Acta Oeconomica 73 (2023) 4, 561–577
DOI: 10.1556/032.2023.00044

AKADÉMIAI KIADÓ

Impact of investment and R&D expenditures on company performance in the industry 4.0 era

JANA ŠIMÁKOVÁ* and TOMÁŠ PRAŽÁK

School of Business Administration in Karviná, Silesian University in Opava, Univerzitní nám. 1934/3, 733 40 Karviná, Czech Republic

Received: July 22, 2022 • Revised manuscript received: December 8, 2022 • Accepted: February 22, 2023

Check for updates

ABSTRACT

This paper aims to evaluate the influence of investment and R&D expenditures on the performance of large companies that are headquartered in the Europe using regression analysis of the generalized method of moments. The independent control variables are GDP per capita and the interest rate represented by the yield of 10-year state bonds. The sample period is 2010–2018. Our result shows that the growth of R&D expenditures and investments negatively affected the profitability ratios of the firms in the year of implementation. While concentrating on the macroeconomic control variables, the results support an assumption about the positive effects of GDP on the majority of the net income, ROA and ROE estimates. On the other hand, negative effects of interest rates were found.

KEYWORDS

financial performance, R&D expenditures, investments, industry 4.0, GMM

JEL CLASSIFICATION INDICES

G30, D20

1. INTRODUCTION

Market development, globalization, growing competitiveness and innovations have led to the arrival of the Industry 4.0 period, which has brought changes and challenges in many aspects,

* Corresponding author. E-mail: simakova@opf.slu.cz

AKJournals

such as production, trade, consumption, growth, employment and the character of firm investments. The necessary component in the adoption of 4.0 principles is a respective investment at any rate. In particular, research and development (R&D) expenditures may be considered a significant factor for profit and company development. As Pervan and Kramaric (2020) stated, if a company is innovative, develops and produces new outputs, adopts new production processes and technologies, and meets increasing and changing customer needs with higher cost efficiency and sufficient quality, it can generate and preserve a company's competitive advantage in the market. Therefore, firm investments, especially at least partially in R&D, help to maintain or improve its market position.

The influence of Industry 4.0 and respective investments and R&D expenditures have been investigated in many studies from the perspective of different methodological approaches, sample periods, countries and industries. However, many authors (e.g., Kiel et al. 2017; Moeuf et al. 2018; Müller et al. 2018; Xu et al. 2018; Piccarozzi et al. 2018) pointed out that there were still numerous gaps in the relevant literature. Due to the Industry 4.0 technical core and features, the current scientific literature has devoted much attention to technical, production and social fundamentals and challenges, whereas the discussion lacks a detailed and comprehensive economic analysis of its relevant benefits and challenges from a different perspective on varying company sizes, industry sectors, and the company's role as an Industry 4.0 provider or user. The sustainability of these opportunities and challenges is also not well understood. Furthermore, the majority of studies is devoted to macroeconomic importance and effects. The call for a proper analysis of the impacts of Industry 4.0 on the performance of companies in various sectors and countries is clearly relevant.

Our aim is to evaluate the influence of investment and R&D expenditures on the performance of large companies that are headquartered in the European market. In accordance with this aim, the following research questions (RQ) are proposed:

RQ1: What are the effects of respective investments and R&D expenditures on company performance?

RQ2: What are the sector-specific effects of respective investments and R&D expenditures on company performance?

RQ3: What are the country-specific effects of respective investments and R&D expenditures on company performance?

Macroeconomic factors shape a company's performance and could potentially lead to persistent changes in supply and demand (Šimáková et al. 2019). Therefore, in addition to the micro-variables representing the company's performance and related investments and expenditures on R&D, the model will also include control macro-variables in the analysis. The analysis is applied to the sample period between 2010 and 2018. Due to the lack of data that covers the whole pandemic era (COVID-19), the data do not use later years to avoid possible biases from the dataset. Therefore, it is believed that it represents a relevant time range, including the features of Industry 4.0 and the initial phase of company investments. The corporate level reflects Industry 4.0 according to the few specifics of the environment where it acts, in the way it is structured, and, above all, how it is managed. Therefore, geographic differentiation from the European market in this case is one of the basic preconditions for isolating the specifics of the 4.0 era. The findings from the last decade indicate that top R&D investors headquartered in Europe specialize in a relatively broad number of technologies. According to Daiko et al. (2017), this suggests potential technological advantages in industries based on the requirements for heterogeneous competencies and company strategies. The other R&D expenditure specific to the European companies is specialization in technologies considered important in terms of the key social challenges. European industry has lost the leading position in many aspects in the past two decades. Therefore, even the European Commission considers elements of Industry 4.0 to be crucial, especially ICT-related technologies, and the process of digitalization is promoted as a major factor for the European Union (EU) to maintain its leading role in several industries (European Commission 2015, 2016).

2. LITERATURE REVIEW

During the Industry 4.0 era, empirical studies have isolated some typical features in making investments and R&D expenditures. In general, it can be assumed that investment and R&D expenditures have a positive effect on economic growth and company performance. This was already been proven by several empirical studies (e.g., Yang – Lin 2007; Coad – Rao 2008). Investments and R&D expenditures usually lead to greater productivity (Griliches 1981), create greater cost efficiency, and enable the development of new products according to market needs (Bernstein – Mamuneas 2006). Raymond and St-Pierre (2004) showed that higher R&D expenditures significantly improve profitability. Yanni and Weiguo (2014), Songur and Heavilin (2017), Colbeck and Ozkan (2018) pointed out that R&D investment was always followed by a higher return and stock price. Thus, the company's performance was supported.

