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Krakow University of Economics
Centre for Strategic and International Entrepreneurship
Department of International Trade
ul. Rakowicka 27, 31-510 Kraków, Poland
phone +48 12 293 5929, -5376, -5307, -5381, -5327
e-mail: ier@uek.krakow.pl
www.ier.uek.krakow.pl

Secretariat and Editorial Office

Mrs. Anna Marcinek-Markowska
Building U, Room 300, phone +48 12 293 5929

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Mutual information between the main foreign subindices: The application of copula entropy around WHO's declaration date at the time of the COVID-19 pandemic

Henryk Gurgul, Robert Syrek

ABSTRACT

Objective: The objective of this article is to investigate the dependencies between selected European subindices before and during the COVID-19 pandemic.

Research Design & Methods: The main analysis was quantitative. We used copula entropy and Pearson's correlation. We considered the closing prices of sectoral indices from France (CAC sectors), Germany (DAX sectors), the UK (FTSE sectors), and the US (SP sectors), along with the main indices from these countries, that is CAC40, DAX, SP500, and FTSE100 (we collected the data from the database investing.com for the period from 4 January 2017 to 30 March 2023). We performed all analyses using R along with supplementary packages.

Findings: When it comes to indications of the strength of dependence before and after the event (the outbreak of the COVID-19 pandemic) in relation to mutual information (delta) and linear correlation, we saw the biggest differences for the German market. For the DAX sectors, linear correlation underestimates post-event dependencies. The dependencies for other countries were similar on average. For half of the sectors (all markets), we recorded an increase in dependence after the event. A sector where we recorded growth in all countries was the TECH sector.

Implications & Recommendations: The dependence measurement using mutual information expressed in terms of copulas has many advantages. It is not limited to measuring linear correlations. It can also capture a nonlinear correlation. Furthermore, it not only measures the dependence degree, but also considers the dependence structure, which is more than a correlation. Moreover, there was no assumption about the ellipticity of marginal and joint distribution. This dependence measure even allows for the modelling of the dependence of variables with different cumulative distribution functions.

Contribution & Value Added: The novelty of this article is that it compares the results of dependence measurements by linear correlations and mutual information expressed in terms of copula entropy. Considering the indices and subindices of the main European stock markets, when both measures of dependence were used, we obtained significantly different results in both subperiods under investigation (i.e. before and after March 11, 2020).

Article type:	research article
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INTRODUCTION

The world has faced many medical crises, for example, SARS-COV in 2003, MERS-COV in 2012, and Ebola in 2014. However, the one that had the greatest influence on the world economy was COVID-19. The first reports on this disease were published in December 2019 in China.

China was the first country where COVID-19 broke out. China was also the first country in the world to implement measures to overcome the COVID-19 pandemic. Considering scientific investment methods, investors try to obtain higher profits and/or reduce investment losses. One of the best-known investment strategies is diversification. According to this strategy, assets are distributed to stocks from different sectors. Its main goal is to avoid investment losses caused by investing in closely dependent assets.

The COVID-19 pandemic was the source of the greatest recession in the world's economy since the global financial crisis of 2008. A very useful piece of advice for investors trying to optimise their investment during the COVID-19 pandemic was to identify the structure and changes in the interdependence between the various sectors.

The World Health Organization (WHO) announced the outbreak of the COVID-19 pandemic on 11 March 2020. Consequently, most countries in the world used various measures to slow down the spread of the virus. These measures significantly impacted many aspects of the behaviour and life of societies around the world. COVID-19 impacted global financial markets severely. The main observation was a slowdown in the global economy.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Economic and social issues, which are related to one another, are the subject of numerous academic articles. In these contributions, the negative influence of the COVID-19 pandemic (Goodell, 2020 among others) especially on trade, tourism, transportation and employment has been proven (Leduc & Liu, 2020). Some compare the effects of the spread of COVID-19 and its consequences to those of an economic crisis (Sharif *et al*., 2020).

Some authors have proven the effects of the pandemic on the returns of financial markets (Ashraf, 2020; Zhang *et al*., 2020; Aslam *et al*., 2020 a,b,c) and/or their volatility (Albulescu, 2020; Bakas & Triantafyllou, 2020; Zaremba *et al*., 2020; Okorie & Lin, 2020).

Rizwan *et al*. (2020) proved the systemic risk to banking in eight leading economies. All of them were strongly impacted by COVID-19. The authors found that the systemic financial risk of these countries rose significantly during the pandemic period.

Some articles have focused on the performance of stocks in numerous sectors or countries. Mazur *et al*. (2020) investigated the return rate of the healthcare, food, natural gas, and software sectors. They found that the performance of these sectors was satisfactory during COVID-19. However, they detected that some sectors, such as the crude petroleum, real estate, entertainment and hospitality sectors, declined considerably. Moreover, these sectors exhibited great volatility.

Shehzad *et al*. (2020) compared the pandemic's effects on the stock market to the impact of global financial crises. They found that COVID-19 affected the American and European stock markets more strongly than the financial crisis. Moreover, the pandemic affected economic communication throughout the world and was the source of a financial crisis.

For market participants, it is crucial to analyse the interrelations in the stock market. This is significant concerning diversifying investment and building investment portfolios during the pandemic. It is important from the point of view of risk management of the financial market, which is considered by financial regulators.

In recent years, some authors have attempted to investigate the interdependence between stock markets (Sukcharoen & Leatham, 2016; Long *et al*., 2016; Qiao *et al*., 2016; Long *et al*., 2017a, b; Surya *et al*., 2018; Alomari *et al*., 2018; Ji *et al*., 2019; Kodres & Pritsker, 2002; Barberis *et al*., 2005; Chiang & Zheng, 2010; Wang & Hui, 2018). These researchers have applied, among other models, the GARCH model, the Copula model, Granger causality test, and the DCC model. The goal was to detect the interdependence structure between different stock sectors in the countries under consideration.

Contributions to the interrelation structure of the stock markets have detected which sector plays the most important role in a national economy in a country under investigation. These studies provide new opportunities for investors to build an optimal assets portfolio (Poynter *et al*., 2015). Moreover, in Europe, there are few studies concerned with the interdependence structure of stock sectors during the period of the COVID-19 pandemic.

The copula entropy applied in this article consists of copula theory and information theory. We can summarise the axiomatic properties of copula entropy in the following points: they are multivariate, symmetric, non-negative, they display zero if and only if independent, they are invariant to monotonic transformation and equivalent to the correlation coefficient in Gaussian cases. The advantages of using copula entropy are the following: they are model-free, distribution-free, non-parametric, tuning-free, insensitive to parameters, they converge well, they are easy to implement, there is a low computation burden, they are interpretable with physical meanings and are supported by rigorous mathematics. Copula entropy can measure association information and dependence structure information simultaneously. The copula function describes the dependence between variables. Mutual information is applied to quantify the dependence. There is a relation between copula theory and information theory. We can express mutual information as copula entropy, *i.e.* in terms of copulas. Copula entropy does not impose restrictions on the dimension of multiple variables.

One of the first and best-known contributions using copula entropy is Zhao and Lin's article (2011). In their article, they constructed the copula entropy model based on the copula and entropy theory. Thus, the copula entropy model reflected the advantages of both of them. Their method is useful in measuring not only the linear correlation, but also the nonlinear one. Furthermore, it measures not only the dependence degree, but also its structure. Zhao and Lin suggest copula entropy models with two and three variables. The goal was to measure dependence on stock markets. This approach is an extension of copula theory and is based on Jaynes's information criterion. The research sample consisted of 12 stock indices from 12 countries selected using two methods. Zhao and Lin selected respective copula functions to represent three different economic situations: recession, boom, and interim. Having completed the two experiments, they provided a comparative analysis. The authors established that changes in three-variable dependence across the three economic situations are less obvious than in the case of two-variable dependence. Zhao and Lin (2011) used the copula entropy model to measure stock market correlations, compared with the linear correlation coefficient and mutual information methods, which have the advantages of being dimensionless and can capture non-linear correlations.

Ma and Sun (2011) proved the equivalence between copula entropy and mutual information. They showed that mutual information is essentially an entropy. This article suggests a new way of understanding and estimating mutual information using the copula function. The authors define the entropy of the copula, as called copula entropy. This is defined as a measure of the dependence uncertainty represented by the copula function. Then mutual information is shown to be equivalent to negative copula entropy. With this equivalence, mutual information can be estimated – as the authors demonstrate – by first estimating the empirical copula and then estimating the entropy of the empirical copula. Therefore, the mutual information estimate is an estimation of the entropy, which reduces the complexity and computational requirements. Tests demonstrate that this method is more effective than the traditional one.

This article concerns the dependence of the US, British, German and French subsectors of the stock markets during the pandemic period. Our goal – to study the subsectors of the leading economies around the time of the outbreak of COVID-19 on 11 March 2020 – seems to be interesting. Moreover, the results may be useful for investors operating in these markets.

Our main research question concerned how the dependencies of subindices changed before and after the event day (11 March 2020 – on that day the World Health Organisation declared the state of epidemic threat throughout the world). We investigated the dependence of the subindices of world-leading stock markets using the approach of mutual information before and after the event day. Based on the literature review, we formulated the following hypothesis:

H1: The dependencies of the subindices of world-leading stock markets were essentially greater after the event day.

We investigated whether dependence behaviour at the time was similar for the indices and subindices of the countries under consideration. For this goal, we used mutual information based on copula entropy. Another research problem concerned changes over time in Pearson's correlation and mutual information concerning event day. This leads us to the second hypothesis:

H2: The use of mutual information measure and linear correlation produced quite different results in the period under study.

To verify these hypotheses, we compared the results of mutual information and Pearson's correlation before and after event day and explained the possible differences concerning linear and nonlinear dependence notions.

After Introduction, Literature Review and Hypotheses Development we start with the presentation of Research Methodology. Based on the described methodology we conduct empirical analysis and discuss the results in the chapter Results and Discussion. In the final part of the paper we summarised main results and indicate further studies.

RESEARCH METHODOLOGY

Mutual Information and Copula Entropy

One of the most important terms of information theory is entropy, which measures the average amount of information and mutual information that is used to model dependence. For discrete random variable X entropy is given by:

$$H(X) = -\sum_{x\in\mathcal{X}} p(x)\log_m p(x) \tag{1}$$

in which $\mathcal{X}$ is the support set and $p(x)$ is the probability of the event x. The unit of entropy is bit if the logarithm base is equal to 2 (if the base is e then the unit is called nat and if 10 then the unit is dit). Conditional entropy measures the entropy of variable Y when the values of X are known, and is given by:

$$H(Y|X) = -\sum_{y\in y}\sum_{x\in\mathcal{X}} p(x,y)\log\frac{p(x,y)}{p(x)} \tag{2}$$

in which $p(x,y)$ and $p(y)$ represent joint and marginal probability. Given the above definitions, mutual information is given by $MI(X,Y) = H(X) - H(Y|X)$, which in terms of distributions and joint probability distribution is given by:

$$MI(X,Y) = \sum_{y\in y}\sum_{x\in\mathcal{X}} p(x,y)\log\frac{p(x,y)}{p(x)p(y)} \tag{3}$$

Mutual information measures the amount of information of one variable contained in another and is non-negative and bounded by entropies of each variable but not normalised (like the Pearson correlation coefficient). Following Joe (1989), to normalise mutual information one can use transformations using the formula $\delta = \sqrt{1-\exp(-2MI)}$ (Joe, 1989). The definitions given above are reformulated in terms of integrals for continuous variables.

The term copula entropy combines both information and copula theories (for definition and properties of copulas see for example Nelsen, 2006). For bivariate copula with density $c(u,v)$ is given by:

$$H_C(U,V) = -\int_0^1\int_0^1 c(u,v)\log c(u,v)\,dudv \tag{4}$$

Ma and Sun (2011) proved that copula entropy is equal to the negative of mutual information, $MI = -H_C$. From the equation above, we see that copula entropy is the expected value of the logarithm of copula density and the double integral can be computed as a mean:

$$H_C(U,V) = -E[\log c(u,v)] = -\frac{1}{n}\sum_{t=1}^{n}\log c(u_t,v_t) \tag{5}$$

Ma and Sun (2011) also implemented a method for estimating mutual information in a non-parametric way. It is worth mentioning that for some families of copulas mutual information is expressed explicitly. An example is the Gaussian copula for which mutual information is equal to $-\frac{1}{2}\ln(1-\rho^2)$.

The Database and Descriptive Statistics

We consider the closing prices of the sectoral indices for France (CAC sectors), Germany (DAX sectors), the UK (FTSE sectors) and the US (SP sectors), along with the main indices from these countries, that is CAC40, DAX, SP500, and FTSE100 (we collected the data from investing.com database). Tables 1, 2, 3, and 4 provide sector abbreviations.

Table 1. Full names and abbreviations of CAC sectors

Sector number	Name of CAC sector	Abbreviation
	Basic Materials	BASIC
2	Consumer Goods	CGOOD
3	Consumer Service	CSERV
4	Financials	FIN
5	Health Care	HEALTH
6	Industrials	IND
7	Oil & Gas	OIL
8	Technology	TECH
9	Utilities	UTIL

Source: investing.com

Table 2. Full names and abbreviations of DAX sectors

Sector number	Name of DAX sector	Abbreviation
1	Automobile	AUT
2	Banks	BANK
3	Chemicals	CHEM
4	Consumer&Cyclical	CONS
5	Financial Services	FIN
6	Industrial	IND
7	Insurance	INS
8	Media	MED
9	Pharmaceuticals&Healthcare	PHA
10	Retail	RET
11	Software	SOFT
12	Technology	TECH
13	Telecom	TELE
14	Transportation&Logistics	TRAN
15	Utilities	UTIL

Source: yahoo.finance.com

Table 3. Full names and abbreviations of FTSE sectors

Sector number	Name of FTSE sector	Abbreviation
1	Banks	BANK
2	Basic Resources	BAS
3	Chemicals	CHEM
4	Cons.& Materials	CONST
5	Food & Beverage	FOOD
6	Health Care	HEALTH
7	Ind. Goods & Ser.	INDGS
8	Insurance	INS
9	Media	MED
10	Oil & Gas	OIL
11	Per. & Household	PERS
12	Retail	RET
13	Technology	TECH
14	Telecom.	TELE
15	Travel & Leisure	TRAV
16	Utilities	UTIL

Source: investing.com.

Table 4. Full names and abbreviations of SP sectors

Sector number	Name of SP sector	Abbreviation
1	Communication Services	COMM
2	Consumer Discretionary	CONSD
3	Consumer Staples	CONSS
4	Energy	ENERG
5	Financials	FIN
6	Health Care	HEALTH
7	Industrials	IND
8	Information Technology	INF
9	Materials	MAT
10	Real Estate	REST
11	Utilities	UTIL

Source: yahoo.finance.com

On 11 March 2020, the World Health Organisation (WHO) announced the COVID-19 pandemic. We divide the time series of logarithmic returns with this date and refer to this as event day. For all series, we computed descriptive statistics (mean, standard deviation, kurtosis, and skewness) along with normality and autocorrelation testing. The Jarque-Bera tests confirmed departure from normality.

RESULTS AND DISCUSSION

Main Index: Sectoral Index Dependence

We investigate the strength of dependence by computing mutual information for all sectoral indices and the main index for a given country. We computed this measure using copula entropy. We divided the time series of returns with the event day and for each calculated the probability integral transform. To do this, we filtered our time series using vector autoregression models for conditional means, GARCH type models for conditional variance and skew *t* for conditional distributions. We selected the copulas that fit the best from the selected families. We limited the choice of copulas to a set investigated by Tenzer and Elidan (2016). These authors established a monotonic relationship between the mutual information and the copula dependence parameter. This means that the strength of dependence increases as the parameter increases. We limited the set of potential copulas to those investigated by the authors but in the case of Archimedean copulas we added their rotated versions (survival copulas). We chose copulas that fit the best dataset using the Bayesian information criterion. For comparison purposes, for all pairs, we computed the linear correlation coefficient (for raw returns). In Figure 1, we present the strength of dependence according to the delta parameter and linear correlation coefficient (red before the event, green after the event).

Of the CAC sectors UTIL (0.54) and IND (0.91) had, respectively, the lowest and highest values before the event, whereas after the event HEALTH (0.57) and IND (0.91) had the lowest and highest values. In six cases, dependence was greater after the event with the largest percentage change (41%) in the case of UTIL. We observed the highest drop for HEALTH (about 19%). When we consider linear correlation, the situation is identical with some different values. For DAX, the results based on delta and linear correlation were different. Whereas the sectors with the weakest (RET) and strongest (CHEM) dependence after the event were the same (0.32 and 0.91 for delta and 0.26 and 0.93 for linear correlation), before the event, we noticed some difference. The minimal values of delta and correlation were both for the UTIL sector (0.44 and 0.71) but the maximum was for CHEM (0.88) and INS (0.93). We noted the main difference when considering dependence changes in terms of percentage. In 10 of 15 cases, the delta parameter was greater after the event (with the highest value of change 43% for UTIL and the lowest one for RET -51%). For the linear correlation, the lowest was also for RET (-64%) but the highest was for CONS with only 3%. Only in three cases, dependence was greater after the event. For FTSE sectors, INDGS had the highest delta value either before or after the event with values of 0.86 and 0.88 respectively (the lowest ones

were UTIL 0.47 and TECH 0.57). Linear correlation coefficients give similar indications: the highest value before and after for INDGS (0.9 and 0.91), and for INDGS and HEALTH the lowest (UTIL with a value 0.56 and HEALTH with a value 0.62). The vast majority of sectors have positive percentage changes with the highest ones for FOOD and UTIL for delta (32% and 25%) and UTIL and FOOD for correlation (25 and 21). In the case of SP sectors, we noticed the same sectors with minimal and maximal values of dependence parameters either before (UTIL and INF, respectively) and after the event (ENRG and INF). For the delta parameter, these values before the event were 0.31 and 0.91, whereas for linear correlation – 0.62 and 0.95. After the event, they were 0.59 and 0.89 for delta and 0.72 and 0.94 for correlation. Both for delta and correlation, we noticed an increase in dependence for the six sectors with the highest values for UTIL (102% for delta and 30% for correlation). We observed the largest decrease in dependence for ENERG (about 9% for both measures of dependence).

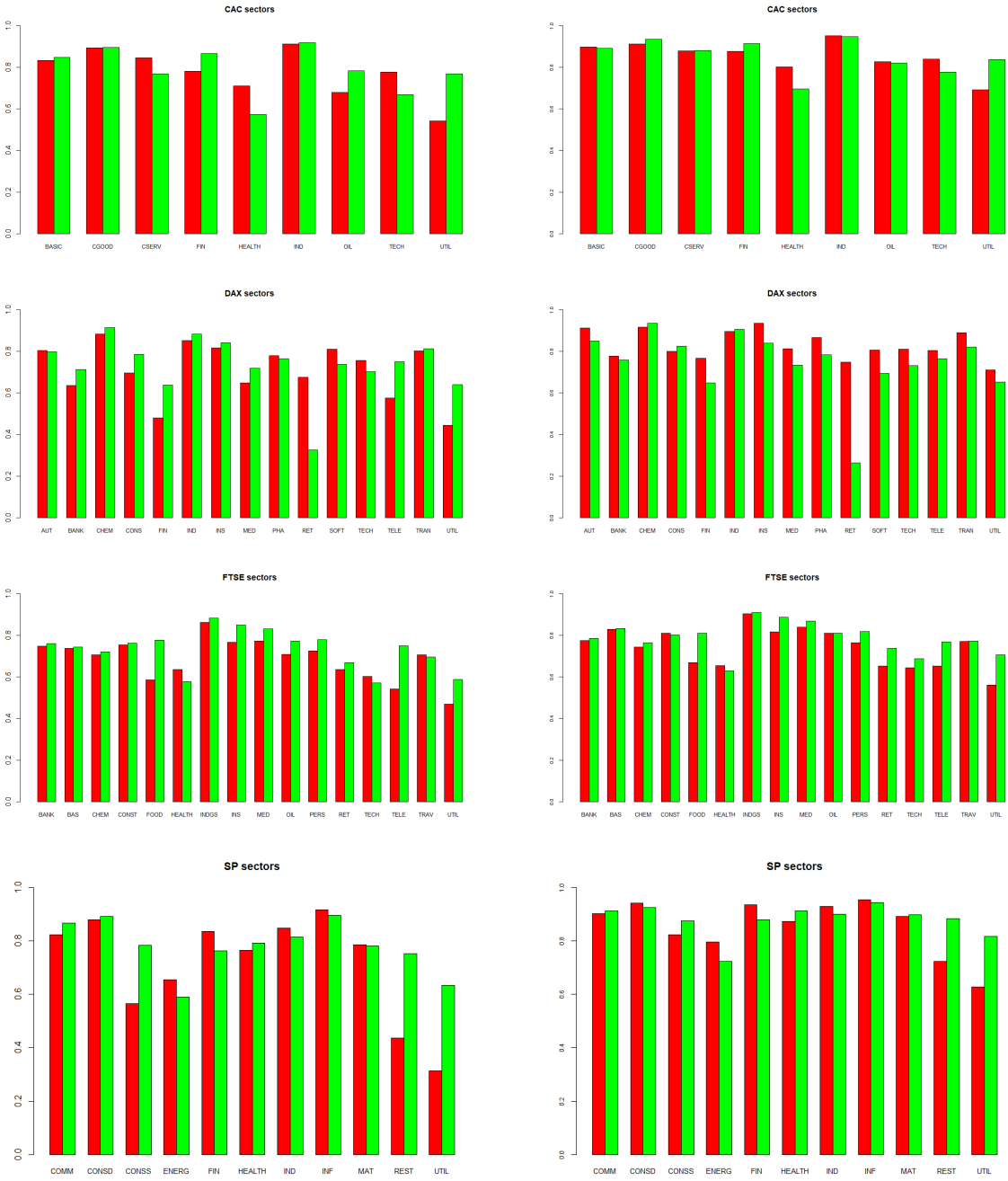

Figure 1. Delta (left) and linear correlation (right)
Source: own elaboration.

