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The outstanding role of digitalisation and environmental protection in enhancing corporate competitiveness

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This study aims to explore Hungarian industries and manufacturing branches demonstrating the highest air pollutant emission intensities, unifying digitalisation and environmental protection tools into comprehensive categories, and designating differentiating single attributes and categories of digitalisation and environmental protection regarding competitiveness. Few studies have explored the nexus between competitiveness, digitalisation, and environmental protection. This study applies the independent samples t-test, principal component analysis, and non-hierarchical cluster analysis. The critical industrial areas include energy supply, agriculture, and emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products). More competitive and typically small- and mid-sized Hungarian companies are more intensely impacted by a shortage of qualified workforce, which impedes their innovation activities compared to less competitive firms. Additionally, the more competitive group outperforms the other group in both digitalisation and environmental protection. However, achieving better competitiveness does not necessitate a higher performance in any of the two fields within the more competitive group.

Keywords: competitiveness, digitalisation, environmental protection

In a rapidly changing world, and with the dawn of the Fourth Industrial Revolution, competitiveness has been redefined. The ability to adapt to fast-changing circumstances and the readiness to employ modern technologies are a few challenges that companies incessantly face. The market is increasingly transforming into a complex space, customers' expectations are rising, stringent regulations are in place, and a sustainable development framework is narrowing firms' leeway. Within this context, this study focuses on digitalisation and environmental protection. Contrary to digitalisation, which introduces new perspectives with immense opportunities, expenditure on protecting nature

– exceeding compulsory norms – is often considered by corporate decision-makers as an undesired premature cost without economic advantages. Striving to diminish environmental loads would be crucial as the global economy has become inconsistent with ecological conditions in the past decades. Further, climate change, as one of the planetary boundaries (i.e., resource limitations and ecological thresholds of the Earth), has become a significant topic of discussion worldwide. By opting for decarbonisation pathways, countries should be impelled to realise slopes in reducing greenhouse gases, which enable them to remain within Earth's ecological threshold. To alleviate the negative impacts of climate change, this study argues for deepening both digitalisation and environmental protection at the enterprise level.

The Competitiveness Research Centre (CRC) of the Corvinus University of Budapest has regularly published its findings in the domain of competitiveness of Hungarian small- and mid-sized enterprises (SMEs) since 1996. The progress in the field of environmental protection can be captured merely from the fourth report released in 2010, whereas digitalisation appeared in 2019 as part of the sixth phase. The nexus between competitiveness, environmental protection, and digitalisation presents numerous research gaps. Corporate competitiveness comprises offering products to customers amidst accomplishing social norms in a manner that they are inclined to pay a price, resulting in higher profitability than that realised by competitors. A country's economy can be considered competitive if it can sustainably produce, use, and sell products and services within the framework of global competition by increasing the welfare of its citizens and the benefits of its production factors *(Chikán et al., 2019a, p. 19).* In the widest sense – and in the economic context – digitalisation ranges from the conversion of a process from an analogue format to a digital one without any different-in-kind changes through creating business models exploiting digital opportunities until their diffusion, restructuring the entire system *(Gartner, 2022).*

This article was actuated by disclosing conclusions that simultaneously improve the position of domestic companies and introduce amelioration to society and nature in the short term by moderating environmental harms and steering attention to the inherent potential of digitalisation. The favourable constellation of decisive corporate and market circumstances perceived in the circle of best-practice Hungarian companies may compel their competitors and market players in other industries to adopt their methods. Three research questions (RQ) were formulated. After inventorying the industries and manufacturing branches most affected by air pollutant emission intensities (RQ1), an attempt was made to create principal components describing digitalisation and environmental protection using multiple variables (RQ2).

Based on this, this study reveals the relationship between corporate competitiveness and progress in the field of both environmental protection and digitalisation by designating measures enabling the rise from the less to the more competitive company group (RQ3). Correspondingly, the main findings from principal component analysis (PCA) and cluster analysis establish the significance of practice: the list of emission-intensive industries and manufacturing branches, possible principal components of digitalisation and environmental protection, and the differentiating principal components regarding competitiveness complemented by distinguishing single attributes.

1. Literature review

One of the discourses pursued in management science journals is explicitly targeted at or potentially expandable to domestic SMEs by investigating them from various business, management, and organisational perspectives. This study aimed to join this series of articles by conducting a critical literature review to provide practice-oriented recommendations for stakeholders. As mentioned earlier, digitalisation has been in the limelight since 2019. Therefore, articles published from 2019 formed the basis of the review to align the most frequently explored research fields. The literature review aims to identify a possible research gap in the nexus between corporate competitiveness, environmental protection, and digitalisation.

