Has COVID-19 Transformed Crisis into Digital Acceleration? A Decade-Long Analysis of ERP Adoption across Countries

Aleksandra Radić

University of Belgrade, Technical Faculty in Bor, Serbia
aradic@tfbor.bg.ac.rs

Sanela Arsić

University of Belgrade, Technical Faculty in Bor, Serbia
sarsic@tfbor.bg.ac.rs

Đorđe Nikolić

University of Belgrade, Technical Faculty in Bor, Serbia
djnikolic@tfbor.bg.ac.rs

Lidija Krstić

University of Belgrade, Technical Faculty in Bor, Serbia
lkrstic@tfbor.bg.ac.rs

Abstract: COVID-19 had a profound and far-reaching impact on digital transformation across various sectors and countries. However, it remains unclear whether it reduced structural differences in technology adoption or reinforced existing digital divides. This study examines ERP adoption dynamics across countries, including the effect of COVID-19. Using secondary data from the Eurostat database for the period 2015-2025, the study applies K-means clustering to examine cross-country differences in the share of enterprises adopting ERP systems for functional information exchange. Cluster analysis identified three statistically distinct groups: digital leaders, followers, and late adopters. Digital leaders maintain consistently high ERP adoption levels throughout the observed period. Digital followers start at a lower level than digital leaders but show the most dynamic growth. Late adopters display the lowest ERP adoption levels throughout the decade. Descriptive trends indicate a post-pandemic acceleration, suggesting COVID-19 as a potential catalyst for

intensified ERP adoption. Based on the study's outcomes, policy implications are suggested and future research directions are proposed.

Keywords: ERP systems, COVID-19, cluster analysis.

1 Introduction

Enterprise Resource Planning (ERP) systems are among the most important digital infrastructures in modern organisations, as they enable the integration of business processes and facilitate information sharing across functional areas [1]. At the macroeconomic level, these systems are also significant, as the diffusion of ERP systems reflects the broader digital maturity of national economies and their capacity to implement complex information systems.

The persistence of digital disparities across countries presents a significant scientific and policy challenge, particularly in the context of external shocks such as the COVID-19 pandemic. COVID-19 created uncertainty in the business environment and global economy, prompting companies to optimise their use of information technology [2]. During the crisis, organisations faced pressure from internal and external stakeholders, as well as concerns about their existence and survival, and had to focus on adopting emerging IT applications. The study [3] stated that, within a short period, employees had to perform their tasks without physical access to offices, while companies needed to accelerate digital transformation and rapidly implement new solutions.

Among the most widely adopted business software solutions were ERP systems, which are increasingly implemented across various industries as the backbone of companies. For example, SAP, a leading German software producer providing ERP system solutions, reported that demand for ERP systems is steadily growing and, in some markets, growth has exceeded expectations [4]. Similarly, [5] reported that ERP systems were among the largest categories of enterprise software spending, with an estimated annual growth rate of 7.1% from 2018 to 2022.

COVID-19 intensified the need for these systems within organisations, bringing about one of the biggest changes in the workplace: the limited presence of employees on company premises and the shift to teleworking [6].

While the pandemic accelerated digital transformation in many businesses and sectors, it remains unclear whether it reduced inter-country disparities by triggering a generalised digital response or whether pre-existing structural differences persisted or even intensified. In light of this research question, the present study examines the trajectory of ERP adoption across countries, including the impact of COVID-19.

Although previous studies consistently show that the COVID-19 pandemic accelerated ERP adoption, most findings are based on empirical evidence from single-country or single-company contexts. Existing research has largely used survey-based approaches conducted in specific national environments, which may limit the generalisability of the conclusions.

In this context, the use of advanced statistical methods offers a valuable complementary methodological approach. This enables systematic evaluation across diverse national contexts, which can strengthen existing empirical findings and provide a more comprehensive understanding of ERP adoption dynamics under COVID-19 conditions.

Extending the analysis beyond single-country empirical settings and applying statistical methods to a larger sample of countries may help to reinforce and generalise previous conclusions, while also offering a novel methodological perspective within ERP adoption trajectory research. By analysing the evolution of ERP adoption in 27 countries over a ten-year period and identifying structurally homogeneous groups of countries using K-means clustering, this study brings new cross-country insights.