Dependence of Subindices

In this section, we investigated the dependence between subindices for a given country. We applied the methods described in the previous sections. Due to the large number of pairs, we present the degree of dependency in heatmaps. Figure 2 presents computed delta parameters (before and after the event).

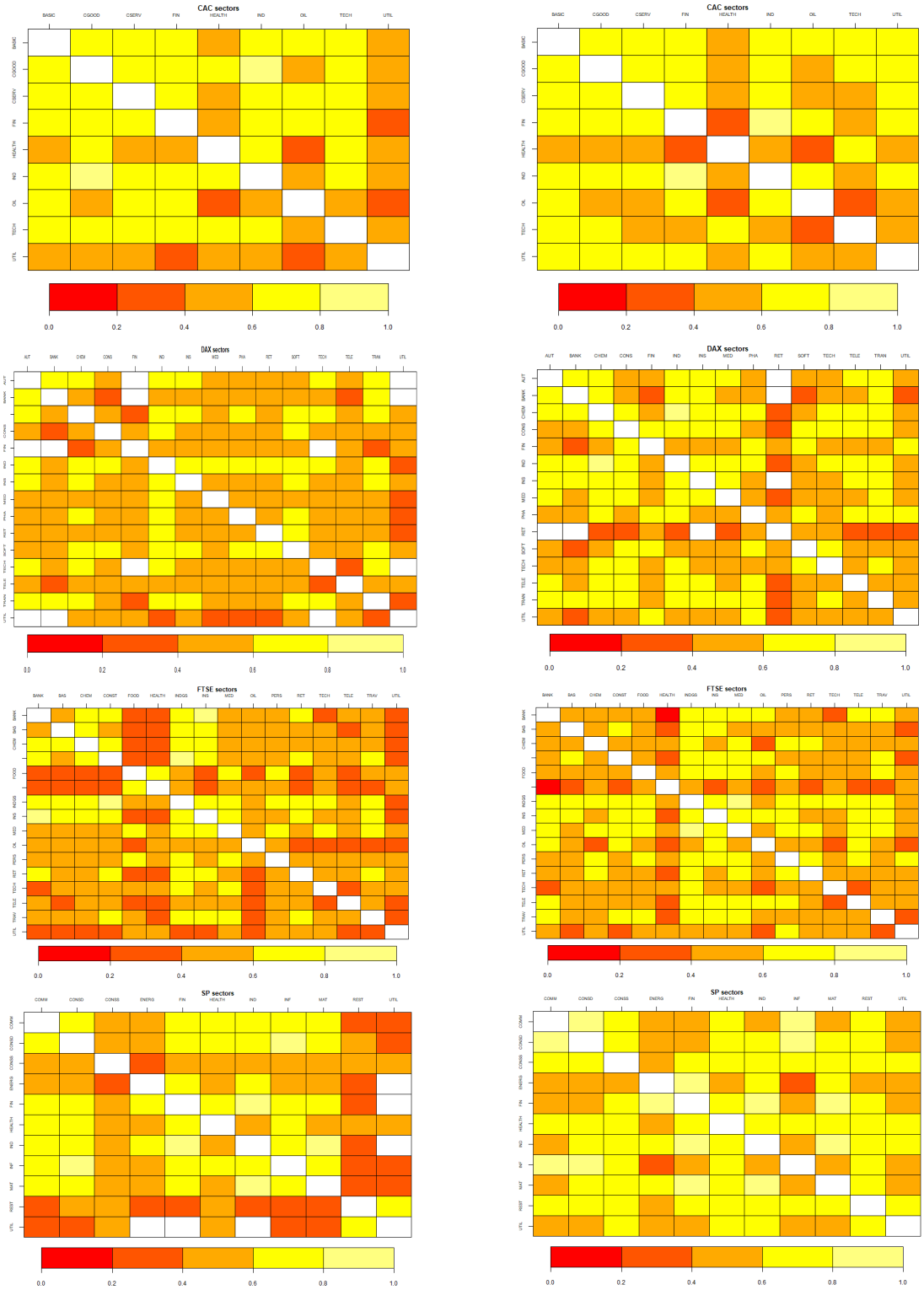

Figure 2. Heat maps of parameters delta before (left) and after (right) the event (from top to bottom France, Germany, GB and USA)

Source: own elaboration.

After the event, there is a general increase in dependence between sectors for DAX, FTSE, and SP. The number of pairs with greater dependence was 63 pairs out of 105 for DAX, for FTSE 75 out of 128, and for SP 38 out of 55.

In Table 5, we present the three weakest (bottom rows) and three strongest (top rows) relationships before and after the event.

Table 5. Selected weakest and strongest relationships based on the delta parameter

Before event		After event	
CAC sectors			
IND - CGOOD	0.81	IND - FIN	0.85
TECH - IND	0.79	OIL - FIN	0.79
CSERV - CGOOD	0.78	CGOOD - BASIC	0.76
OIL - HEALTH	0.40	TECH - OIL	0.38
UTIL - FIN	0.39	HEALTH - FIN	0.35
UTIL - OIL	0.38	OIL - HEALTH	0.32
DAX sectors			
IND - CHEM	0.77	IND - CHEM	0.82
TRAN - AUT	0.74	INS - IND	0.80
TRAN - IND	0.73	IND - BANK	0.79
TECH - FIN	0.28	RET - CHEM	0.26
UTIL - AUT	0.27	TELE - RET	0.22
UTIL - TECH	0.26	RET - IND	0.21
FTSE sectors			
INS - BANK	0.82	MED - INDGS	0.85
INDGS - CONST	0.81	INS - INDGS	0.78
INS - CONST	0.76	INDGS - CONST	0.77
RET - HEALTH	0.24	UTIL - TRAV	0.24
UTIL - OIL	0.22	TRAV - HEALTH	0.23
UTIL - CHEM	0.21	HEALTH - BANK	0.18
SP sectors			
MAT - IND	0.81	IND - FIN	0.89
INF - CONSD	0.80	MAT - IND	0.89
IND - FIN	0.80	INF - CONSD	0.87
UTIL - CONSD	0.27	ENERG - COMM	0.43
UTIL - INF	0.26	UTIL - ENERG	0.42
REST - ENERG	0.25	INF - ENERG	0.37

Source: own study.

The subindices that form pairs for the strongest and weakest relationships were largely the same before and after the event. The strongest relationships were for SP sectors and this was the only case when the weakest relationship after the event was stronger than the weakest one before the event. Among the sectors for which we noted the weakest dependencies before the event, there was often UTIL, while among the strongest after the event there was IND.

It is interesting to see how much dependency increases. In Figure 3 below, the percentage changes were presented as heatmaps. Table 6 gives the three strongest and weakest changes.

We noticed that the largest percentage changes were the smallest in general for the CAC sectors and the largest for the SP sectors. We observed the smallest changes again for the CAC sectors, but the largest ones for the DAX sectors. Given δ_{ij}, the dependence parameter between i and j subindices, we computed $S_i = \sum_j \delta_{ij}$, which reflects the sum of parameters δ of a certain subindex with all of the other subindices (presented in Figure 4).

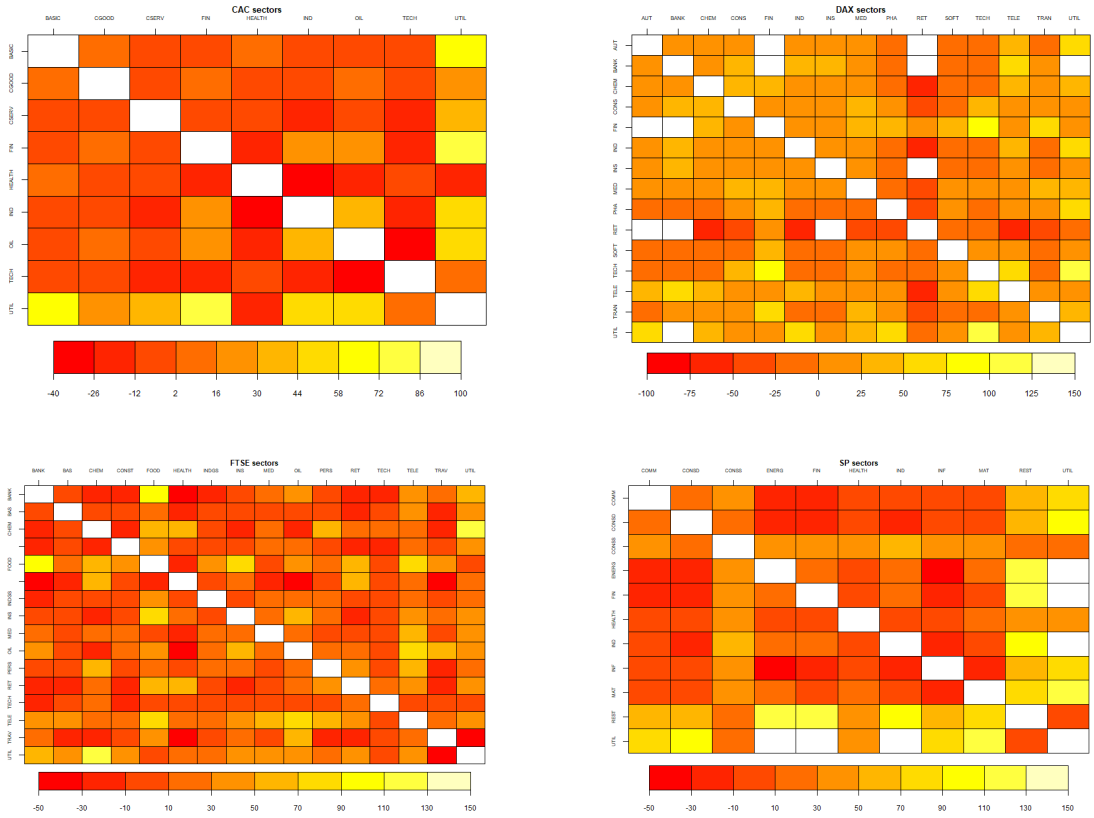

Figure 3. Heat maps of percentage changes of parameter δ
Source: own elaboration.

Table 6. Selected smallest and largest percentage changes of δ

CAC sectors		**DAX sectors**	
UTIL - FIN	80.96	UTIL - TECH	103.01
UTIL - BASIC	64.24	TECH - FIN	99.8
UTIL - OIL	55.01	TELE - TECH	64.91
TECH - IND	-25.17	TELE - RET	-50.42
HEALTH - FIN	-25.77	RET - CHEM	-56.45
TECH - OIL	-29.52	RET - IND	-67.3
FTSE sectors		**SP sectors**	
UTIL - CHEM	129.85	REST - FIN	125.54
FOOD - BANK	91.81	UTIL - MAT	118.34
TELE - OIL	79.79	REST - ENERG	114.92
UTIL - TRAV	-39.18	FIN - CONSD	-22.04
TRAV - HEALTH	-40.5	INF - FIN	-28.68
HEALTH - BANK	-44.53	INF - ENERG	-32.15

Source: own study.

We can see from Figure 4 above that for five out of nine CAC sectors S_i was greater after the event (BASIC, CGOODS, FIN, OIL and UTIL) with the greatest percentage change for UTIL (almost 35%). The smallest percentage change was for the HEALTH and TECH sectors (about 13%).

For DAX sectors, only S_i was. smaller after the event only in three cases (INS, SOFT and RET with the largest decrease 48%). We noted the largest increase of more than 50% for FIN and UTIL. In the case of FTSE sectors in only 4 out of 16 (BAS, HEALTH, TECH, TRAV) the percentage change was negative (for HEALTH it is about 3%). The FOOD and TELE sectors increased the most (about 30%). In the case

of SP sectors, the situation was different and we noticed a positive change for all sectors with the highest value over 100% for UTIL (the smallest for INF with about 2%).

For purposes of comparison, we computed the linear correlation coefficients for raw stock returns. We present illustrations of these calculations with similar figures and tables. The heat map in the Figure 5 below illustrates the strength of dependence between all sectors according to linear correlation. We based the legend for these figures on the minimum and maximum of all dependencies.

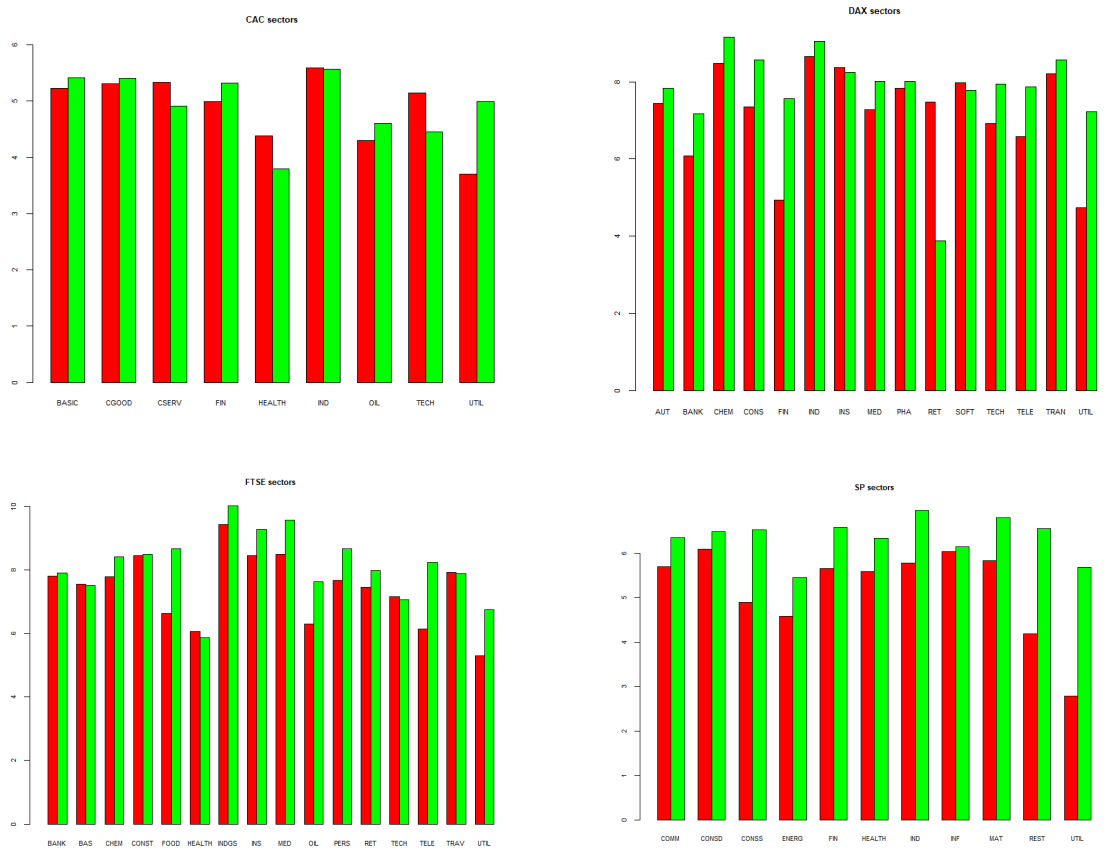

Figure 4. S_i of each sector before (red) and after the event (green)
Source: own elaboration.

In the case of CAC sectors, the number of pairs for which correlations after the event increases was equal to 16 and in all cases correlation coefficients are positive. For DAX sectors, dependence was greater only for 8 pairs after the event and for one pair (RET – BANK), we observed a negative but small correlation. Both for FTSE and SP, the number of pairs for which we observe an increase in dependence exceeded 70%. Furthermore, pairs of subindices for which we noted the strongest and weakest relationships were similar to those from mutual information, with the exception of the weakest relations for DAX sectors (presented in Table 7).

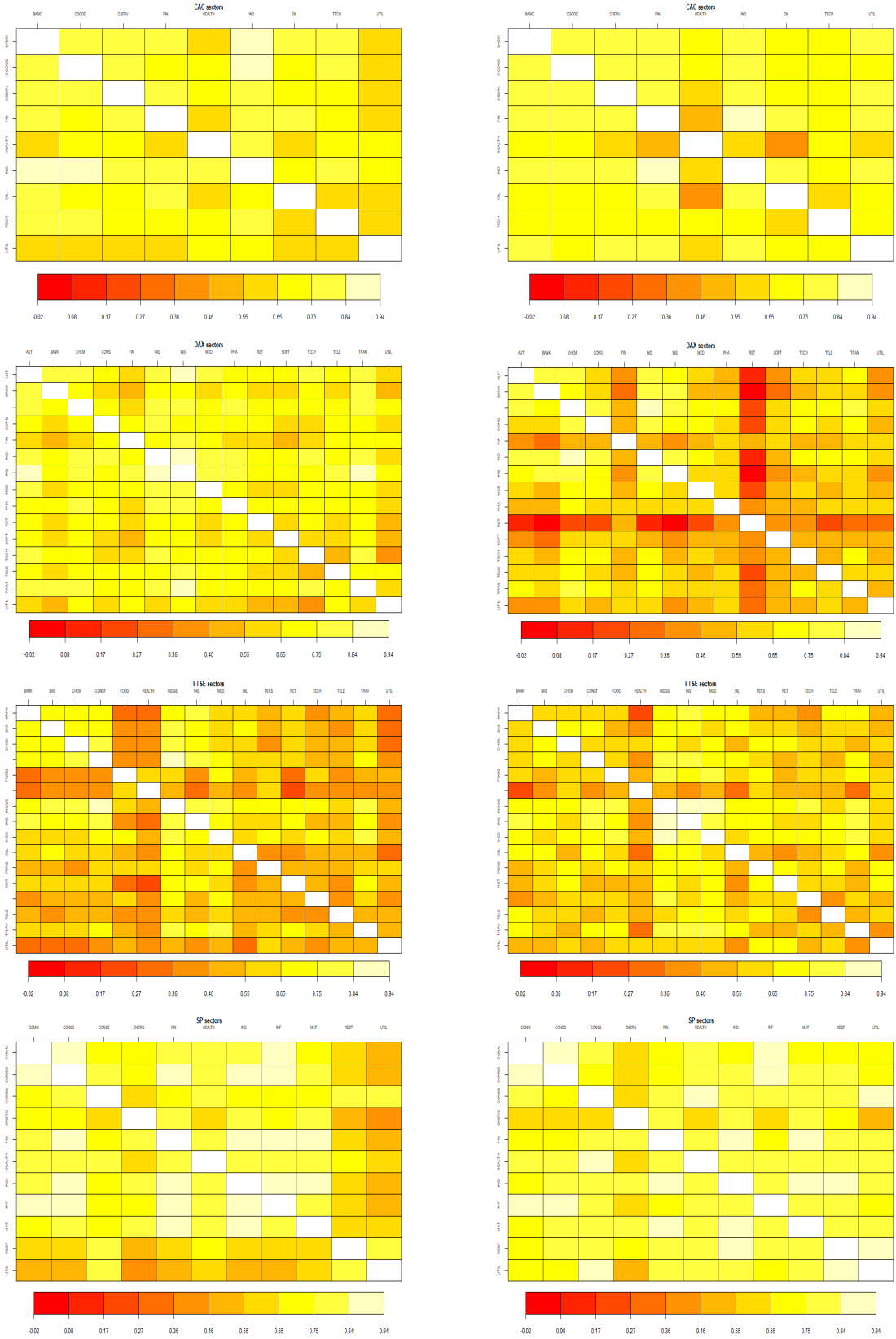

Figure 5. Heat maps of correlation coefficients before (left) and after (right) the event
Source: own elaboration.

Table 7. Selected weakest and strongest relationships based on linear correlation

Before event		After event	
CAC sectors			
IND - BASIC	0.85	IND - FIN	0.90
IND - CGOOD	0.85	IND - CGOOD	0.84
CSERV - CGOOD	0.84	CSERV - BASIC	0.83
UTIL - BASIC	0.56	TECH - OIL	0.56
UTIL - FIN	0.56	HEALTH - FIN	0.48
UTIL - OIL	0.55	OIL - HEALTH	0.42
DAX sectors			
INS - AUT	0.87	IND - CHEM	0.85
INS - IND	0.86	IND - AUT	0.81
TRAN - INS	0.85	INS - IND	0.81
UTIL - RET	0.51	RET - AUT	0.10
FIN - BANK	0.50	RET - INS	0.01
UTIL - TECH	0.45	RET - BANK	-0.02
FTSE sectors			
INDGS - CONST	0.85	INS - INDGS	0.87
INS - BANK	0.84	MED - INDGS	0.86
MED - INDGS	0.83	TRAV - INDGS	0.82
INS - HEALTH	0.29	OIL - HEALTH	0.35
UTIL - CHEM	0.27	TRAV - HEALTH	0.30
RET - HEALTH	0.22	HEALTH - BANK	0.26
SP sectors			
IND - FIN	0.91	IND - FIN	0.93
INF - CONSD	0.91	MAT - IND	0.93
MAT - IND	0.89	INF - CONSD	0.91
UTIL - INF	0.51	ENERG - CONSS	0.56
UTIL - COMM	0.51	INF - ENERG	0.56
UTIL - ENERG	0.44	UTIL - ENERG	0.55

Source: own study.

