustering approach identifies homogeneous groups of countries with similar patterns of cloud technology adoption and reveals typical models of digital development (Figure 2).

Based on the analysis results, three clusters were identified, reflecting different levels and trajectories of digital development.

The first cluster, "Advanced Integration," includes countries with high levels of cloud technology adoption across most economic sectors. This group consists of Sweden, Finland, the Netherlands, Ireland, Denmark, and Malta. These countries consistently demonstrate very high adoption levels, particularly in the information and communication sector, where values exceed 90% (Finland – 97.31%, Sweden – 92.60%, the Netherlands – 91.01%). High levels are also evident in professional activities (above 80%) and manufacturing (above 70%). The sectoral structure of cloud technology adoption in these countries is relatively homogeneous, reflecting the deep integration of digital technologies into enterprise business processes and a high degree of digital maturity.

The second cluster, "Transitional Adoption," represents the largest group of countries and is characterised by moderate levels of cloud technology adoption and moderate sectoral variation. This cluster includes Germany, Austria, Czechia, Italy, Spain, France, Estonia, Lithuania, Cyprus, Slovenia, Poland, Latvia, Luxembourg, Croatia, and Hungary. Across most sectors, adoption levels in these countries range between 40% and 70%, although in some sectors, particularly information and communication, they exceed 80% (Germany – 87.99%, Estonia – 82.78%, Lithuania – 86.01%). This structure reflects a gradual and systematic expansion of cloud technology adoption, despite the persistence of sectoral disparities.

The third cluster, "Early-stage Adoption," includes countries with relatively low levels of cloud technology adoption, namely Bulgaria, Romania, Greece, Portugal, and Slovakia. In these countries, adoption levels in most sectors remain below 30–40% (e.g. Bulgaria – 14.09% in manufacturing; Romania – 21.20%), indicating that digital transformation is still at an early stage. Nevertheless, relatively high adoption levels are observed in the information and communication sector (Bulgaria – 56.22%, Romania – 59.72%), highlighting pronounced sectoral asymmetry in cloud technology adoption.

