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Evaluating Economic Efficiency through Digital Technologies

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Abstract. *The rapid advancement of digital technologies has generated increased interest among researchers to investigate and evaluate the impact of these technologies on economic efficiency. The purpose of this study is to identify and analyze the influence of digital technologies on economic efficiency in the countries of Europe and the European Union (EU) over seven years (2016-2022), for which the necessary data was found. The fundamental question of the study is: which countries in the European Union and across the entire European continent exhibit a trend of increasing revenues from the ERP system market, and among these, where is an influence on GDP observed? A group of 42 countries was analyzed, consisting of 27 countries from the European Union and 15 non-member countries, and the period studied ranges from 2016 to 2022. The study reveals that, generally, in countries where revenues from the ERP market are on the rise, there is a positive trend in economic efficiency. The study's estimates suggest that the level of internet usage in a country and the workforce with an advanced level of education significantly influence GDP per capita at the level of the countries in the European Union and the entire European continent. The conclusions of our study are based on theoretical predictions and the relevant results of other studies. The research indicates that ERP systems, as part of digital technologies and other macroeconomic factors, play an important role in stimulating economic efficiency in the European Union member states and those outside the union.*

Keywords: ERP, economic efficiency, EU countries, digital technologies

Introduction

Many researchers have analyzed the economic implications resulting from advancements in digital technologies, particularly in terms of increasing economic efficiency and stimulating overall economic growth. Research shows that digital technologies contribute to economic growth, productivity, and employment.

The implementation of ERP (Enterprise Resource Planning) systems helps companies to reduce overall costs, including labor costs, to shorten delivery times, and to increase profitability (Gessa et al., 2023).

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The purpose of this paper is to analyze the impact of ERP systems, as part of digital technologies, on economic growth and we aim to answer the following research questions:

RQ1: How can ERP systems, as part of digital technologies, contribute to economic growth in European countries?

RQ2: How do European countries differ in terms of the relationship between digital technologies and economic growth?

The development of digital technologies has generated new employment opportunities, stimulated e-commerce, improved human resource development, facilitated information dissemination, and had a positive impact on labor productivity. An indicator of economic performance is the GDP, as it represents a country's ability to generate valuable goods and services. The increase in GDP reflects a rise in total production of goods and services, highlighting economic efficiency. In the majority of small and medium-sized enterprises, the motivation for implementing ERP systems was driven by the desire to adapt technologically to new digital technologies (Gessa et al., 2023). The acceleration of economic growth in the European states that are part of developed economies is due to progress in adopting and using Information and Communication Technologies (ICT) (Fernández-Portillo et al., 2020).

This study makes a significant contribution to the literature from the perspective of examining the impact of ERP systems as part of digital technologies on economic growth in 42 European countries, including 27 members of the European Union.

The paper is structured as follows: Section 2 is dedicated to the analysis of the literature, Section 3 includes the presentation of data and methodology, Section 4 discusses the results and discussions, and Section 5 focuses on conclusions and the limitations of the research.

Literature review

Advances in digital technologies that have improved the quality of life and led to economic efficiency have resulted in economic growth. There are numerous studies that have analyzed the impact of information technologies on global economic growth (Appiah-Otoo & Song, 2021) or in specific regions (Jin et al., 2023; Nguyen et al., 2020; Toader et al., 2018).

The study by Appiah-Otoo & Song (2021) (Appiah-Otoo & Song, 2021) highlighted that information technologies lead to economic growth in both rich and poor countries, and the gains from ICT in poor countries are greater than those of rich countries.

The development of Information and Communication Technology (ICT) is increasingly recognized as a key factor stimulating economic growth, rather than just a consequence of it (Nguyen et al., 2020).

The study by Donou-Adonsou (2019) (Donou-Adonsou, 2019) examines how education influences the effect of information and communication technology on economic growth, comparing states with higher and lower access to education.

A higher level of digital technology competence has a positive impact on economic performance (Skorupinska & Torrent-Sellens, 2017). ERP (Enterprise Resource Planning) systems provide support in optimizing the internal business processes of organizations, increasing efficiency and facilitating decision-making.