The paper is organised as follows. The Theoretical Background provides a literature review on the topic. The Research Method section explains the methodological approach and statistical methods used. The main study outcomes are presented in the Results and Discussion section. The Conclusion highlights the study summary, implications, limitations, and future research agenda.

2 Theoretical Background

The measures introduced to mitigate the spread of COVID-19 led to increased use of technology and accelerated technological innovation. This helped to minimise harmful consequences for people's work activities, overall health, and wellbeing.

The transformation of business models into digital formats was widely adopted in response to dynamic environmental changes and has become more prevalent since the onset of the COVID-19 pandemic. One such trend was the growing adoption of ERP systems, driven by high demand for e-commerce. Furthermore, most institutions and organisations had to adapt their existing infrastructure by switching to digital tools to ensure smooth business processes. This enabled companies to survive during this challenging period [7]

Academics and researchers pay particular attention to the impact of COVID-19 on ERP system adoption. The study by [6] showed that cloud-ERP systems affected human resources' productivity during the COVID-19 era. Similarly, [3] used a survey to collect empirical data from small and medium enterprises in the Veneto

region of Italy before and after the outbreak of the COVID-19 crisis. The results showed that complexity and investment remain barriers to ERP system adoption, as do financial resources, employee training, and digital skills.

The study [8] tested the moderating role of COVID-19 on the relationship between digital accounting system use and system performance among manufacturing small and midium enterprises in Jordan. The main outcomes showed significant moderating effects, indicating that COVID-19 prompted the enterprises studied to upgrade their use of digital technologies. These findings highlight the importance of external environmental shocks in stimulating positive use of digital tools.

Research by [9] investigated the relationship between ERP applications and supply chain performance in steel re-rolling industries in Bangladesh during the COVID-19 pandemic. The findings support significant relationships among the variables studied, highlighting the role of easy and reliable data access and sharing, as well as improved efficiency and effectiveness.

The study by [10] examined the effects of the COVID-19 pandemic as a moderating variable on the adoption of cloud-based ERP systems. The study revealed a strong impact of COVID-19 on the Diffusion of Innovation theory and Technology-Organisation-Environment framework models, as well as on adoption intention, suggesting that COVID-19 has altered businesses' perceptions.

Based on referenced studies, the COVID-19 pandemic can be conceptualised as a significant external driver that accelerated digital transformation and reshaped organisations' technological priorities. The literature indicates that the pandemic increased the perceived necessity of integrated information systems, particularly ERP solutions, as firms were forced to ensure business continuity under conditions of remote work, disrupted supply chains, and heightened environmental uncertainty. These findings imply that the pandemic not only increased demand for ERP systems but also redefined them as critical enablers of organisational resilience and adaptability in turbulent environments.

3 Research Method

This study uses secondary data from the Eurostat database [11]. The selected indicator measures the percentage of enterprises that use an ERP software package to share information across functional areas within the organisation. The initial dataset included 36 European countries and covered six observation years within a ten-year period: 2015, 2017, 2019, 2021, 2023, and 2025. However, due to incomplete data for some years, countries with missing values for any year were excluded from the analysis. Specifically, Portugal, Sweden, Iceland, the United Kingdom, Bosnia and Herzegovina, Montenegro, North Macedonia, Albania, and Serbia were omitted to ensure methodological consistency. After data cleaning and

filtering, the final dataset comprised 27 countries with complete observations for all six years (Table 1).