As above, we computed percentage changes in dependence (now based on the linear correlation coefficient). Figure 6 and Table 8 below show the results (the smallest and largest changes).

The scale of changes was similar only for the highest values of FTSE changes and for the smallest changes in the CAC and SP sectors. Similarly to S_i, we computed the sum of correlation coefficients between a given sector and all the other sectors. Figure 7 presents the results.

In the case of CAC sectors, we noted the same cases for which the sum of the correlation coefficients increased, with the highest increase for UTIL (about 22%). The smallest value was for HEALTH (about 10%). For all DAX sectors, the sum of the coefficients was smaller after the event, with the highest percentage change for RET (about 61%), which we can clearly see in the figure above. In the case of FTSE sectors, all percentage cases were positive with about a 30% increase for FOOD and UTIL (the smallest increase is noted for TRAV, with a value of 1.5%). For two SP sectors (CONSD and ENERG), the change was negative but not greater than 1% (the smallest for INF with about 2% and the highest for UTIL with a 27% change).

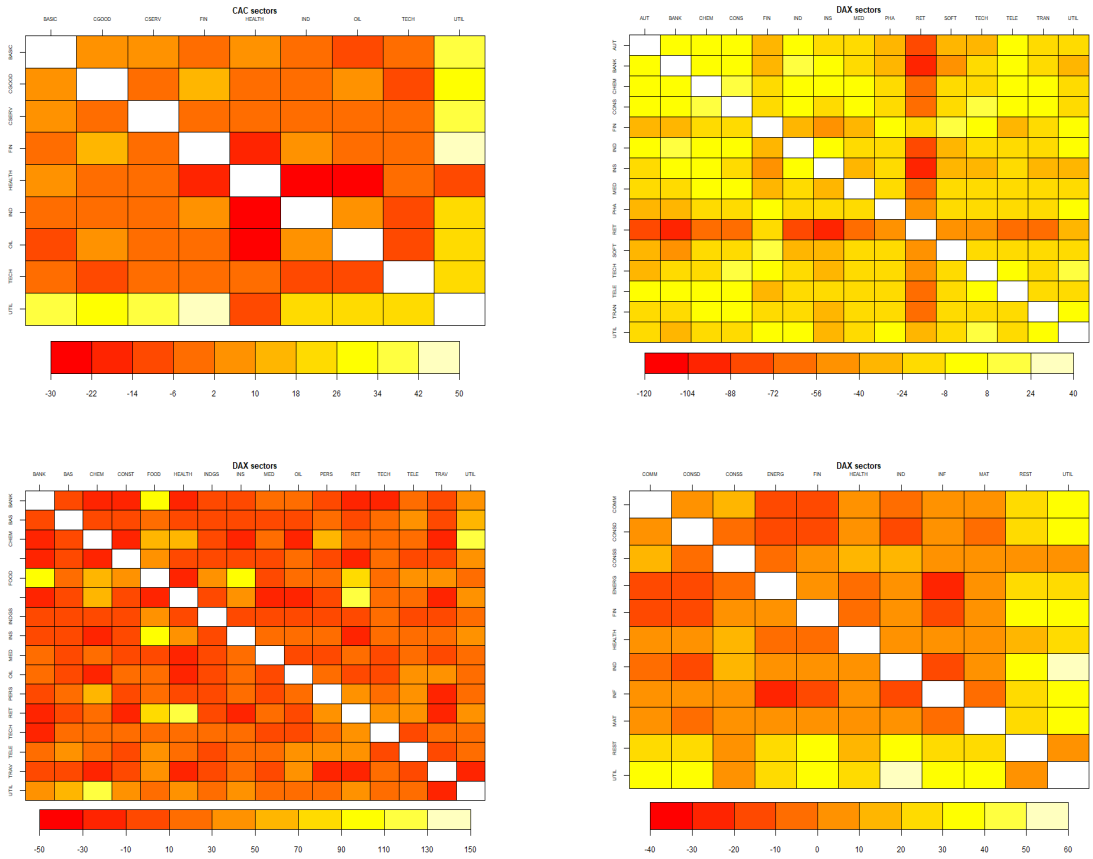

Figure 6. Heat map of percentage changes of correlation coefficients
Source: own elaboration.

Table 8. Selected smallest and largest percentage changes in correlation coefficient

CAC sectors		**DAX sectors**	
UTIL - FIN	45	IND - BANK	21.18
UTIL - BASIC	35.29	UTIL - TECH	16.03
UTIL - CSERV	35.26	CONS - CHEM	15.39
HEALTH - FIN	-18.74	RET - AUT	-84.02
IND - HEALTH	-23.46	RET - INS	-98.11
OIL - HEALTH	-24.53	RET - BANK	-103.29
FTSE sectors		**SP sectors**	
RET - HEALTH	117.58	UTIL - IND	52.45
UTIL - CHEM	113.35	UTIL - MAT	39.4
INS - FOOD	100.25	UTIL - FIN	38.04
TRAV - RET	-21.28	INF - FIN	-15.7
CONST - CHEM	-22.18	ENERG - CONSD	-16.11
TRAV - HEALTH	-26.62	INF - ENERG	-20.99

Source: own study.

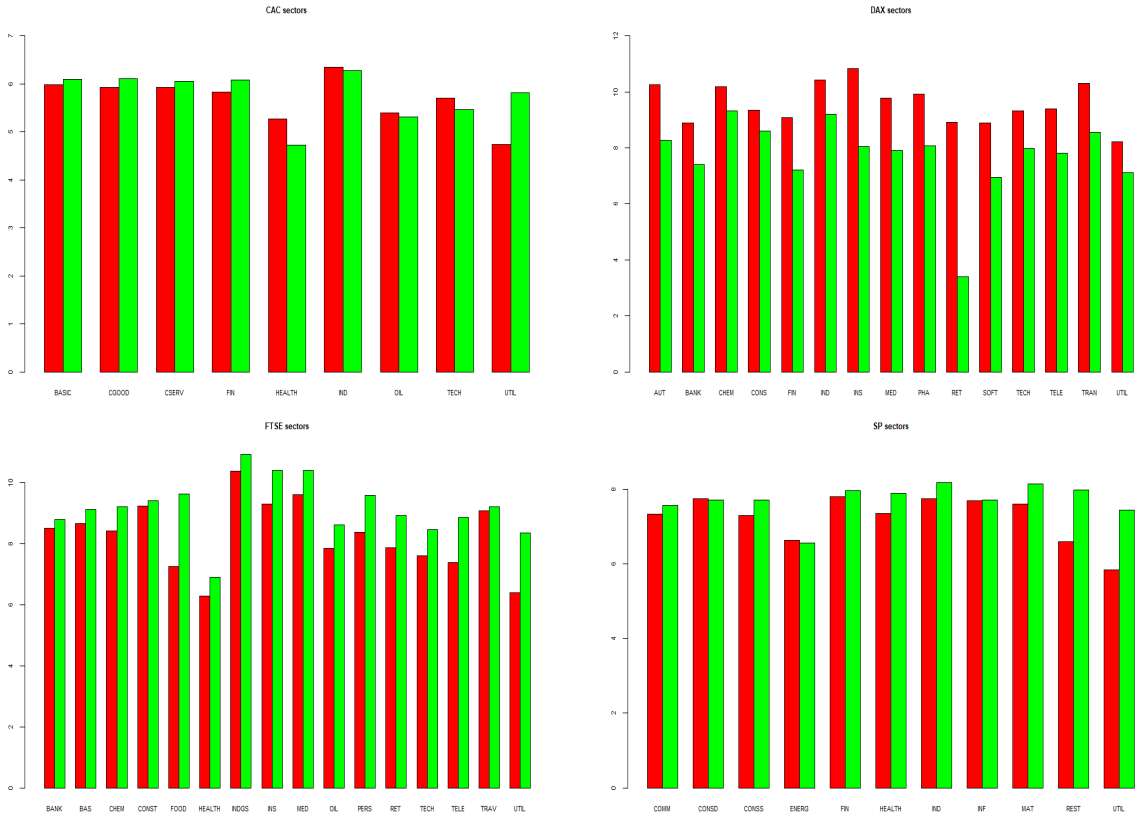

Figure 7. Sum of correlation coefficients of each sector before and after the event
Source: own elaboration.

CONCLUSIONS

To summarise, dependence measurement using mutual information expressed in terms of copulas has many advantages. It is not limited to measuring linear correlations. It can also capture a non-linear correlation. It measures the degree of the dependence and considers the dependence structure, which is more than correlation. Moreover, there is no assumption about the ellipticity of marginal and joint distribution. It even allows the dependence of variables with different cumulative distribution functions to be modelled.

When it comes to indications of the strength of dependence before and after the event in relation to mutual information (delta) and linear correlation, we saw the biggest differences for the German market. For DAX sectors, linear correlation underestimated post-event dependencies. The dependencies for other countries were similar on average, for half of the sectors (all markets), we recorded an increase in dependence after the event. In all countries, we recorded growth in the TECH sector.

The subindices that form pairs for the strongest and weakest relationships were largely the same before and after the event both for mutual information and linear correlation. The strongest relationships were SP sectors, and this is only the case when the weakest relationship after the event was stronger than the weakest one before the event. We noted the weakest dependencies before the event with pairs with UTIL, while the strongest ones after the event – with IND.

When considering positive percentage changes based on measuring mutual information, we noticed that the largest ones were for the SP sectors and the smallest ones for the CAC sectors. We observed the smallest changes for the CAC sectors but the largest ones for DAX. For linear correlation, the scale of percentage changes was similar only for the highest values of FTSE changes and for the smallest changes in the CAC and SP sectors.

For the sum of the dependence parameters of a subindex with all of the other subindices, we observed the clearest situation for SP sectors, for which we noticed a positive change for all sectors with the highest UTIL (for CAC and DAX this is also the case). For correlation, the similar parameter was smaller after the event for all DAX sectors and this was the biggest difference with respect to mutual information. Interestingly, the UTIL sector recorded the largest positive changes, as was the case with the measure based on mutual information.

In most cases, financial time series had a dependence structure that could not be captured by models based on elliptical distributions. Another problem came from the dynamic behaviour of conditional moments of the time series. For this reason, to properly describe the dependence structure we recommend using copula and information theories.

In this article, we use static copulas. However, the parameters that reflect dependencies can be dynamic over time. Another limitation of this study was the lack of high-frequency data with respect to subindices.

In further studies, high-frequency data should be used to describe risk represented by conditional variances (realized variances) of time series and models based on both dynamic copulas and an information theory approach.

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Authors

The contribution share of authors is equal and amounted to 50% for each of them.

Henryk Gurgul

Professor at AGH University of Science and Technology in Krakow, Department of Applications of Mathematics in Economics. His research interests include econometrics, financial econometrics, international financial markets, and input-output models. Author of more than 200 publications. Visiting professor at universities in Graz and Klagenfurt (Austria), Erlangen-Nuernberg, Greifswald, Ilmenau, Saarbruecken (Germany), Trieste and Siena (Italy), Valencia (Spain), Koper (Slovenia), Joensuu (Finland). Honours: Awarded in 2007 the most prestigious prize for economics in Poland Bank Handlowy w Warszawie S.A. Award (Citi Bank), in 2015 awarded the Medal of Honour, University of Graz, Austria.

Correspondence to: Prof. dr hab. Henryk Gurgul, AGH University of Science and Technology in Krakow, Department of Applications of Mathematics in Economics, Ul. Al. Mickiewicza 30, 30-059 Kraków, Poland, e-mail: henryk.gurgul@gmail.com

ORCID http://orcid.org/0000-0002-6192-2995

Robert Syrek

PhD, Assistant Professor at the Institute of Economics, Finance and Management, Faculty of Management and Social Communication at the Jagiellonian University in Krakow. His main areas of research interest include time series analysis and forecasting, financial econometrics and modelling the dependence structures of financial time series (especially using copula functions).

Correspondence to: Dr Robert Syrek, Institute of Economics, Finance and Management, Faculty of Management and Social Communication, Jagiellonian University, ul. prof. St. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: robert.syrek@uj.edu.pl

ORCID http://orcid.org/0000-0002-8212-8248

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Comparison of international digitalisation indexes: A quantitative analysis perspective

Agnieszka Choczyńska, Septia Rani, Justyna Tora

ABSTRACT

Objective: The objective of the article is to compare the available digitalisation indexes in the EU (European Union) and Pacific Asia. The first step to tackling the between-country digital gap is to measure digital development. However, the available indexes differ substantially in terms of construction, metric used, and the areas they cover.

Research Design & Methods: The first part of the study is a descriptive analysis of the scope and metrics used by three digitalisation indexes: digital economy and society index (DESI), ASEAN digital integration index (ADII) and digital intelligence index (DII). In the second part, we approach the problem from a quantitative perspective, using correlation coefficients and comparing countries' rankings obtained using different indexes. Lastly, we performed clustering analysis with the use of an agglomerative algorithm with Euclidean distances and the Ward method. The data covers 13 countries from the Pacific Asia and 24 from the EU.

Findings: We found that the specifications of indexes differ considerably, not only in the choice of particular metrics but in whole digitalisation areas. Some indexes include overall economic or social development measures that are not strictly related to the digital sphere. Despite that, for countries covered by two indexes, we found high correlations of scores: 0.932 between ADII and DII, and 0.883 between DII and DESI. Comparing rankings and using clustering analysis, we found that the indexes for Pacific Asia are more similar than for the EU, possibly because Asian countries are more heterogeneous both in digital and economic development.

Implications & Recommendations: Any study of the digital divide and its causes is affected by the choice of digitalisation measure. We found that DII and ADII indexes include some socio-economic metrics that may interfere with the results in the studies of the links between economic and digital development. Although the indexes' scores are quite highly correlated, in some cases, they can judge a country's development very differently. This is a problem, especially in the EU, where countries are more similar in digital development than in Pacific Asia.

Contribution & Value Added: The study compares digitalisation indexes from a quantitative perspective that has not yet been established in the literature. It shows how different indexes perform in ranking and clustering procedures. Researchers can use our article as a guide in choosing digitalisation indexes for the EU and ASEAN countries.

Article type: research article

Keywords: digitalisation index; index comparison; clustering; ASEAN; EU

JEL codes: O33; O57

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INTRODUCTION

One of the key phenomena transforming society and business today is digitalisation. According to Stolterman and Fors (2004), digitalisation refers to 'the changes associated with the widespread use of digital technology in all facets of human society.' Digitalisation has facilitated the creation of new business models by allowing businesses to use data and technology to develop innovative products and services. The use of digital communication services increases productivity across all industries (Nadiri *et al*., 2018). However, it has also raised some concerns, which include the digital divide.

The digital divide is a 'division between people who have access to and use of digital media and those who do not' (van Dijk, 2020). The extent of the digital divide can occur both within (van Dijk & Hacker, 2003) and across nations. In the latter case, the main causes of the digital divide are the economic (Billon *et al.*, 2010) and educational asymmetries (Cruz-Jesus *et al.*, 2018). However, as Cruz-Jesus *et al.* (2018) found, digital disparities within a country may also hinder its overall digital development. Although, in general, the world is on the path to digital convergence (Borowiecki *et al*., 2021), the gap between the countries advancing digital technology and the ones that lag is growing (Chen, 2019). In light of this, efforts to close this gap have become increasingly crucial. The first step is to measure the digitalisation progress and look into the gap's causes.

There are several indexes dedicated to that purpose. Each index has its characteristics, such as different Key Performance Indicators (KPIs), geographical coverage, data sources, periods of measurement, data aggregation methods, and even the areas of digitalisation covered by the index. According to research conducted by Kotarba (2017), the overall number of digital KPIs already exceeds 100 items, raising the problem of selecting the best metrics to monitor digitalisation progress with limited control budgets (Doong & Ho, 2012).

To compare the digitalisation progress between two regions we need a set of measures that (a) are available for both regions in the same or highly comparable form, and (b) cover crucial digitalisation areas. The first issue arises from the fact that some of the indexes are prepared by regional institutions and cover only a limited number of countries. The second is caused by the lack of agreement on what measures best suit the task of measuring digitalisation.

Our study focused on two regions, *i.e.* European Union (EU) and Pacific Asia. Should we compare the Digital Development Index (DDI) scores, the EU has a higher average (69.9) than Pacific Asia (62.1). However, the latter includes the most digitally developed country. Singapore with a DII score of 98.8 is over ten points higher than the most advanced European country – Finland.

In the EU, the digital economy and society index (DESI) is used to summarise indicators of Europe's digital performance and track the progress of EU countries. It consists of clearly defined sections on human capital, infrastructure, business, and government. The index is constructed by the European Commission and published annually since 2014.

Another considered index is the ASEAN digital integration index (ADII). It was created to provide evidence-based measures, so that ASEAN could assess its accomplishments in achieving its digital integration framework (ASEAN Digital Integration Index Report 2021, 2021). Index scores were computed in one round, but the data comes from global and longitudinal sources, so they can be reproduced further back in time and for other countries. Most of its underlying compounds are composite indicators themselves, gathered from outside sources. This index is provided by the ASEAN Coordinating Committee on Electronic Commerce (ACCEC).

Some institutions have also developed indexes to measure digitalisation on the global level. Among them are the digital intelligence index (DII) by the Fletcher School at Tufts University (Digital Intelligence Index, 2020), used in this study, and the World Digital Competitiveness (WDC) by the International Institute for Management Development. They differ in methodology, number of countries covered, and data availability. Some indexes, like WDC, only publish the ranking, not the underlying scores.

In this study, we approached the differences between indexes from a quantitative perspective, that has not yet been established in the literature. Our results show that despite differences in underlying measures and construction, considered indexes give quite similar results, especially in the ASEAN region. However, the inclusion of socio-economic metrics in the digitalisation indexes may interfere with the interpretation of these findings.

The remainder of the article is as follows. Firstly, we will describe the structure and dimensions of digitalisation covered by each index. Secondly, we will perform a quantitative analysis of their comparability. Lastly, we will draw conclusions and some recommendations.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Previous Studies

There is limited research on the comparability of digitalisation indexes. A paper by Kotarba (2017) covers an analysis of metrics used to measure digitalisation activities with five main levels, moving from the metrics of the digital economy to society, industry, enterprise, and clients. We discussed and analysed qualitatively the similarities and differences between key performance indicators on each level.

Another paper by Stankovic *et al.* (2021) examined the relations between the digital competitiveness index and several economic performance indicators, such as GDP per capita, labour productivity, and employment rate. Moreover, Korzhyk *et al.* (2023) did a comparative study of different digitalisation indexes. They analysed the indexes' similarity by their coverage, methodology, ranking, structure, and weighting methodology. The study also proposed a new digitalisation index.

Digitalization Dimensions

Although designed to measure the same concept, digitalisation indexes differ substantially. They use different measures and vary in the areas of socio-economic life considered as parts of the digitalisation process. Typically, an index consists of several sub-indexes (pillars), computed from the scores of particular measures. Figure 1 presents the structure of pillars in three considered indexes. We provide shortened names used for convenience in brackets.

Though some of the pillars seem to have direct or at least similar counterparts in at least two indexes, their underlying measures may still substantially differ, as we will demonstrate later. To reliably compare indexes' content, we defined seven dimensions, namely (1) digital skills, (2) government, (3) cybersecurity, (4) businesses and trade, (5) innovation and research & development, (6) internet infrastructure, and (7) legislation. For instance, all three indexes include measures of internet infrastructure. DESI has the connectivity pillar dedicated solely to them. In the ADII, they are located in institutions & infrastructure pillar with some measures of government dimension. In the DII, they are split between two pillars, *i.s.* demand and supply. In the next sections, we will review how indexes covered particular digitalization dimensions. From that, we draw hypotheses about indexes comparability for the quantitative study.

Digital Skills Dimension

Digital skills refer to the knowledge and abilities required to use technology effectively in various settings. These skills encompass a wide range of areas, such as information and literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari *et al.*, 2022). Moreover, digital skills serve as an increasingly influential factor in the other dimensions of digitalisation, such as the use of e-government (Rodriguez-Hevía *et al.*, 2020).

Digital skills gained the special attention of researchers after the COVID-19 pandemic, as it deepened the dependence on technology and digital exclusion (Li, 2022). Insufficient digital skills may hinder online education, thus deepening the digital divide between students (van de Werfhorst *et al.*, 2022). Table 1 depicts the indicators used by each index to measure digital skills.