Poon, Rajapakse, and Eu-Gene (2012) (Poon et al., 2012) provide a comprehensive analysis of the economic impact of Enterprise Resource Planning (ERP) systems in their work "Economic Impact of the Adoption of Enterprise Resource Planning Systems: A Theoretical Framework." They emphasize how ERP systems contribute to the transformation of organizational economics, enhancing performance, skills, and business process efficiency. The authors underscore the role of

ERP in sectors such as petrochemicals, where it is essential for survival due to its facilitation of information sharing. The adoption of ERP leads to internal improvements and significant external network effects within a supply chain, showcasing its value as a capital investment that enhances output and efficiency. This study aligns with the findings of other researchers like Dewan & Kraemer (2000) (Dewan & Kraemer, 2000) and Litan & Rivlin (2001) (Litan & Rivlin, 2001) who have documented the positive relationship between ERP implementation and cost savings, productivity, and market responsiveness.

Al Muhayfith and Shaiti (2020) (AlMuhayfith & Shaiti, 2020) highlight the evolution of ERP systems to ERP II, which significantly expands the capabilities of traditional ERP systems. This advancement enables firms to extend their operational boundaries, facilitating collaboration and communication with external entities such as partners, customers, and even competitors. This extension is critical for fostering open innovation, as it allows firms to view the outside world as a rich source of inspiration and strategically involves other organizations in their innovation processes. Such a paradigm shift underscores the role of extended ERP systems in not just internal management efficiency but also in enhancing external collaborative innovation.

Maciulyte-Sniukiene and Butkus (2020) (Maciulyte-Sniukiene & Butkus, 2020) assert that the advancement of Information and Communication Technologies (ICT) plays a pivotal role in economic growth, primarily through its influence on countries' value added and GDP. The development and utilization of ICT by businesses, governments, and individuals significantly contribute to productivity and economic growth across multiple channels, including capital deepening and innovation implementation at various levels. However, they note that the impact of ICT on productivity varies depending on factors like a country's productivity level, ICT development, and the metrics and methods used in research.

In their analysis of digitalization and its impact on economic growth in the EU, Mura and Donath (2023) (Mura & Donath, 2023) observe significant heterogeneity among EU countries and the UK in terms of GDP per capita, productivity, and digitalization. They note that the level of digitalization in business processes, marketing, environmental policies, and individual digital skills varies widely across these nations. The study finds that digitalization broadly has a positive impact on economic growth in the EU-28. It highlights general digitalization trends in the EU-15 and EU-13 groups, without delving into individual country specifics. Additionally, the study utilizes the Digital Economy and Society Index (DESI) developed by the European Commission to assess digitalization progress and confirms that digitalization positively influences economic growth, thereby validating their research hypothesis.

In their study, Maciulyte-Sniukiene and Butkus (2020) (Maciulyte-Sniukiene & Butkus, 2020) found that investments in Information and Communication Technologies (ICT) within EU member states positively impact productivity. However, they note that this effect typically emerges after a two-year delay. Moreover, the impact of ICT on productivity is significantly more pronounced in countries with relatively higher productivity levels. This suggests that nations with advanced ICT infrastructure and higher usage rates are better positioned to leverage ICT for further productivity gains.

Based on the European Investment Bank (2023) (Bank, 2023) study, the EIBIS Corporate Digitalisation Index is a comprehensive tool for evaluating digital adoption across the European Union and the United States. This index, detailed in the report "Digitalisation in Europe 2022–2023: Evidence from the EIB Investment Survey," groups countries based on their digitalization levels and includes various components such as the use of advanced digital technologies, responses to digital uptake during COVID-19, and investment in software, data, and employee training. The

index leverages firm-level data collected in 2022, offering insights into different nations' digital infrastructure and strategic monitoring systems.

In their report, the European Investment Bank (2023) (Bank, 2023) presents key findings from the EIBIS Corporate Digitalisation Index, highlighting that the European Union is narrowing its digital adoption gap with the United States, with several European countries surpassing the US. European firms often perceive digital infrastructure as a more significant barrier to investment than US firms, and are less likely to have increased their digitalization during the COVID-19 pandemic. The report also identifies Finland and Denmark as leading European digital nations, followed by Belgium and Sweden. It further notes top EU performers in various digitalization aspects: Slovenia in advanced digital technologies, Austria in digitalization uptake during the pandemic, Estonia for digital infrastructure, Malta for software and data investment, France for employee training investment, and Finland for formal strategic business monitoring.