However, each industry and company are affected by different characteristics that have specific effects on its performance. Del Monte and Papagni (2003) confirmed the positive effect of R&D on the company performance of the Italian companies, but the assumed relationship was proven only to sales ratio. R&D expenditure effects on other performance measures remain free of any relationship. Pervan and Kramaric (2020) investigated the influence of R&D expenditure on the performance of the largest companies in the Croatian manufacturing industry in 2018. They suggested that R&D expenditure may positively and negatively influence firms' performance, depending on the regressors employed in the model. Chen et al. (2019) suggested the negative influence of R&D (observed in the current year) on company performance, however, there is the following positive effect of lagged R&D expenditure.

The literature points out the specific characteristics of the company and the environment where it operates as the crucial factors in the overall effect of investment and R&D on company performance. In general, they can be divided into the following main factors: size of the company, industry sector, and location of business operations.

2.1. Size of company and industry concentration

Studies show that both enterprise size (Schröder 2016) and industry concentration have a significant impact on the volume of realized investments and on realized R&D expenditures. Hou and Robinson (2006) suggested that lower concentrations of any industry and larger companies both lead to a higher level of R&D expenditures. However, the efficiency in the scale of production is increased, and companies can expand product variety up to one-to-one solutions, reducing even the difference between large and small companies (Weller et al. 2015). Sher and Yang (2005) found that greater R&D expenditures are predictors of increased firm performance and that low and moderate levels of R&D clustering positively moderate the relationship between innovative capability and performance.

2.2. Industry sector

The approach to investments and R&D is assumed to be affected even by the sector in which the company operates. In the survey of Dernis et al. (2019), one can find the differences in strategies in investments and R&D from the perspective of different industries. Companies in the technology sector represent significant shares of the total workforce of top R&D investors, notably in computer and electronics, transport equipment and machinery. Computers, electronics and transport equipment are top sectors from the perspective of a number of companies and R&D investments. Computers, electronics, machinery, wood and paper seem to be technological development-oriented sectors, while electricity, gas, steam, pharmaceuticals and transport services are seen as relatively more science-oriented.

Regardless of the analysed industry, the assumed positive effects can be supported. For instance, Bettiol et al. (2019) investigated the relationship between investments in digital technologies and firm performance. The results show the positive impacts on the company's performance and the role of robotics and laser cutting in this relationship. Ehie and Olibe (2010) analysed the influence of R&D on the company market value of the US manufacturing and services industries, and found a positive influence. Oztürk and Zeren (2015) examined the impact of R&D expenditure on firm performance in the manufacturing industry in Turkey. Their results indicated that R&D expenditure has a positive effect as it increases the sales.

2.3. Region and economic development

The process of formation of Industry 4.0 varies by the perspective of economic development of the country where the company operates. Industry 4.0 started earlier and was aimed at marketing and social results in the developed economies. In contrast, developing economies face institutional and financial barriers. The initiators of 4.0 Industry formation processes in the developing countries are mostly private companies (Bogoviz et al. 2019), not state institutions. Baller et al. (2016) refer to the Global Information Technology Report, which is dedicated to big data research in 148 countries. This study focuses on the effectiveness of legislation, the quality of the education system, the use of ICT, and their impact on the development of new products and services. According to the results, Industry 4.0 formation has been most affected by the economies of the Asian Tigers, Northern Europe, and some Western European countries (especially Luxembourg, Switzerland and the United Kingdom). Otherwise, Europe (Finland, Sweden and Norway) appears to be the most dynamic at the level of national economies as well as Denmark in regard to smaller countries. These economies are rated by investing heavily in the development of their digital potential. They make full use of ICT and primarily address the relevance of investments in the right conditions. Within the EU, there is also a significant difference between the use of ICT within Western and Northern Europe and within Central and Eastern European countries.

Daiko et al. (2017) emphasized that location matters for the type of innovative activity. They showed that a broad technological knowledge base is in the EU, the US and Japan. Conversely, Korea and China are more based on ICT-specialized conglomerates. Moreover, the European and US-headquartered top R&D investors seem to dedicate substantial efforts to developing technologies related, for instance, to health and the environment, which are fundamental to addressing major social challenges. Furthermore, top corporate R&D investors' headquarters and subsidiaries appear concentrated geographically. For instance, Germany and the United Kingdom rank among the top five locations in terms of the number of both headquarters and subsidiaries (Dernis et al., 2019).

Given the main conclusions and assumptions of the previous studies, our research focuses on the effects of investment and R&D expenditures on company performance with several specifics. Following the studies of Chen et al. (2019) and Freihat – Kanakriyah (2017), we consider R&D as one of the most-used measurement standards of innovation and, thus, the fundamental assumption of Industry 4.0 adoption. This approach is even in line with Švarcová et al. (2019), who noted the high correlation between Industry 4.0 and R&D projects, or is in line with Zhang et al. (2020), who argued that R&D expenditures are considered to be the elements of innovation. Attention was focused on the profitability of enterprises, namely, return on assets, return on equity and net income. We assumed that distinguishing between companies with and without R&D expenditures allows us to isolate the expected effects of Industry 4.0 principles implementation. The size of the enterprise, location, affiliation with the industry, and industry concentration are primarily considered as the factors to explain and implicate the results.