Government Dimension

Governments in each country play an important role in the digitalisation process, especially in ensuring that digitalisation benefits all citizens and promotes inclusive economic growth. Some of the key roles might be in the form of policy formulation, digital infrastructure development, and digital skills development (Kafel *et al.*, 2021). Table 2 presents the measurements dedicated to this dimension.

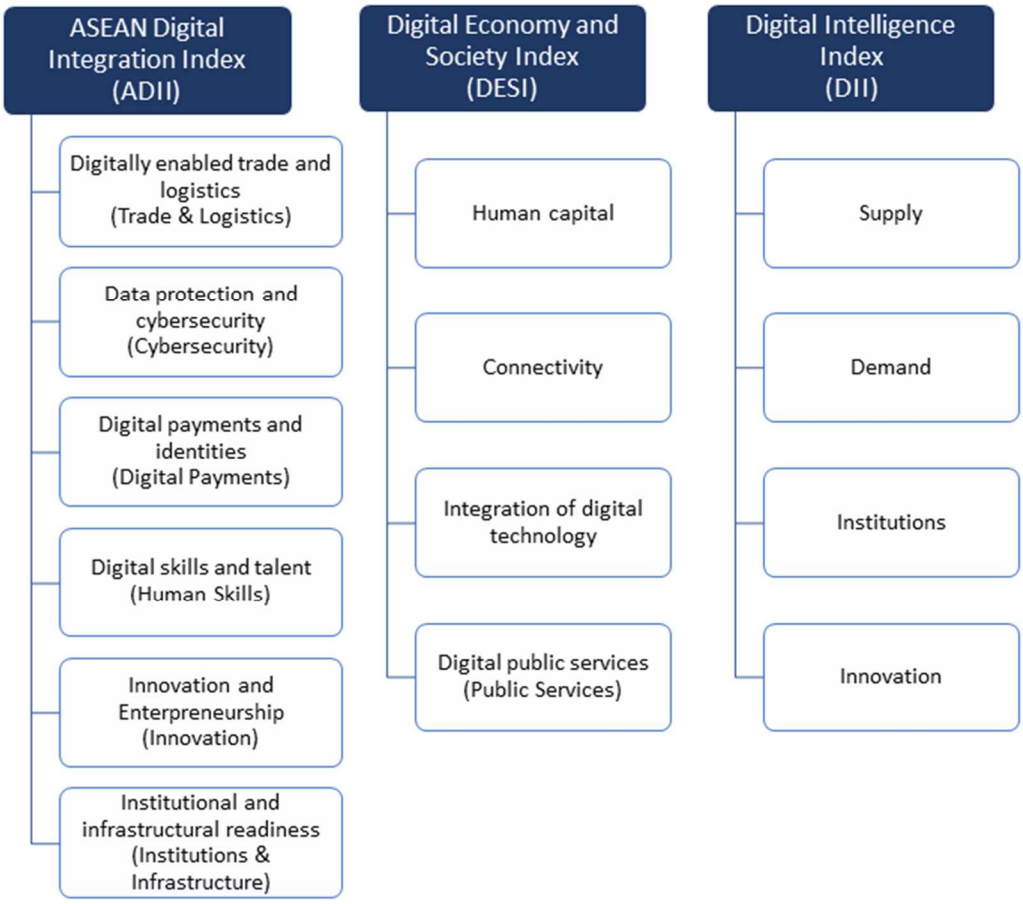

Figure 1. Structures of the analysed indexes
Source: own elaboration based on indexes' specification.

Table 1. The indicators used by ADII, DESII, and DII to measure digital skills

Index	Indicators for measuring digital skills	Pillar
ADII	Graduates in STEM	Human Skills
	Employment in knowledge-intensive services	Human Skills
	Active population skills	Human Skills
	Graduates skills	Human Skills
DESI	At least basic digital skills	Human Capital
	Above basic digital skills	Human Capital
	At least basic digital content creation skills	Human Capital
	ICT specialists	Human Capital
	Female ICT specialists	Human Capital
	Enterprises providing ICT training	Human Capital
	ICT graduates (% of graduates with a degree in ICT)	Human Capital
DII	Ability to adopt (literacy rate, human development index, GINI index)	Demand
	Ability to demand (disposable income per capita, middle-class households, GNI per capita, consumer credit per capita)	Demand
	Consumer spending (consumer expenditure, retailing per capita)	Demand
	Class digital divide	Demand
	Gender digital divide	Demand
	Rural digital divide	Demand
	Financial inclusion (% of the population using internet banking)	Demand
	Use of digital money	Demand
	Use of mobile digital money	Demand
	Talent availability	Innovation

Source: indexes' specifications.

Table 2. The indicators used by ADII, DESI, and DII to measure government

Index	Indicators for measuring government	Pillar
ADII	National identity cards	Digital Payments
	Digitalized ID system	Digital Payments
	Availability of government services	Institutions & Infrastructure
	Responsive government	Institutions & Infrastructure
DESI	e-Government users	Public Services
	Pre-filled forms	Public Services
	Digital public services for citizens	Public Services
	Digital public services for businesses	Public Services
	Open data (to what extent countries have an open data policy in place)	Public Services
DII	Effectiveness of institutions	Institutions
	Transparency	Institutions
	Government digital uptake	Institutions
	Government facilitation of ICT	Institutions

Source: indexes' specifications.

Cybersecurity Dimension

According to the International Telecommunication Union (2009), 'cybersecurity' is the collection of tools, policies, security concepts, security safeguards, guidelines, risk management approaches, actions, training, best practices, assurance, and technologies that can be used to protect the cyber environment and organisation and user's assets.

Table 3 shows the indicators used by each index to measure cybersecurity. Moreover, ADII has dedicated indicators to assess the cybersecurity performance of each country within its scope. Meanwhile, for DESI and DII, no indicators were found to measure this dimension. In ADII, most of the data sources used to calculate the indicators were gathered from the United Nations and ITU – Global cybersecurity index (ASEAN digital integration index report, 2021).

Table 3. The indicators used by ADII, DESI, and DII to measure cybersecurity

Index	Indicators for measuring cybersecurity	Pillar
ADII	Data protection measures	Cybersecurity
	Legislative cybersecurity capabilities	Cybersecurity
	Institutional cybersecurity capabilities	Cybersecurity
	Technical cybersecurity capabilities	Cybersecurity
	International cooperation	Cybersecurity
DESI	–	–
DII	–	–

Note: '-' means that the index did not measure the current dimension.
Source: indexes' specifications.

Businesses and Trade Dimension

Business and trade have been significantly impacted by digitalisation. This has changed how businesses run and made new types of trade possible (Nadiri *et al.*, 2018). Table 4 shows the indicators used by each index to measure businesses and trade in the digitalisation context.

Table 4. The indicators used by ADII, DESI, and DII to measure businesses and trade

Index	Indicators for measuring businesses and trade	Pillar
ADII	Support for trade/customs processes	Trade & Logistics
	Certificates and signatures	Trade & Logistics
	International standards for trade documents	Trade & Logistics
	Trade and transport infrastructure	Trade & Logistics
	Logistics services (measures the competence and quality of logistics services)	Trade & Logistics
	Banking platforms users	Digital Payments
	Financial transactions users	Digital Payments
DESI	SMEs with at least a basic level of digital intensity	Digital Technology
	Electronic information sharing	Digital Technology
	Social media (% of enterprises using)	Digital Technology
	Big data (% of enterprises analysing big data from any data source)	Digital Technology
	Cloud (% of enterprises buying cloud computing services)	Digital Technology
	AI (% of enterprises using any AI technology)	Digital Technology
	ICT for environmental sustainability	Digital Technology
	e-Invoices (% of enterprises sending e-invoices)	Digital Technology
	SMEs selling online (% of SMEs selling online)	Digital Technology
	e-Commerce turnover (% of SMEs' total turnover from e-commerce)	Digital Technology
	Selling online cross-border	Digital Technology
DII	Business practices	Innovation
	Postal delivery	Supply
	Traditional transport	Supply
	Access to financial institutions	Supply
	Electronic payments	Supply

Source: indexes' specifications.

Innovation, Research & Development Dimension

Digitalization and innovation have a reciprocal relationship. Digitalisation will support the innovation, research, and development processes, and vice versa. Szeles (2018) finds R&D expenditures to be one of the most important stimulants of digital development. Table 5 shows the indicators used by each index to measure innovation and R&D in relation to digitalisation. From the three indexes, only DESI did not include the aspects of innovation and R&D in its measurement.

Table 5. The indicators used by ADII, DESI, and DII to measure innovation, research & development

Index	Indicators for measuring innovation, research & development	Pillar
ADII	Collaboration in R&D	Human Skills
	Venture capital	Innovation
	R&D expenditure (as % share of GDP)	Innovation
	Innovative companies	Innovation
	Starting a business	Innovation
DESI	–	–
DII	Financing	Innovation
	Startup capacity	Innovation
	Value capture	Innovation
	Research and development	Innovation

Source: indexes' specifications.

Internet Infrastructure Dimension

The Internet infrastructure is the base of digital development. However, it may be the source of the digital divide, as it is highly dependent on the country's income (Doong & Ho, 2012). Table 6 shows the indicators used by each index to measure internet infrastructure. Both DESI and DII indexes include several KPIs of

internet infrastructure and usage, while ADII is restricted to only two. As Myovella *et al*. (2020) found out, mobile internet measures are more important in the Sub-Saharan region, while fixed broadband in the OECD countries. Any global measure of digitalisation should include at least these two measures.

Table 6. The indicators used by ADII, DESI, and DII to measure internet infrastructure

Index	Indicators for measuring internet infrastructure	Pillar
ADII	Mobile users	Institutions & Infrastructure
	Internet users	Institutions & Infrastructure
DESI	Overall fixed broadband take-up (% of households)	Connectivity
	At least 100 Mbps fixed broadband take-up	Connectivity
	At least 1 Gbp stake-up	Connectivity
	Fast broadband (NGA) coverage	Connectivity
	Fixed very high capacity network (VHCN) coverage	Connectivity
	Fibre to the premises (FTTP) coverage	Connectivity
	5G spectrum (the amount of spectrum assigned and ready for 5G use within the so-called 5G pioneer bands)	Connectivity
	5G coverage (% of populated areas with coverage by 5G)	Connectivity
	Mobile broadband take-up	Connectivity
	Broadband price index	Connectivity
DII	Device affluence	Demand
	Fixed broadband uptake	Demand
	Mobile broadband uptake	Demand
	Communications infrastructure	Supply
	Electricity	Supply
	Internet speed	Supply
	Mobile access affordability	Supply
	Mobile access availability	Supply

Source: indexes' specifications.

Legislation Dimension

The legislation dimension might have a big intersection with the government dimension, but we decided to separate it into another cluster, because the government does not always form all legislation. In some countries, other parties or groups may have the power to create laws, such as a constitutional court, a popular referendum, or a citizen's initiative. For instance, in Switzerland, citizens can propose and vote on laws through a system of direct democracy known as the citizen's initiative (Rachwał, 2014). Table 7 shows the indicators used by each index to measure legislation. In this case, DESI did not have any indicators that directly related to the legislation.

Table 7. The indicators used by ADII, DESI, and DII to measure legislation

Index	Indicators for measuring legislation	Pillar
ADII	Frameworks for transactions	Digital payments
	Intellectual property protection	Innovation
	Legal framework	Institutions and infrastructure
DESI	–	–
DII	Bureaucracy	Institutions
	Legal Environment for Businesses	Institutions
	ICT Regulatory Environment	Institutions

Source: indexes' specifications.

Summary and Hypotheses Development

A summary of dimension coverage can be found in Table 8. We can see that only ADII measures the cybersecurity dimension, while DESI and DII do not include that dimension in their metrics. Moreover, DESI did not include innovation and R&D or legislation in its metrics.

Table 8. Comparison of ADII, DESI, and DII

Dimension	Index		
	ADII	DESI	DII
Digital skills	+	+	+
Government	+	+	+
Cybersecurity	+	-	-
Businesses and trade	+	+	+
Innovation and R&D	+	-	+
Internet infrastructure	+	+	+
Legislation	+	-	+

Source: own study.

The descriptive part of our study shows, that although most dimensions seem to be covered in all indexes, the underlying indicators can be widely different. However, two different indicators can accurately measure the same concept. If this was the case, the analysed indexes could still be used interchangeably, because they would give comparable scores, even if based on different data.

Based on the qualitative comparison, we expect different indexes to give inconsistent results. However, ADII and DII are supposed to be more similar to each other than DESI and DII, because they cover almost the same dimensions. Due to its narrow focus, DESI may not be comparable with DII. Our reasoning can be stated in two hypotheses:

H1: Both DESI and DII do not give consistent digitalisation scores.

H2: Both ADII and DII do not give strictly consistent scores, but they are more similar than in the case of DESI and DII.

RESEARCH METHODOLOGY

The chapter focuses on quantitative analysis. The empirical research consists of two stages. Firstly, we used Pearson correlation coefficients to evaluate the relationship between the different indexes. Pearson's correlation coefficient is a measure used to assess the linear relationship between two continuous random variables. It takes values in the range from -1 to 1. The closer the absolute value of Pearson's correlation coefficient is to 1, the stronger the linear relationship between two variables (Schober *et al.*, 2018).

Moreover, we constructed and compared the ranking of countries according to each index. This helps us determine if two indexes would consistently answer the question of which of two given countries in 'better' in terms of digitalization. If this is not the case, the research of digitalisation is highly dependent on the choice of index. As evidenced by Kravchenko *et al.* (2019), the global ranking of countries may vary substantially according to different indexes.

In the third stage, we performed a cluster analysis. Cluster analysis is a set of methods that extract naturally occurring groups of the study population based on their similarity of specified characteristics. Using the distance function, the algorithm in hierarchical clustering combines each element of the set into larger and larger groups until a single cluster containing all objects is obtained. This is the so-called agglomeration method (James *et al.*, 2021). In this work, we used the Euclidean distance to determine the distances between analysed objects. Then, to group the object, we used the Ward method based on variance analysis. The Ward method aims to minimise the sum of the squared deviations about the group means at each stage of the algorithm (Ward, 1963). In other words, its goal is to minimize the total within-cluster variance. This method is considered the most efficient, even though it seeks to create small clusters (Stanisz, 2007).

We performed all computations on the interactions of the indexes, *i.e.* sets of countries included in both of them. Only the comparisons between ADII vs DII and DESI vs DII were possible since ADII and DESI did not have any countries in common. The data comes from 2019, as this year was available in all three datasets. Although digitalisation is a fast-paced process, our study focuses

on the structural differences between indexes, and not the current state of digitalisation itself. Therefore, the use of the most recent data is not as important here.

The quantitative analysis includes both the direct index values and the values of its constituent sub-indexes. We sourced ADII data from the ASEAN digital integration index report (2021). The Digital Planet website, which is an interdisciplinary research initiative of the Fletcher School's Institute for Business in the Global Context, provided the DII data (Digital Intelligence Index, 2020). Furthermore, we obtained the DESI data from the official website of the European Union (Digital Economy and Society Index, 2022).

RESULTS AND DISCUSSION

Indexes Correlations

Table 9 presents the number of observations in each dataset (on the diagonal), the number of observations shared by two datasets (below the diagonal), and Pearson's correlation coefficients between indexes. Out of 15 countries in ADII, DII reports values for 13 (87%, lacks values for Brunei Darussalam and Myanmar). The correlation between indexes was 0.932, which indicates they were highly comparable. DII includes 24 out of 27 countries reported in DESI (89%, without Malta, Cyprus, and Luxembourg), and the correlation is also at a promising level of 0.883.

Table 9. The number of observations and Pearson Correlation Coefficients between metrics

Index	DII	ADII	DESI
DII	90 obs.	0.932	0.883
ADII	13 obs.	15 obs.	–
DESI	24 obs.	–	27 obs.

Source: own study.

Ranking Comparison

Table 10 presents the comparison of values and ranks between ADII and DII. Singapore occupies the first place in both rankings. The only noticeable difference was that Japan came second according to ADII, but only fifth in DII. To examine this outlier, we analysed the scores of indexes at the pillars' level, compared with regional averages and South Korea, which came after Japan in ADII but outperformed it according to DII (Table 11).

Table 10. Comparison of values and ranks between ADII and DII

Country	DII score	ADII score	Rank according to ADII	Rank according to DII
Singapore	98.82	80.70	1	1
South Korea	83.09	75.73	3	2
New Zealand	80.46	75.62	4	3
Australia	80.09	74.94	5	4
Japan	77.76	76.51	2	5
Malaysia	69.03	72.85	6	6
China	61.89	70.68	7	7
Thailand	53.04	67.24	8	8
Indonesia	47.72	57.45	9	9
Vietnam	46.79	57.26	10	10
Philippines	44.29	53.99	11	11
Cambodia	32.31	37.60	12	12
Laos	32.14	36.57	13	13

Source: own study.

The high position of South Korea in DII clearly comes from supply (91.55) and demand (100) pillars, both significantly higher than the scores for Japan. It has also got a bit higher note in the innovation pillar. However, Japan was better when it came to institutions.

However, according to ADII, Japan performed better in all categories but institutions & infrastructure and innovation (although here only by a fraction). Interestingly, the institutions pillar, present in both indexes, gives an inconsistent ranking. This difference seems to come from the pillar definitions rather than specifics of these two countries, since the DII average for the region is way lower than scores for both South Korea and Japan. In contrast, according to ADII, Japan scored below the regional average, and South Korea barely surpassed it. Looking deeper into the pillars' construction, ADII's institutions & infrastructure contains indicators of mobile phones and internet users, digital government services and legal framework for digital innovation. On the other hand, DII's Innovation pillar has more indicators measuring governmental use of digital technology and broad legal environment, while the internet uptake was located in the Demand pillar (where, indeed, Japan scored lower than South Korea).

Table 11. Analysis of the discrepancies between Japan's and South Korea's scores

Index	Pillar	Japan	South Korea	ASEAN average
DII	Supply	79.78	91.55	64.13
	Demand	84.18	100	67.04
	Institutions	75.83	64.06	54.49
	Innovation	62.95	68.61	50.83
ADII	Trade & Logistics	93.36	89.28	71.63
	Cybersecurity	90.93	88.42	74.77
	Digital Payments	82.00	81.42	68.28
	Innovation	77.32	77.92	58.30
	Human Skills	54.77	53.77	51.15
	Institutions & Infrastructure	60.67	63.59	62.24

Source: own study.

Similarly, Table 12 contains the values and ranks for countries covered by DII and DESI. The first two places belong undisputedly to Finland and Denmark. Sweden comes third in DESI and the Netherlands in DII, but their scores are almost identical in both countries and we could call it a tie. The tails of the rankings are also consonant with Greece and Romania occupying the last two positions, but the middle hosted some major differences. Germany landed in the fifteenth place in the DESI ranking, while DII gave it fifth place. Meanwhile, Spain was high on the DESI ranking (5), but only in the fourteenth position according to DII. Countries like Lithuania, Latvia, and Croatia also got a lot higher position in DESI, compared to DII, while Poland, Czechia, Belgium, and France scored better in DII.

Table 13 shows the breakdown for the two most striking cases: Germany and Spain. The numbers are clear. All scores of DII pillars were higher for Germany, while the opposite was true for DESI pillars. Moreover, Spain in DII and Germany in DESI scored below the EU average in all cases but one (the supply pillar for Spain was a little better).

We saw no direct counterparts of one index in another, but DESI's Public Services should roughly represent DII's institutions, minus indicators of the legal environment. Interestingly, this is where we see the biggest differences between countries. DII defines areas of digitalisation by innovation, and supply and demand side. At the same time, DESI splits indicators between hardware (infrastructure) and human adoption, further divided between citizens (human capital) and businesses (integration of digital technology). Therefore, it is not straightforward to map these pillars from one index to another. However, in large part, they are based on similar indicators. For example, both cover mobile and fixed broadband uptake, internet speed and prices, technical staff training and availability, gender disparity, or digital public services. Thus, both indexes should give corresponding scores in aggregation.

Table 12. Comparison of values and ranks between DESI and DII

Country	DII score	DESI score	Rank according to DESI	Rank according to DII
Finland	87.30	0.1353	1	1
Denmark	87.17	0.1301	2	2
Netherlands	85.48	0.1263	4	3
Sweden	85.07	0.1299	3	4
Ireland	82.32	0.1167	6	5
Germany	79.27	0.0959	15	6
Estonia	76.66	0.1164	7	7
Austria	75.42	0.1030	9	8
Belgium	74.51	0.1000	13	9
France	72.99	0.0987	14	10
Czechia	68.68	0.0930	16	11
Lithuania	68.02	0.1055	8	12
Slovenia	67.35	0.1022	11	13
Spain	66.95	0.1176	5	14
Portugal	65.75	0.1008	12	15
Latvia	65.06	0.1025	10	16
Poland	63.58	0.0744	21	17
Slovakia	63.01	0.0831	19	18
Italy	61.27	0.0859	18	19
Hungary	57.75	0.0805	20	20
Bulgaria	57.14	0.0701	22	21
Croatia	56.60	0.0877	17	22
Greece	56.54	0.0638	23	23
Romania	54.06	0.0559	24	24

Source: own study.

