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The Impact of Production Digitalization Investments on European Companies' Financial Performance

Aiste Lastauskaite * and **Rytis Krusinskas**

School of Economics and Business, Kaunas University of Technology, Donelaicio St. 73, 44249 Kaunas, Lithuania
* Correspondence: aiste.lastauskaite@ktu.edu

Abstract: Businesses investing in production digitalization equipment are supposed to benefit from increased productivity, enhanced efficiency, and revenue growth. Despite the increasing use of digital technologies in business, many companies still struggle to measure and maximize their returns from production digitalization investments. This research assesses the impact of production digitalization investments on companies' financial performance (operating revenue) for European businesses in the period of 2013 to 2021. To achieve this target, we performed a Fixed Effects Panel Regression analysis, using a sample size of 5706 records from the Orbis database for 30 countries, covering 634 business units. The production digitalization investment in this research is expressed by a calculated variable value, measured as the annual change in a company's Plant and Machinery value, adjusted with corresponding an annual depreciation value for the assets. The regression output was analyzed by considering the characteristics of the company size and business location. The results suggest that companies in Eastern Europe benefit more from production digitalization than those in Western Europe. The analysis highlights the tendency for the company costs of the employee and intangible fixed asset value to increase as production digitalization investments grow. Additionally, it shows that large companies tend to gain more from such investments than smaller ones. The analysis provides support and guidance for businesses' production digitalization investment strategic decision-making processes.

Keywords: production digitalization; investment; Europe; company's financial performance

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1. Introduction

Digitalization is a performance tool for business development (Nasiri et al. 2020). It is a business trend that affects single individuals and companies of all sizes and operational sectors in all fields of activity (Hossnofsky and Junge 2019; Lichtenthaler 2021). The impacts of digitalization have the potential to shape the future of business in a unique way, unlike any other technological change (Hossnofsky and Junge 2019). In the research literature, the concept of technological digitalization does not have a common definition, and terms such as 'digitalization', 'digital change', and 'digital transformation' are commonly used in the same context. Verhoef et al. (2021) discuss three stages of digital transformation: digitization, digitalization, and digital transformation. Digitization refers to the automation of daily tasks, digitalization refers to the integration of digital tools as robots into business processes, and digital transformation refers to the introduction of new business models which incorporate digital platforms. In this work, the concept of production digitalization represents the integration of any tangible digital assets such as robots, smart production systems, software, and others (Horvat et al. 2018, 2019; Hsu and Spohrer 2009).

Following government encouragement and market conditions, numerous businesses include digital transformation activities in their business strategy (Zeng et al. 2022). Understanding the potential return on investment in technological digitalization is crucial for businesses' strategic long-term planning (Zeng et al. 2022). Researchers highlight multiple benefits for digital technology integration into business, such as resource savings, improved efficiency and lead time, business flexibility, developed new revenue streams, transparency of operations, smoothened communication, and promoting innovation (Ladeira et al. 2019; Cette et al. 2022; Bleicher and Stanley 2017; Heredia et al. 2022; Peng and Tao 2022). However, not all companies manage to reach the expected benefits of digitalization (Zeng et al. 2022) and there are doubts about digitalization's direct impact on financial performance (Viete and Erdsiek 2020; Li et al. 2021; Faff et al. 2013). The situation when firms invest in digital transformation and do not obtain the expected benefit is called the digitalization paradox (Gebauer et al. 2020; Guo et al. 2023).

The assessment of the financial impact on businesses has generated increasing interest among researchers (Hess et al. 2016). By employing regression models, researchers uncover different aspects of the impact area and present contradictory and inconsistent findings. For example, research conducted by Guo et al. (2023) showed a negative result of digital transformation on business, attributable to an increased operation cost rate and managerial expenses, as well as a reduced total asset turnover. In contrast, Zeng et al. (2022)'s regression model confirmed a positive increase in the value of return on assets (ROA). Therefore, many businesses are facing the dilemma of whether and to what extent they should invest in digitalization to achieve a valuable financial outcome (Zeng et al. 2022). To resolve this dilemma, it is necessary for researchers to conduct more extensive examinations and provide quantitative and reliable evidence of the impact of digitalization investments on businesses' financial results.

The year 2020 made a remarkable mark in the history of businesses' digitalization. It was the year when the COVID-19 pandemic hit firms around the globe with restrictions on physical interactions and forced them to fundamentally change their way of working (Amankwah-Amoah et al. 2021). A range of government-enforced measures, such as social distancing, obliged many firms to accelerate digitalization actions at short notice (Sostero et al. 2020). The pandemic forced many firms to shift to remote work and operate online. It also accelerated the change from paper to digital document processing. These changes in businesses had a direct impact on the large-scale and unavoidable adoption of digitalization (Amankwah-Amoah et al. 2021; Pinzaru et al. 2020). However, with the sudden growth in production digitalization, the question of financial benefit to firms has arisen. This is, in other words, whether production digitalization investments that were supposed to be quickly absorbed and the new tools that were supposed to be quickly implemented brought valuable higher financial performance results.

Digitalization process success in businesses is also impacted by countries' historical, cultural, and development differences (Jovanović et al. 2018; Nelson and Ellis 2019; Hartl and Hess 2017). It is important to consider that post-Soviet bloc countries in Europe experienced significant stagnation in technology adaptation and development during the Soviet era, lacking access and the required infrastructure to use technology and to engage in the earlier technological digitalization processes. Following the collapse of the Soviet bloc, these countries undertook a very rapid development (jump) in digital technology adaptation (Akatkin and Yasinovskaya 2019). In contrast, Western Europe countries experienced steady development and growth in digital skills and infrastructure during the same period. This historical aspect has led to a notable imbalance in digitalization maturity and the digitalization adaptation capabilities of these countries.