3. METHODS AND DATA SPECIFICATIONS

This paper constructs econometric models to assess the effect of investment and R&D expenditures on a company's performance. To decrease the possible biases, the company's performance is expressed in three different ways to compare the results with altered measurements. First, it is standard to use return on assets (ROA), such as in the analysis of Pervan and Kramaric (2020). Second, return on equity (ROE) is used as an additional dependent variable in alternative models to obtain more robust results. Net income is also employed in the research, as it is one of the most traditional financial performance metrics, especially from the perspective of business. Its interpretation can be misleading as its single use can lead you to prioritize short-term profits over long-term success. Hence, this indicator is indexed in this paper to assess the effects on its development trend rather than its absolute value. Following the purpose of the analysis, the main independent variables are the indicators of realized investments (INVEST) and respective R&D expenditures (R&D). As the macro-environment is one of the crucial factors of a company's performance (Šimáková et al. 2019), the control independent variables GDP per capita and the interest rates represented by the yield of 10-year state bonds (INT) are incorporated into the analysis as well.

The initial phase of the research involves the construction of a database of company data and selected macroeconomic factors. For this purpose, the Orbis database for company data and the Eurostat database for macroeconomic data are used. The fundamental criterion in company data is the published investment values of individual companies in the EU countries and the United Kingdom. Available observations cover annual data for the period between 2010 and 2018.

To evaluate the relationship of the variables under study, it is necessary to define the criteria by which individual firms will be classified into different group categories. Factors for companies grouping include the NACE economic activity areas, company size, industry concentration (Peer group size), the country in which the firm operates, and the R&D expenditures. Due to the needed consistency in the data, only large companies are involved in the modelling. The Orbis database defines large companies by operating revenues greater than 10 million EUR, total assets higher than 20 million EUR, or the number of employees higher than 150. All companies incorporated in the analysis fulfil at least one of the criteria. The basic characteristics of the companies investigated can be seen in Table 1.

The total number of companies monitored is 440 from 20 European countries. This sample is split to isolate the effects of investments and R&D expenditures in terms of specific aspects. A total of 248 enterprises operate in manufacturing, 168 in services, 16 in agriculture and 8 in construction.[1] Another categorization criterion is Peer group size, where enterprises are evenly distributed according to their concentration, as seen in Table 1. From these countries, the analysis is applied only to Finland, France, Germany and the United Kingdom. In these countries, the data availability is for more than 50 companies, which is considered the minimum relevant number for results implications. Furthermore, these countries are among the top European R&D investors. In one of the final models the analysis is applied to companies that had R&D expenditures in the observed period, this category covers 202 companies.

For a better overview of the variables of interest, basic descriptive statistics can be seen in Table 2. The observed results show the values of mean, median, maximum and minimum values, and standard deviation (Std. Dev.) in addition to presenting the normal distribution of the data. The Jarque-Bera testresults show that the data do not have a normal distribution. Therefore, correlation and regression analyses are used.

Due to the restrictions stemming from annual data and relatively short time series, it is appropriate to use the Generalized Method of Moments (GMM) with panel data to estimate the tested effects in the observed period. The basic prerequisite for the application of time and panel data is their stationarity. According to Brooks (2002), stationarity implies stochastic stability within the behaviour of individual data. The variance of the time series should be constant, and the covariance structure should be invariant over time. He defines a stationary data series as a time series with a constant mean, constant variance and constant autocovariance for any given lag time. In our study, testing the stationarity of panel data will be interpreted based on the results of the Levin, Lin and Chu test (2002), which examines the stationarity of the data series y_{it} as a function of H0: $\rho i = 1$ for $i = 1\ldots,N$ and H1: $-1 < \rho i = \rho < 1$ for $i = 1\ldots,N$, where the objective is to reject the null hypothesis of non-stationarity of the data series at a chosen statistical significance level α. To ensure the stationarity of the data, the time series needed to be free of outliers. For this reason, the time series in absolute terms (net income, investment, R&D expenditure and GDP) had to be indexed. The other values remained in their original versions to establish the authenticity of the measurements.

Subsequently, it is possible to use the correlation analysis method. Correlation is a reciprocal linear relationship between the changes in two variables. The basic element of correlation analysis is the correlation matrix, where the statistical significance of the relationship between

[1]Due to the low number of enterprises in the construction sector, this category was not monitored.

Table 1. Number of companies under investigation

NACE	Manufacturing	Services	Agriculture	Construction	Total
Number of companies	248	168	16	8	440
Peer group size	0–2,000 (1)	2,001–10,000 (2)	10,001–50,000 (3)	50,001–150,000 (4)	
Number of companies	101	147	118	74	440
Country	Finland	France	Germany	United Kingdom	
Number of companies	53	72	73	97	295 *

Source: Orbis; Authors' calculations.
Notes: * The remaining 145 companies are headquartered in countries where fewer than 50 companies published investment values.

two variables can be observed (Dougherty 2011). The resulting value of the correlation coefficient is reflected in the subsequent construction of the regression models. High values of the correlation coefficient may result in bias in other tests. In the case of a high correlation between individual regressors, multicollinearity can be considered.