Table 13. Analysis of Germany's and Spain's cases

Index	Pillar	Germany	Spain	EU average
DII	Supply	79.48	77.17	75.51
	Demand	85.35	78.84	79.45
	Institutions	83.51	63.97	68.69
	Innovation	61.82	41.01	48.53
DESI	Connectivity	0.0820	0.1030	0.0811
	Public Services	0.1291	0.1700	0.1347
	Human Capital	0.1063	0.1214	0.1117
	Integration of Digital Technology	0.0661	0.0760	0.0684

Source: own study.

Possibly, in the cases of some countries (like Germany and Spain), the differences between them accumulated in the indicators that were only included in one of the indexes, hence such a great dismatch. For example, DII devotes a large part of the demand pillar to general macroeconomic indicators, such as disposable income or consumer expenditure, and its innovation pillar measures mostly the availability of capital. It is only natural that a wealthier country, such as Germany, would receive a higher score, regardless of the actual digitalisation level. On the other hand, DESI measures qualities like a level of digital skills among the population, which are better developed in Spain and not covered by DII.

Clustering Analysis

We may assess the similarity of existing indexes by comparing the connections between countries created based on the structure of each index. For this purpose, we performed a cluster analysis using the more detailed data at the pillars' level. Instead of one value for a country, we have a set of pillar scores. The clustering algorithm will find the countries that are not only at a similar level of digital development,

but also have similar structure of that development, *i.e.* the same pillars are relatively well or underdeveloped. Consequently, we obtained a dendrogram showing the relationships between the selected countries. By creating several independent diagrams depicting these links based on the different sets of pillars that make up the analysed indexes and comparing them with each other, we assessed the similarity of the existing indexes.

Figure 2 presents a comparison of two created dendrograms based on two different sets of pillar connections between countries. On the left are the results of grouping countries by DII pillars, and on the right are the results of clustering by DESI pillars. The X-axes posted below the diagrams reflect the distance between the successively merged countries or groups of countries. The lower the joint of two countries or two groups of countries is, the more similar the values of their indicators are to each other. Between the dendrograms, there are lines connecting the names of the corresponding countries. The green and purple colours indicate those pairs of connections that are the same in both cases. It is easy to see that there are only two such cases (Slovakia – Italy, and Belgium – Austria). This means that only those pairs of countries are combined at the same stage (have the most similar values of pillars) in both indexes. Connections between other countries differ on these dendrograms.

In Figure 2, one bigger group of countries overlaps in both dendrograms. It includes the Netherlands, Denmark, Finland, Sweden, and Ireland. This group consists of countries containing the highest values of the DII and DESI indexes (each in the top 6). Unsurprisingly, it stands out from the other groups. Connections between the other countries are more diverse, as indicated by the numerous intersections of lines connecting the corresponding names of countries. Lots of differences in connections between countries and groups of countries suggest that the pillars in the DII and DESI indexes are not the same.

Figure 3 presents the clustering of countries based on DII pillars (on the left) and ADII pillars (on the right). In this case, we created connections for 13 countries (for those that appeared in the DII and ADII indexes). Compared to the diagrams created from the DII and DESI pillars, the dendrograms in Figure 3 are much more similar. There are still only two pairs of countries (Laos – Cambodia and New Zealand – Australia) that are combined at the same stage in each graph, but there are no big differences between the other connections. The smaller number of intersections of lines connecting the corresponding names of countries and the similarity of the connections show that the analysed pillars of the DII and ADII indexes are quite similar.

We assessed the similarity of dendrograms by two coefficients: Baker and Cophenetic correlations. The first depends on the position of the branches, but it does not take into account their heights. On the other hand, the value of the Cophenetic correlation coefficient is affected by the heights of branches (Baker, 1974; Sokal & Rohlf, 1962). We obtained Baker's correlation coefficient of 0.83 from DII and DESI, and 0.93 between DII and ADII's dendrograms. The Cophenetic coefficients were 0.78 and 0.96 respectively. This suggests that the compared dendrograms were highly similar. However, in the case of connections created from DII and ADII pillars, the similarity was more apparent, as evidenced by the higher values of both correlation coefficients.

Discussion

As pointed out by other authors (*e.g.* Kotarba 2017), we found little homogeneity in the analysed digitalisation indexes. Both the particular choice of measurements and their aggregation into pillars were different in DESI, DII, and ADII. However, we noticed that the values of the indexes were still highly correlated and gave similar ratings. Thus, our empirical analysis gave new insight into previously only descriptive comparisons.

We noticed that global (DII) and regional indexes (DESI, ADII) were more correlated in Southeast Asia, where the countries were more diverse in terms of digital and economic development. Thus, the results of the studies using a digitalisation index as a dependent or independent variable (see, *e.g.* Jovanović *et al.*, 2018; Kryzhanovskij *et al.*, 2021) may depend on the index chosen, especially if they are made in a group of similarly developed countries.

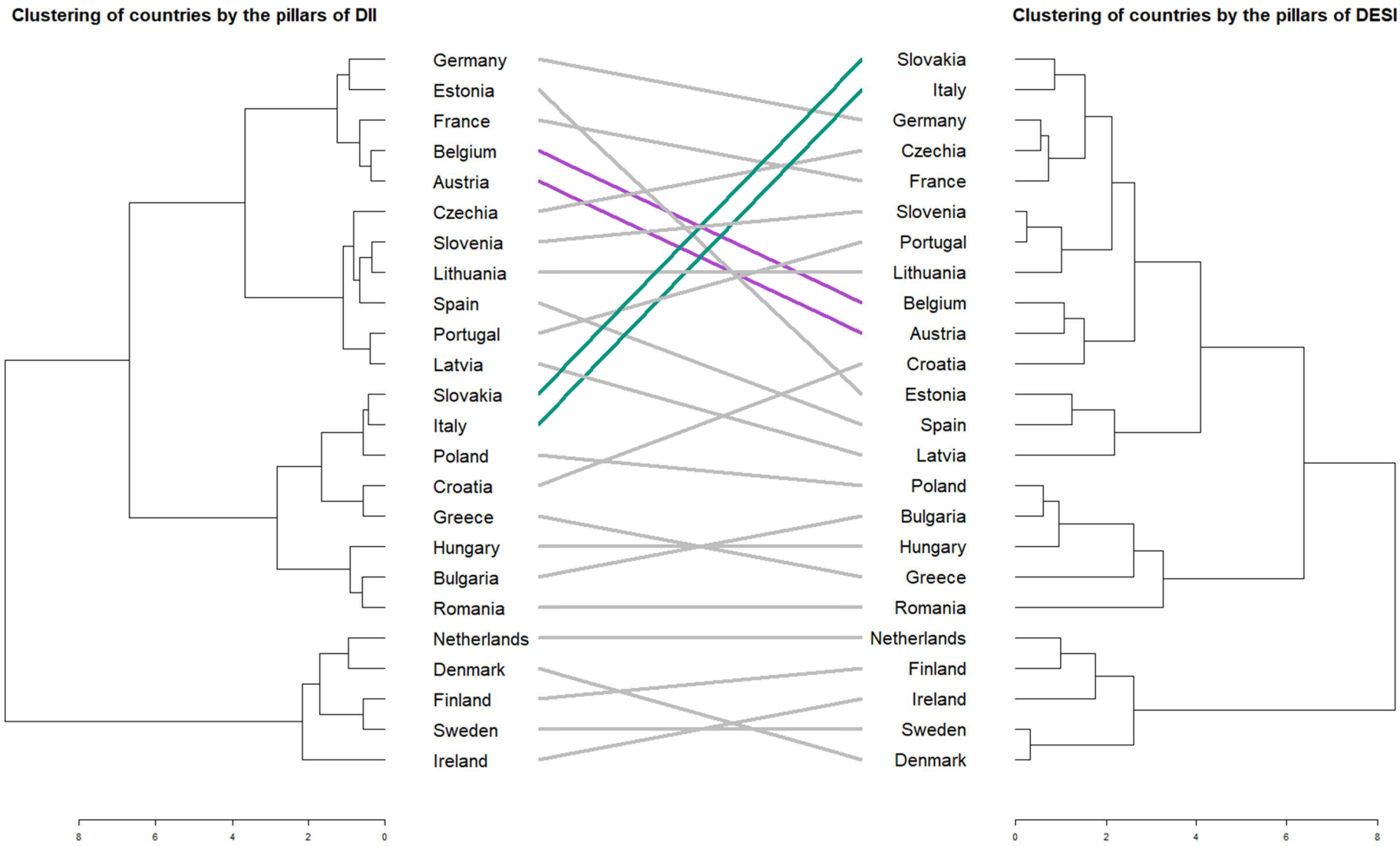

Figure 2. The clustering of countries based on DII pillars (on the left) and DESI pillars (on the right)

Source: own elaboration.

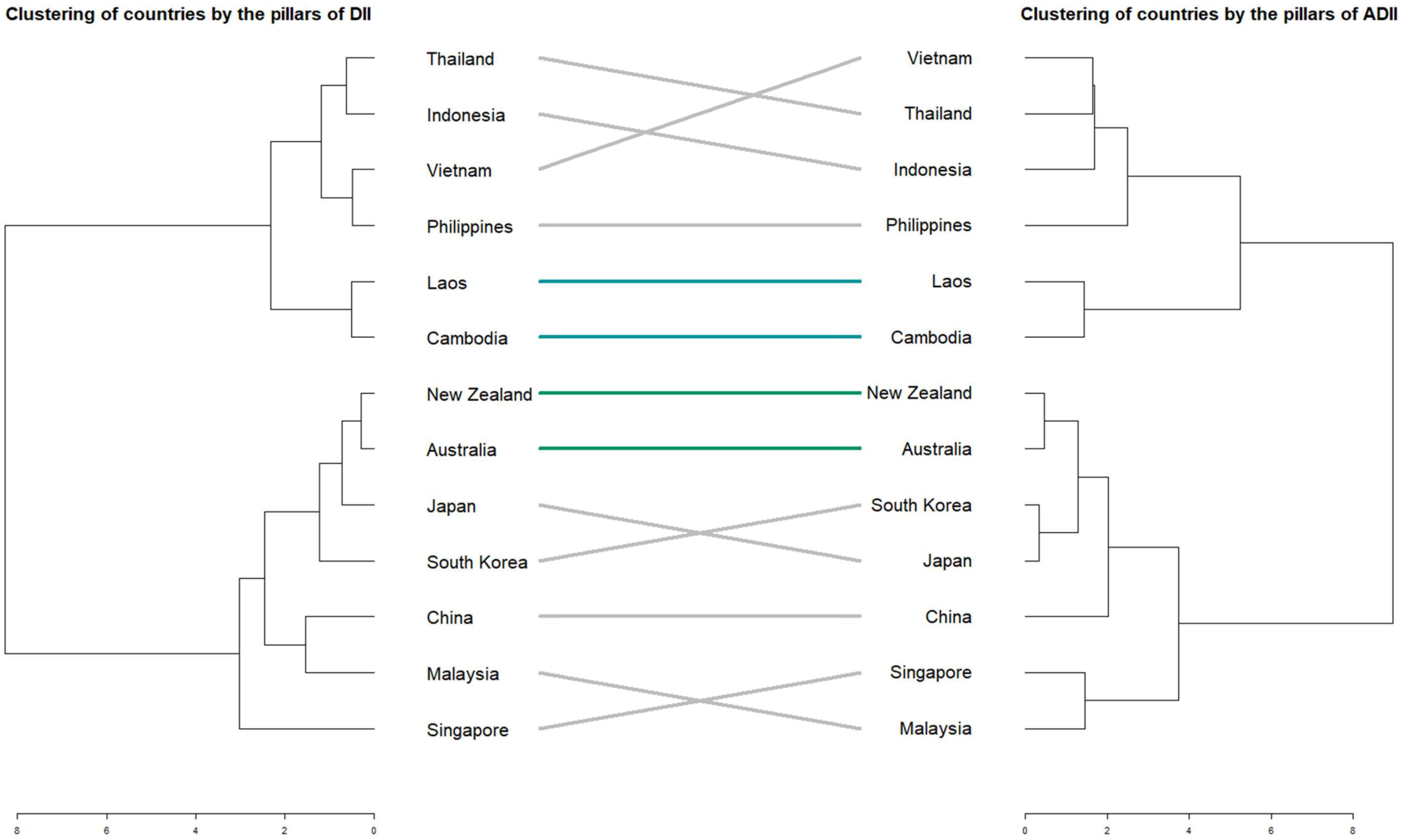

Figure 3. The clustering of countries based on DII pillars (on the left) and ADII pillars (on the right)

Source: own elaboration.

CONCLUSIONS

We aimed to compare indexes measuring digitalisation in the European Union, Southeast Asia, and in the global context, respectively DESI, ADII, and DII indexes. We described the detailed composition of each index and demonstrated how the differences impacted their comparability. Our main finding was that the considered indexes were indeed highly comparable: 0.93 correlation between ADII and DII in ASEAN and 0.88 between DESI and DII in the EU. This disproves our hypothesis that indexes would be incomparable, but is in line with the prediction, that we would find a greater resemblance between DII and ADII. However, we found that this is more likely to result from the dependence between economic and digital development than from the actual similarity in the index definition.

Considering this, further research may use the available index to measure and compare the digitalisation progress between nations and regions, especially between the region of the European Union and Southeast Asia. From the comparison, we may get insight into which areas the digital divide exists and start to investigate the root cause of the gap and find possible solutions to it. However, there are still some cases in which the indexes give inconsistent scores, so any research will be affected by the choice of digitalisation metric.

Out of the three investigated indexes, DESI is the most precise digitalisation measure. It consists of four pillars. The Human Capital pillar covers the proliferation of basic and advanced digital skills in society and the availability of ICT specialists. Connectivity pillars cover fixed and mobile internet infrastructure availability and prices. Next, the Integration of the Digital Technology pillar measures the adoption of digital technology in the business sector, while Digital Public Services describes the availability and usage of digital public services. However, DESI omits some potentially important aspects of digitalisation, such as cybersecurity or the legal environment.

Noteworthy, ADII fills these gaps by including the cybersecurity pillar and a few indicators of the legal framework for electronic transactions and intellectual property protection even though the other pillars are less precise. For example, they cover aspects such as transport infrastructure, availability of venture capital or R&D expenditure (regardless if it is related to digital companies).

However, DII goes even further. In the demand pillar – apart from internet usage and digital affluence – there are strictly macroeconomic measures, such as the GINI index or consumer spending. The institutions pillar has a measure for e-government development, but also the effectiveness of institutions, corruption control or tax rates. The supply pillar provides measures of traditional transport and postal services, and the innovation pillar is not restricted to digital innovation.

It is true that digitalisation does not form out of the void and depends on economic development (Mubarak, *et al.*, 2020). However, the DII score could increase simply because of economic advancement, even if the digital development of the country had not increased. Moreover, its comparability to other indexes may stem from the relationship between economic and digital development. In that case, in an economically diverse region, DII may be more comparable to other measures of digitalisation, but it will lose its relevance for a group of countries on a similar development level. Here, the EU group is more homogenous than ASEAN. The greater similarity of rankings and clustering between ADII and DII (compared to the DESI-DII pair) may result both from more similar index composition and higher dependence of score on economic development.

Furthermore, in the case of the EU, the similarity of the digitalisation process is also affected by index construction. In our clustering analysis, only the cluster of the most digitalized countries persisted in both indexes. In other words, the way one defines the pillars will affect which countries are deemed to be similar in their road to digitalization.

The data availability somewhat limited our study. Firstly, we could only use pillar-level aggregations without the underlying measurements. Secondly, not all countries are covered by all indexes, and our sample was rather small in the Pacific Asia region. Lastly, the digitalisation indexes are computed only once in a few years, so the data is already quite outdated. Especially if we consider the fast-paced changes in the IT industry. Still, our findings may help researchers and managers prepare and interpret international comparisons. The knowledge of similarities and differences between

globalisation indexes is a key to the correct analysis of digital development and digital divide and should not be dismissed as just the methodological detail.

Concluding, our findings mean that any studies on digitalization in economic or social contexts would be dependent on the choice of indexes. Many of the indexes include indicators related to overall economic development rather than strict digitalization, which can lead to inconsistent results.

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Authors

The contribution share is AC: 45% (conceptualisation, calculations, literature writing), SR: 30% (writing), JT: 25% (methodology, calculations).

Agnieszka Choczyńska

Agnieszka Choczyńska is a research and teaching assistant. Her research interests include Financial Markets, Econometrics, and Economic Sentiment.

Correspondence to: mgr Agnieszka Choczyńska, Department of Management, AGH University of Krakow, ul. Antoniego Gramatyka 10, 30-067 Kraków, Poland. e-mail: agachocz@agh.edu.pl

ORCID http://orcid.org/0000-0001-7134-567X

Septia Rani

Septia Rani is a research and teaching assistant. Her research interests include Artificial Intelligence, Data Science, and Information Hiding.

Correspondence to: Cs. Septia Rani, Department of Informatics, Universitas Islam Indonesia, Jalan Kaliurang Km 14.5, Sleman, Daerah Istimewa Yogyakarta 55584, Indonesia. e-mail: septia.rani@uii.ac.id

ORCID http://orcid.org/0000-0002-8635-1797

Justyna Tora

Justyna Tora is a research and teaching assistant. Her research interests include Econometrics and Demand Modelling.

Correspondence to: mgr Justyna Tora, Department of Management, AGH University of Krakow, ul. Antoniego Gramatyka 10, 30-067 Kraków, Poland. e-mail: jtora@agh.edu.pl

ORCID http://orcid.org/0000-0002-6653-9004

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Creative destruction and development of the global economy

Agnieszka Szczepkowska-Flis, Anna Kozłowska, Małgorzata Kokocińska

ABSTRACT

Objective: The objective of the article is to empirically recognize the significance of creative destruction for the development of contemporaneous global economy, in particular: (1) the influence of creation and destruction on development processes and how this influence changed over time; (2) the effects of creation and destruction on disparities in the level of development between the so-called 'countries of the South and the North.'

Research Design & Methods: We conducted the econometric analysis for the years 1970-2020, which we divided into four analytical periods. We used time series data from the UNCTAD database for 220 countries, the group of developing countries, and the group of developed countries. We used evometrics to measure creative destruction, which enabled its decomposition into the innovation effect (creation) and the selection effect (destruction). Modelling comprised two economic categories: GDP *per capita* dynamics and development gap index, relating them to the innovation and selection effects. We used linear regression and estimated the parameters using the OLS.

Findings: Our results showed that both creation and destruction had a positive influence on the global GDP *per capita* dynamics and destruction played a dominant role in this process. Its impact increased over time. The growth of creation and destruction resulted in the increased dynamics of the development gap, which we can consider as a specific cost of development based upon creative destruction. In the period of profound geopolitical transformations in the world economy (1982-1998) creation did not affect the development of the global economy and the dynamics of development gap.

Implications & Recommendations: Our results indicate that the full use of the development potential created by innovations requires uninterrupted operation of not only creation, but also properly functioning destruction. Some scholars postulate eliminating destruction from development processes. However, this may lead to a prosperity loss. The cost of creative destruction is not destruction as such but its erroneous operation caused, for example, by institutional, political, and economic factors. In the context of the economic policy of developing countries, this statement implies that solutions aimed at stimulating innovations should be accompanied by activities facilitating the transfer of resources from less to more effective uses.

Contribution & Value Added: Modification of the theoretical construction of Schumpeter, enabling both theoretical and empirical analysis of the role of creative destruction in the processes of development of the world economy. The use of evometrics as a tool for measuring creative destruction at the level of the global economy. The results of the study constitute an important contribution to the discussion on the role of creative destruction in development processes, especially concerning destruction, which is commonly assigned a pejorative meaning and identified with the cost of implementing innovations.

Article type:	research article
Keywords:	creative destruction; economic development; development gap; global economy; evometrics
JEL codes:	O10, F01, F63

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INTRODUCTION

In the light of profound structural and market transformations of the contemporaneous world economy, resulting from and accompanying the internationalization and emergence of the global economy, it is hard to disagree with Misala's opinion (2009) that while the overall economic goal, *i.e.* the growth of a broadly understood well-being has been and continues to be a kind of constant magnitude, conditions for its accomplishment are subject to changes. Characteristic features in the development of the modern world economy are not only the increasing complexity and rate of the processes, or specific events compression (of 'time-space' type) (Misala, 2009) but also, and perhaps above all, a more and more noticeable syndrome of the so-called 'economy of impermanence' (Mączyńska, 2012). The capacity to create new technologies, increasing at an exponential rate, and the multiplicative nature of the implemented technologies (Kurzweil, 2005) consolidate the impermanence trend, being responsible for the fact that the linear progression model no longer adequately describes the world. Moreover, changes occurring in the global economy in recent decades do not involve simple quantitative growth or qualitative leaps but are experienced as a kind of cataclysm – accumulated effects of a 'continuous discontinuous change' (Borkowski, 2001).