Furthermore, business size itself, in the context of digitalization investments, influences company performance (Ribeiro-Navarrete et al. 2021; Buer et al. 2021). The research literature presents conflicting opinions, highlighting digitalization benefits and challenges for small, medium, and large companies. For example, larger firms face fewer resource constraints compared to small companies (Becheikh et al. 2006; Horváth and Szerb 2018), and they can financially support digitalization activities in unexpected events.

From the business financial management point of view, each strategic business decision as well as production digitalization investments should result in financial profit and business growth. Therefore, the business's main interest is to make such decisions that would result in improved financial well-being, a better market position, and a competitive advantage. While competition is very acute, digital investments and strategies related to them are crucial. The assessment of the financial impact on businesses has generated increasing interest among researchers (Hess et al. 2016). Through the employment of regression analyses, scholars reveal various dimensions of the impact area, leading to findings that are often contradictory and inconsistent. For instance, the study by Guo et al. (2023) showed that digitalization negatively affected businesses due to a rise in operational costs and managerial expenses, along with a decrease in total asset turnover. Conversely, the regression analysis by Zeng et al. (2022) confirmed a positive impact on the return on assets (ROA) value. Thus, numerous companies are confronted with the challenge of deciding if, and to what degree, they should implement digitalization investments to secure a significant financial benefit (Zeng et al. 2022). Addressing this dilemma requires researchers to undertake more comprehensive studies and offer quantitative and reliable data on how digitalization influences business financial performance, taking into account factors like company size and the region of operation.

This paper addresses the impact of production digitalization on the companies' financial performance of European companies. Data from 634 European business units, covering 30 countries are analyzed. The total sample size covers 5706 records. The analysis was conducted over a 9-year period from 2013 to 2021 and includes the pandemic crisis period. Furthermore, using a regression analysis, the output is compared, taking into consideration the specifics of the company size and business location. This study aims to analyze the impact of production digitalization investments on business, specifically addressing conditions such as company size and European geographic region. Moreover, it investigates which financial indicators most accurately reflect the impact of production digitalization investments, and how we can measure the expected effect. Additionally, it analyzes what patterns can be identified between the level of production digitalization investment and financial performance, considering European geographic region and company size differences. Furthermore, this research distinguishes itself by evaluating production digitalization investments not through the lens of specific technology but by considering technological shifts in industries. The paper extends the available literature on production digitalization investment's impact on business financial performance across different company sizes, and Western and Eastern Europe regions, identifying key financial indicators and patterns. The key benefit of the analysis is in providing quantitative evidence for guidelines on where to focus strategic targets to gain maximum financial return from production digitalization investments.

2. Literature Review and Hypothesis Development

Production Digitalization Investment's Impact on Business Financial Performance: Evaluation of Region and Company Size Differences

Digitalization is reshaping the fundamentals of business processes (Ghosh et al. 2022). The integration of digital technologies into business processes, such as production, sales, and management, creates competitive advantages for companies (Akhtar et al. 2019). There is no general agreement in the research literature on the impact of digitalization on business financial performance. For instance, research conducted by Huang et al. (2020) and Liu et al. (2023) confirmed the positive impact of digitalization on business financial performance. Huang et al. (2020)'s study showed a positive and significant impact on 8 financial metrics, including labor productivity, return on assets (ROA), and profit margin. Meanwhile, Liu et al. (2023) investigated Chinese manufacturing firms during the period of 2008–2017 and provided empirical evidence supporting a positive correlation between the adaptation of digital technologies and company performance. Furthermore, the results of the study by Peng and Tao (2022) showed that digitalization reduces costs, increases revenue, and improves efficiency, with explanatory variables such as a return on assets, profit margin, and innovation output. Based on the above findings, the following hypothesis was proposed:

H1. *Production digitalization investment has a positive impact on business financial performance.*

Controversially, a negative digitalization impact was confirmed by Jardak and Hamad (2022), Guo and Xu (2021), and Viete and Erdsiek (2020). These controversial research results and conflicting conclusions directly demonstrate the need for further and more complex examinations of digitalization's impact on business financial performance.

The European region consists of Western Europe and post-Soviet Eastern Europe countries, which are different from each other considering their historical, cultural, and technological developmental differences that have shaped their digital landscapes (Jovanović et al. 2018; Nelson and Ellis 2019; Hartl and Hess 2017). Notably, the legacy of the Soviet era has left Eastern countries at a digital crossroads, facing a unique set of challenges for digital transformation. Post-Soviet Eastern European countries, characterized by a period of significant technological stagnation, have been contrasted with the steady growth and development observed in Western Europe. Following the Soviet era, Eastern Europe focused on a rapid catch-up with digital technology, facing limited investment and a shortage of a digitally skilled workforce (Akatkin and Yasinovskaya 2019). Dzarasov and Gritsenko (2022) further underscore the low level of digitalization prevalent throughout the post-Soviet period, which has resulted in uneven digital development across these regions. The cultural differences between post-Soviet and Western European countries are deeply ingrained in their way of living, influencing attitudes towards technology adoption, innovation, and digitalization (Choi et al. 2014). Culture in Eastern Europe is influenced by historical attitudes towards risk and individual initiatives (Schwartz and Bardi 1997).