Studies published in the Budapest Management Review (BMR) deal with almost all of the current business, management, or organisational issues, with a predilection for the evolving field of Industry 4.0, incorporating, amongst others, the following: the spread of its technologies *(Baksa et al., 2020);* its practice by production units related to technology, strategy, and organisation *(Demeter et al., 2020);* related opportunities offered by pricing strategies *(Rekettye, 2020);* its interaction with digitalisation *(Freund–Jámbor–Nagy, 2020; Ternai, 2020; Csizmadia et al., 2021).* This latter dimension furnished further RQs in the area of the effects of digitalisation projects on sustainability *(Diófási-Kovács, 2020),* the relationship between information and communication technology (ICT) use and environmental performance *(Diófási-Kovács–Nagy, 2020),* Artificial Intelligence (AI) technologies *(Danyi–Iványi–Veres, 2020; Harmat–Pistrui, 2022),* the advancement of the digital resource system and the applied digital approach *(Gubán–Sándor, 2021),* determinants of digital transformation in the sales industry *(Gáti–Nagy–Pelsőci, 2021),* or the digital entrepreneurial ecosystem *(Komlósi–Páger–Szerb, 2020).* Human resource management is a popular research field in the context of Industry 4.0 *(Keszey–Tóth, 2020; Abonyi–Kovács–Pató Gáborné Szűcs, 2021),* digitalisation *(Baksa–Marciniak–Móricz, 2020; Csillag et al., 2020; Bencsik, 2021, Michalec–Németh–Tóth-Kaszás, 2021),* and factors hindering the innovation activity of enterprises *(Kiss, 2021).*

External articles were reviewed in addition to the BMR. *Matolcsy (2020)* expounded in rough lines on how structural reforms can make Hungarian society and economy more competitive and sustainable. *Boikova et al. (2021, p. 14)* identified four factors when investigating competitiveness and its relationship with economic growth in the circle of European economies. These include macroeconomic stability, research–development–digitalisation, foreign direct investment, and trade openness. *Chikán et al. (2022)* scrutinised the relationship between firms' capabilities and competitiveness. In a previous study, the same editors highlighted that at least 80% of the companies considered production/services, sales, quality management, and logistics as activities with significant contributions to company performance. Conversely, 68% similarly evaluated environmental protection *(Chikán et al. 2019b, p. 41). Csesznák–Wimmer (2021, pp. 145–147)* deduced that more responsive and competitive firms outpace those lagging behind in digital preparedness. According to the corporate phenomenon, *Cahyadi–Magda (2021)* indicated a positive relationship between each pair of digital readiness, innovation, and competitiveness at the country level.

Following my objective, identifying a bundle of easy-to-implement tools, with particular reference to Hungarian SMEs, is a possible research gap. Consequently, this study endeavours to provide statements contributing to corporate competitiveness, penetration of digitalisation, and environmental health through the spread of best practices. Based on the literature review and available data, three RQs were formulated. This study aims to disclose the following:

- First, how can industries and manufacturing branches be characterised and ranked in relation to each other in terms of their air pollutant emission intensities through the example of the Hungarian economy (using the statistics of the Hungarian Central Statistical Office, HCSO) (RQ1)?
- Second, which set of measures is the most appropriate for dimension reduction by creating the principal components of digitalisation and environmental protection (by relying on the database of CRC) (RQ2)?
- Third, which of the single attributes (RQ3a) and principal components (RQ3b) in digitalisation or environmental protection can be considered as differentiating in terms of competitiveness?

2. Methodology

2.1 Method

Quantitative analyses were carried out on the basis of the available data.

RQ1 and RQ2: Answering these questions requires dimension reduction. Exploratory factor analysis is an appropriate multivariate method. This creates new factors that are uncorrelated linear combinations of the variables involved. Thus, PCA addresses both issues.

RQ3a: The prerequisites (tests of normality and homogeneity of variances) and tests of equality of means were performed in the case of RQ3a. Both the Kolmogorov–Smirnov and the Shapiro–Wilk tests are appropriate to determine whether the subsamples follow a normal distribution. If the prerequisites are fulfilled, both the independent samples t-test and one-way ANOVA are apt to test the equality of means.

RQ3b: Kolmogorov–Smirnov tests, independent samples t-tests, and cluster analysis (non-hierarchical cluster analysis, also known as k-means cluster analysis) were employed, enabling the creation of relatively homogeneous company groups. Pearson correlation coefficients were determined for the interrelationship between variables to measure the linear correlation between the two datasets.

All calculations were performed using IBM SPSS Statistics Version 27 and Microsoft Excel *(Szüle, 2016, pp. 9–32).*

2.2 Data collection

RQ1: To gain insights into the recent status of air pollution arising from the national economy, 20 industries and 13 branches of manufacturing were evaluated by involving 12 relevant air pollutant emissions intensities based on the gross value added (GVA) by applying current prices. The intensities are uniformly expressed in kg/million HUF. In addition to carbon dioxide (CO_2, the selected data: carbon dioxide with emissions from biomass), miscellaneous greenhouse gases can aggravate global warming. Dinitrogen oxide (N_2O), methane (CH_4), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulphur hexafluoride (SF_6) can exacerbate the climate crisis due to their multiple global warming potential compared to carbon dioxide. Additionally, acidifying gases [nitrogen oxides (NO_x), sulphur oxides (SO_x), ammonia (NH_3)], ozone precursors [carbon monoxide (CO), non-methane volatile organic compounds (NMVOC)], and particulate matters [with a diameter of 10 μm or less (PM_{10}), or its subset: with a diameter of 2.5 μm or less ($PM_{2.5}$); as $PM_{2.5}$ forms part of PM_{10}, only the latter broader category was selected] damage human and environmental health and man-made capital *(HCSO, 2021a)*.