When considering the development of the modern global economy, it is impossible to ignore various types of imbalances increasing on a global scale: social, demographic, and ecological (Aghion *et al.*, 2021; Begović, 2021; Courvisanos, 2012). Although imbalance as such is not a core of the problem but the driving force of progress, the disparities deepening on the world's scale (poles of wealth and poverty) make us reflect on the effects of an explosive development of the so-called 'innovation civilization' (Borkowski, 2001). According to Mączyńska (2012, p. 170), successive waves of innovations lead 'not only to a desirable "creative reconstruction" or creative destruction, but also to the destruction involving irreversible, or hardly reversible, far-reaching effects, social, economic, ecological, and spatial which radically change the situation and living conditions of people, businesses, institutions, and countries'. Currently, we see in the literature that scholars replace a belief in technological progress as an antidote to all the world's ailments ensuring an increase in global welfare with questions about socially acceptable costs of innovations and ways 'to harness' creative destruction (Aghion *et al.*, 2021).

The need for an in-depth discussion postulated by Mączyńska (2012) as regards creation and destruction in the world economy, particularly important in the context of events of the last few decades (financial crisis 2007/2008, COVID-19 pandemic) was an incentive for us to undertake the analyses with an aim to empirically recognize the significance of creative destruction in the development of modern global economy, in particular, to examine:

- the influence of creation and destruction on development processes and to determine whether this influence was subject to change over time;
- effects of creation and destruction on disparities in the level of development between the so-called 'countries of the North and the South.'

Schumpeterian theory of economic development and evolutionary economics constituted the theoretical frameworks for our research concept. The application of Schumpeterian theory for the analysis of the development of the world economy required modifications which would consider the global research perspective, leaving the essence of creative destruction unchanged. Those modifications concerned:

- the structure of an economic system and the transfer of creation and destruction waves in that system;
- the way creation and destruction are manifested.

We formulated the conclusions based on econometric analysis for the years 1970-2020. The research exploited a time series of data coming from the UNCTAD database for 220 countries, the entire world economy, the group of developing countries, and the group of developed countries. Moreover, we applied evometrics in contrast to the usual measures of creative destruction used in the relevant literature (indicators based on entries/exits of firms (firm rotation), job creation/job destruction (employment rotation),

patents, or instability of financial indicators). Evometrics is a method of quantification of creative destruction. It originates from biological sciences – Fisher's theorem on natural selection (Andersen, 2004a; Frank, 1997) – and Price applied it to describe the mechanism of evolutionary processes (Andersen, 2004b; Gardner, 2020; Price, 1970). It allows for the decomposition of creative destruction into the innovation effect and the selection effect (Andersen, 2004a) at various levels of data aggregation. To our knowledge, so far scholars have not used this method as a tool to measure creative destruction at the level of the global economy. Applying evometrics in our study made it possible to combine the conceptual sphere with the empirical level/plane and to enrich the considerations of numerous authors, who typically base their research on qualitative analysis, with conclusions resulting from strictly quantitative analyses.

In the next part of the article, we presented a theoretical concept of the impact of creative destruction on the development of the global economy (multi-structure). In the following part of the article, we included information about the data/indicators used in the empirical analysis and the research method. In the fourth part, we presented the results of the econometric study and their interpretation. In the last part of the article, we included the most important conclusions and limitations of our research, as well as directions for further studies.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

According to Schumpeter's theory (1939, 1949), broadly understood innovations are the source of development processes, while creative destruction is a mechanism through which the economy enters higher growth paths. The introduction of innovations, equivalent in Schumpeter's theory to the creation of new entities, disrupts the existing economic equilibrium and triggers the processes of imitation and knowledge diffusion – a wave of creation. New methods of production, new goods and services, new sales techniques, and new technological-organizational solutions implemented within the frameworks of innovations differentiate economic entities. In turn, this differentiation is the basis for the functioning of market selection. The entities which become ineffective in the new conditions are forced either to reduce the scope of their activities or to terminate them. This *de facto* means pushing old products, technologies, organizational types, etc. out of the market, *i.e.* the wave of destruction. Therefore, the core of creative destruction described by Schumpeter is two inextricably linked phenomena:

- construction of qualitatively different, new elements of an economic system – creation;
- elimination of old, ineffective elements of the economic structure – destruction.

The consequence of creative destruction is the transformation of the economic structure combined with the improvement of effectiveness.

The Schumpeterian economic system (a two-level, closed economy) where innovations are exclusively endogenous and creative destruction occurs only inside a traditionally defined national economy, cannot be directly applied to the analysis of modern development processes. Internationalization, globalization, and international integration are responsible for the fact that national economies are no longer relatively autonomous systems; they lose 'their distinctiveness' and become interrelated components of a wider system, where economic processes occur not only within but also beyond the borders of its member countries. The world economy is assumed to be a multi-level economic system (multi-structure) created by national economies (macro level) and their internal structures (meso-, micro-levels) which, through international and institutional links shaping it, constitutes the global space for the operation of creative destruction and development processes. The development of multi-structure is a consequence of the processes occurring at the lower hierarchical levels and the mechanism of development impulses' transmission (creative destruction) is consistent with a multi-level version of the Price equation (Andersen, 2004a). The construction of the multi-level version of the Price equation is based on two assumptions:

- innovation (creation) is any new differentiation, regardless of the source of its origin and the system's hierarchical level. According to Fisher, such a variance is the basis for the functioning of selection (destruction), which, in turn, restricts this variance. According to Fisher's theorem, if selection favours the degree to which a given trait is present among individuals of a population, then the rate

of change in the average value of that trait is proportional to the differentiation (variance) of that trait in a given population (Andersen, 2004c). The greater the variance of a trait, the greater the intensity of selection processes;
- the result of creation and destruction occurring at a given level of the structure is the creation at a higher hierarchical level (*i.e.* a new variance of the elements belonging to that level) (Figure 1).

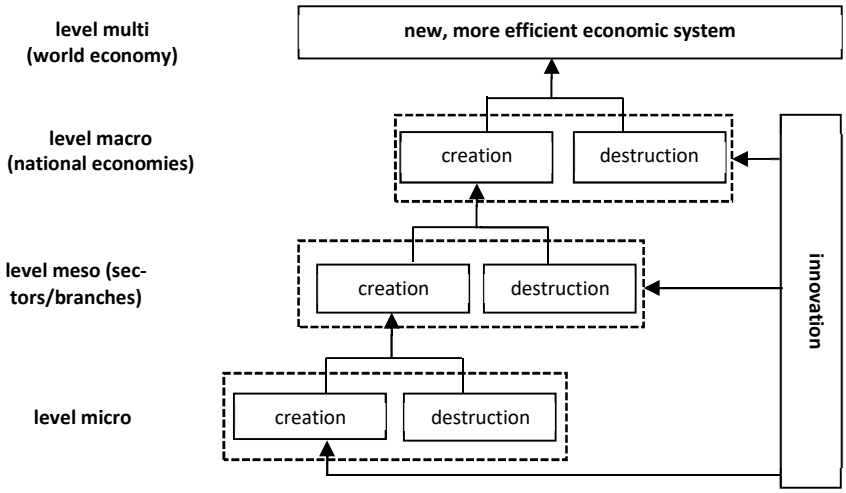

Figure 1. The mechanism of transmission of creative destruction in a multi-structure
Source: own elaboration.

The presented mechanism of creative destruction transmission implies that the innovation (creation), differentiation it involves, and selection (destruction) based upon this differentiation, in contrast to Schumpeter's views, are not only the attributes of processes occurring at the micro-level (inside individual entities and among them) but they are also manifested at all levels of the structure of world economy. At the level of national economies (macro level), creative destruction occurring at the lower levels of the structure (meso-, micro) is visible in differentiated rates of their growth (creation) and in changes of their shares in the world economy (destruction). The mechanism of selection, 'promoting' better economies, is responsible for the fact that their share in the world economy increases, simultaneously limiting the share of weaker economies. Therefore, destruction does not involve a literal demolition (elimination) of national economies, but it involves a reduction of their importance in the global system, pushing out economically, technologically, and resource-weaker economies to the peripheries of the world economy. The ultimate result of creative destruction is, at least in the assumptions, the creation of a new, more effective world economy, characterized by a higher rate of economic growth. We concretised those theorems in the research hypothesis:

H1: Creation and destruction positively influence the development of the world economy.

Considering that creation results in additional differentiation, whereas selection leads to its limitation, we formulated the second research hypothesis:

H2: Creation causes an increase of disparities in the level of development between 'the South and the North' economies, whereas destruction contributes to the reduction of those disproportions.

The basis for verification of the hypotheses was empirical research, the concept of which we present further in the article.

RESEARCH METHODOLOGY

In the study, we used yearly statistical data published by UNCTAD for 220 countries, the entire world economy, the group of developing countries, and the group of developed countries in the years 1970-

2020. The time range of the research was dictated by the availability of accessible comparable time series. We expressed all data in fixed prices for the year 2015.

According to evolutionary economists, different historical periods are characterized by variable dynamics of technological progress and different significance of innovation and imitation for economic growth (Fagerberg & Verspagen, 2002). Therefore, we distinguished four subperiods of analysis, while considering important events for the development of the world economy, such as the oil crises of the 1970s, the debt crisis, dot-com boom (technological innovation), and financial crises (financial innovation – financial engineering). The analysed subperiods covered the years: 1970-1981, 1982-1998, 1999-2008, and 2009-2020. Since the decision to select cut-off dates for the subperiods was arbitrary, we tested its validity using the Chow breakpoint test.

We subjected two economic categories to econometric modelling:

- the development of the world economy measured by GDP *per capita* dynamics (variable *G*),
- the development gap index which measures changes of disproportions in the level of development between the developing and developed countries. This index is expressed as dynamics of the difference between the levels of GDP *per capita* in the developed and developing countries (variable *D_L*),

assuming that these categories are influenced by the processes of creative destruction occurring in the world economy, *i.e.* inside and among national economies constituting the multi-structure.

To estimate the processes of creative destruction in the world economy, we applied evometrics (*evolutionary econometrics*) (Andersen, 2004a; Andersen *et al*., 2006). It permits the decomposition of creative destruction processes into the selection effect (variable *ES*) measuring destruction, and the innovation effect (variable *EI*) which is the measure of creation. We calculated the values of creative destruction indexes based on the GDP of individual countries according to the formulae:

$$ES_t = \frac{\sum_j u_{jt}\left(w_{jt} - w_t\right)^2}{w_t} \tag{1}$$

$$EI_t = \frac{\sum_j u_{jt} w_{jt} \Delta w_{jt}}{w_t} \tag{2}$$

in which:

$w_{jt} = \frac{GDP_{jt}}{GDP_{jt-1}}$ - absolute reproduction coefficient of country *j* in year *t,*

Δw_{jt} - change in reproduction coefficient of country *j* in year *t*,

u_{jt} - share of country *j* in generating world economy's GDP in year *t,*

$w_t = \sum_j u_{jt}\, w_{jt}$ - weighted average reproduction coefficient of the world economy in year *t*.

Since in the years 1970-2020 geopolitical changes occurred in the world economy – the emergence of the new and liquidation of the old countries (*e.g.* the collapse of the USSR and Yugoslavia and unification of Germany), the number of national economies being the basis for calculating the innovation and selection effects differed in particular periods.

According to the multi-level version of Price equation (Andersen, 2004a), the value of innovation effect (*EI*) shows the aggregated, visible at the level of the world economy, result of creative destruction processes taking place within national economies of the analysed countries. The selection effect (*ES*) expresses the results of 'market selection,' occurring among national economies and observed at the level of the world economy.

We analysed the role of creative destruction in the development of the world economy in two stages. In the first stage estimations included the parameters of regression equations, in which the development index of the world economy (variable *G*) was the explained variable:

$$G = C + \alpha_1 EI + \alpha_2 D1 * EI + \alpha_3 D2 * EI + \alpha_4 D3 * EI \tag{3}$$

$$G = C + \alpha_1 ES + \alpha_2 D1 * ES + \alpha_3 D2 * ES + \alpha_4 D3 * ES. \tag{4}$$

We assigned the binary variables the following values: *D1* = 1 for the years 1982-1998, *D2* = 1 for the years 1999-2008, *D3* = 1 for the years 2009-2020.

To compare the force of influence exerted by innovation and selection effects on GDP *per capita*, we estimated parameter of analogous regression equations using standardized values of independent variables (*EI_S*, *ES_S*).

In the second stage, we analysed the influence of innovation and selection effects on the development gap index (variable *D_L*):

$$D\_L = C + \alpha_1 EI + \alpha_2 D1 * EI + \alpha_3 D2 * EI + \alpha_4 D3 * EI \quad (5)$$

$$D\_L = C + \alpha_1 ES + \alpha_2 D1 * ES + \alpha_3 D2 * ES + \alpha_4 D3 * ES. \quad (6)$$

We used binary variables in all regression equations to find out whether the influence of innovation and selection effects on dependent variables (*G*, *D_L*) was subject to changes over time. The statistical insignificance of parameters α_2, α_3, and α_4 implies that the influence of *EI*, *ES* in the distinguished subperiods 1982-1998, 1999-2008, 2009-2020 did not differ from the subperiod 1970-1981. On the other hand, the statistical significance of parameters α_2, α_3, and α_4 means that the influence of the innovation effect and/or selection effect on the dependent variables was different in the distinguished subperiods. The force of impact of the independent variable exerted on the dependent variable in the years 1982-1998, 1999-2008, and 2009-2020 was defined, respectively, by the sums of coefficients: $\alpha_1 + \alpha_2$, $\alpha_1 + \alpha_3$, $\alpha_1 + \alpha_4$, whose statistical significance was verified by the Wald test.

Before the estimation of regression equations, we checked for variables' stationarity using the Augmented Dickey-Fuller test (ADF test) (Greene, 2012). To estimate regression parameters, we applied the ordinary least squares (OLS) method. We checked the normality of residuals' distribution with the Jarque-Bera test (Hill *et al*., 2011). To verify the assumption of homoskedasticity of the regression residuals we used the Breusch, Pagan, and Godfrey test (Gujarati, 2004; Hill *et al*., 2011; Greene, 2012). To verify the hypothesis about the lack of autocorrelation of the residual component, we used the Breusch and Godfrey test (Gujarati, 2004). When we found the autocorrelation of the residual component, we applied the OLS with AR errors (Wooldridge, 2002; Baltagi, 2005). When the autocorrelation of residuals was accompanied by heteroskedasticity, we used the OLS with the heteroskedasticity and autocorrelation consistent standard errors (HAC) (Greene 2012). The statistical significance of the test results was at the level α = 0.05.

We present the results obtained from empirical analyses and their interpretation in further parts of the article. We paid special attention to the results which are most important from the viewpoint of the research goal. Detailed results of the analysis will be made available at the reader's request.

RESULTS AND DISCUSSION

The unit root test revealed the stationarity of all the variables accepted for the study (Table 1). The results of the Chow breakpoint test showed that there were grounds to reject the null hypothesis of no structural change in years 1982, 1999, 2009, and therefore confirmed the validity of the adopted division of the research period into four analytical subperiods (Table 2).

Table 1. Results of the ADF test with constant and linear trend (H0: Variable has a unit root)

Variable	ADF test statistic	Probability
EI	-6.772586	0.0000
ES	-4.459568	0.0044
G	-4.452718	0.0045
D_L	-5.743512	0.0001

Source: own study based on calculations in EViews 11.

Table 2. Results of the Chow breakpoint test (H0: No breaks in 1982, 1999, 2009)

Equation	Wald statistic	Probability
$G = C + \alpha * EI$	41.53129	0.0000
$G = C + \alpha * ES$	90.61262	0.0000

Source: own study based on calculations in EViews 11.

The results of the estimation of parameters of regression equations (3) and (4) (Table 3, Models A and B) show that creative destruction was a statistically significant factor shaping the development of the world economy in the studied period.

Table 3. Estimation results of parameters of equations (3)-(6)

Explanatory variables	*Model A (HAC)*	*Model B (HAC)*	*Model C (AR(1) errors)*	*Model D (AR(1) errors)*	*Model E*	*Model F (HAC)*
C	**101.69 [0.18]**	**-2.99 [1.06]**	**101.66 [0.27]**	**101.76 [0.44]**	**101.97 [0.24]**	-8.72 [5.90]
EI	**51.54 [9.31]**	–	–	–	**59.68 [23.74]**	–
*D1*EI*	**-66.98 [19.93]**	–	–	–	**-66.29 [32.56]**	–
*D2*EI*	-4.60 [10.97]	–	–	–	-4.33 [44.07]	–
D3 EI*	22.89 [23.93]	–	–	–	21.85 [30.33]	–
ES	–	**100.86 [1.04]**	–	–	–	**107.07 [5.67]**
*D1*ES*	–	0.19 [0.10]	–	–	–	0.39 [0.23]
*D2*ES*	–	**0.60 [0.05]**	–	–	–	-0.32 [0.46]
*D3*ES*	–	**0.70 [0.07]**	–	–	–	-0.63 [0.37]
EI_S	–	–	**1.02 [0.46]**	–	–	–
*D1*EI_S*	–	–	**-1.14 [0.51]**	–	–	–
*D2*EI_S*	–	–	-0.20 [0.82]	–	–	–
*D3*EI_S*	–	–	0.42 [0.48]	–	–	–
ES_S	–	–	–	**2.53 [0.04]**	–	–
*D1*ES_S*	–	–	–	0.09 [0.06]	–	–
*D2*ES_S*	–	–	–	-0.03 [0.08]	–	–
*D3*ES_S*	–	–	–	**0.12 [0.06]**	–	–
Statistics	R^2= 0.51; ^R^2= 0.46	R^2= 0.99; ^R^2= 0.99	R^2= 0.56; ^R^2= 0.5	R^2= 0.99; ^R^2= 0.99	R^2= 0.38; ^R^2= 0.32	R^2= 0.88; ^R^2= 0.87

Notes: Standard errors in parentheses. Statistically significant coefficients are in bold. In the models B, D, and F, we omitted two influential observations (1971 and 1972) and one untypical observation (1992) in the estimation process.
Source: own study based on calculations in EViews 11.

Both the innovation and the selection effects had a positive influence on the dynamics of GDP *per capita* in all the studied subperiods, except the years 1982-1998, when the innovation effect played a passive role in the development processes.[1] Considering that changes occurring in the years 1982-1998 were defined by some economists as 'specific innovation of the world economy' (Zielińska-Głębocka, 2012) within the frameworks of which a massive reshuffle of economic forces took place among different

[1] The sum of regression parameters for variables *EI* and *D1*EI* (Table 3, Model A) did not significantly differ from 0 (Wald test: H0: $\alpha_1 + \alpha_2 = 0$; F statistics = 0.77; p = 0.39).

regions and centres of the world, the obtained result may raise some doubts. However, we should pay attention to the fact that this specific kind of innovation was largely triggered by exogenous, politically conditioned factors. In that subperiod, the development of the global economy was influenced by conditions other than the innovation effect, which does not imply that innovation processes and creative destruction they involved had no place, especially because market selection continued to stimulate the growth of GDP *per capita* dynamics. Moreover, in the successive subperiods under analysis, the impact of the selection effect on the development of the global economy was getting stronger and stronger.[2]

We may draw similar conclusions as concerns the role of creative destruction in the development processes of the global economy from the results obtained by estimations of the regression equations, using standardized values of independent variables (*EI_S*, *ES_S*) (Table 3, Models C and D). The comparison of parameter values in both regression equations shows a predominant significance of the selection effect for the dynamics of the global GDP *per capita*. In the whole period under analysis, regression parameters for independent variable *ES_S* were higher than the values reported for independent variable *EI_S*, and in the years 2009-2020 the force of impact exerted by the selection effect on variable *G* was over 2.5 times stronger than that of the innovation effect.[3]

Table 3 presents the results of the estimation of regression equations for dependent variable *D_L* obtained during the second stage of research (Models E and F). Based on the obtained results, we may state that both the innovation effect and the selection effect were the factors which positively influenced variable *D_L* – an increase in the values of variables *EI* and *ES* essentially increased the dynamics of the development gap. Such a result implies that the growth of creation and destruction accelerated the increase of differences in the levels of GDP *per capita* between the developed and developing countries. This regularity did not apply to the innovation effect in the years 1982-1998, *i.e.* the period of the so-called 'specific innovation of the world economy.'[4]

Summarizing our results, we may conclude that:

- in the years 1970-2020 both creation and destruction positively influenced the dynamics of GDP *per capita*. This result means a positive verification of hypothesis H1;
- a specific 'cost' of the development of the world economy, based upon the creative destruction, was widening of the gap between the levels of GDP *per capita* in the groups of developed and developing countries. Therefore, such a result cannot be the basis for a positive verification of hypothesis H2 with reference to the selection effect;
- in the years 1982-1998, a period of profound geopolitical transformations in the global economy, creation was not an active component of the creative destruction mechanism shaping the development of the world economy and the development gap. In the other subperiods, the impact of creation on the development of global economy remained unchanged;
- the force of influence exerted on the world economy by the innovation and selection effects indicated that the destruction played a leading role in that process as its influence in the last two subperiods under analysis was getting stronger and stronger.