Considering historical, cultural, and digital development challenges shaping the digital landscapes of Western and Eastern European countries, a hypothesis was raised to test the differences in the impact of technological digitalization on business financial performance across these regions. The following hypothesis was constructed:

H1.2. *The impact of production digitalization investment on business financial performance differs significantly between Western and Eastern European countries.*

Furthermore, company size also has an influential role in the digitalization impact on company performance (Buer et al. 2021). For example, small companies more often face difficulties in technology adaptation than bigger ones (Nguyen 2009). Small and medium-sized companies often have problems such as lower productivity, difficult access to additional financial resources, and prolonged technology integration time (Telukdarie et al. 2023; Thrassou et al. 2020). Müller et al. (2018)'s research confirmed that Industry 4.0 technologies' implementation results are affected by company size, where the favor goes to larger and medium-size companies. Company size is directly associated with business financial well-being, available additional investments, and in general, technological capability (Reichert and Zawislak 2014). Small companies associate digitalization as an expensive activity (Bokša et al. 2020). Furthermore, small businesses lack bargaining power with suppliers to acquire the best packages and support for technology integration agreements (Malekifar et al. 2014). Based on this context, the following hypothesis was formed:

H1.3. *The size of the business investing in production digitalization impacts its financial performance*.

Additionally, there are several important research limitations to discuss. First, most of the available existing academic research work has been narrowed in its technology scope, focusing on measuring and evaluating the impact of digitalization on company performance, considering specific technology from individual countries' datasets (Dalenogare et al. 2018; Duman and Akdemir 2021; Scott et al. 2017). For example, Dalenogare et al. (2018) focused on Industry 4 technologies in Brazilian industries, whereas Cette et al. (2022) relied on an analysis of 1065 French firms with a focus on cloud and big data technologies. However, digitalization today is more about the joint effect of multiple digital technologies on the business level than about the impact of a single technology (Bharadwaj et al. 2013; Kim et al. 2021). Second, to the best of our knowledge, the research literature does not address the differential impacts of technological digitalization across geographic regions and company sizes. This research extends the literature and offers a more comprehensive analysis by evaluating the combined impact of digital technologies across businesses, investigating the specifics of regional differences and business size, and utilizing data from 30 European countries.

3. Data and Methodology

For the analysis, company-level data from the Orbis database were used, with a sample size of 5706. An analysis was performed utilizing the STATA statistical software. The geographic area covered Eastern and Western Europe. According to the NACE code, companies included in the analysis belonged to the following sectors: manufacturing, wholesale and retail, transport and storage, postal and courier services, hotels and tourism, professional and technical services, other services, and education. The dataset was aggregated and winsorized at 1 to 99 percent in order to eliminate outlier effects. A financial performance indicator was used as the dependent variable, and records with missing profitability data were dropped. The final sample consisted of 634 business units.

In this study, data from 634 business units spread across 30 European countries were analyzed. Data was segmented into Eastern and Western European regions. The dataset consisted of 81 unique business names from Eastern Europe and 553 unique business names from Western Europe. Furthermore, the whole data sample of 634 companies were categorized based on their size, considering the number of employees per company. Specifically, the dataset included 20 unique company names of very small businesses, 70 unique company names of small enterprises, 137 unique company names of a medium size, and 511 unique company names of large businesses. This detailed breakdown allowed for insights into how investment in technological digitalization impacts business financial performance across Eastern and Western European regions. Results should be interpreted with caution due to the limited number of very small companies available in the dataset.

Data represented a period of 9 years (2013–2021), which allowed us to distinguish comparatively long-term trends. The period also included the COVID-19 pandemic, which had a significant impact on digitization trends (Amankwah-Amoah et al. 2021; Pinzaru et al. 2020).

Variables have been selected with reference to the available literature on the subject of measuring the digitalization impact on business financial performance (Zeng et al. 2022; Sanchez-Riofrio et al. 2022; Yu et al. 2019; Jacobs et al. 2016). Variable definitions including calculation components are presented in Table A1. In the research work, digital technologies affected firm performance through variables like changes in sales, operating revenue, return on assets, return on equity, and others (Heredia et al. 2022; Guo et al. 2023; Martín-Peña et al. 2019). In this study, operating revenue represents business financial performance, which is often used in the literature as a business financial performance indicator.

Production digitalization investment (furthermore—digital investment (*di*)) is the main independent variable in the analysis, expressed as follows:

$$di_{i,t} = pm_{i,t} - \left(pm_{i,t-1} - pmd_{i,t}\right) \quad (1)$$

where *pm* is the Plant and Machinery value in thousands of Euros for an individual company, represented as *i*, the time period is *t*, and *pmd* represents the Plant and Machinery depreciation value in thousands of Euros.

Due to the absolute numbers' correlation with company size, in the regression model, all variables were divided by the number of employees per company. For example, large companies naturally have higher operating revenues and higher expenses for employees. Relative size measures allowed us to control for the size effect.

This study examined the impact of production digitalization investments on business financial performance. To accomplish this, a fixed effects ordinary least squares (OLS) regression model of the following form was constructed:

$$or_{i,t} = a + b_1 coste_{i,t} + b_2 intfass_{i,t} + b_3 rde_{i,t} + b_4 netp_{i,t} + b_5 di_{i,t} + b_6 tanfass_{i,t} + \varepsilon \quad (2)$$

where *or* is the operating revenue of the company *i* in year *t*; following this, *coste* is the cost of employees, *intfass* is intangible fixed assets, *rde* is research and development expenses, *netp* is the net profit, *di* is digital investment, and *tanfass* is tangible fixed assets. The company name is used as the panel identifier and year as the time variable. The fixed effect implies that the model controls for fixed effects at the company level.

The regression method was chosen with reference to the studies of Zeng et al. (2022), Guo et al. (2023), and Sanchez-Riofrio et al. (2022). A regression specification error test (RESET) was included to enhance the reliability and account for potential nonlinearities.