Due to the large amount of input data, panel regression methods are often used to analyse the relationships and associations between data in a bivariate space where time and cross-sectional data are combined. Panel data can be used when there is a set of units that are related or very close in certain characteristics and for which observations are repeated over time. Hansen (2014) showed how to exploit moment conditions by using a dynamic GMM model to produce realistic and reliable estimates with less stringent model assumptions than other regression methods. The final GMM model satisfies the conditions of consistency, asymptotic normality and asymptotic efficiency in the class of all estimators that use no information other than that contained in the moment conditions. The relationship between the dependent variables (net income, ROA and ROE and the independent variables (amount of investment, amount of R&D expenditure, GDP and interest rate) can be expressed by a regression equation for the GMM model in the form:

$$L_{it} = \alpha_1 + \beta_1 * \Delta L_{it-1} + \beta_2 * X_{1it} + \beta_3 * X_{2it} + \ldots + \beta_n * X_{nit} + \varepsilon_{it}, \tag{1}$$

where L_{it} captures the dependent variable that represents the performance of the firm at time t, ΔL_{it-1} is the lagged explanatory variable of the previous year, and X_{nit} incorporates the explanatory variables. The signs of α_1 and ε_{it} represent the model constant and the residual component of the model in the GMM framework.

To ensure that the results obtained are sufficiently predictive, all explanatory variables are tested for their statistical significance. At the same time, it is also important to test and verify the overall robustness of the observed model through the Sargan-Hansen J-test (Hansen 1982). The Sargan-Hansen J-test determines the extent to which the method can provide the same results

Table 2. Descriptive statistics

	GDP	INVEST	R&D	INT	NI	ROA	ROE
Mean	31,315.0	217,019.3	−138693.1	2.218677	388,924.7	2.962062	5.871070
Median	30,870.0	3,546.512	0.000000	1.740000	25,483.50	3.561000	9.037000
Maximum	80,470.0	2,267,100	3,144.000	22.50000	7,152,337	87.69200	418.8200
Minimum	13,500.0	−127322.0	−8591000.	−0.330000	−8450000.	−90.36700	−766.7580
Std. Dev.	6,937.40	1,226,037.	672,729.6	2.241003	1,978,173.	10.11642	41.09745
Skewness	2.96055	11.50613	−7.447400	4.072541	16.90416	−2.688309	−5.779183
Kurtosis	19.8960	162.7512	66.39165	29.59862	497.1822	25.35545	96.04352
Jarque-Bera	52,888.4	4,298,249.	699,658.8	127,681.8	4,048,424	86,988.92	1,415,668.
Probability	0.00000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	3,960	3,960	3,960	3,960	3,960	3,960	3,960

when loaded with moderate parameter changes. The null hypothesis of the J-test assumes that the model is robust. The resulting decision on the robustness of the model is then supported on the basis of statistical significance, where the results of the likelihood ratio test should be higher than the chosen significance level of 5%.

4. RESULTS

To correctly evaluate the relationship between the observed variables using the GMM method, it is necessary to meet the conditions of stationarity of time series and multicollinearity of regressors. To meet stationarity, it is necessary to index the values of investment, R&D expenditure, and GDP per capita. Subsequently, the stationarity condition is already satisfied by all-time series. At the same time, the condition of noncorrelation of the regressors is also satisfied, the results of which are shown in Table 3. Correlation above 0.8, multicollinearity, is not demonstrated in any of the cases. In all cases, the lagged value of the dependent variable of *Y(-1)* is statistically significant. The development of the delayed dependent variable thus has a direct positive impact on the development of the dependent variable in the following year. Based on the control results of the Sargan/Hansen test, all models are robust. The results of the probability test are higher than the chosen significance level of 5%, which indicates a correct estimate of the given GMM parameter.

The results allowed us to answer the first research questions.

RQ1: What are the effects of respective investments and R&D expenditures on company performance?

The results in Table 4 show that the investments have a significant impact on the dependent variables, namely, net income, ROA and ROE. While net income is positively affected and the net income variable increases with the growth of investments, this relationship is reversed in the case of ROA and ROE. Another statistically significant variable is GDP, which has a positive effect on net income and ROA. The interest rate coefficient is found to be statistically significant only in the model for ROA. In this case, ROA is negatively affected by the interest rate indicator. R&D expenditures are found to be statistically insignificant in the models without any categorization. These results reflect the fact that there are also firms in the sample that did not report R&D expenditures in the observed period.