Data for creating emissions intensities: Air pollutant emissions by branches (2018), GVA (2018) (current price) *(HCSO, 2020; HCSO, 2021b)*.

RQ2, RQ3a, and RQ3b: A survey measuring the competitiveness of Hungarian firms with more than 50 employees was conducted during 2018–2019 by the CRC with the participation of 234 enterprises operating in Hungary. In total, 209 entities remained in the final sample: 172 SMEs and 37 large companies. The major industries include manufacturing (54%) and trade (21%), and 3/4 of these companies are held by domestic private owners. The CRC dataset, incorporating approximately 2,700 variables, predominantly comprised nominal and ordinal scale variables. The survey aimed to identify the determinants of corporate competitiveness and the prevailing tendencies *(Chikán et al., 2019b, p. 4)*.

2.3 Data analysis

RQ1 and RQ2: Regarding the PCA, five prerequisites were considered:

(i) The relationship between the sample size (n) and the number of variables (p) is confined by the rule of thumb, $n>5p$.

(ii) If the value of the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy (MSA) is at least 0.5, the sample can be considered appropriate for PCA.

(iii) The null hypothesis of Bartlett's test of sphericity (the correlation matrix is an identity matrix – the variables are independent) can be rejected.

(iv) The diagonal of the anti-image correlation matrix contains the MSA for each variable, and applying the previous threshold of 0.5 can be utilised for omitting variables.

(v) If all communality values exceed 0.25 post extraction, each variable can be part of the model.

Table 1

Prerequisites of the PCA

Denomination	Industries and manufacturing branches (RQ1)	Digitalisation (RQ2)	Environmental protection (RQ2)
Sample size (n)	33	209	209
Variables (p)	Case 1: 6, Case 2: 7	27	25
(i) n>5p	Fulfilled if p = 6, violated if p = 7	Fulfilled	Fulfilled
(ii) KMO	Fulfilled (each KMO≥0.5)		
(iii) Bartlett	Fulfilled (each p-value of 0.000)		
(iv) MSA	Fulfilled (each MSA≥0.5)		
(v) Communality	Fulfilled (all communality values exceed 0.25)		
Rotation method	Varimax with Kaiser Normalisation		

RQ1: First, restricting the investigation to the three major greenhouse gases – CO_2, CH_4, and N_2O – still captures 97.8% of the total greenhouse gas emissions in the case of the observed industries/branches. The set of variables is compiled via four steps by conducting the PCA on the dataset, as shown in Table 2. The rotated component matrices are extractable from Table 3.

Table 2

Determining the set of variables

Step	Number of variables	KMO	Decision rule
1	After excluding the three greenhouse gases with the lowest share (HFC, PFC, SF_6): 9; n<5p	0.412	Taking the lowest MSA from the anti-image matrix: PM_{10}: MSA = 0.089
2	After excluding PM_{10}: 8; n<5p	0.462	Taking the lowest MSA from the anti-image matrix: CH_4: MSA = 0.097
3	After excluding CH_4: 7; n<5p	0.654	To ensure a clear structure, the rotated component matrix suggests discarding NO_x.
4	After excluding NO_x: 6; n>5p is fulfilled.	0.548	p = 6 is reached; thus, the process is terminated.
Final set of the available molecules		CO_2, N_2O, SO_x, NH_3, CO, NMVOC	

Table 3

Interrelatedness between air pollutants and components (rotated correlation coefficients in parentheses)

Air pollutants	p = 7 molecules		p = 6 molecules	
	Component 1	Component 2	Component 1	Component 2
Greenhouse gases	N_2O (0.976)	CO_2 (0.967)	N_2O (0.971)	CO_2 (0.960)
Acidifying gases	NO_x (0.724) NH_3 (0.973)	NO_x (0.631) SO_x (0.965)	NH_3 (0.967)	SO_x (0.958)
Ozone precursors	NMVOC (0.780)	CO (0.637)	NMVOC (0.801)	CO (0.667)

RQ2: First, dimension reduction was performed to manage 52 variables of 11 components; six components pertain to digitalisation (see Table 4), and five are part of environmental protection (see Table 5).

RQ3a: A total of 322 nominal or ordinal scale variables were selected for single attributes. The prerequisites (tests of normality and of homogeneity of variances) and tests of equality of means were performed.