In order to account for possible differences in geographical region (H1.2) and company size (H1.3), the data were segmented, and a regression analysis was performed separately for each group. Two geographical regions, Eastern and Western Europe, were used in the analysis, where Eastern Europe includes countries that were once part of the Soviet bloc. Company size, considered in terms of the number of employees per company, was categorized based on the European Commission definition (2003) of very small size (up to 10 employees), small size (11–50 employees), medium size (51–250), and large companies (251 and more employees). This segregation allowed us to investigate how the relationship between dependent and independent variables varies with regards to company size and geographical region.

For a robustness check of the model, a quartile-based comparative analysis was included. Following this method, the dataset was sorted by the digital investment (di) values in an ascending order and divided into 4 quartiles. The first and third quartiles of digital investment (Q1 and Q3) were compared, as the fourth quartile (Q4) contained insufficient observations per company over time to support a robust fixed effects analysis. This methodological approach enhanced the credibility of the results.

Before running the regression analysis, the Augmented Dickey–Fuller (ADF) test was run for all time-series variables. The results of the test indicated that all variables used in the analysis became stationary after the first differencing, as p-values were less than 0.05. Variables in use did not have a unit root. Furthermore, using a Hausman specification test, we found that the chi-squared statistic was 16.63 with a p-value close to zero (refer to Table A2). Finally, we calculated variance inflation factors (VIFs) for the variables of interest, excluding the fixed effects, finding that the VIFs for the explanatory variables were all below 3 (refer to Table A3).

4. Empirical Results

Table 1 presents the variables, which were used in the analysis together with their main descriptive statistics. Table 1 also provides a detailed segmentation of the financial variables across Eastern and Western Europe regions, highlighting differences in independent variables. All variables in Table 1 are relative size measures, where values are divided by the number of employees per company. All numerical data in the analysis are annual data. The dataset covers 5706 observations, which represent a wide variety of companies. From Table 1, it is important to note that the mean of operating revenue per employee in Europe is around EUR 285,000, with a wide range ranging from EUR 1000 to EUR 13 million. The skewness (Skew) value of 13.191 suggests that the distribution is heavily right-skewed, meaning there are a small number of companies with revenues significantly higher than the majority of firms in dataset. The production digitalization investment has an average of EUR 77,000 per employee, representing a commitment to digitalization within the range of the dataset. The kurtosis (Kurt) value of 486.138 is extraordinarily high, which suggests a very peaked distribution with thick tails. Furthermore, the average of the research and development expenditures variable is relatively low compared to other variables. It also has a Skew value of 15.841 in Europe, which suggests a significant right-skewness. This pattern indicates that most companies spend relatively low amounts on research and development expenditures, with a few companies spending substantially more. From Table 1, key regional differences can be noted between Eastern and Western Europe, notably in operating revenue and tangible fixed assets, with Western European companies generally reporting higher figures. Eastern European companies show lower average costs of employees (coste) and a smaller scale in intangible assets (intfass), indicating a divergence in resource allocation and investment priorities. Additionally, the scale of digital investment (di) and R&D expenses (rde) is more modest in Eastern Europe, reflecting variations in innovation focus and digital transformation strategies across the regions.

Table 1. Variables definition and descriptive statistics for European regions.

Reg.	Variable	Abbr.	Obs	Mean	Median	Std. Dev.	Min	Max	Skew	Kurt
Europe	Operating Revenue th Eur	or	5706	285	206	457	1	13,520	13.191	267.638
	Cost of employees th Eur	coste	5706	54	52	48	4.1×10^{-2}	2766	32.026	1708.202
	Intangible Fixed Assets th Eur	intfass	5706	64	21	209	0	9783	25.744	1010.584
	Tangible Fixed Assets th Eur	tanfass	5706	104	43	334	7.2×10^{-2}	9098	14.464	277.361
	R&D expenses th Eur	rde	5706	9	0	54	0	1760	15.841	351.778
	Net profit th Eur	netp	5706	−4	6	111	−1983	614	−7.538	92.328
	Digital Investment th Eur	di	5706	77	35	178	0.006	6942	16.694	486.138
Eastern Europe	Operating Revenue th Eur	or	729	159	93	241	1	3127	5.621	52.191
	Cost of employees th Eur	coste	729	23	17	30	4.1×10^{-2}	346	6.996	63.414
	Intangible Fixed Assets th Eur	intfass	729	11	1	32	0	447	6.391	62.022
	Tangible Fixed Assets th Eur	tanfass	729	162	38	609	1	7740	8.211	82.96
	R&D expenses th Eur	rde	729	4.94×10^{-1}	0	5	0	97	13.079	187.372
	Net profit th Eur	netp	729	-8.81×10^{-1}	2	111	−1802	614	−8.806	135.945
	Digital Investment th Eur	di	729	39	17	62	4.23×10^{-1}	481	3.398	16.447
Western Europe	Operating Revenue th Eur	or	4977	303	219	478	2	13,520	13.044	254.399
	Cost of employees th Eur	coste	4977	59	55	49	2.81×10^{-1}	2766	35.18	1862.314
	Intangible Fixed Assets th Eur	intfass	4977	71	26	222	0	9783	24.393	900.239
	Tangible Fixed Assets th Eur	tanfass	4977	96	44	270	7.2×10^{-2}	9098	17.17	419.003
	R&D expenses th Eur	rde	4977	10	43	58	0	1760	14.848	308.862
	Net profit th Eur	netp	4977	-4	7	111	−1983	551	−7.357	86.121
	Digital Investment th Eur	di	4977	82	39	188	6E-3	6942	16.032	441.683

Source: The authors' calculation using data from the ORBIS database. Note: Variables presented in this table are adjusted to provide relative size measures. For example, 'Operating Revenue' represents 'Operating Revenue per Employee.' All figures are normalized by dividing them by the total number of employees per company. Values smaller than 1 are presented in the scientific notation. In this notation, 'E' represents 'times ten raised to the power of.'