Year → Country ↓	2015	2017	2019	2021	2023	2025
Belgium	74.11	77.51	75.21	78.45	79.87	84.38
Bulgaria	41.38	35.52	40.13	40.1	37.42	41.94
Czechia	57.99	53.07	68.05	63.74	55.12	76.38
Denmark	74.31	67.59	72.11	76.19	84.1	85.3
Germany	79.73	62.37	55.62	62.27	67.39	67.68
Estonia	39.70	41.43	42.91	42.65	57.08	64.04
Ireland	42.13	45.00	48.57	50.9	53.7	56.08
Greece	66.61	65.94	75.45	63.58	63.97	72.98
Spain	60.02	66.12	66.55	70.49	77.89	79.99
France	67.20	67.11	73.08	72.21	68.67	80.06
Croatia	48.14	46.75	47.43	45.59	47.78	51.8
Italy	61.79	64.77	60.68	59.56	65.2	71.88
Cyprus	74.51	60.76	60.61	56.19	63.67	59.8
Latvia	27.92	48.29	47.32	62.02	58.39	56.05
Lithuania	58.88	64.78	65.98	66.45	52.12	60.69
Luxembourg	58.06	60.27	61.48	60.23	66.14	69.33
Hungary	36.01	31.05	31.97	45.47	63.79	61.07
Malta	41.37	41.91	46.2	58.32	66.5	71.05
Netherlands	69.23	72.55	73.38	66.77	74.94	76.37
Austria	70.29	68.33	69.98	73.44	68.11	66.41
Poland	46.51	53.56	53.87	59.76	63.49	68.65
Romania	33.26	35.56	30.17	20.95	31.41	41.05
Slovenia	57.12	58.5	56.8	65.14	63.96	66.9
Slovakia	48.05	46.54	47.95	49.68	46.4	45.01
Finland	64.19	68.44	69.8	72.03	81.56	80.64
Norway	54.1	58.19	62.9	62.73	67.04	66.77
Türkiye	32.59	26.15	37.17	45.66	47.17	45.91

Table 1
Initial dataset

The initial dataset serves as the input for K-Means Cluster Analysis. This statistical method is widely used in research as a non-hierarchical clustering technique. The main objective of K-Means Cluster Analysis is to form clusters, or groups of countries, and to identify similarities within these clusters [12-13]. While hierarchical cluster analysis uses a single algorithm, K-Means Cluster Analysis employs a partitioning algorithm [14].

A key question in K-Means Cluster Analysis is how to determine the number of clusters [14]. In this study, K-Means clustering based on ERP implementation data was applied to identify three structurally stable groups of countries: digital leaders, digital followers, and late adopters. The number of clusters is determined primarily conceptually and in accordance with the research goal, rather than solely statistically. The aim is to group countries or entities into an interpretatively meaningful number of categories suitable for comparison and recommendations. Therefore, the number of clusters was set to three.

4 Results and Discussion

This research provides a data-driven perspective on the dynamics of ERP diffusion and contributes to the broader discussion of digital convergence and divergence within countries. Particular attention is paid to the COVID-19 period to assess whether it produced a homogenising effect or reinforced structural digital disparities.

K-means cluster analysis was used to identify structurally homogeneous groups of countries. The analysis classified countries according to similarities in their ERP digitalisation trajectories. Figure 1 presents the cluster memberships of the countries. Cluster 1 consists of Belgium, Denmark, Lithuania, Cyprus, Czechia, Germany, Finland, Slovenia, Norway, Spain, the Netherlands, Luxembourg, Austria, France, Italy, and Greece. Cluster 2 includes Hungary, Slovakia, Poland, Latvia, Malta, Croatia, Estonia, and Ireland. Cluster 3 comprises Romania, Türkiye, and Bulgaria.

Figure 1
Cluster memberships of the countries

Table 2 and Figure 2 present the final cluster centres, showing the average value for each year within each cluster.

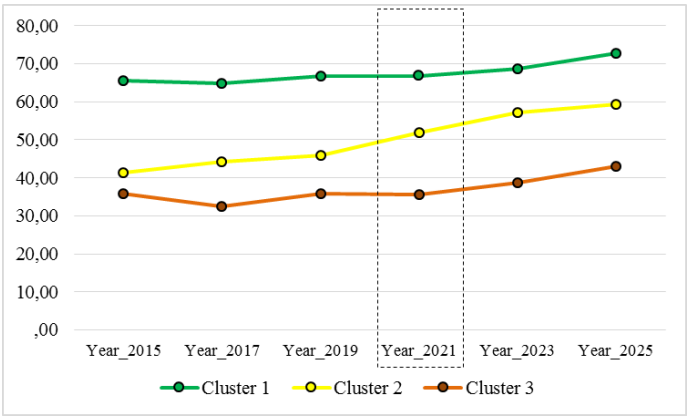

Figure 2

Graphical representation of final cluster centres

Cluster 1 comprises the countries with the highest levels of ERP implementation throughout the observed period, compared to Clusters 2 and 3. Therefore, these countries are Digital leaders. Cluster 2 includes countries with medium levels of ERP implementation and can be considered Digital followers. Cluster 3 consists of countries with the lowest levels of ERP implementation during the observed period, compared to the other two clusters. Therefore, these countries are Late adopters.