RQ3b: After the PCA, Kolmogorov–Smirnov tests and independent samples t-tests were performed to reveal the differentiating principal components. Finally, applying cluster analysis and calculating the Pearson correlation coefficients as alternative methods made it possible to draw conclusions regarding the relationships between corporate competitiveness, digitalisation, and environmental protection.

3. Findings

RQ1: Figure 1 illustrates 20 industries. Those that may not be indicated (professional, scientific, and technical activities; public administration and defence, compulsory social security; education; human health and social work; arts, entertainment, and recreation; other services; activities of households as employers) can be found in the left lower corner in the proximity of information and communication.

Figure 1

Location of the 20 industries in the space of air pollutant components based on the regression component scores (p=6)

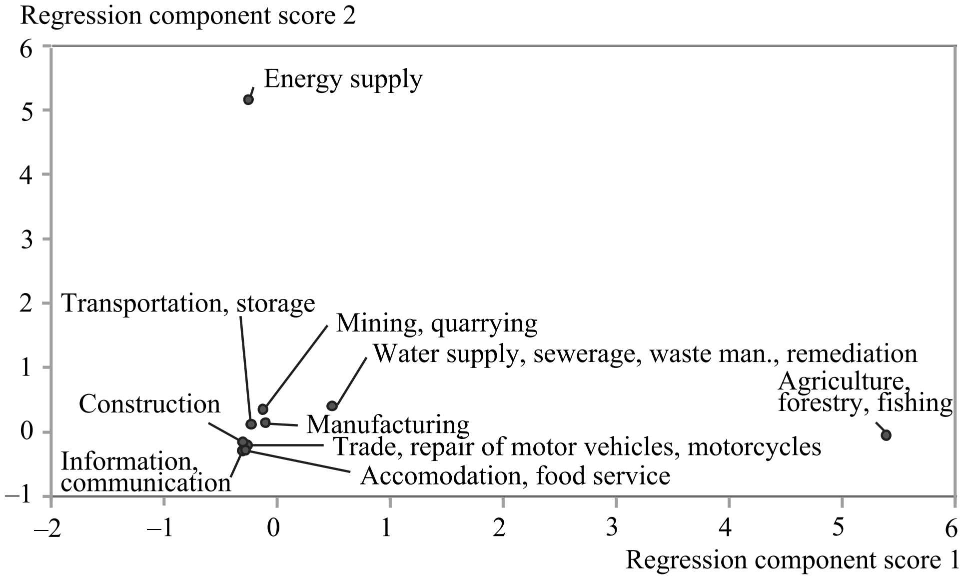
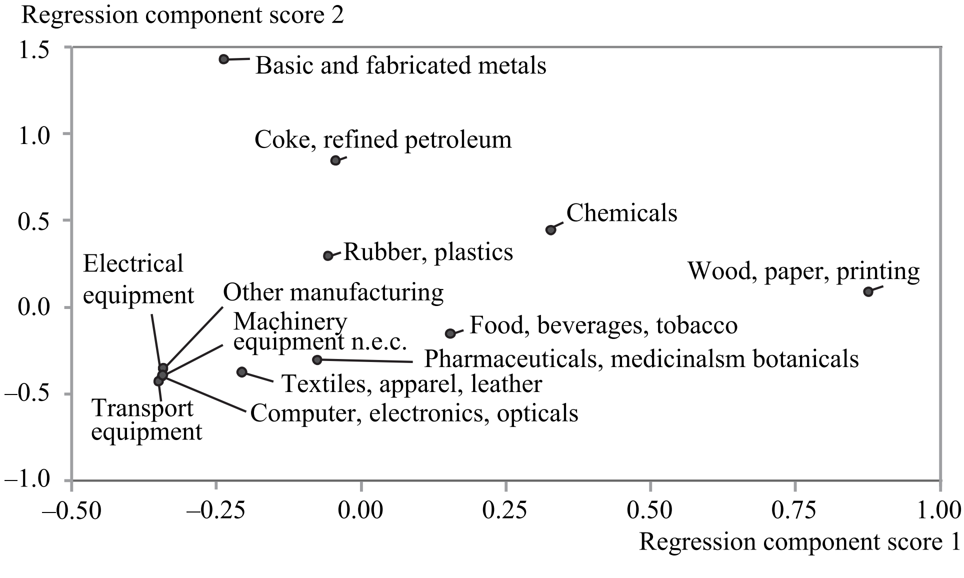


Figure 2

Location of 13 manufacturing branches in the space of air pollutant components based on the regression component scores (p = 6)



The maps facilitate easy identification of the industries and manufacturing branches, showing striking intensity in at least one of the components. The preponderance of the first component can be perceived in the case of agriculture, forestry, and fishing (largest N_2O, NO_x, NH_3, and NMVOC intensity) and the manufacture of wood and paper products and printing (less but still salient NMVOC and NO_x intensity). Conversely, the 2nd component dominates in energy supply, owing to the largest intensities of CO_2 and SO_x plus noteworthy NO_x and CO emissions. The same applies to the manufacture of coke and refined petroleum products (CO_2, NO_x, and SO_x), rubber and plastic products and other non-metallic mineral products (CO_2, NO_x, and SO_x), and basic metals and fabricated metal products, except machinery and equipment (largest CO intensity, SO_x). Owing to the considerable intensities of CO_2, NO_x, SO_x, and NMVOC, both components prevail regarding the manufacture of chemicals and chemical products. The remaining industries and branches show lower emissions levels for the investigated air pollutants.