The dataset covers a sample from very small and large companies where the number of employees varies from 6 to 189 thousand employees. Descriptive statistics of variables based on company size are presented in Table 2. To achieve comparable numbers, all variables in the analysis are divided by the number of employees in the business unit. Based on the detailed statistics presented in Table 2, several key differences across company sizes can be highlighted. First, large companies demonstrate a higher median in operating revenue (op) per employee, suggesting a more efficient utilization of workforce in generating revenue compared to smaller companies. The skewness (Skew) value of 6.052 for large companies indicates a right-skewed distribution, meaning that while the majority of large companies have revenues around the median, there is a long tail of companies that earn significantly more. Furthermore, despite small companies having a higher mean in tangible fixed assets (tanfass), it is the very small companies that exhibit a significantly higher mean in intangible fixed assets (intfass), indicating a potential focus on intellectual property and non-physical assets within smaller businesses. Moreover, the R&D expenses (rde) of medium-sized companies show moderate mean values, but it is the small companies that exhibit higher R&D expenses (rde) on average, possibly reflecting a strategic investment in innovation to enhance competitiveness. In addition, net profit (netp) trends demonstrate that large companies tend to be more profitable on average, with a positive net profit (netp) mean, contrasting with the negative mean net profit (netp) observed in very small companies, highlighting the financial challenges smaller companies may face. Lastly, digital investment (di) as a relative measure shows that large companies invest more in digital technologies per employee, possibly due to greater financial resources and a strategic emphasis on technological digitalization.

Table 2. Variables definition and descriptive statistics by company size.

Co. Size	Variable	Abbr.	Obs	Mean	Median	Std. Dev.	Min	Max	Skew	Kurt
Very small	Operating Revenue th Eur	or	104	540.726	200.683	1471.996	19.178	10,603.875	5.743	37.9
	Cost of employees th Eur	coste	104	87.786	74.88	46.921	34.225	288.1	2.137	8.294
	Intangible Fixed Assets th Eur	intfass	104	187.541	8.952	723.612	0	6526.046	7.096	59.275
	Tangible Fixed Assets th Eur	tanfass	104	50.78	4.818	203.704	1.746	1578.5	6.348	44.35
	R&D expenses th Eur	rde	104	19.181	0	113.441	0	915.2	6.566	47.152
	Net profit th Eur	netp	104	−223.487	−112.654	361.832	−1983.432	136.571	−2.313	9.021
	Digital Investment th Eur	di	104	31.929	14.021	48.542	2.8	227.167	2.818	10.572
Small	Operating Revenue th Eur	or	348	314.722	127.898	922.057	3.995	13,520.756	10.765	138.122
	Cost of employees th Eur	coste	348	87.45	68.434	158.149	7.356	2766.082	14.309	238.993
	Intangible Fixed Assets th Eur	intfass	348	76.631	11.581	243.399	0	3652.747	10.08	137.953
	Tangible Fixed Assets th Eur	tanfass	348	289.242	17.322	987.749	0.541	9098.005	5.79	41.514
	R&D expenses th Eur	rde	348	46.309	0	178.767	0	1760.364	5.674	41.27
	Net profit th Eur	netp	348	−133.481	−27.041	299.459	−1802.269	545.385	−2.644	12.245
	Digital Investment th Eur	di	348	96.312	28.683	389.373	0.7	6942.003	15.755	276.221
Medium	Operating Revenue th Eur	or	841	247.058	153.24	413.349	1.789	4222.104	6.052	46.749
	Cost of employees th Eur	coste	841	54.117	54.58	33.46	4.408	198.817	0.741	3.722
	Intangible Fixed Assets th Eur	intfass	841	44.882	8.174	117.329	0	1306.818	5.649	45.138
	Tangible Fixed Assets th Eur	tanfass	841	62.001	38.274	71.493	0.171	654.233	2.587	13.991
	R&D expenses th Eur	rde	841	16.469	0	61.349	0	523.569	4.73	27.481
	Net profit th Eur	netp	841	−21.187	0.711	101.873	−778.623	551.303	−1.962	16.495
	Digital Investment th Eur	di	841	58.449	31.528	66.11	0.206	487.805	1.802	7.267
Large	Operating Revenue th Eur	or	4412	284.109	216.773	344.929	8.326	8388.141	6.052	46.749
	Cost of employees th Eur	coste	4412	51.144	50.847	26.621	0.041	751.503	0.741	3.722
	Intangible Fixed Assets th Eur	intfass	4412	63.983	25.387	191.42	0	9783.27	5.649	45.138
	Tangible Fixed Assets th Eur	tanfass	4412	99.475	46.426	250.623	0.072	5492.634	2.587	13.991
	R&D expenses th Eur	rde	4412	5.162	0.603	12.362	0	164.93	4.73	27.481
	Net profit th Eur	netp	4412	14.261	8.332	34.369	−385.943	614.25	−1.962	16.495
	Digital Investment th Eur	di	4412	80.6	36.884	167.499	0.006	3272.066	1.802	7.267

Source: The authors' calculation using data from the ORBIS database. Note: Variables presented in this table are adjusted to provide relative size measures. For example, 'Operating Revenue' represents 'Operating Revenue per Employee.' All figures are normalized by dividing them by the total number of employees per company.