Based on the research questions regarding the influence of digital technologies on economic efficiency in European countries, we have formulated hypotheses that underlie our research: Hypothesis H1 examines the impact of ERP systems on increasing economic efficiency within European states, and Hypothesis H2 investigates the differences in revenues generated by the ERP system market between countries in the European Union and other European countries that are not members of the union.

The research hypotheses are formulated as follows:

H1. The impact of ERP on economic efficiency in all European countries is positive.

H2. There are differences in the revenues from the ERP system market between countries in the European Union and in other European countries that are not members of the union.

Methodology

The research conducted is based on a quantitative study of how digital technologies, through ERP systems, influence economic growth among countries in Europe. The study uses data pertaining to 42 countries of the European continent, including the 27 members of the European Union. The study's data covers the period 2016-2022, and the variables are: GDP per capita as an indicator for expressing economic efficiency, revenues from the ERP system market, the degree of internet use, and the workforce with advanced education in each country. The data were transformed into logarithmic form to reduce heteroscedasticity. Table 1 describes the variables, their coding, definition, and unit of measurement. Data on economic efficiency, the degree of internet use, and the workforce with advanced education are from the World Bank, while ERP market revenues are from statistical data on the platform statista.ro.

Based on previous studies (Mura & Donath, 2023), we used the following econometric model based on the equation:

$$GDP = \alpha_0 + \alpha_1 ERP + \alpha_2 LABOR + \alpha_3 INTERNET + \alpha_4 PoliticalStability + \epsilon$$

Where the dependent variable is GDP, representing GDP per capita.

The independent variables are:

- ERP market revenues (ERP). ERP systems include both locally sold software through transactional licenses or subscriptions and cloud-based software (Statista, 2023).
- Workforce with advanced education ($LABOR$). Represents the ratio of the workforce with advanced education to the working-age population with advanced education (World Bank Open Data, 2023c).

- Individuals using the internet ($INTERNET$) represent the percentage of the population that has used the internet (from any location) in the last 3 months. The internet can be accessed via a computer, mobile phone, personal digital assistant, gaming machine, digital TV, etc. (World Bank Open Data, 2023b).
- Political stability ($PoliticalStability$) is a measure of political instability and/or politically motivated violence, including terrorism. Political stability creates an attractive environment for investors and technological development, thereby favoring economic development.

A dummy variable was defined to group European countries based on their membership in the European Union:

- The DUMMY_EU variable has a value of 1 for EU countries and 0 for non-EU countries.

Table 1 presents the variables, their descriptions, and the resources used.

Table 1. Variables

Indicator	Description	Unit of Measure	Source
GDP	Natural logarithm of GDP per capita.	U.S. Dollars	(World Bank Open Data, 2023a)
ERP_REVENUE	Natural logarithm of ERP market revenues.	U.S. Dollars	(Statista, 2023)
LABOR_ADV_EDU	Represents the ratio of the workforce with advanced education to the working-age population with advanced education.	Percentage	(World Bank Open Data, 2023c)
INTERNET	Individuals using the Internet from the total population.	Percentage	(World Bank Open Data, 2023b)
DUMMY_EU	1 if from the European Union, 0 otherwise.		
STAB_POL	Political stability and absence of violence/terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.	Units of a standard normal distribution, ranging from 0 to 1	(Kaufmann et al., 2010; World Bank Open Data, 2023d)

Source: Authors' own processing.

For the data analysis, a linear regression was conducted using the Jamovi application (The jamovi project, 2023), and the validation tests performed on the regression model were:

- F-statistics for model validation
- Diagnosing multicollinearity using VIF (Variance Inflation Factor)
- Testing for normality in the residual series

Descriptive statistics for each variable are presented in Table 2. The dataset contains 294 observations, the mean for GDP is 9.97, the median for GDP is 10.00, the minimum value for GDP is 7.69, and the maximum value for GDP is 11.8.

Table 2. Descriptive Statistics

	GDP	ERP_REVENUE	LABOR_ADV_EDU	STAB_POL	INTERNET
N	294	294	284	294	286
Mean	9.97	17.60	78.20	0.583	82.30
Median	10.00	17.40	78.70	0.609	83.40
Standard deviation	0.93	1.89	4.87	0.134	10.8
Minimum	7.69	14.50	56.60	0.098	46.70
Maximum	11.80	21.50	91.80	0.824	99.70

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

Results and discussions

In the research, correlation analysis between variables, regression analysis, and the t-test were conducted to identify differences between two groups of countries: those that are members of the European Union and those that are not.