RQ2: Tables 4 and 5 tabulate the total variance explained by the components by exceeding 50% in each case.

Table 4

Total variance explained by the underlying component of digitalisation

(%)

Name of the component	Total variance explained
Preparedness for digitalisation	73.780
Corporate level of digitalisation	71.325
Digitalisation applied by leading enterprises of the industry	83.596
Basic digitalisation tools	75.134
Advanced digitalisation tools	74.310
Technology use and change	50.147

Table 5

Total variance explained by the underlying component of environmental protection

(%)

Name of the component	Total variance explained
Advanced environmental management tools	57.600
Basic environmental management tools	56.185
Environmental and social aspects of sustainability	65.244
Sustainability performance compared to competitors	79.219
Procurement	72.450

Tables 6 and 7 align the rotated correlation coefficients of the component matrices.

Table 6

Rotated correlation coefficients of the underlying component of digitalisation

Preparedness for digitalisation	
Management's understanding of challenges and opportunities	0.720
Clearly defined digital business strategy	0.820
Regulated digital transformation projects	0.810
Allocated sufficient financial resources	0.870
Availability of knowledge and abilities in technology	0.855
A free way for bottom-up digitalisation initiatives	0.888
Rapid digital solutions to challenges	0.899
Bearing risks coupled with innovative digital solutions	0.881
Tracking cutting-edge digital solutions of the industry	0.879
Conscious tentative use of technologies for testing their applicability	0.907
Outstripping competitors in digital technological innovations	0.902
Corporate level of digitalisation	
Digitalised operation	0.777
Automated processes	0.811
Built-in digital solutions	0.914
Internet of Things (IoT)	0.869
Digitalisation applied by leading enterprises of the industry	
Automated processes	0.847
Built-in digital solutions	0.940
IoT	0.953
Basic digitalisation tools	
Web shop (online sales)	0.867
Corporate social media tools	0.867
Advanced digitalisation tools	
Software robots	0.844
Big Data	0.882
Predictive analytics	0.860
Technology use and change	
Technology as the main resource	0.820
Rapidly evolving technology	0.791
Contribution of ICT to corporate success	0.639
Applying automation and industrial robots	0.547

Table 7

Rotated correlation coefficients of the underlying component of environmental protection

Advanced environmental management tools	
Written environmental policy	0.729
Training in environmental protection for employees	0.646
Audit of environmental protection activities	0.780
Accounting system with entries about expenditures on environmental protection	0.813
Public environmental/sustainability/CSR report	0.813
Basic environmental management tools	
Measuring the performance of environmental protection activities	0.783
Applying environmental protection criteria in employee assessment	0.798
Measuring carbon dioxide emissions (carbon footprint)	0.660
Environmental and social aspects of sustainability	
Customers' perception of being an environmentally conscious/socially responsible company	0.812
Comparative advantages in environmental management practices	0.810
Mitigating business risks requires mitigating environmental protection risks	0.834
Offering products whose sales are meaningfully influenced by environmental protection/social aspects	0.794
Excelling in reshaping the industry along social and environmental aspects	0.891
Impacting the regulation of environmental protection affecting the industry	0.852
Operating in an ethical industry	0.744
Operating in a sustainable industry	0.716
Central role of sustainability in strategy-making	0.803
Sustainability performance compared to competitors	
Share of environmental protection from total expenditures	0.812
Water use per product unit	0.890
Material use per product unit	0.894
Waste generation per product unit	0.922
Energy use per product unit	0.895
Harmful emissions per product unit	0.922
Procurement	
Applying environmental protection criteria in procurement	0.851
Applying geographical distance when assessing procurers	0.851

RQ3a (single attributes): Only one item from the 322 variables in the areas of digitalisation and environmental protection proved to be differentiating regarding competitiveness between the more and less competitive firms (see Table 8). More competitive companies shared that the shortage of qualified workforce impeded their innovation activity between 2016 and 2018 more intensely compared to the less competitive group.

Table 8

Test results related to the shortage of qualified workforce

Kolmogorov–Smirnov test (significance level) H0: $X_1 \sim N(\mu_1, \sigma_1)$, $X_2 \sim N(\mu_2, \sigma_2)$	Homogeneity of variances (based on mean) (significance level) H0: $Var(X_1) = Var(X_2)$	Independent samples t-test or one-way ANOVA H0: $\mu_1 = \mu_2$
$p_1 = 0.200$, $p_2 = 0.200$	p = 0.942	Less than 0.001

RQ3b (principal components): The Kolmogorov–Smirnov test confirms the normal distribution of both subsamples of company groups at a significance level of 5% for each principal component. Table 9 recapitulates whether the company groups can be differentiated along the specific principal component by testing the null hypothesis of equality of means of company groups.