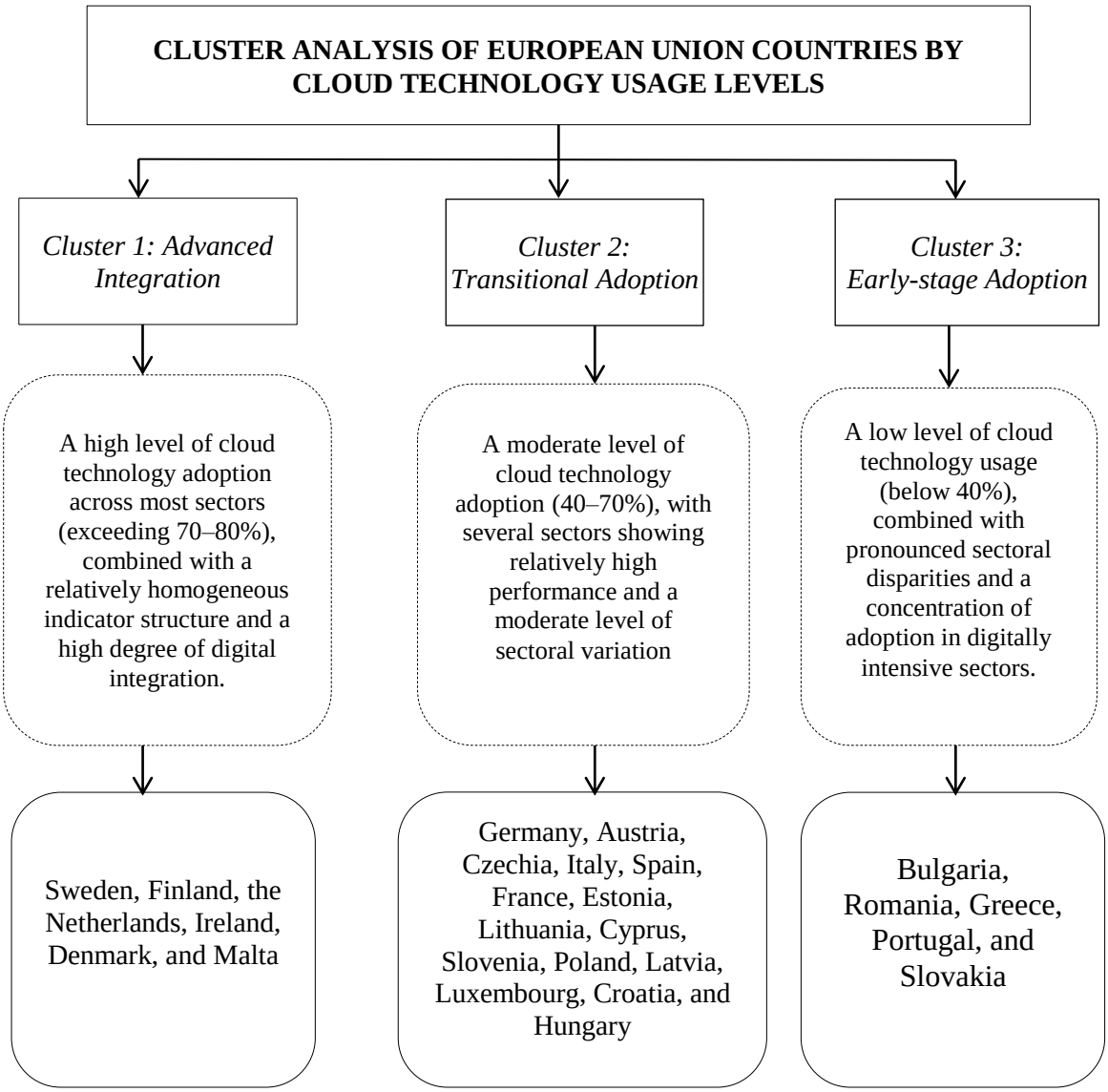

Figure 2. Cluster Analysis of European Union Countries by Cloud Technology Usage

Source: compiled by the authors.

A comparative analysis of the identified clusters highlights a clear relationship: higher levels of cloud technology adoption are associated with a more homogeneous distribution across economic sectors. In the leading countries, digitalisation extends across the economy as a whole, whereas in less developed countries cloud technology adoption remains more fragmented and concentrated mainly in digitally intensive sectors.

Overall, the cluster analysis highlights substantial structural heterogeneity among European Union countries in terms of both the level and the nature of cloud technology adoption. The identified clusters reflect different models of adoption, ranging from highly integrated and digitally advanced to early-stage and fragmented. These findings provide a basis for further research into the factors shaping such differences, as well as their implications for the efficiency of enterprise accounting processes.

The clustering results also make it possible to generalise the multidimensional characteristics of cloud technology adoption and identify common adoption patterns across European Union countries. This contributes to a deeper understanding of cross-country variation and supports the interpretation of cloud technology adoption as a comprehensive indicator of economic digital transformation.

Conclusions and prospects for further research. The study highlights significant cross-country and cross-sectoral variation in cloud technology usage across European Union countries. The findings indicate an uneven pattern of adoption, reflected both in differences in overall usage levels and in the variability of sectoral structures.

The analysis of dynamics over the period 2021–2025 reveals a general upward trend in cloud technology adoption across most EU countries. At the same time, the pace of this process differs considerably: alongside countries with consistently high adoption levels, there are countries with lower initial levels but substantially higher growth rates, reflecting a process of catch-up development.

The sectoral analysis confirmed structural differences in cloud technology usage. The highest levels are observed in information and communication activities and professional, scientific and technical activities, whereas more traditional sectors, such as construction and transportation, display considerably lower levels of usage. This reflects differences in the pace and intensity of digital transformation across economic activities.

Multidimensional analysis enabled the results to be synthesised into three clusters of countries based on the level and structure of cloud technology adoption. The “Advanced Integration” cluster includes countries with high and relatively homogeneous adoption levels across most sectors; the “Transitional Adoption” cluster comprises countries with moderate levels and moderate sectoral variation; whereas the “Early-stage Adoption” cluster includes countries with lower levels and fragmented adoption patterns. The analysis also demonstrates that higher overall levels of cloud technology adoption are associated with lower sectoral asymmetry, reflecting a more balanced trajectory of digital transformation.

Overall, the findings indicate that cloud technology adoption across EU countries is driven by a combination of macroeconomic and sectoral factors that shape distinct trajectories of digital development.

Future research should focus on evaluating the efficiency of cloud technology adoption, particularly its impact on productivity, enterprise financial performance, and economic competitiveness.

Funding. *This research was implemented under project no. 2025-1.2.1-HU-RIZONT-2025-00047, with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the 2025-1.2.1-HU-RIZONT funding scheme.*

Conflict of interest. *Given that the authors are affiliated with the institution publishing this journal, which may pose a potential conflict of interest or suspicion of bias, the final decision on publication of this article (including reviewers and editors) is made by members of the editorial board who are not employees of this institution.*

AI Usage Declaration. *During the preparation of the manuscript, the authors partially used artificial intelligence tools, including ChatGPT, for text translation and editing. All results, conclusions, and interpretations are solely the authors' own work.*