The correlation analysis between variables, presented in Table 3, identified the following correlations:

- a strong direct correlation between INTERNET and GDP (r = 0.802)
- a strong direct correlation between STAB_POL and GDP (r = 0.756)
- a strong direct correlation between ERP_REVENUE and GDP (r = 0.588)
- a strong direct correlation between STAB_POL and INTERNET (r = 0.592)
- moderate direct correlations between ERP_REVENUE and INTERNET (r = 0.435) and LABOR_ADV_EDU and STAB_POL (r = 0.196)

Table 3. Correlation Matrix

	ERP_REVENUE	GDP	LABOR_ADV_EDU	INTERNET	STAB_POL
ERP_REVENUE	—	0.588	-0.130	0.435	0.196
GDP	0.588	—	0.377	0.802	0.756
LABOR_ADV_EDU	-0.130	0.377	—	0.387	0.446
INTERNET	0.435	0.802	0.387	—	0.592
STAB_POL	0.196	0.756	0.446	0.592	—

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

The regression model developed is a linear regression model that aims to estimate the value of the dependent variable GDP per capita, based on the values of the independent variables: ERP_REVENUE, LABOR_ADV_EDU, INTERNET, DUMMY_EU, STAB_POL.

The regression model used is as follows:

GDP = A + B x ERP_REVENUE + C x LABOR_ADV_EDU + D x INTERNET + E x DUMMY_EU + F x STAB_POL

For the developed regression model, the correlation coefficient R value of 0.927 indicates a strong and positive association between the dependent variable and the independent variables (Table 4) considered.

The obtained value of the determination coefficient R-squared of 0.857 indicates that the independent variables explain 85.7% of the variation of the dependent variable (Table R1), which means that the model is quite good.

Table 4. Model Fit Measures

R	R^2	Adjusted R^2	F	df1	df2	p
0.927	0.860	0.857	334	5	272	< .001

Source: Authors' processing using the Jamovi application (The jamovi project, 2023)

The F-value of 334.00 for $p < 0.001$ indicates that the dependent variable is significantly different from zero when the independent variables are included in the model (Table 4).

The VIF (variance inflation factor), which measures the collinearity among independent variables, has values (Table 5) below 5 for each of them, indicating that there is no significant collinearity among them.

Table 5. Collinearity Statistics

	VIF	Tolerance
ERP_REVENUE	1.45	0.690
LABOR_ADV_EDU	1.47	0.682
INTERNET	2.07	0.484
STAB_POL	2.30	0.435
DUMMY_EU	1.51	0.660

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

For the developed regression model (Table 6), the explanations of the regression coefficients for the independent variables are:

- ERP_REVENUE: For each unit increase in ERP revenues, the GDP is estimated to increase by 0.1651 units.
- LABOR_ADV_EDU: For each unit increase in advanced education of the workforce, the GDP is estimated to increase by 0.0172 units.
- INTERNET: For each unit increase in internet access, the GDP is estimated to increase by 0.0323 units.
- STAB_POL: For each unit increase in political stability, the GDP is estimated to increase by 2.5952 units.
- DUMMY_EU: EU countries are estimated to achieve a GDP that is 0.5183 units higher than non-EU member countries.

Table 6. Model Coefficients – GDP

Predictor	Estimate	SE	t	p
Intercept	1.4423	0.43746	3.30	0.001
ERP_REVENUE	0.1651	0.01353	12.21	< .001
LABOR_ADV_EDU	0.0172	0.00515	3.35	< .001
INTERNET	0.0323	0.00274	11.77	< .001
STAB_POL	2.5952	0.23735	10.93	< .001
DUMMY_EU	0.1583	0.05430	2.92	0.004

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

The resulting regression model is as follows:

GDP = 1.4423 + 0.1651 x ERP_REVENUE + 0.0172 x LABOR_ADV_EDU + 0.0323 x INTERNET + 2.5952 x STAB_POL + 0.1583 x DUMMY_EU

The residual analysis performs a comparison of the standardized residuals with a normal distribution, checking if the data follow a normal distribution. In this research, the residual analysis (Figure 1) indicates a good fit of the residuals with a normal distribution.