Table 9

Results of tests of homogeneity of variances and independent samples t-tests

Name of the component	Levene's test for equality of variances (significance level) H0: $Var(X_1) = Var(X_2)$	t-test for equality of means (significance level) H0: $\mu_1 = \mu_2$ (1) Equal variances assumed (2) Equal variances not assumed	Relationship between group means
Preparedness for digitalisation	0.202	(1) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Corporate level of digitalisation	Less than 0.001	(2) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Digitalisation applied by leading enterprises of the industry	0.023	(2) 0.153	No significant difference: $\mu_1 = \mu_2$
Basic digitalisation tools	0.006	(2) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Advanced digitalisation tools	0.031	(2) 0.182	No significant difference: $\mu_1 = \mu_2$
Technology use and change	0.051	(1) 0.004	Different: $\mu_1 \neq \mu_2$

(Table continues on the next page.)

(Continued.)

Name of the component	Levene's test for equality of variances (significance level) H0: $Var(X_1) = Var(X_2)$	t-test for equality of means (significance level) H0: $\mu_1 = \mu_2$ (1) Equal variances assumed (2) Equal variances not assumed	Relationships between group means
Advanced environmental management tools	0.398	(1) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Basic environmental management tools	0.442	(1) 0.927	No significant difference: $\mu_1 = \mu_2$
Environmental and social aspects of sustainability	0.307	(1) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Sustainability performance compared to competitors	0.009	(2) Less than 0.001	Different: $\mu_1 \neq \mu_2$
Procurement	0.047	(2) 0.001	Different: $\mu_1 \neq \mu_2$

4. Discussion

RQ1: The circle of the identified industries and branches from the PCA encompasses energy supply, agriculture, forestry, and fishing, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products). This enumeration is partly on the list of difficult-to-decarbonise sectors requiring substantial efforts disclosed by the International Energy Agency, such as chemicals, iron and steel, cement, pulp and paper, and aluminium *(IEA, 2020)*.

RQ3a: More competitive companies shared that the shortage of qualified workforce impeded their innovation activity between 2016 and 2018 more intensely than the less competitive group.

Table 10

Summary of responses regarding the impact (ranging from 1 /slight/ to 5 /severe/) of shortage of qualified workforce on innovation activity

Company group	Share of smaller impact (1, 2, 3)	Share of larger impact (4, 5)	Number of respondents	Average
More competitive SMEs	40.230%	59.770%	87	3.621
Less competitive SMEs	65.574%	34.426%	61	2.852
More competitive large companies	2/5	3/5	20	3.700
Less competitive large companies	2/3	1/3	15	2.667
Not classified	N/A	N/A	26	
Total			209	

Note: N/A = not available or not applicable.

Although Hungary-specific proportions are not disclosed in the Digital Economy and Society Index (DESI) report, European Union figures depict the current trends and foreshadow those to be expected. Although ICT specialists accounted for 3.9% of total employment in 2018 in the EU28, 64% of large enterprises and 56% of SMEs encountered difficulties due to the shortage of ICT specialists in the labour market while recruiting ICT specialists during the year. The DESI report does not detail the distribution based on competitiveness. Low levels of digital literacy cause the digital knowledge gap perceived between SMEs and large companies, regarding advanced technologies (e.g., AI, IoT, Cloud Computing, Big Data) and basic digital solutions (e.g., Enterprise Resource Planning, E-commerce). Assuming the extensibility of this gap along with competitiveness within SMEs, this conforms to the differentiating factors of corporate level of digitalisation (e.g., IoT), basic digitalisation tools (e.g., web shop), and technology use and change (e.g., rapidly evolving technology). However, it confutes the nature of advanced digitalisation tools (e.g., Big Data) being not distinguishing (see Table 9). According to the DESI report, only 17% of SMEs utilised Cloud Services (e.g., hosting of the database, customer relationship management), and 12% benefitted from Big Data analytics *(DESI 2020 [2021] pp. 12–13, 51).* The CRC dataset produces similarities. A total of 19/172=11.047% of SMEs utilised Big Data, which nearly coincides with the DESI report. Large firms demonstrated a slight advancement, with 5/37=13.514%; nevertheless, a comparison with the DESI report is not ensured.