Recorded research results are convergent with those of the studies concerning the significance of market competition and selection in economic processes, according to which a full exploitation of the development potential created by innovations requires not only an undisturbed spread of the new knowledge (diffusion and imitation) but also the elimination of ineffective elements from the market, thus creating a space for new, better solutions. In the economy, the presence of factors disturbing destruction, such as *e.g.* market regulations and frictions, which inhibit the effective flow of labour

[2] Regression parameters for variables *D2*ES* and *D3*ES* were positive and statistically different from zero (Table 3, Model B). The force of impact of variable *ES* on dependent variable *G* in the years 1982-1998 did not significantly differ from that observed in the subperiod 1970-1981 and reached a value of 100.86. In the two successive subperiods, it amounted to: 101.46 in the years 1999-2008 and 101.56 in the years 2009-2020.

[3] The force of impact of the innovation effect in all the distinguished subperiods is expressed by value α_1= 1.02 (Table 3, Model C). The force of impact of the selection effect in the last subperiod is represented by the sum of regression coefficients $\alpha_1 + \alpha_4 = 2.66$ (Table 3, Model D).

[4] Wald test for zero hypothesis: H0: $\alpha_1 + \alpha_2 = 0$; F statistic = 0.09; p = 0.77 (Table 3, Model E).

(Ahmadiani *et al*., 2022; Elfayoumi, 2022); intra- and inter-sectoral barriers to the mobility of production factors (entry/exit barriers, transaction costs) (Bartelsman *et al*., 2004); economic policy oriented towards businesses protection (zombie companies) (Di Mauro & Syverson, 2020); intentional activities of enterprises to protect themselves from the effects of market selection (Tripsas, 1997) – all this leads to inefficient allocation of resources and their wastage. The productivity 'wedge' between the existing and optimal allocation of resources reflects the scale of institutional and market distortions that cause Schumpeter's selection and reallocation are not working properly (Bennett, 2021; Irandoust,2023; in print; Näf, 2022). In the context of the transmission mechanism of creative destruction impulses in the multi-structure presented in this study, this conclusion implies that the results of disturbances in the correct functioning of market selection at lower hierarchical levels (micro- meso-, macro) accumulate, leading finally to the weakening of development processes observed at the level of the world economy.

CONCLUSIONS

Our study confirmed that the development of the global economy requires not only innovation (creation), but also destruction. Moreover, in the last two subperiods of our analysis, destruction, whose essence is the elimination of inefficiency from the market and pro efficient allocation of resources, was decisive for the growth of GDP *per capita* of the world economy. Marginalization, even negation of the positive sense of destruction, or attributing the commonly known pejorative meaning to this word may lead to a false conclusion that elimination or limitation of destruction will make it possible to avoid the costs of development based upon innovations. However, our results lead to the conclusion that the loss of prosperity may be a real cost for the economy where destruction is 'harnessed.' Bearing in mind that the growth of destruction resulted in increased disparities between the developed and developing countries, this statement may raise some controversies. If, according to the expectations, the innovation effect increased differences in the levels of development, the result obtained for the selection effect contradicts the conclusions drawn from the catch-up hypothesis (Findlay, 1978), testifying in favour of the technological accumulation hypothesis (Castellani & Zanfei, 2007; Dunning & Lundan, 2008). Therefore, internationalization emphasized by many authors (foreign direct investment flows, international trade), which increases the supply of accessible technological knowledge, facilitates its diffusion, and widens sales markets, as well as intensified R&D activities (Grossman & Helpman, 1994; Sharma & Mishra, 2023) does not lead to the equalization of development levels through the mechanisms based on competition and selection.

When discussing the reduction of disproportions in the level of economic development, the authors focus on the problems of developing countries, linked with a deficit of innovations or implementation of new technologies. Our study suggests that the reason does not lie in the deficit of innovations or in the problems with imitation and diffusion of knowledge but in disturbances in the functioning of destruction. In the context of developing countries' policy, this statement implies that the solutions aimed to stimulate innovations should be accompanied by the activities facilitating the transfer of resources from the less to the more efficient applications, *e.g.* those removing the structural and institutional rigidity, characteristic of the countries from that group.

Our study is not without limitations. Firstly, our regression models did not allow for the separation of short- and long-run effects of creative destruction, which, according to the results of Asravor and Sackey's (2023) based on ARDL models, may be different – destruction processes play a greater role in the short run, and the domain of creation is the changes observed in a longer time horizon. Secondly, our classification of countries (developed/developing) is based on the distinction between developed and developing regions with the understanding that being part of either developed or developing regions is through the sovereign decision of a state (UNCTAD, n.d.). Therefore, this classification cannot be considered precise, and an alternative solution could be groups defined by economic criteria, for example, the classification of countries used by the World Bank according to income levels. Considering the positive correlation empirically confirmed for 166 countries between the number of patents per million of population and GDP *per capita* (Gürler, 2022), the division of countries based on the level of income may indirectly reflect the level of their technological development, which is important for

Schumpeterian (innovative) dynamism based on the ability to innovate and efficiency (Ahmadiani *et al*., 2022). Thirdly, the research concept presented here is certainly based upon a very simplified picture of how the world economy functions. Although our assumptions include differences in the levels of economic development, they omit many elements, significant for the modern world economy, such as *e.g.* international political, institutional, and economic connections which are responsible for the fact that the world economy may be treated as an economic system, a multi-structure. In this context, economic connections reflected in the share of individual countries in the global economy (in foreign trade, FDI flows) seem particularly important because numerous studies confirm the positive impact of trade liberalization and international flows of production factors on the efficiency of resource reallocation and productivity growth (Asravor & Sackey, 2023; Mao & Xu, 2023).

In our opinion, the reported results and general conclusions may be a starting point for the analyses which, to a higher extent, would adjust the theoretical concept to the conditions in which the modern world economy functions. In particular, such a research scheme should include:

- the possibility that creative destruction exerts a different influence on economic development in different groups of countries (developed/developing countries, high/low-income countries, countries of high/low technology level etc.);
- synergy effects among different groups of countries, which would make it possible to determine whether and how the processes of creative destruction in one group of countries modify the impact of creative destruction on economic development in the other group;
- internationalization, globalization, and integration of the markets of goods/services and production factors seen as the processes which modify the influence of creative destruction on economic development and the size of the development gap.

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Authors

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Agnieszka Szczepkowska-Flis
PhD in Economics (2004, Poznan University of Economics and Business, Poland); Assistant Professor at the Kazimierz Wielki University (Poland). Her research interests include economic development, creative destruction, business cycle, technological progress, and foreign direct investment.
Correspondence to: PhD Agnieszka Szczepkowska-Flis, Kazimierz Wielki University, Department of Law and Economics, Plac Weyssenhoffa 11, 85-072 Bydgoszcz, Poland, e-mail: agnieszka.szczepkowska-flis@ukw.edu.pl
ORCID http://orcid.org/0000-0003-3946-426X

Anna Kozłowska
PhD in Economics (2012, Poznan University of Economics and Business, Poland); Associate Professor at the Poznan University of Economics and Business (Poland). Her research interests include economic development, creative destruction, business cycle, and technological progress.
Correspondence to: Prof. Anna Kozłowska, PhD, Poznan University of Economics and Business, Department of Economics, Al. Niepodległości 10, 61-875 Poznań, Poland, e-mail: anna.kozlowska@ue.poznan.pl
ORCID http://orcid.org/0000-0002-2527-3641

Małgorzata Kokocińska
Professor (2013), Department of International Economics and Market Analyzes, University of Zielona Góra (Poland). Her research interests include economic development, convergence, sector SME, and sustainable growth.
Correspondence to: Małgorzata Kokocińska, Zielona Góra, University of Zielona Góra, https://wez.uz.zgora.pl/, Faculty of Economics and Management, Department of International Economics and Market Analyzes, ul. Podgórna 50, 65-246 Zielona Góra, Poland, e-mail: m.kokocinska@wez.uz.zgora.pl
ORCID http://orcid.org/0000-0002-6464-5268

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The impact of farm direction on the cost and quantity of used fertilizer

Sebastian Kubala

ABSTRACT

Objective: The level of costs and the volume of fertilizers used are largely determined by the situation in world markets and the decisions of state authorities. Moreover, individual farms have different characteristics. Therefore, the objective of the article is to investigate the relationship between the production direction of the European Union farms, the level of fertilizer purchase costs and the amount of P2O5, K2O, and N applied in mineral fertilizers.

Research Design & Methods: The research focused on the purchase cost of fertilizers (€) and the amount of P2O5, K2O, and N applied in mineral fertilizers (q). To illustrate the direction of farm production, I used data relating to the eight agricultural types distinguished in the Farm Accountancy Data Network (FADN) database. I applied one-way ANOVA variance to achieve the research objective. However, as all the assumptions of the ANOVA model were not met, I used the non-parametric Kruskal-Wallis test.

Findings: The most frequent differences in the case of fertilizer costs are found between crop and livestock-oriented farm types. Fewer differences can be observed for farms that are oriented at the same food source. For the amount of compounds used in mineral fertilizers, identical differences are found for P2O5 and K2O. In the case of N, the main differences are linked to farms of the following types: field crops, milk, and granivores.

Implications & Recommendations: The conducted research clearly indicates that the production direction of farms in the European Union countries significantly influences the variation in both the costs incurred for the purchase of fertilizers and the amount of individual chemical compounds used in mineral fertilizers. Individual production specializations are therefore differently exposed to possible adverse political and economic developments. An analysis of the opportunities and threats to the use of mineral fertilizers by individual farm specializations is recommended. At the same time, it is justified to indicate the main determinants causing the existing differentiation.

Contribution & Value Added: The added value of the study is to determine how the production direction of the EU farms influences the costs incurred for the purchase of fertilizers and the quantity of the various types of chemical compounds used in mineral fertilizers.

Article type: research article

Keywords: agriculture; FADN; analysis of variance; crop production; livestock production

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INTRODUCTION

One of the most important production factors of farms causing an increase in yields and improving the quality of crops is fertilization. It is the basis for assessing the farming intensity (Igras & Kopiński, 2007). As indicated by Malingreau *et al.* (2012), fertilizers are at the heart of the challenge of sustainable agricultural development, which aims to reconcile increasing demand for food products, respect for the environment, as well as improving farm livelihoods. The lack of fertilizer use would lead to a decrease in agricultural productivity contributing to higher food costs (Oerke, 2005; Brunelle *et al.*, 2015). On the other hand, the use of mineral fertilizers on the farm significantly affects the environment

(Gaviglio *et al.*, 2017; Czyżewski *et al.*, 2019). Indeed, excessive use of fertilizers contributes, among others, to eutrophication and water pollution or air pollution (Zhang *et al.*, 2015).

Basic fertilizers used on farms include nitrogen, potassium, and phosphate fertilizers (Kirilenko & Dronin, 2022). However, the Russian-Ukrainian crisis has caused turbulence in the fertilizer market. Liadze *et al.* (2022) indicate that fertilizer prices have increased by 30% since the beginning of the war in Ukraine. In turn, this contributes to an assessment of the profitability of their use and, consequently, their reduction or the search for alternative farming methods (Alexander *et al.*, 2022; Shahini *et al.*, 2022; Colussi *et al.*, 2022).

Different types of farms are characterized by different levels of incurring costs on means of production, including but not limited to fertilizers (Beckmann & Schimmelpfennig, 2015; Kubala, 2022). Nevertheless, some of them may be characterized by similar approaches to management and technology (Martinho *et al.*, 2022). What is lacking in previous work is an analysis of the relationship that exists between the type of farm production in the EU countries, the level of fertilizer purchase costs and the amount of the different types of chemical compounds used in mineral fertilizers. Therefore, the main aim of the study was to investigate the relationship between the production type of the EU farms and the level of fertilizer purchase costs and the amount of P2O5, K2O, and N applied in mineral fertilizers. Moreover, the results obtained are intended to show, how the production direction of the EU farms influences the costs incurred for the purchase of fertilizers and the amount of particular types of chemical compounds used in mineral fertilizers. The added value is to quantify these differences. The research is distinguished by the use of FADN data, which is a representative data collection system covering various types of European Union farms, as well as the use of ANOVA analysis.

Achieving the adopted goal was based on the formulation of the following research questions:

- Which production lines on farms are characterized by the highest and lowest costs of purchasing mineral fertilizers?
- Which production lines on farms are characterized by the highest and lowest amounts of particular types of chemical compounds in mineral fertilizers?
- Does the direction of production on European Union farms affect the level of the cost of purchasing mineral fertilizers?
- Does the direction of production on European Union farms affect the amount of particular types of chemical compounds used in mineral fertilizers?

The structure of the article comprises several parts. In the first part, I will present a literature search on fertilizer research. The next section will discuss the research methodology, both the research methods and the variables considered. Then, I will present the research results and discussion. The last part of the article will illustrate the final conclusions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Fertilization-related research is a relatively frequently undertaken topic and relates to both the supply and demand spheres. Therefore, the topics of research work in this area include the efficiency of fertilizer production, emissions of pollutants, the amount of fertilizer used by farms, or the amount of costs incurred on fertilizer.

Ladha *et al.* (2005) indicate that inorganic soil fertilization yields up to 50% higher compared to unfertilized crops, while De Ponti *et al.* (2012) highlight the greater efficiency of using inorganic fertilizers compared to natural fertilizers by 20-30%.

In contrast, Blanco (2011) and Hernandez and Torero (2013) emphasize the high degree of concentration of mineral fertilizer production, as well as the relatively large share of mineral fertilizer trade in international trade. Although mineral fertilizers are used worldwide, only a fraction of countries produce them. Consequently, other countries depend on imports of individual or all groups of fertilizers.

Van Grinsven *et al.* (2013) reached an interesting conclusion. In their study, they refer to environmental aspects and indicate that the European Union suffers between 35 EUR and up to 350 million EUR in losses per year due to nitrogen in fertilizers leaking into the environment. Zalewski (2008),

Zhang *et al.* (2015) and Rudinskaya and Náglová (2021) reached similar conclusions. They all claim that intensive crop production in European countries is largely associated with the supply of nitrogen in mineral form to the soil, which in turn negatively impacts the environment. At the same time, it is associated with a poorer quality of some agricultural products. This poses a major challenge, as there has been a significant increase in the use of nitrogen fertilizers in EU countries in recent years (Matyka, 2013; Ossowska, 2017). Important conclusions are reached by Czyżyk (2011), whose research focused on the analysis of on-farm mineral fertilizer consumption rates. He indicated that on many farms the level of mineral fertilization is too high and exceeds the values recommended for sustainable agriculture. Therefore, it is necessary to know which types of farms use the most mineral fertilizers.

The interesting findings were also presented by, among others, Piwowar (2013) describing selected issues concerning the problem of fertilization and the most important problems related to the implementation of the principles of sustainable fertilization in Poland, or Świtłyk (2022), who assessed the technical efficiency and productivity of mineral fertilization in Poland. In turn, Artyszak (2022) focused on aspects of changes in fertilization between 2006 and 2021. In his work, he indicated that fertilization is dominated by nitrogen, despite the fact that the vast majority of plant species take up more potassium. At the same time, Artyszak (2022) drew attention to the need to revise the main objectives of the Green Deal due to the situation in Europe caused by the war in Ukraine.

Noteworthy, the creation of initiatives to reduce the risks associated with fertilizers should start with an examination of the knowledge, attitudes, and behaviour of farms regarding the use of these production inputs (Koh & Jeyaratnam, 1996; Aldosari *et al.*, 2018). Nowadays, the European Union's internal policies, as well as the pursuit of the United Nations goals, oblige the countries belonging to the EU structures to act to reduce the negative environmental effects of mineral fertilizer use. This means that the decisions made will have a different impact on individual types of farm operations. The biggest changes will affect those farms that use the most mineral fertilizers. Managed policy is one of the decisive factors influencing changes in mineral fertilizer management in the Western European region (FAO, 2016). Others include the strong saturation of the region's food market (Mrówczyński, 2011), the drive to optimize fertilizer use or the increasing pressure to produce healthy food (Zalewski & Piwowar, 2018).

These empirical results allowed me to assume the following research hypotheses:

H1: The distribution of the value of the incurred cost of purchasing fertilizers by the European Union farms in each production direction of these farms is the same (the production direction of the European Union farms does not significantly affect the achieved value of the incurred cost of purchasing fertilizers by these farms).

H2: The distribution of the value of the amount of P2O5, K2O, N applied in mineral fertilizers by the EU farms in each production direction of these farms is the same (the production direction of the EU farms does not significantly affect the amount of P2O5, K2O, N applied in mineral fertilizers by these farms).

This topic is extremely important for several reasons. The costs incurred for the purchase of fertilizers are basic farm expenses, while the amount of chemical compounds used in mineral fertilizers contributes significantly to the environmental impact. The amount of costs and the quantity of fertilizers used are largely determined by the situation on world markets, as well as policy decisions. The increased interest in this topic is therefore extremely necessary at present due to the instability in the Central and Eastern European region, as well as the new European Union regulations on fertilizer products. The war in Ukraine is contributing to high fertilizer prices and restrictions on the use of fertilizers. Indeed, Russia is one of the largest producers of fertilizers in the world and the largest exporter. In turn, in addition to the clear advantages of sustainable agriculture and increased food quality, the Farm to Fork strategy also has disadvantages for the EU countries in terms of a decline in agricultural productivity, which in turn may contribute to higher food prices (Dobrin *et al.*, 2022). It is therefore reasonable to keep a constant eye on both the costs incurred on fertilizers and the amount of chemical compounds used in mineral fertilizers in the various farm production lines. This is all the more so because an accurate knowledge of the level of costs is necessary to actually determine the level of profitability of an organization (Samuelson &

Marks, 2006). The research carried out will make it possible to determine whether or not all production specializations are equally exposed to possible political and economic disadvantages.

RESEARCH METHODOLOGY

The study uses data from the FADN system. This makes it possible to select a representative sample according to the criterion of agricultural type, which determines the production specialization of farms (Goraj *et al.*, 2006). Conducted research based on such samples of farms allows us to formulate conclusions that will apply to the entire population of farms. Irz and Jansik (2015) as well as Kelly *et al.* (2018) emphasize the significant potential of the FADN database to provide answers to many important questions related to the agricultural sphere.

The undertaken studies focus on the purchase cost of fertilizers (€) and the amount of P2O5, K2O, and N applied in mineral fertilizers (q). In the FADN database, these variables are marked by the following symbols: SE295, SE296, SE297, SE298. All countries belonging to the structure of the European Union were taken into account in the research.

To illustrate the production direction of farms, I used data relating to the eight agricultural types distinguished in the FADN database. I distinguished the following farm types:

- Field crops (A);
- Horticulture (B);
- Wine (C);
- Other permanent crops (D);
- Milk (E);
- Other grazing livestock (F);
- Granivores (G);
- Mixed (H).

In the case of the cost of purchasing fertilizers, the study period covered the years 2005-2020. Due to limitations in the availability of statistical data, in the case of the quantities of individual chemical compounds used in mineral fertilizers, the study period covered the years 2014-2020.

One-way ANOVA variance was used to achieve the research objective. ANOVA resolves the existence of differences between averages in several populations (Rutherford, 2011; Aczel & Sounderpandian, 2018). ANOVA tests the hypothesis of equality of means, viz:

H0: $m_1 = m_2 = \ldots = m_k$

H1: $m_1 \neq m_j \; for \; certain \; l \neq j$

The ANOVA method has a number of assumptions (Stanisz, 2007):

1. The independence of the random variables in the populations (groups) under consideration.
2. Measurability of the analysed variables.
3. Normality of the distribution of the variables in each population (group).
4. Homogeneity of variance in all populations (groups).

I tested the assumption regarding the normality of the distribution of the variables in each population (group) using the Shapiro-Wilk test. As indicated by Ahad *et al.* (2011) and Prabhaker *et al.* (2019), this test has greater power to detect non-normality than other tests. To check whether there are grounds to reject the null hypothesis (data distribution follows a normal distribution), I used a p-value. If the p-value is lower than the assumed significance level of 5%, there are no grounds to reject the null hypothesis of normality of the distribution of the analysed characteristic.

I performed the test for homogeneity of variance across all populations (groups) using the Bartlett test. It focuses on comparing the weighted arithmetic mean of the variance with the weighted geometric mean of the variance. It is based on a statistic that has an asymptotic distribution χ^2. If at least one of the assumptions of the ANOVA model is not met, it is reasonable to use the non-parametric Kruskal-Wallis test (van Hecke, 2010). The interpretation of this test is similar to that of a parametric one-way ANOVA, except that this test speaks of equality of mean ranks rather than mean values.

RESULTS AND DISCUSSION

In the first stage of the research, I focused on analysing the basic statistics of the dependent variables (Table 1). In the case of the cost of purchasing fertilizers, the lowest level was characterized by farms of the type: other permanent crops, wine, and other grazing livestock. I observed the highest level of costs incurred in the type: field crops and horticulture, which results from the need for greater use of fertilizers in this type of crops. Smaller values were observed in farms oriented towards grain-eating animals, milk and the mixed type. Growing feed for livestock requires significant use of fertilizers and plant protection products.