The Pearson correlation results are presented in Table 3. It was also used to test the multicollinearity between variables. The results show that the correlation coefficient for digital investment (di) is significantly positive, suggesting that digital investment (di) is positively correlated with business financial performance. The Pearson correlation presented in Table 3 shows strong interdependencies among variables used in the regression analysis. Notably, the operating revenue (or) shows a very high correlation with the cost of employees (coste) of 0.941, suggesting that as companies increase their employee-based expenses, there is a corresponding significant increase in operating revenue. It highlights the importance of human capital for the financial profitability of business. Similarly, tangible fixed assets (tanfass) exhibit a substantial correlation with digital investment (di) at 0.844, indicating that firms investing heavily in physical assets also tend to invest significantly in digital technologies. Furthermore, R&D expenses (rde) are positively correlated with nearly all variables but show a slightly lower correlation coefficient with tangible fixed assets (tanfass). The net profit (netp) also shows strong correlations with operating revenue (op), cost of employees (coste), and intangible fixed assets (intfass), highlighting the relationship between a firm's financial profitability and its business strategy.

Table 3. The Pearson correlation matrix for variables used in regression analysis.

No.	Variables	1	2	3	4	5	6	7
1	or	1						
2	coste	0.941 ***	1					
3	intfass	0.782 ***	0.776 ***	1				
4	tanfass	0.852 ***	0.804 ***	0.689 ***	1			
5	rde	0.745 ***	0.780 *	0.643 ***	0.607 ***	1		
6	netp	0.814 ***	0.783 ***	0.736 ***	0.736 ***	0.730 ***	1	
7	di	0.789 ***	0.768 ***	0.630 ***	0.844 ***	0.671 ***	0.677 ***	1

Source: The authors' calculation using data from the ORBIS database. Note: *** $p < 0.01$, * $p < 0.1$.

Table 4 presents a detailed view of the fixed-effect regression analysis (based on Equation (2)) and the RESET test results, exploring technological digitalization's impact on business financial performance across different regions and company sizes. The positive and significant coefficient for digital investment (di) in the main model underscores the beneficial role of technological digitalization in enhancing business financial performance, supporting hypothesis H1.1. Technological digitalization has a positive impact on business financial performance. This observation is particularly noteworthy in the Eastern European context, where digital investments yield a higher coefficient (0.572) compared to the Western region (0.297), suggesting a potentially greater impact of technological digitalization on financial performance in the Eastern Europe region. This observation provides partial support for hypothesis H1.2.

Table 4. Fixed-effect regression analysis indicating the impact on business financial performance.

Variables	Main Model (Fixed-Effect) (Coeff./Std. Error)	Eastern Europe (Coeff./Std. Error)	Western Region (Coeff./Std. Error)	Very Small Companies (Coeff./Std. Error)	Small Companies (Coeff./Std. Error)	Medium size Companies (Coeff./Std. Error)	Large Companies (Coeff./Std. Error)
coste	3.481/0.124 (***)	8.751/0.419	3.440/0.134	1.616/5.498	0.181/0.172	2.719/0.334	2.068/0.127
intfass	0.119/0.018 (***)	−0.502/0.234	0.129/0.019	0.025/0.254	0.176/0.083	0.130/0.067	0.259/0.013
tanfass	0.058/0.027 (**)	−0.173/0.017	0.195/0.059	0.520/6.021	0.065/0.018	0.225/0.103	0.116/0.029
rde	0.732/0.113 (***)	−0.190/0.864	0.773/0.119	−0.218/2.785	0.918/0.089	0.720/0.152	1.247/0.471
netp	0.583/0.045 (***)	0.187/0.033	0.758/0.057	0.103/1.086	0.295/0.035	1.035/0.058	0.852/0.062
di	0.441/0.052 (***)	0.572/0.173	0.297/0.079	2.902/12.290	−0.054/0.204	0.417/0.171	0.054/0.038
Constant	43.218/5.109 (***)	−34.083/9.765	43.030/6.033	302.354/581.036	268.607/24.670	65.792/19.943	127.258/6.210
Model Summary							
Observations	5706	729	4977	104	348	841	4412
R-squared	0.464	0.463	0.472	0.003	0.451	0.386	0.382
RESET Test							
SS	288,316,237	12,450,849	267,895,723	9,116,545.9	181,144,486	29,459,103	102,152,830
df	7	7	7	7	7	7	7
MS	41,188,033	1,778,692	38,270,817	1,302,363	25,877,783	420,8443.	14,593,261
F	258.88	42.69	218.26	0.58	77.27	30.73	152.06
Prob>F	0.00	0.00	0.00	0.7674	0.00	0.00	0.00
R-squared	0.241	0.2930	0.2352	0.0408	0.6140	0.2053	0.1947
Adj R-squared	0.240	0.2862	0.2341	−0.0291	0.6061	0.1986	0.1934
Root MSE	398.87		418.75	1493.3	578.72	370.04	309.79

Note: *** $p < 0.01$, ** $p < 0.05$. Source: The authors' calculation based on data from the ORBIS database.

The differences in digital investment's (di) impact across groups of company sizes shows that while medium-sized and large companies benefit significantly, the impact on very small companies, though positive, is based on a limited sample and can not be conclusive. Furthermore, large companies demonstrate the most substantial positive impact, aligning with hypothesis H1.3. The size of business investing into technological digitalization impacts its financial performance.

Further investigating the coefficients across all variables, can be noted that the cost of employees (coste) is higher in Eastern Europe, indicating regional differences in labor-related expenses and their influence on business financial performance. The fixed-effect regression analysis reveals a layered relationship between both intangible (intfass) and tangible fixed assets (tanfass) and business financial performance. The tangible fixed assets (tanfass) variable shows a stronger association in the Western region and for larger companies, possibly due to their extensive physical operations base. In addition, intangible fixed assets (intfass) show a negative coefficient in Eastern Europe, suggesting a differential utilization of such assets in this specific region.