RQ3b: Although equality of group means cannot be rejected in the case of three principal components (advanced digitalisation tools, digitalisation applied by leading enterprises of the industry, and basic environmental management tools, as shown in Table 9), more competitive companies outperform the other group. This aligns with the finding from the CRC survey that a prerequisite of digitalisation, informatics, is declared mandatory for remaining competitive by 62% of the respondents. Informatics can ensure a competitive advantage for a short period (13% of the companies) or even a longer duration (3%) *(Chikán et al., 2019b, p. 26). Csesznák–Wimmer (2021 pp. 145–147)* indicated a significant interrelatedness between competitiveness and digital preparedness, irrespective of the basic properties of firms (company size, owners, main activity, export orientation, etc.): those who are better at competitiveness outpace the laggers in digital preparedness as well. Surprisingly – and as partly outlined above – the component of advanced digitalisation tools missed being qualified as a differentiator. The latest achievements, such as predictive analytics, software robots, and Big Data, are rarely employed; in each case, 12-12% of the firms integrated them into their operations *(Chikán et al., 2019b, p. 29).* Additionally, the null hypothesis of equal group means cannot be rejected in the case of digitalisation applied by leading enterprises of the industry. During 2006–2008, more than 40% of the companies in the CRC sample invested in environmental protection. It can be presumed that since then, thanks to the progress made over the last decade and a half, basic environmental management tools have become a must *(Chikán et al., 2010, p. 33).*

To underpin the findings by an alternative method, similar to the Competitiveness Index, a comprehensive Technology Index was introduced based on the previous six principal components of digitalisation. Owing to the overlap, halved weights were assigned to components (2a) and (2b). The reason for the correction in (3a) and (3b) is that they are subsets of a common broader category. After these assumptions were made, an arbitrary choice was made for uniform distribution. Table 11 lists the weights used to unify the principal components of the Technology Index.

Table 11

Applied weightings for the Technology Index

(%)

Name of the component	Weighting
(1) Preparedness for digitalisation	25
(2a) Corporate level of digitalisation	12.5
(2b) Digitalisation applied by leading enterprises of the industry	12.5
(3a) Basic digitalisation tools	12.5
(3b) Advanced digitalisation tools	12.5
(4) Technology use and change	25

By building the union of the subsamples, the Pearson correlation coefficient between the Technology Index and the standardised Competitiveness Index is weak at 0.289, and the p-value of the test of zero correlation is less than 0.001. The Pearson correlation coefficient is not significant in either group – they can be considered zero. This is in line with the presumed phenomenon that digitalisation does not entail the improvement of competitiveness in the more competitive group. Moreover, it does not explain the advancement in the less competitive group (see Table 12).

Table 12

Pearson correlation coefficients between the Technology Index built from the principal components and the standardised Competitiveness Index

Sample	Pearson correlation coefficient	Test of zero correlation (p-value)
Union of the subsamples	0.289	less than 0.001
More competitive group	0.051	0.598
Less competitive group	0.122	0.267

After the Technology Index, an analogous Environmental Protection Index for compressing the five principal components of environmental protection was created. Halved weights were assigned to components (1a) and (1b) as they are subsets of a common broader category. For simplicity, equal weights were assigned to the components. Table 13 lists the arbitrarily selected weights for each specific part of the Environmental Protection Index.

Table 13

Applied weightings for the Environmental Protection Index

(%)

Name of the component	Weighting
(1a) Advanced environmental management tools	12.5
(1b) Basic environmental management tools	12.5
(2) Environmental and social aspects of sustainability	25
(3) Sustainability performance compared to competitors	25
(4) Procurement	25

By merging the two groups, the Pearson correlation coefficient with the standardised Competitiveness Index is weak (0.380), and the p-value of the test of zero correlation is less than 0.001. Additionally, the assumption for the more competitive group is confirmed by an insignificant correlation, as the null hypothesis cannot be rejected. Nevertheless, at a significance level of 10%, the null hypothesis can be rejected for the less competitive group (see Table 14).

Table 14

Pearson correlation coefficients between the Environmental Protection Index built from the principal components and the standardised Competitiveness Index

Sample	Pearson correlation coefficient	Test of zero correlation (p-value)
Union of the subsamples	0.380	less than 0.001
More competitive group	0.070	0.465
Less competitive group	0.198	0.069

Alternative quantitative analyses were performed to verify the findings related to RQ3b. Commensurate with the specificities of the dataset, running a series of non-hierarchical cluster analyses could provide an alternative way of judging previous statements based on the final cluster centres; the results confirm and refute the findings partly. The group means underpin that – apart from advanced digitalisation tools, digitalisation applied by leading enterprises of the industry, and basic environmental management tools – accelerating digitalisation and/or environmental protection entails improved competitiveness when promoting from the less to the more competitive status. Within-group investigations provided the assumption that less competitive firms can make progress in competitiveness with unfolding digitalisation. However, comparing the digitally better performing cluster with the most competitive cluster in the more competitive group clarifies the presumed phenomenon that other factors play a more crucial role beyond digitalisation in determining competitiveness. Interestingly, these conclusions elucidate that, beyond a certain level, competitiveness is not coupled with excelling in all the investigated dimensions of digitalisation. Similarly, intensifying environmental protection (apart from procurement) within the less competitive group is likely to be accompanied by an increase in competitiveness. Nevertheless, the contribution of enhanced environmental protection to competitiveness is not shown in the case of more competitive firms. Scrutinising the final cluster centres confirms the loose relationship determined by the Pearson correlation coefficients for the entire sample.