References

1. Eurostat. (2026). *53% EU enterprises used paid cloud services in 2025*. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20260203-1
2. Mujalli, A., Wani, M. J. G., Almgrashi, A., Khormi, T., & Qahtani, M. (2024). Investigating the factors affecting the adoption of cloud accounting in Saudi Arabia's small and medium-sized enterprises (SMEs). *Journal of Open Innovation: Technology, Market, and Complexity, 10*(2), 100314. https://doi.org/10.1016/j.joitmc.2024.100314
3. Lutfi, A. (2022). Understanding the Intention to Adopt Cloud-based Accounting Information System in Jordanian SMEs. *International Journal of Digital Accounting Research, 22*(2). https://doi.org/10.4192/1577-8517-v22
4. Khayer, A., Talukder, M. S., Bao, Y., & Hossain, M. N. (2020). Cloud computing adoption and its impact on SMEs' performance for cloud-supported operations: A dual-stage analytical approach. *Technology in Society, 60*, 101225. https://doi.org/10.1016/j.techsoc.2019.101225
5. Ma, D., Fisher, R., & Nesbit, T. (2021). Cloud-based client accounting and small and medium accounting practices: Adoption and impact. *International Journal of Accounting Information Systems, 41*, 100513. https://doi.org/10.1016/j.accinf.2021.100513
6. Sastararuji, D., Hoonsopon, D., Pitchayadol, P., & Chiwamit, P. (2021). Cloud accounting adoption in small and medium enterprises: An integrated conceptual framework. In *Proceedings of the 2nd International Conference on Industrial Engineering and Industrial Management (IEIM 2021)* (pp. 32–38). Association for Computing Machinery. https://doi.org/10.1145/3447432.3447439
7. Vo Van, H., Abu Afifa, M., Nguyen, N., & Bui, D. V. (2025). Cloud accounting: A systematic literature review. *Global Knowledge, Memory and Communication*. Advance online publication. https://doi.org/10.1108/GKMC-04-2024-0246
8. Rawashdeh, A., & Rawashdeh, B. (2023). The effect of cloud accounting adoption on organizational performance in SMEs. *International Journal of Data and Network Science, 7*(1), 411–424. https://doi.org/10.5267/j.ijdns.2022.12.010
9. Ahmad, S., Ghidan, E., & Yousef, S. (2022). The adoption of cloud accounting information system in Jordanian financial firms: Influencing factors. *Uncertain Supply Chain Management*, 10(4), 1315–1322. https://doi.org/10.5267/j.uscm.2022.7.008
10. Pangastuti, D. A., & Aligarh, F. (2024). Factors affecting cloud accounting adoption in SMes using the TOE Framework. *International Conference of Business and Social Sciences*, *4*(1), 574–585. https://doi.org/10.24034/icobuss.v4i1.540

11. Limba, F. B., Sapulette, S. G., & Talla, A. (2025). The role of cloud-based accounting systems in enhancing financial information quality. *International Journal of Financial Economics*, *2*(3), 895–913. URL: https://wikep.net/index.php/IJEFE/article/view/291/305
12. Andayani, W., Adib, N., Arif, Moh. E., Indrayani, Wahyuni, S., Murdianingrum, S. L., & Widiastutik, R. (2026). The adoption of cloud accounting in Indonesian Small and Medium Enterprises (SMEs): exploring drivers, challenges and implications for performance. *Cogent Business & Management*, 13(1). https://doi.org/10.1080/23311975.2025.2603023
13. Zaharia, M., Bălăcescu, A., & Ene (Vasile), C. M. (2022). Enterprises' use of cloud computing services: Disparities and similarities in the European Union in 2021. *Journal of Research and Innovation for Sustainable Society*, *4*(1), 46–54. URL: https://www.researchgate.net/publication/359545921_ENTERPRISES'_USE_OF_CLOUD_COMPUTING_SERVICES_DISPARITIES_AND_SIMILARITIES_IN_THE_EUROPEAN_UNION_IN_2021
14. Pisar, P., Hunady, J., Khawaja, S., & Qureshi, F.H. (2024). The Digital Transformation of European Union Countries before and during COVID-19. *Business Systems Research*, *15*(1), 22-44. https://doi.org/10.2478/bsrj-2024-0002
15. Tudor, C., Florescu, M., Polychronidou, P., Stamatiou, P., Vlachos, V., & Kasabali, K. (2025). Cloud Adoption in the Digital Era: An Interpretable Machine Learning Analysis of National Readiness and Structural Disparities Across the EU. *Applied Sciences*, *15*(14), 8019. https://doi.org/10.3390/app15148019
16. Eurostat. (2026). *Cloud computing services used by enterprises (isoc_cicce_use)*. https://doi.org/10.2908/ISOC_CICCE_USEN2

Отримано:	*13.02.2026*	*Beérkezett:*	*2026.02.13*	*Received:*	*13.02.2026*
Прийнято до друку:	*24.04.2026*	*Elfogadva:*	*2026.04.24*	*Accepted:*	*24.04.2026*
Опубліковано:	*29.05.2026*	*Megjelent:*	*2026.05.29*	*Published:*	*29.05.2026*