The R&D expenses (rde), while positive in all models, are significantly higher in larger companies, highlighting the scalability of technological digitalization benefits and its direct correlation with enhanced business financial performance. The net profit (netp) positive impact, noted especially in large companies, highlights the cumulative advantage of scale, digital investment (di), and R&D expenses (rde) in impacting business profitability. This analysis underscores the importance of a balanced investment strategy for both physical and intellectual assets.

Looking into the explanatory power of the models, the R-squared values reported in Table 4 show differences across segments. With an R-squared of 0.464 in the main model, a considerable portion of the variance in business financial performance is accounted for, underscoring the significant role of the included variables. Moreover, the regional analysis reveals a slightly higher R-squared value for the Western Region (0.472) compared to Eastern Europe (0.463). It may suggest that the model is more effective at explaining financial performance variations in Western European companies. However, the difference is not highly significant. In addition, among company sizes, the R-squared values decrease from small (0.451) to medium (0.386) and large (0.382) companies, indicating a diminishing model fit as company size increases. This trend may reflect the increasing complexity of factors impacting larger businesses' financial performance. The very small companies' model set up stands out with an R-squared value of only 0.003, significantly lower than the others, highlighting the model's limited explanatory power due to limited sample size.

The results of the RESET tests for all models (except very small companies) indicate possible specification errors, suggesting that the equation model may be missing key variables or interactions. This underscores the need for further enhancement of the model in future studies. There is a need to explore additional variables, such as sector-specific variables or macroeconomic variables, that could improve the model's robustness and explanatory power. Table 5 details the outcomes of the robustness test, which compares the coefficients across the first (Q1) and third (Q3) quartiles of digital investment (di). This test is used to check the stability of the main regression model across different levels of digital investment.

Table 5. Robustness test results comparing quartile Q1 and quartile Q3.

Variables	Main Model (Fixed-Effect) (Coeff./Std. Error) Q1	t Q1	P > |t| Q1	Main Model (Fixed-Effect) (Coeff./Std. Error) Q3	t Q3	P > |t| Q3
coste	2.797/0.244	11.44	0.000	4.543/0.161	28.05	0.000
intfass	0.020/0.0565	0.36	0.720	0.073/0.096	0.77	0.443
tanfass	−0.087/0.101	−0.87	0.385	0.069/0.059	1.16	0.245
rde	0.543/0.142	3.80	0.000	0.171/0.515	0.33	0.740
netp	0.934/0.064	14.59	0.000	0.588/0.114	5.14	0.000
di	0.752/0.516	1.46	0.145	0.098/0.074	1.31	0.190
Constant	69.295/16.808	4.12	0.000	81.514/10.504	7.76	0.000

Source: The authors' calculation based on data from the ORBIS database.

The robustness test results show major differences in the coefficients between the first (Q1) and third (Q3) quartile for several variables. The coefficient for cost of employees (coste) almost doubles from the first to third quartile, suggesting that the impact of employee costs on financial performance intensifies with higher levels of digital investment (di). Furthermore, the coefficients for the net profit (netp) and the constant values show significant variations between the first and third quartile, suggesting that financial performance can vary across different investment levels. The findings from the robustness test suggest that the model requires refinement to consistently capture the effects across varying intensities of digital investment (di).

5. Conclusions

Technological advancement encourages businesses to invest in digital technologies (Nasiri et al. 2020; Ghosh et al. 2022). It has become a success factor for businesses across various aspects such as innovation, competitiveness, and efficiency (Ladeira et al. 2019; Cette et al. 2022; Bleicher and Stanley 2017; Heredia et al. 2022; Peng and Tao 2022). Existing research work on the relationship between investment in production digitalization and business financial performance presents mixed results, pointing to impact differences considering region and company size aspects. As companies increasingly focus on digital technologies to enhance business performance, understanding the connection between digital investment and financial performance becomes vital. Moreover, in the context of global events, such as the COVID-19 pandemic, which accelerated the technological digitalization process, digital investment has become a survival strategy for businesses. This study addresses the research gap on production digitalization investment's impact on business financial performance in the European region and explores the difference of impact on company size and regional factors. The research's insights support business decision makers to achieve maximum benefit in digitalization investment strategies.

The results of the analysis of 5706 companies across 30 European countries demonstrate that digitalization investment plays a significant role in balancing business financial performance, and this impact differs across company sizes and regions within Europe. By utilizing a fixed-effect regression model, the research evaluates the impact on business operating revenue. The empirical results presented in the analysis align with the existing research literature in several ways. First, the finding that production digitalization positively impacts business financial performance supports the observations made by Huang et al. (2020) and Liu et al. (2023), who confirmed the significant positive impact of production digitalization on financial metrics and overall company performance. Additionally, it supports the proposed hypothesis H1, highlighting the beneficial role of digitalization in enhancing business financial performance.

The differences in the impact of technological digitalization between Eastern and Western European countries, as well as across company sizes, offer empirical evidence for discussions by Jovanović et al. (2018) and Buer et al. (2021). The findings suggest that the impact of digitalization investment increases operating revenue. This trend varies by business location, with companies in Eastern European countries benefiting more than those in Western Europe. The observed impact reflects the rapid catch-up with production digitalization in Eastern European countries after the post-Soviet period, confirming the discussion by Akatkin and Yasinovskaya (2019). This aligns with hypothesis H1.2 and suggests that businesses operating in the Eastern European region with historically lower levels of production digitalization demonstrate more pronounced benefits from such investments. This finding underscores the importance of considering regional differences in maturity of digitalization, as discussed by Hartl and Hess (2017) and Nelson and Ellis (2019). Furthermore, the impact is more pronounced among medium to large-sized businesses. The variation in production digitalization impact across company sizes contributes to discussions by Ribeiro-Navarrete et al. (2021) and Müller et al. (2018). The variation in magnitude of production digitalization impact across company sizes reflects business differences in resource, technology capability, and strategic priorities (H1.3). The analysis also highlights the tendency for the costs of employees per company and the intangible fixed asset value to increase with the growth of digital investment.