RQ1: Evaluating domestic industries and manufacturing branches by means of air pollutant emission intensities indicates the simultaneous reduction of emissions and the most critical areas: energy supply, agriculture, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products).

RQ2: Principal components of digitalisation incorporate preparedness for digitalisation, corporate level of digitalisation, digitalisation applied by leading enterprises of the industry, basic digitalisation tools, advanced digitalisation tools, and technology use and change. The principal components of environmental protection comprise advanced environmental management tools, basic environmental management tools, environmental and social aspects of sustainability, sustainability performance compared to competitors, and procurement.

RQ3a: More competitive companies are more intensely affected by a shortage of qualified workforce, impeding their innovation activity.

RQ3b: More competitive companies are better prepared for digitalisation, attain a higher level of digitalisation, and demonstrate the advanced application of basic digitalisation tools and technology. Further, they may undergo a technology change, build more on advanced environmental management tools, attribute greater significance to environmental and social aspects of sustainability, and outperform their competitors based on environmental indicators. Additionally, in these companies, environmental protection appears more definitely as a procurement criterion. Conversely, digitalisation applied by leading enterprises of the industry, instruments of advanced digitalisation, and basic environmental management are not differentiating. Within-group investigations led to the assumption that less competitive firms can progress in competitiveness by unfolding any digitalisation or environmental protection components (except for procurement). Contrarily, if better group membership is attained, the positive impact of advancement in the principal components of competitiveness ceases to exist.

5. Conclusion, limitations, and further research

RQ1: The Hungarian Climate Protection Act (XLIV./2020) deals only with the abatement of greenhouse gas emissions. However, the analysis led to the findings that instead of addressing decarbonisation as isolated climate action, combining decarbonisation and elimination of other air pollutants should be prioritised by accentuating power generation, agriculture, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products). Industries and branches demonstrating the highest carbon dioxide intensity embody difficult-to-decarbonise sectors and areas with ample leeway for low-carbon technologies.

RQ2: Digitalisation can be captured by the possible set of six principal components: preparedness for digitalisation, corporate level of digitalisation, digitalisation applied by leading enterprises of the industry, basic digitalisation tools, advanced digitalisation tools, and technology use and change. Environmental protection can be divided into five subareas: advanced environmental management tools, basic environmental management tools, environmental and social aspects of sustainability, sustainability performance compared to competitors, and procurement.

RQ3a: For more competitive companies, the shortage of qualified workforce is a hindering factor in the performance of innovation activities.

RQ3b: More competitive companies outperformed the less competitive ones in all investigated dimensions, except digitalisation applied by leading enterprises of the industry, instruments of advanced digitalisation, and basic environmental management. The presumed within-group phenomena can be disclosed by splitting both groups into clusters. First, the positive impact of the principal components of competitiveness cannot be confirmed based on the more competitive group. Second, deepening digitalisation or environmental protection (except for procurement) promotes the competitiveness of less competitive firms.

Each model has a few limitations. First, the results of the first PCA were influenced by the selected air pollutants. Given the limited number of variables, relevant air pollutants, such as methane and particulate matter, were removed from the model. Although carbon footprint facilitates more accurate measurement of overall carbon dioxide emissions, data inadequacy rendered its utilisation impossible. Second, the database encompasses companies operating either in manufacturing (54%) or trade (21%), which is not representative of the structure of the national economy. Involving more industries could improve the applicability of the findings based on the second PCA. Third, achieving climate neutrality requires decoupling steady economic growth from greenhouse gas emissions. However, currently, the survey does not provide any information about greenhouse gas or carbon dioxide emissions. Augmenting the questionnaires with appropriate sections could facilitate future investigation of the propelling springs of digitalisation and estimating its potential in decarbonisation so that the penetration of digitalisation can be accelerated. By widening the scope of the questionnaires, the influencers of digitalisation may be revealed. Inventorying the common attributes may help overcome the hindrances perceived in the case of less competitive enterprises neglecting digitalisation in these dimensions and establishing the bases of openness and commitment to digitalisation. Another valuable extension of the questionnaire can be performed by proceeding from mere environmental protection to the circular economy.

As a broader outlook towards ecological economics, it is possible to provide full employment and high quality of life to all despite the Earth's limited resources and ecological thresholds. This research provides findings as a slice of the toolkit, leading to the accomplishment of this tenet by recommending that SMEs take brisk steps towards both the scrutinised areas.

Acknowledgements

TÁRKI Zrt. collected data between October 2018 and July 2019. The support for data collection was provided by OTP Nyrt. and Vállalatgazdaságtan Tudományos és Oktatási Alapítvány. The author is grateful for the valuable remarks and impulses provided by Gábor Harangozó (Corvinus University of Budapest).

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