Subsequently, the data were categorized according to the enterprises that reported R&D expenditures in the sample period. In this case, the results of the relationship between the level

Table 3. Correlation matrix

Parameter	INVEST	R&D	GDP	INT
INVEST	X	−0.2899	0.0122	−0.0315
RD	−0.2899	X	−0.0272	0.0587
GDP	0.0122	−0.0272	X	−0.2111
INT	−0.0315	0.0587	−0.2111	X

Table 4. The results of β coefficients and J-statistics of the complete model and the model with R&D

Model	Model without categorizing data			Model with R&D expenditures		
	NI	ROA	ROE	NI	ROA	ROE
INVEST	0.0002 **	−3.93E-06 ***	−0.0001 *	0.0002 *	−3.26E-06 *	−0.0001 *
R&D					−0.1435 **	−0.2367 **
GDP	6.9016**	0.0484***		5.1877 ***		
INT		−0.1837*				
L(t-1)	0.1549 *	0.2091 *	0.1715 *	0.1452 *	0.0709 *	0.1444 *
J-stat.	33.9231 **	25.4723 **	33.309 **	28.8253 **	25.6832 **	24.6143 **

Notes: *, ** and *** represent statistical significance at the level of 1%, 5% and 10%, respectively.

of investment and the financial performance of the enterprises are almost identical to previous models. In contrast, this model shows the effect of R&D expenditures on ROA and ROE as significant factors. The results suggest that ROA and ROE decrease as expenditure increases. Among the control macroeconomic variables, only the positive effect of GDP on net income was found.

RQ2: What are the sector-specific effects of respective investments and R&D expenditures on company performance?

Another aspect of our analysis is the field of economic activity based on NACE.[2] It is possible to divide the enterprises into manufacturing, agriculture and services to obtain the relevant results. The resulting values of the interrelationships are shown in Table 5. Among the observed variables, the indicators of realized investments, R&D expenditures and interest rates have a statistically significant impact on the development of financial results in *manufacturing*. For investments, a positive effect on net income and a negative effect on ROA and ROE can be observed. R&D expenditures and interest rates are suggested as having a negative impact on ROA and ROE. GDP growth causes an increase in net income. Looking at the *agricultural companies*, differences in the resulting relationships are evident. The investment values are consistent with the previous results. However, the GDP results, in particular, show the specificities of this sector. In the case of the analysis in *services*, very low statistically significant relationships can be observed. Only the interest rate indicator can be considered as a significant determining factor.

The monitored companies were further divided according to industry concentration (Table 6). The enterprises with the lowest concentration (Peer group size 1) are identified as having the most statistically significant variables. In the case of net income and ROA, all variables are significant. Growth in investment in these firms results in an increase in Net income and a decrease in ROA and ROE. The opposite relationships can be observed in the case of the remaining variables, except for the relationship between GDP and ROA.

[2]NACE: statistical classification of industry sectors.

Table 5. The results of β coefficients and J-statistics of NACE models

Model	Model NACE – Industry			Model NACE – Agriculture			Model NACE – Services		
	NI	ROA	ROE	NI	ROA	ROE	NI	ROA	ROE
INVEST	0.0003 **	−4.20E-06 ***	−0.0001 *	0.0229 ***	−0.0001 *	−0.0003 ***			
R&D		−0.1833 *	−0.3223 *	3.0888 *			32.1218 ***		
GDP	10.7523 *			−25.8466 *	−0.2578 *	−0.8213 * *	7.8525 **		
INT		−0.1725 **	−0.5949 *		0.3458 **			−0.3361 *	−0.6111 *
L(t–1)	0.3982 *	0.2299 *	0.1021 *	0.3064 *	0.2079 *	0.3923 *	0.0839 *	0.1357 *	0.2846 *
J-stat.	27.1626 **	28.1912 **	32.180 **	11.5244 **	13.496 **	13.9861 **	37.9294 **	36.933 **	28.549 **

Notes: *, ** and *** represent statistical significance at the level of 1%, 5% and 10%, respectively.

Table 6. The results of β coefficients and J-statistics of Peer group size models

Model	Model Peer group size 1			Model Peer group size 2		
	NI	ROA	ROE	NI	ROA	ROE
INVEST	0.0003 *	−2.19E-06 *	−9.25E-06 *	0.0010 *		0.0002 ***
R&D	−112.2257 *	−0.2943 ***			−0.1797 *	−0.2556 ***
GDP	−5.9994*	0.1618 *	−0.5252 *	13.6193 *		
INT	−30.0112 *	−0.2448 *			−0.1713 **	
L(t−1)	0.3753 *	0.4673 *	0.3547 *	0.0309 *	0.2103 *	0.1672 *
J-stat.	28.9749 **	29.5039 **	28.5398 **	35.5026 **	33.8905 **	31.9702 **
Model	**Model Peer group size 3**			**Model Peer group size 4**		
	NI	**ROA**	**ROE**	**NI**	**ROA**	**ROE**
INVEST				0.0024 ***		
R&D		−0.1452 *		7.2518 *		−0.3334 **
GDP		0.0765 **		24.8076 *		0.1292 ***
INT		−0.3129 *	−0.3902 **	−20.3431 *		
L(t−1)	0.0075 *	0.1243 *	0.1617 *	0.0047 *	0.0866 *	0.0265 *
J-stat.	28.1184 **	23.8911 **	29.6306 **	38.1934 **	31.5759 **	34.6308 **

Notes: *, ** and *** represent statistical significance at the level of 1%, 5% and 10%, respectively.

Less significant relationships can be seen when analysing Peer group size 2. In this case, the growth of net income is positively influenced by investments and GDP. On the other hand, the growth of R&D expenditures and interest rates causes a decrease in ROA. A rise in ROE is caused by investment increasing and R&D expenditures decreasing in a given year.