	Cluster 1	Cluster 2	Cluster 3
Y_2015	65.51	41.23	35.74
Y_2017	64.77	44.32	32.41
Y_2019	66.73	45.78	35.82
Y_2021	66.84	51.80	35.57
Y_2023	68.73	57.14	38.67
Y_2025	72.85	59.22	42.97

Table 2

Final cluster centers

According to [15], the COVID-19 pandemic began in March 2020 and ended in May 2023. Based on this, the present study considers 2021 as the year of COVID-19 impact within the examined ten-year period.

Digital leaders (Cluster 1) demonstrate consistently high ERP adoption levels throughout the observed period. Initial values in 2015 (65.51) already indicate a relatively mature stage of ERP diffusion. A steady upward trend is evident, culminating in the highest value in 2025 (72.85). The stability between 2015 and

2021 suggests structural digital maturity, while the more pronounced increase after 2021 may indicate accelerated digital transformation in the post-COVID period.

Digital followers (Cluster 2) start at a lower level in 2015 (41.23) compared to Cluster 1, but show the most dynamic growth pattern. The increase becomes especially marked after 2019, with a notable jump between 2019 (45.78) and 2021 (51.80). By 2025, the value reaches 59.22, indicating a convergence trend towards higher digital maturity. This suggests that countries in this cluster may also have experienced digital acceleration triggered by external shocks, such as the COVID-19 crisis, leading to intensified ERP implementation.

Cluster 3 exhibits the lowest ERP adoption levels throughout the period. Although a gradual upward trend is present from 35.74 (2015) to 42.97 (2025), the growth rate remains moderate compared to Cluster 2.

Table 3 presents the ANOVA test results. This test was applied to examine statistically significant differences among the clusters of countries.

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Y_2015	2198.29	2	52.303	24	42.03	0.000
Y_2017	1985.29	2	37.027	24	53.62	0.000
Y_2019	1933.73	2	39.857	24	48.52	0.000
Y_2021	1522.73	2	55.004	24	27.68	0.000
Y_2023	1273.89	2	71.616	24	17.79	0.000
Y_2025	1351.33	2	62.264	24	21.70	0.000

Table 3

ANOVA results

According to these results, there are statistically significant differences among clusters across all observed years (Sig = 0.000). Therefore, each observed year contributed significantly to cluster differentiation, confirming the robustness of the identified country typology.

Conclusion

This study examines the evolution of ERP adoption across European countries over a ten-year period, investigating whether distinct digital transformation trajectories can be identified at the cross-country level. Using K-means cluster analysis, countries were grouped according to the percentage of enterprises implementing ERP systems. The results reveal three relatively balanced and structurally differentiated clusters: digital leaders, digital followers, and late adopters. However, descriptive trends indicate a post-pandemic acceleration, suggesting COVID-19 as a potential catalyst for intensified ERP adoption. ANOVA results confirm statistically significant differences among clusters for all years, supporting the

robustness of the classification. From a policy perspective, the results highlight the need for differentiated digital transformation strategies, particularly for late adopters. Methodologically, the study contributes to the literature by demonstrating the applicability of clustering techniques in longitudinal cross-country analyses of technological adoption, offering an alternative to single-country or firm-level studies.

Despite its contributions, this study has some limitations. The first concerns the use of only one indicator, namely the percentage of enterprises implementing ERP systems, and the limited scope to expand the analysis to a broader international context beyond the observed countries, as the initial data set covers only European countries. Another shortcoming of the research is the failure to use formal cluster validation methods, such as the silhouette score, elbow method, or other measures of partition quality.

Future research could extend the analysis by incorporating additional macroeconomic and digital infrastructure indicators to further explain the observed cluster structure. Additionally, fuzzy cluster analysis could be applied to obtain results that may serve as a basis for comparison.

Acknowledgement

The research presented in this paper was carried out with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia within the framework of financing scientific research work at the University of Belgrade, Technical Faculty in Bor, in accordance with the contract with registration number 451-03-34/2026-03/ 200131.