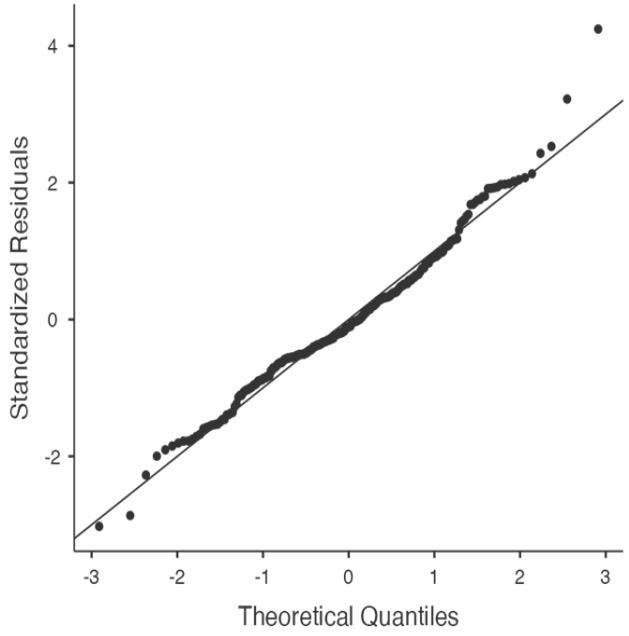

Figure 1. Residual Analysis

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

Based on the obtained regression model, Hypothesis H1 is confirmed, meaning that the impact of ERP on economic efficiency in all European countries is positive.

To test Hypothesis H2, two T statistical tests were conducted. The first test is carried out to analyze the revenues obtained from the ERP system market for two groups of countries: one group with countries in the European Union compared to another group with countries that are not in the European Union.

Table 7. Independent Samples T-Test for analyzing the ERP market revenues for EU member countries and those that are not EU members.

	Statistic	df	p
ERP_REVENUE	-16.4	292	<0.001

Source: Authors' processing using the Jamovi application (The jamovi project, 2023).

The results of the independent T-test (Table 7) show that there is a significant difference between the revenues obtained from the ERP system market in the two groups analyzed. The revenues obtained from the ERP system market of the countries in the European Union are significantly higher than the revenues obtained from the ERP system market of the countries that are not members of the union. The t-value of -16.4 means that the difference in ERP income between the two groups is not random ($p<0.001$).

Based on the T-test conducted, Hypothesis H2 is confirmed, meaning there are differences in the revenues from the ERP system market between countries in the European Union and other European countries that are not members of the union.

Conclusion

This study aimed to analyze and evaluate the practical impact of using ERP systems as part of the digital technology infrastructure on economic growth in European countries and the European Union during the period 2016–2022.

The linear regression model developed indicates that all the independent variables included in the model have a positive impact on GDP. EU countries are estimated to achieve a higher GDP than non-EU countries and other countries of the continent.

Our empirical estimates show that revenues obtained from the ERP system market, as part of digital technologies, have a positive impact on GDP per capita. Regarding the influence of macroeconomic factors, it was observed that the level of internet access and the workforce with higher education have a positive impact on GDP per capita across all European countries. Digital technologies have a significant impact on economic growth as other studies have shown (Mura & Donath, 2023).

Our research results demonstrate the importance of developing digital technologies and justify our proposal to prioritize them in governmental policies aimed at stimulating economic growth.

The main limitation of the conducted research is that the analysis only refers to European states, specifically the member states of the European Union. As future research directions, we intend to expand the analysis to include data for other countries. We are considering extending the exploration of the effect of using digital technologies in various groups of countries, considering their different levels of development.

Additionally, these findings emphasize the transformative role digital technologies play in reshaping economic landscapes across Europe, suggesting that investments in such technologies can be a key driver of sustainable long-term development. This aligns with global trends towards

digitization and brings to light a potential pathway for countries outside the European Union to enhance their economic performance. Furthermore, the study underlines the necessity of continuous research and investment in digital infrastructure, highlighting that technological progress is not only beneficial but crucial for maintaining competitiveness in the evolving global economy. These insights provide valuable guidance for policymakers, decision takers and business leaders which build the future economic resilience and growth of their communities.

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