The financial results of firms falling by concentration into Peer group size 3 have the least statistically significant variables. The growth in ROA is affected by the decline in R&D spending, GDP growth and interest rates. Interest rates also have a significant effect on ROE. The individual variables had an impact on net income and ROE in the most concentrated firms, in Peer group size 4: net income is affected by growth in investment, R&D expenditure, GDP, and a decline in interest rates. ROE, on the other hand, is negatively affected by growth in R&D expenditure and a decline in GDP in a given year.

RQ3: What are the country-specific effects of respective investments and R&D expenditures on company performance?

The complex analysis focuses on the financial performance of 440 companies operating in 20 European countries in this paper. However, for the last data classification according to business operations location, the precondition of at least 50 companies in the country under study was used. This minimum number of companies to be estimated is considered a satisfying requirement for obtaining the relevant results. Only four countries, namely, Finland, France, Germany and the United Kingdom, met this condition. Subsequently, 295 enterprises operating in these countries were monitored altogether. According to the results in Table 7, the growth of net income in Finland is influenced by the growth of investment and GDP. Conversely, net income increase is monitored following the decline in R&D expenditure. Only macroeconomic indicators had an impact on the other two profitability indicators studied (ROA and ROE), with the profitability of firms in Finland increasing with GDP growth and falling interest rates.

In France, the model showed that net income growth is influenced by growth in investment, R&D expenditure and GDP growth. This is also the case for ROE, which is influenced by growth in investment, R&D expenditure, GDP growth and decreasing interest rates. The change in ROA in France is positively influenced by R&D spending and negatively influenced by interest rates.

The third examined country is Germany. Increasing net income is affected by the growth of investment and GDP. In contrast, their increase is caused by the decrease in R&D expenditure during the period under analysis. The decrease in ROA is caused by the increase in R&D expenditure and interest rates and the decrease in GDP. Furthermore, the results also highlighted the positive effect of both investment and GDP and the negative effect of interest rates on the change in ROE in Germany.

Table 7. The results of β coefficients and J-statistics of models for countries

Model	Finland			France		
	NI	ROA	ROE	NI	ROA	ROE
INVEST	0.1000 **			0.0044 *		0.0001 **
R&D	−131.1446 *			4.7407 *	0.0541 ***	0.2743 **
GDP	40.0098	0.2794 *	0.4994 *	2.0752 ***		1.3293 *
INT		−0.4949 *	−2.2148 *		−0.1997 ***	−2.1604 *
L(t-1)	0.1279 *	0.1582 *	0.1190 *	0.0265 *	0.0501 *	0.1047 *
J-stat.	35.3833 **	29.0615 **	29.0901 **	28.8231 **	32.9359 **	35.7739 **
Model	**Germany**			**United Kingdom**		
	NI	**ROA**	**ROE**	**NI**	**ROA**	**ROE**
INVEST	0.0098 **		0.0005 ***	0.0445 ***		
R&D	−7.2399 **	−0.0711 ***		60.9449 *	−0.2066 **	−1.4443 **
GDP	24.3918 *	0.2326 *	1.7439 *	12.8469 **	0.1225 **	0.8243 *
INT		−0.5583 *	−3.8109 *			
L(t-1)	0.3796 *	0.1987 *	0.1626 *	0.0026 *	0.1994 *	0.2689 *
J-stat.	39.0049 **	29.8478 **	32.1855 **	35.0289 **	26.0646 **	28.7545 **

Notes: *, ** and *** represent statistical significance at the level of 1%, 5% and 10%, respectively.

The last analysis is applied to firms operating in the United Kingdom. Net income is positively influenced by growth in investment, R&D expenditure and GDP. The ROA and ROE results are influenced in the same way. While the growth in R&D expenditure caused a decline in profitability, in contrast, the growth in GDP affected the growth in corporate profitability.

5. DISCUSSION

The estimated models presented in the previous section show some effects, which can be generalized. One can find the prevailing statistically significant effects in Table 8. On the other hand, there are some group-specific characteristics.

While concentrating on the macroeconomic control variables that form the environment of Industry 4.0 adoption, the results support an assumption about the positive effects of GDP on the majority of the net income, ROA and ROE estimates. In this case, GDP can be considered as a proxy for the demand for the company's products, and thus, can lead to overall higher financial performance. The exceptions seem to be the companies only in the agricultural sector. Šimáková et al. (2019) consider this sector, in which consumer expenditures on food remain rather constant in relative terms. Thus, GDP growth does not necessarily lead to a greater performance of companies in this industry.

The interest rates are considered as a proxy for foreign sources of capital. Thus, they influence the expenditure side of investments in new equipment but, more importantly, in new technology and R&D in the Industry 4.0 era. McCorkler (1988) confirmed that the increasing interest rates are followed by an increase in the cost of capital, and thus, it can contract demand. The results of our research confirm the indirect relationship in these terms; however, the exception is the agriculture sector again. This is probably caused by higher public expenditures and EU/national subventions to promote the agriculture sector, providing funds for innovations and research in the agricultural sector in comparison to the individual companies.[3]

The most important variables from the perspective of the purpose of this paper are net income, ROA and ROE. Despite the fact that statistically significant coefficients of

Table 8. Prevailing significant effects

	NI		ROA		ROE	
INVEST	11	+	5	-	8	-
R&D	8	+	8	-	6	-
GDP	12	+	7	+	7	+
INT	2	-	10	-	6	-

[3]The current state of the EU's long-term strategy for agricultural research and innovation is described in more detail in the report by McEldowney (2019).

macroeconomic control variables are noticeably higher, a clear relationship can be observed between the observed investment, R&D factors and financial performance. However, the estimated coefficients are relatively mixed. They seem to be highly dependent on the proxy used for the financial performance of the company. This is fully in accordance with Del Monte and Papagni (2003), who point out the mixed results caused by the performance measures used. For instance, only net income is observed to be positively affected by the realized investments in all estimated models. Contrary investments are found to be a negative factor in order to increase the ROA in a given year, also as in the case of ROE (except for France and Peer group size 2). R&D expenditures seem to be a negative factor for ROA and ROE, except for France.