These results contribute to a larger body of literature examining the impact of digitalization investment on business financial performance. These results also offer valuable guidance for business strategy creators and shareholders in order to maximize expected profits. Strategically, the observed positive impact of production digitalization on business financial performance highlights the strategic value of digital investments for improving competitiveness, business innovation, and financial business efficiency. Digitalization strategies should account for the initial digital maturity of the country, as demonstrated by businesses in the Eastern European region finding a pronounced benefit of increased growth and catch-up with companies in the Western European region. Strategy creators in segments of medium to large-sized companies should prioritize production digitalization investments, as the results indicate a stronger impact on operating revenue.

Additionally, the research findings suggest that digital investment is not just about adopting new technologies in business, it requires a comprehensive approach. This includes developing the digital skills of employees and focusing on intangible assets, in addition to production digitalization and concentration on fixed assets. By understanding complex relationship between variables, financial outcome, and influencing segments, strategy creators can enhance their digitalization strategies.

The potential limitations of this research are regional and industry specific variations. While the sample covers 30 European countries and a wide range of industries, there are no controls for differences related to the cultural approach to digitalization, regulatory frameworks, or industry specific conditions. The sample covers a limited number of small business units, where the majority of companies belong to medium to large size businesses. Furthermore, the RESET test results for the main model underscore the need for further possible enhancement of the model. There is a need to explore additional variables, such as sector-specific variables or macroeconomic variables, that could improve the model's robustness and explanatory power. Additionally, the robustness test comparing the first (Q1) and third (Q3) quartile results reveals variations in the influence of production digitalization investments (di); therefore, future research could focus on the varied impacts of production digitalization investments across different investment quartiles.

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Appendix A

Table A1. Variable definitions including calculation components.

Variables	Symbol	Definition	Measurement
Operating Revenue	*or*	The total revenue generated from a business primary operation.	In thousands of Euros
Production digitalization investment	*di*	Investment in production digital assets, assessed through changes in Plant and Machinery values adjusted for depreciation.	Calculated as $di_{i,t} = pm_{i,t} - \left(pm_{i,t-1} - pmd_{i,t}\right)$ In thousands of Euros

Table A1. *Cont.*

Variables	Symbol	Definition	Measurement
Number of Employees	*noe*	The total number of full-time employees at a company.	Count of employees
Intangible Fixed Assets	*intfass*	Long-term, non-physical assets such as patents, trademarks, and copyrights held by the business.	In thousands of Euros, adjusted for the effects of amortization
R&D Expenditures	*rde*	Funds spent on research and development activities to innovate and introduce new products or services.	In thousands of Euros
Plant and Machinery Value	*pm*	The value of the physical assets used in the production of goods and services.	In thousands of Euros for current financial year
Plant and Machinery Depreciation	*pmd*	The annual depreciation expense for Plant and Machinery, representing the cost of the asset consumed during the year.	In thousands of Euros for current financial year
Cost of Employees	*coste*	The total expenses incurred by the company for its employees, including salaries, benefits, and related taxes.	In thousands of Euros
Net Profit	*netp*	The total profit of the company after deducting all expenses, taxes, and costs from its total revenue.	In thousands of Euros
Tangible Fixed Assets	*tanfass*	Physical, long-term assets such as buildings, machinery, and equipment owned by the business.	In thousands of Euros

Source: The authors' calculation using data from the ORBIS database. Note: All variables in regression models are divided by the number of employees (*noe*).

Table A2. Regression analysis and VIF results.

Variable	Coefficient	Std. Error	t-Value	P > |t|	95% Conf. Interval	VIF
coste	3.377658	0.137498	24.57	0	3.108111 to 3.647205	1.6
intfass	0.134007	0.026352	5.09	0	0.0823463 to 0.1856668	1.08
tanfass	0.087002	0.021427	4.06	0	0.0449969 to 0.1290075	1.83
rde	0.107757	0.108679	0.99	0.321	−0.1052944 to 0.3208084	1.24
netp	0.815786	0.055757	14.63	0	0.7064813 to 0.925091	1.38
di	0.35469	0.042531	8.34	0	0.2713133 to 0.4380662	2.05
_cons	58.53096	8.196971	7.14	0	42.46178 to 74.60014	N/A
Number of obs	5706					
F(6, 5699)	294.60					
Prob > F	0.0000					
R-squared	0.2367					
Adj R-squared	0.2359					
Root MSE	400.03					
Mean VIF	1.53					

Source: The authors' calculation using data from the ORBIS database. Note: VIF values assess multicollinearity, with values > 4 indicating high multicollinearity.

Table A3. Hausman test results.

Variable	Fixed	Random	Difference	Std. Err.	Chi-Square	Prob > Chi-Square
coste	3.481176	3.45774	0.0234357	0.0448005		
intfass	0.1186349	0.120141	−0.0015061	0.0032903		
tanfass	0.0579912	0.0650502	−0.007059	0.0112416		
rde	0.7324102	0.6062212	0.1261891	0.0393317		
netp	0.582682	0.6138948	−0.0312128	0.0110532		
di	0.4412479	0.436537	0.0047109	0.0204835		
Hausman Test					16.63	0.0107

Source: The authors' calculation using data from the ORBIS database. Note: the chi-square value of 16.63 and its associated probability leads to the preference for the fixed effect model.

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