References

[1] Malik Abu Afifa, I. Saleh, and Hien Vo Van, “Accounting information quality in the digital era – a perspective from ERP system adoption?,” Global knowledge, memory and communication, Oct. 2023, doi: https://doi.org/10.1108/gkmc-03-2023-0101

[2] Djiantoro and Z. J. H. Tarigan, “Effect of ERP Implementation on Firm Performance Through Information Technology Capability and Inventory Management During the Covid-19 Pandemic,” Petra International Journal of Business Studies, vol. 5, no. 2, pp. 163–173, Dec. 2022, doi: https://doi.org/10.9744/ijbs.5.2.163-173.

[3] P. Roffia and L. Mola, “Is COVID-19 enough? Which underestimated conditions characterise the adoption of complex information infrastructures in small and medium-sized enterprises,” Journal of Business Research, vol. 144, pp. 1249–1255, May 2022, doi: https://doi.org/10.1016/j.jbusres.2021.12.083.

[4] S. News, “SAP Pre-Announces Strong Fourth Quarter and Full-Year 2020 Results,” SAP News Center, Jan. 14, 2021. https://news.sap.com/2021/01/sap-pre-announces-strong-fourth-quarter-and-full-year-2020-results (accessed Feb. 25, 2026).

[5] John, V. Decker, R. Anderson, and G. Leiter, “Licensed for Distribution Magic Quadrant for Cloud Core Financial Management Suites for Midsize, Large and Global Enterprises,” 2019. Available: https://b2bsalescafe.files.wordpress.com/2019/09/gartner-magic-quadrant-for-cloud-core-financial-management-suites-for-midsize-large-and-global-enterprises-may-2019.pdf

[6] X. Yao and M. Azma, “Do cloud-based enterprise resource planning systems affect the productivity of human resources in the COVID-19 era?,” Kybernetes, vol. ahead-of-print, no. ahead-of-print, Nov. 2021, doi: https://doi.org/10.1108/k-03-2021-0243.

[7] S. Alhomdy, F. Thabit, F. H. Abdulrazzak, A. Haldorai, and S. Jagtap, “The role of cloud computing technology: A savior to fight the lockdown in COVID 19 crisis, the benefits, characteristics and applications,” International Journal of Intelligent Networks, vol. 2, pp. 166–174, 2021, doi: https://doi.org/10.1016/j.ijin.2021.08.001.

[8] Lutfi et al., “Antecedents of Big Data Analytic Adoption and Impacts on Performance: Contingent Effect,” Sustainability, vol. 14, no. 23, p. 15516, Nov. 2022, doi: https://doi.org/10.3390/su142315516.

[9] D. Roy Chowdhury, P. Subbarao, and P. Pal Chaudhuri, “Characterization of two-dimensional cellular automata using matrix algebra,” Information Sciences, vol. 71, no. 3, pp. 289–314, Jul. 1993, doi: https://doi.org/10.1016/0020-0255(93)90060-y.

[10] F. Qutaishat, A. Abushakra, L. Anaya, and M. Al-Omari, “Investigating the factors affecting the intention to adopt cloud-based ERP systems during the COVID-19 era: evidence from Jordan,” Business Process Management Journal, vol. 29, no. 3, pp. 653–670, Feb. 2023, doi: https://doi.org/10.1108/bpmj-09-2022-0462.

[11] Europa.eu, 2026. https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_iipn2/default/table?lang=en (accessed Feb. 25, 2026).

[12] “Na, S., Xumin, L., & Yong, G. (2010, April). Research on k-means clustering algorithm: An improved k-means clustering algorithm. In 2010 Third International Symposium on intelligent information technology and security informatics (pp. 63-67). Ieee.,”

[13] Y. Zhang and H.-L. Huang, “The distance and entropy measures-based intuitionistic fuzzy C-means and similarity matrix clustering algorithms and

their applications," Applied Soft Computing, vol. 169, p. 112581, Jan. 2025, doi: https://doi.org/10.1016/j.asoc.2024.112581.

[14] "Mehar, A. M., Matawie, K., & Maeder, A. (2013, December). Determining an optimal value of K in K-means clustering. In 2013 IEEE international conference on bioinformatics and biomedicine (pp. 51-55). IEEE.,"

[15] Northwestern Medicine, "COVID-19 Pandemic Timeline," Northwestern Medicine, Apr. 2025. https://www.nm.org/healthbeat/medical-advances/new-therapies-and-drug-trials/covid-19-pandemic-timeline