These results for investments and R&D expenditures effects correspond to those of Pervan and Kramaric (2020). However, it is assumed that a longer time is needed to see their effects on the company's profitability ratios. The paper inclines toward the opinion of Chen et al. (2019), which suggests a negative influence of R&D, observed in the current year, on company performance. Furthermore, based on the economic intuition, the positive effects of lagged investments and R&D expenditures not only on net income but also on ROA and ROE are assumed.

6. CONCLUSION

The aim of this paper was to evaluate the influence of investment and R&D expenditures on the performance of large companies headquartered in the European market, using Pearson's correlation analyses and the generalized method of moments. Although the resulting model values did not provide any universal conclusions, the prevailing effects could be used to evaluate the resulting relationships between the observed variables. The effects of macroeconomic factors supported the conclusions of economic theories where GDP growth supports the financial health of firms and higher interest rates increase the cost of capital. In the case of the investment and R&D expenditure indicators, the results are not so clear. Analysed companies' net incomes are supposed to be positively affected by them. The research suggests the negative effects of investments and R&D expenditures on ROA and ROE in the observed period. These results are important, especially in short-term decision-making, companies should take into consideration that adopting investment- and R&D-intensive policies could negatively affect their profitability ratios in the near future.

Although adopting the Industry 4.0 principles is related to costly investments, an increasing number of companies follow 4.0 initiators and adopters. Therefore, this paper offers important insights for the European companies from different industries into the adoption of Industry 4.0 processes.

ACKNOWLEDGMENT

The paper was supported by the Ministry of Education, Youth and Sports Czech Republic within the Institutional Support for Long-term Development of a Research Organization 2022 and by the Internal Grant System of Silesian University in Opava within the project "The influence of investment expenses on the financial situation of companies". The support is gratefully acknowledged.

REFERENCES

Baller, S. – Dutta, S. – Lanvin, B. (2016): *The Global Information Technology Report 2016. Innovating in the Digital Economy*. Geneva: World Economic Forum.

Bernstein, J. I. – Mamuneas, T. P. (2006): R&D Depreciation, Stocks, User Costs and Productivity Growth for US Knowledge Intensive Industries. *Structural Change and Economic Dynamics*, 17(1): 70–98.

Bettiol, M. – Capestro, M. – Di Maria, E. – Furlan, A. (2019): *Impacts of Industry 4.0 Investments on Firm Performance: Evidence from Italy*. Marco Fanno Working Papers No. 0233, Padova.

Bogoviz, A. V. – Osipov, V. S. – Chistyakova, M. K. – Borisov, M. Y. (2019): Comparative Analysis of Formation of Industry 4.0 in Developed and Developing Countries. In: Popkova, E. – Ragulina, Y. – Bogoviz, A. (eds): *Industry 4.0: Industrial Revolution of the 21st Century*. Cham: Springer, pp. 155–164.

Brooks, C. (2002): *Introductory Econometrics for Finance*. Cambridge: Cambridge University.

Chen, T. C. – Guo, D. Q. – Chen, H. M. – Wei, T. T. (2019): Effects of R&D Intensity on Firm Performance in Taiwan's Semiconductor Industry. *Economic Research – Ekonomska Istraživanja*, 32: 2377–2392.

Coad, A. – Rao, R. (2008): Innovation and Firm Growth in High-Tech Sectors: A Quantile Regression Approach. *Research Policy*, 37(4): 633–648.

Colbeck, B. – Aozkan, A. (2018): Comparison of Adjustment Speeds in Target Research and Development and Capital Investment: What Did the Financial Crisis of 2007 Change? *Journal of Business Research*, 84: 1–10.

Daiko, T. – Dernis, H. – Dosso, M. – Gkotsis, P. – Squicciarini, M. – Vezzani, A. (2017): *World Corporate Top R&D Investors: Industrial Property Strategies in the Digital Economy*. (A JRC and OECD Common Report.) Luxembourg: Publications Office of the European Union.

Del Monte, A. – Papagni, E. (2003): R&D and the Growth of Firms: Empirical Analysis of a Panel of Italian Firms. *Research Policy*, 32(6): 1003–1014.

Dernis, H. – Gkotsis, P. – Grassano, N. – Nakazato, S. – Squicciarini, M. – Van Beuzekom, B. – Vezzani, A. (2019): *World Corporate Top R&D Investors: Shaping the Future of Technologies and of AI*. (A Joint JRC and OECD Report.) EUR 29831 EN. Luxembourg: Publications Office of the European Union.

Dougherty, C. (2011): *Introduction to Econometrics*. (4th ed.) New York: Oxford University Press.

Ehie, I. C. – Olibe, K. (2010): The Effect of R&D Investment on Firm Value: An Examination of US Manufacturing and Service Industries. *International Journal of Production Economics*, 128(1): 127–135.

European Commission (2015): *A Digital Single Market Strategy for Europe*. COM (2015) 192. Https://Eur-Lex.Europa.Eu/Legal-Content/EN/ALL/?Uri=Celex%3A52015DC0192.

European Commission (2016): *Commission Sets Out Path to Digitize European Industry*. Press Release. Brussels, 19 April 2016. http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=15279.

Freihat, A. R. – Kanakriyah, R. (2017): Impact of R&D Expenditure on Financial Performance: Jordanian Evidence. *European Journal of Business and Management*, 9(32): 73–83.

Griliches, Z. (1981): *R&D Patents and Productivity*. Chicago: NBER, The University of Chicago Press.

Hansen, L. P. (1982): Large Sample Properties of Generalized Method of Moments Estimators. *Econometrica*, 50(4): 1029–1054.

Hansen, L. P. (2014): Uncertainty Outside and Inside Economic Models. *Journal of Political Economy*, 122(5): 945–987.

Hou, K. – Robinson, D. T. (2006): Industry Concentration and Average Stock Returns. *Journal of Finance*, 61(4): 1927–1956.

Kiel, D. – Müller, J. M. – Arnold, C. – Voigt, K. I. (2017): Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0. *International Journal of Innovation Management*, 21: 1740015.

Levin, A. – Lin, C. F. – Chu, C. (2002): Unit Root Test in Panel Data? Asymptotic and Finite Sample Properties. *Journal of Econometrics*, 108(1): 1–25.

McCorkler, C. O. J. (1988): *Economics of Food Processing in the United States*. London: Academic Press.

McEldowney, J. (2019): *EU Agricultural Research and Innovation*. PE 630.358. Brussels: European Parliamentary Research Service.

Moeuf, A. – Pellerin, R. – Lamouri, S. – Tamayo-Giraldo, S. – Barbaray, R. (2018): The Industrial Management of SMEs in the Era of Industry 4.0. *International Journal of Production Research*, 56(3): 1118–1136.

Müller, J. M. – Buliga, O. – Voigt, K. I. (2018): Fortune Favors the Prepared: How SMEs Approach Business Model Innovations in Industry 4.0. *Technological Forecasting and Social Change*, 132: 2–17.

Öztürk, E. – Zeren, F. (2015): The Impact of R&D Expenditure on Firm Performance in Manufacturing Industry: Further Evidence from Turkey. *International Journal of Economics and Research*, 6: 32–36.

Pervan, M. – Kramaric, T. P. (2020): Impact of Research and Development Expenditure on Firm Performance. In: Loster, T. – Pavelka, T. (eds): *The 14th International Days of Statistics and Economics Conference Proceedings*. Prague: Melandrium, pp. 816–825.

Piccarozzi, M. – Aquilani, B. – Gatti, C. (2018): Industry 4.0 in Management Studies: A Systematic Literature Review. *Sustainability*, 10: 3821.

Raymond, L. – St-Pierre, J. (2004): Customer Dependency in Manufacturing SMEs: Implications for R&D and Performance. *Journal of Small Business and Enterprise Development*, 11(1): 23–33.

Schröder, C. (2016): *The Challenges of Industry 4.0 for Small and Medium-Sized Enterprises*. Bonn: Friedrich-Ebert Stiftung.

Sher, P. J. – Yang, P. Y. (2005): The Effects of Innovative Capabilities and R&D Clustering on Firm Performance: The Evidence of Taiwan's Semiconductor Industry. *Technovation*, 25(1): 33–43.

Songur, H. – Heavilin, J. E. (2017): Abnormal Research and Development Investments and Stock Returns. *North American Journal of Economics and Finance*, 42: 237–249.

Šimáková, J. – Stavárek, D. – Pražák, T. – Ligocká, M. (2019): Macroeconomic Factors and Stock Prices in the Food and Drink Industry. *British Food Journal*, 121(7): 1627–1641.

Švarcová, J. – Urbánek, T. – Povolná, L. – Sobotková, E. (2019): Implementation of R&D Results and Industry 4.0 Influenced by Selected Macroeconomic Indicators. *Applied Sciences*, 9: 1846.

Weller, C. – Kleer, R. – Piller, F. T. (2015): Economic Implications of 3D Printing: Market Structure Models in Light of Additive Manufacturing Revisited. *International Journal of Production Economics*, 164: 43–56.

Xu, L. D. – Xu, E. L. – Li, L. (2018): Industry 4.0: State of the Art and Future Trends. *International Journal of Production Research*, 56(8): 2941–2962.

Yang, C. – Lin, C. (2007): Developing Employment Effects of Innovations: Micro Econometric Evidence from Taiwan. *The Developing Economies*, 46(2): 109–134.

Yanni, W. – Weiguo, F. (2014): R&D Reporting Methods and Firm Value: Evidence from China. *Chinese Management Studies*, 8(3): 375–396.

Zhang, M. – Li, B. – Yin, S. (2020): Configurational Paths to Regional Innovation Performance: The Interplay of Innovation Elements Based on a Fuzzy-Set Qualitative Comparative Analysis Approach. *Technology Analysis & Strategic Management*, 32(4): 1422–1435.