Table 1. Basic data of dependent variables in individual groups

Dependent variable: Fertilisers (€)						
Types of agricultural enterprises	**Average**	**Median**	**Min**	**Max**	**Kurtosis**	**Skewness**
A	6964.38	7414.5	5026	7877	-0.86	-0.85
B	5794.62	5606.5	4245	7671	-0.92	0.32
C	1919.75	2009.0	1255	2547	-1.59	-0.06
D	1719.62	1700.5	1067	2401	-1.5	0.04
E	3728.00	3682.5	2469	4917	-0.9	0.06
F	1960.69	1946.5	1609	2323	-0.57	0.31
G	3728.81	4115.5	2232	4978	-1.56	-0.32
H	2777.81	2816.0	1839	3646	-0.79	0.02
Dependent variable: Fertiliser P205 (q)						
Types of agricultural enterprises	**Average**	**Median**	**Min**	**Max**	**Kurtosis**	**Skewness**
A	13.03	15.65	4.46	20.24	-2.13	-0.16
B	4.96	6.33	2.36	7.11	-2.14	-0.22
C	2.88	3.73	1.29	4.08	-2.12	-0.25
D	2.53	3.34	1.06	3.60	-2.18	-0.23
E	4.82	5.51	1.81	7.22	-2.10	-0.15
F	2.73	3.32	0.52	4.43	-2.06	-0.2
G	5.49	6.81	2.84	7.14	-1.91	-0.42
H	4.80	5.17	1.68	7.66	-2.11	-0.08
Dependent variable: Fertiliser K2O (q)						
Types of agricultural enterprises	**Average**	**Median**	**Min**	**Max**	**Kurtosis**	**Skewness**
A	15.24	17.11	5.62	23.12	-2.11	-0.13
B	8.42	10.33	4.07	11.51	-2.06	-0.27
C	3.35	4.44	1.49	4.85	-2.18	-0.22
D	3.27	4.21	1.26	4.83	-2.17	-0.20
E	6.66	7.14	2.61	9.92	-2.09	-0.10
F	3.54	4.18	0.75	5.70	-2.05	-0.20
G	8.00	10.00	3.91	10.96	-1.95	-0.37
H	6.30	6.41	2.38	9.93	-2.11	-0.03
Dependent variable: Fertiliser N (q)						
Types of agricultural enterprises	**Average**	**Median**	**Min**	**Max**	**Kurtosis**	**Skewness**
A	38.74	47.12	13.50	60.46	-2.11	-0.19
B	8.49	9.99	4.40	12.08	-2.10	-0.18
C	4.71	6.62	1.73	6.93	-2.18	-0.24
D	4.53	6.00	1.88	6.73	-2.18	-0.21
E	24.64	27.98	9.46	36.46	-2.09	-0.16
F	10.59	13.29	2.70	17.73	-1.98	-0.23
G	22.64	30.32	8.89	31.88	-2.03	-0.33
H	17.97	20.83	5.78	27.97	-2.10	-0.15

Source: own study.

In the case of the volume of use of individual types of chemical compounds in mineral fertilizers by the EU farms, I observed similar relationships. Both the share of P2O5, K2O, and N in mineral fertilizers is highest on farms of field crops type. Farms targeting granivores, horticulture, and milk follow this sequence for P2O5. For K2O, farms focusing on horticulture, granivores, and milk adhere to this order. In the case of N, farms specializing in milk, granivores, and mixed types follow this pattern. We can observe the smallest magnitudes in farms oriented towards wine, other permanent crops, and other grazing livestock.

Moreover, I created box plots were created (Figure 1).

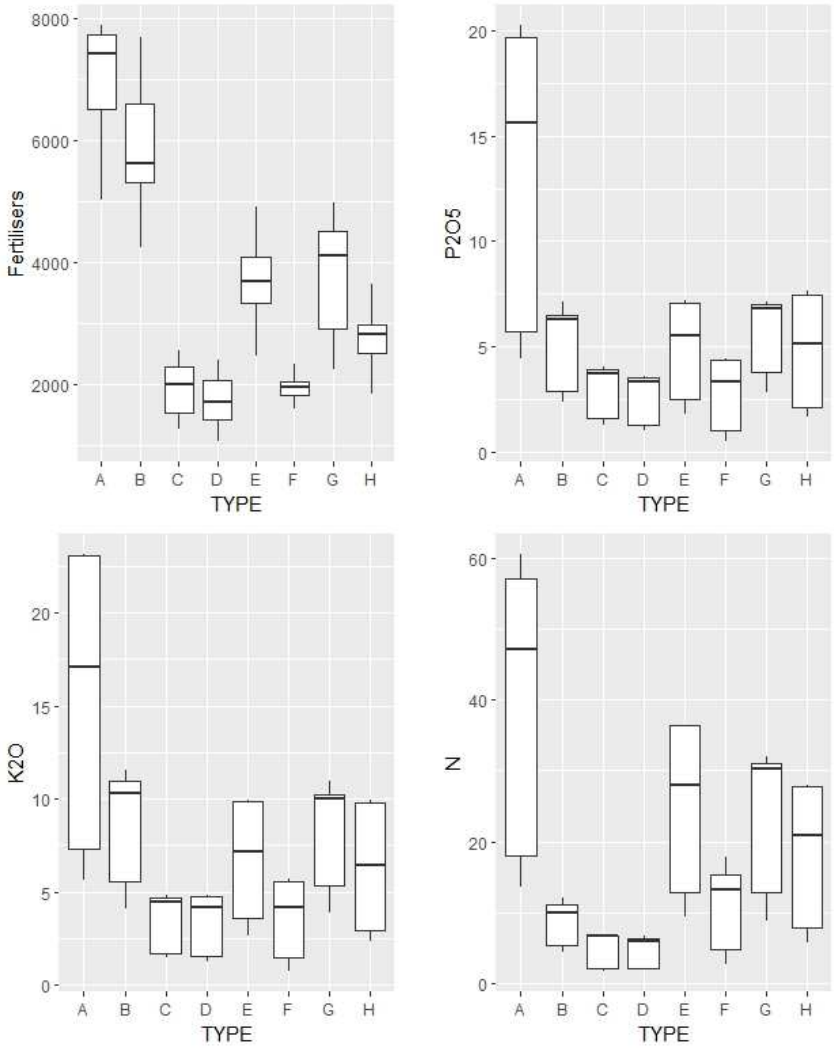

Figure 1. Box plots showing the relationship between the direction of production of the EU farms, the value of the incurred cost of purchasing fertilizers and the amount of each type of chemical compound used in mineral fertilizers by these farms

Source: own elaboration.

In the next step, I checked the normality of the variables' distribution. I included the results of the Shapiro-Wilk test in Table 2. The conducted tests indicate that there is a p-value of less than 5%, which means that there is no normal distribution in each of the groups.

I verified the homogeneity of variance using the Bartlett test. Table 3 presents the results. The test allowed me to conclude that there was no homogeneity of variance in any of the groups considered. This was evidenced by the p-value values as each was less than 5%.

Table 2. Results of the Shapiro-Wilk test

Types of agricultural enterprises	Dependent variable: Fertilisers (€)		Dependent variable: Fertiliser P205 (q)		Dependent variable: Fertiliser K2O (q)		Dependent variable: Fertiliser N (q)	
	W	p-value	W	p-value	W	p-value	W	p-value
A	0.811	0.004	0.796	0.037	0.801	0.042	0.815	0.058
B	0.945	0.416	0.794	0.036	0.816	0.059	0.841	0.101
C	0.926	0.210	0.779	0.025	0.747	0.012	0.729	0.008
D	0.940	0.350	0.743	0.011	0.751	0.013	0.748	0.012
E	0.971	0.852	0.816	0.059	0.822	0.067	0.810	0.052
F	0.965	0.750	0.815	0.057	0.826	0.073	0.864	0.165
G	0.901	0.082	0.771	0.021	0.809	0.050	0.768	0.019
H	0.974	0.900	0.812	0.054	0.810	0.052	0.804	0.045

Source: own study.

Table 3. Bartlett test results

Dependent variable: Fertilisers (€)	
K-squared	p-value
51.835	6.293e-09
Dependent variable: Fertiliser P205 (q)	
K-squared	p-value
33.488	2.147e-05
Dependent variable: Fertiliser K2O (q)	
K-squared	p-value
24.798	0.000824
Dependent variable: Fertiliser N (q)	
K-squared	p-value
42.718	3.781e-07

Source: own study.

The Shapiro-Wilk and Bartlett tests indicated that the assumptions of ANOVA tests were not met for each dependent variable. Therefore, it was reasonable to apply the non-parametric Kruskalla-Wallis test in further considerations (Table 4). Its purpose in the research was to determine the relationship between the direction of production of the European Union farms and the adopted dependent variables.

Table 4. Results of the Kruskal-Wallis rank ANOVA test

Dependent variable: Fertilisers (€)	
Chi-squared	p-value
109.030	< 2.2e-16
Dependent variable: Fertiliser P205 (q)	
Chi-squared	p-value
20.476	0.004629
Dependent variable: Fertiliser K2O (q)	
Chi-squared	p-value
24.661	0.0008714
Dependent variable: Fertiliser N (q)	
Chi-squared	p-value
32.786	2.902e-05

Source: own study.

The obtained values indicated – at the assumed significance level of 5% – that the individual hypotheses, which indicate that the distribution of the value of the incurred cost of purchasing fer-

tilizers/amounts of P2O5, K2O, and N applied in mineral fertilizers by the European Union farms in each production direction of these farms is the same, should be rejected in favour of the alternative hypothesis, according to which at least two production directions differ in terms of the value of the incurred cost of purchasing fertilizers/amounts of P2O5, K2O, and N applied in mineral fertilizers by these farms from the others. This means that the production directions of farms in EU countries significantly differentiate the level of dependent variables adopted for the study.

To determine the reasons for the significant differentiation of the direction of production of farms in the European Union and the values of individual variables, I used a multiple comparison test (Table 5).

Table 5. Dunn test results with Bonferroni correction

Types of agricultural enterprises	Dependent variable: Fertilisers (€)						
	A	**B**	**C**	**D**	**E**	**F**	**G**
B	1.000	-	-	-	-	-	-
C	0.000*	0.000*	-	-	-	-	-
D	0.000*	0.000*	1.000	-	-	-	-
E	0.048	0.459	0.002*	0.000*	-	-	-
F	0.000*	0.000*	1.000	1.000	0.002*	-	-
G	0.033	0.339	0.003*	0.000*	1.000	0.003*	-
H	0.001*	0.004*	0.274	0.062	1.000	0.274	1.000
Types of agricultural enterprises	**Dependent variable: Fertiliser P205 (q)**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
B	0.864	-	-	-	-	-	-
C	0.021*	1.000	-	-	-	-	-
D	0.005*	1.000	1.000	-	-	-	-
E	1.000	1.000	1.000	0.965	-	-	-
F	0.013*	1.000	1.000	1.000	1.000	-	-
G	1.000	1.000	0.833	0.292	1.000	0.602	-
H	1.000	1.000	1.000	0.818	1.000	1.000	1.000
Types of agricultural enterprises	**Dependent variable: Fertiliser K2O (q)**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
B	1.000	-	-	-	-	-	-
C	0.008*	0.089	-	-	-	-	-
D	0.008*	0.085	1.000	-	-	-	-
E	0.730	1.000	1.000	1.000	-	-	-
F	0.016*	0.152	1.000	1.000	1.000	-	-
G	1.000	1.000	0.245	0.234	1.000	0.393	-
H	0.567	1.000	1.000	1.000	1.000	1.000	1.000
Types of agricultural enterprises	**Dependent variable: Fertiliser N (q)**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
B	0.047	-	-	-	-	-	-
C	0.001*	1.000	-	-	-	-	-
D	0.001*	1.000	1.000	-	-	-	-
E	1.000	0.312	0.015*	0.007*	-	-	-
F	0.224	1.000	1.000	1.000	1.000	-	-
G	1.000	0.503	0.029	0.015*	1.000	1.000	-
H	1.000	1.000	0.402	0.240	1.000	1.000	1.000

Note: * - statistically significant differences.
Source: own study.

The obtained results indicated that significant differences in the amount of costs incurred for fertilizers occur for farms oriented towards field crops with farms of the types: wine, other permanent crops, other grazing livestock, mixed, horticulture type with wine, other permanent crops, other graz-

ing livestock, mixed, milk type with wine, other permanent crops and other grazing livestock and granivores type with wine, other permanent crops and other grazing livestock. On the other hand, in the case of the volume of application of individual types of chemical compounds in mineral fertilizers, significant differences are observed in the case of P2O5 and K2O application by farms specializing in field crops with the type wine, other permanent crops and other grazing livestock. In the case of N application, significant differences are observable between the type of field crops and wine, other permanent crops, the type of milk and the type of wine, other permanent crops and between the type of granivores and other permanent crops.

The results obtained are consistent with the studies by Beckmann and Schimmelpfennig (2015), who indicate that a farm type and location have a significant impact on the level of costs incurred, as well as Martinho *et al.* (2022), emphasizing that certain farm types are characterized by similar approaches to management and technology and therefore also by similar levels of incurred costs for fertilizers. Moreover, the obtained results also allowed me to confirm the achievements of Gerrard *et al.* (2012), who found that English horticulture farms incurred the highest cost on fertilizer purchases, and Dabkiene *et al.* (2021) who indicated that the highest level of inorganic fertilizer consumption is found on farms oriented towards field and horticulture, while the lowest level is found on farms specializing in grazing livestock and mixed farms. It is also worth referring to the research of Ribaudo (2011), who presents that certain crop species can consume a higher amount of fertilizers. These should primarily include maize, oilseed rape, and wheat. Similarly, Grzelak and Kryszak (2023) note that fertilizer use is particularly high for field crops.

CONCLUSIONS

The conducted analysis revealed that we may observe the highest level of fertilizer purchase in the case of farms focused on field crops, horticulture, milk and granivores. On the other hand, I observed the highest level of application of P2O5, K2O, N in mineral fertilizers in farms oriented towards field crops.

I verified negatively the hypotheses stating that the distribution of the value of the incurred cost of purchasing fertilizers by the EU farms in each production direction of these farms is the same (H1) and that the distribution of the value of the amount of P2O5, K2O, N applied in mineral fertilizers by the EU farms in each production direction of these farms is the same (H2).

I found the most frequent differences in the case of fertilizer between crop and livestock farm types. Fewer differences can be observed in the case of farms that target the same food source (especially for farms associated with livestock production).

In the case of the amount of chemical compounds used in mineral fertilizers, I observed identical differences for P2O5 and K2O. The main differences were between farms targeting field crops with the type: wine, other permanent crops, and other grazing livestock. In the case of N, the main differences are linked to the farms of the type: field crops, milk and granivores, *i.e.* the types with the highest average consumption of this chemical compound during the period studied.

On the one hand, the observable differences result from the different specifications of crop and livestock production and, on the other hand, from the amount of costs incurred on fertilizers and the degree of consumption of particular types of chemical compounds in mineral fertilizers. It turns out that those farm types characterized by the highest level of costs on fertilizers and the degree of consumption of individual types of chemical compounds in mineral fertilizers have the most significant differences.

The research unequivocally shows that the production direction of farms in the European Union countries significantly influences the differentiation both in the case of incurred costs of purchasing fertilizers and the amount of particular chemical compounds used in mineral fertilizers. The research results show which production specializations are similarly exposed to possible adverse political and economic phenomena. The achieved results are important primarily for state authorities, which, when deciding to limit the use of fertilizers, should also propose other forms of support for individual types of farms. Therefore, I recommend a further analysis of the undertaken topic. In particular, it is advisable to analyse the opportunities and threats to the use of mineral fertilizers by individual farm orientations in the face of significant political and economic changes.

It is important to remember the limitations of the conducted research. A longer time series may indicate other relationships between the studied variables. Moreover, research conducted for individual countries may give different results, which is important due to the agricultural policy pursued at the national level. Therefore, it is recommended that further work should focus on analysing this topic within individual countries. At the same time, it is justified to indicate the main determinants causing the existing differentiation.

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Author

Sebastian Kubala
Assistant Professor at the Department of Organization Development at the Krakow University of Economics (Poland). His research interests include agribusiness, in particular research related to land economy, prices on food markets and agricultural policy of the European Union.
Correspondence to: Sebastian Kubala, PhD, Department of Organization Development, Krakow University of Economics, Rakowicka 27, 31-510 Krakow, Poland, e-mail: kubalas@uek.krakow.pl
ORCID http://orcid.org/0000-0003-4021-9173

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A study of zero-waste behaviour in Polish consumers of cosmetic and personal care products

Iwona Zdonek, Beata Hysa, Dariusz Zdonek

ABSTRACT

Objective: The objective of the article is to identify factors affecting zero-waste intentions and behaviour among consumers of cosmetic and personal care products in Poland.

Research Design & Methods: The research model framework was the theory of planned behaviour (TPB). In February and March 2022 in Poland, we surveyed 344 consumers. We analysed the results with structural equation modelling (SEM). We posited six research hypotheses. We confirmed four of them and falsified two.

Findings: The results showed that both attitudes and perceived behavioural control had a positive impact on zero-waste behavioural intentions regarding cosmetics and personal care products in Poland. On the other hand, the intentions were not affected by subjective norms or awareness of consequences. Regarding zero-waste behaviour, it is significantly determined by intentions and perceived behavioural control.

Implications & Recommendations: The article proposes recommendations for improving the acceptance of zero-waste-inspired innovation.

Contribution & Value Added: The article fills the research gap regarding the impact of zero waste on the implementation of the circular economy. The TPB model has been expanded with an additional construct awareness of consequences. Moreover, the study identifies factors that affect zero-waste intentions and behaviour in the cosmetics industry in Poland.

Article type:	research article
Keywords:	circular economy; sustainable cosmetics; zero-waste behaviour; theory of planned behaviour; structural equation modelling
JEL codes:	D45, D9, D91

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INTRODUCTION

Innovations that support sustainable development are increasingly in demand (Javeed *et al.*, 2022; Nawrocki & Jonek-Kowalska, 2022). This trend is driven by dwindling resources and the climate crisis on the one hand and the growing population, leading to an even greater demand for resources on the other hand. Regrettably, the current economic model is linear. It collects resources, processes them, and disposes of them when they are no longer needed. An average household is estimated to dispose of paper equivalent to six trees, about 500 metal cans, 50 kg of glass, 35 kg of various metals, and 50 kg of plastics a year (Wojciechowski, 2019). According to Chawla *et al.* (2022), approximately 92% of the global industry follows a linear pattern (Chawla *et al.*, 2022).

The circular economy (CE) can be a way to put a stop to wasting valuable resources. Ellen MacArthur Foundation (2022) defined three principles of the circular economy: elimination of waste and pollution, circulation of products and materials, and regeneration of nature (Ellen MacArthur Foundation, 2022). This approach focuses on the sustainable management of resources, in which materials

are reused, shared, repaired, refurbished, regenerated, and recycled to form a closed circuit and minimise the consumption of natural resources (Khajuria *et al.*, 2022). Moreover, Murray *et al.* (2017) demonstrated that the circular economy is an economy model where planning, procurement, production, and reprocessing are designed and managed as both a process and a product (Murray *et al.*, 2017). The goal is to maximise the functioning of the ecosystem and the well-being of people.

The circular economy and effective waste management in particular are key aspects of the smart city concept (Jonek-Kowalska, 2022). Naturally, a successful conversion into the circular economy requires a systemic change in how goods are designed and manufactured. This entails a transformation of the entire supply and value chain and the involvement of multiple stakeholders and sectors of the economy in the circular production and consumption paradigm. The great importance has also been consumer perception, behaviour, and attitudes towards sustainable consumption (Pilch & Miśniakiewicz, 2022). Hence, changes are inevitable in all sectors of the economy, including the cosmetics industry. This branch of industry meaningfully affects the environment at the production and consumption stages. Cosmetic products are emitted into water ecosystems, where their environmental impact is related to bioactivity, toxicity, and bioaccumulation potential (Gao *et al.*, 2018). This is because the current conventional waste processing system has not been designed to handle pollution from cosmetic products. The structural complexity of these pollutions and their low concentrations make them undetectable, and hence difficult to remove with the current wastewater treatment methods. All this is further exacerbated by their reputation as a serious environmental threat (Patel *et al.*, 2020). In light of the above, changes in the cosmetics industry should focus on the production using more environmentally-friendly ingredients, removal of cosmetic substances from wastewater, and replacement of artificial packaging with a greener one (Rocca *et al.*, 2022).

Various concepts are promoted to facilitate the transformation into a circular economy (Borusiak *et al.*, 2021; Nowicki *et al.*, 2023). One of them is zero waste. It is perceived as an innovative and visionary approach to waste management (Zaman & Ahsan, 2019). Zero waste has become part of the sustainable development programmes of many communities, organisations, and cities. The traditional waste management system often destroys the product and its material value, because it focuses on the safe disposal of waste. On the contrary, zero waste strives to preserve the product and resource value by promoting such solutions as reduction, reuse, repair, and recycling (Zaman & Newman, 2021). This way, it implements the principles of the circular economy. Zero waste counters the disposability prevalent in the linear economy and thus opens the way for the marketing of innovative products and solutions. Some examples of zero waste in practice are the sale of refurbished electronics, second-hand clothes, upcycled clothing, water filters to replace bottled water, household compost bins to reduce biodegradable waste in landfills, etc. Therefore, zero waste induces new market behaviour in communities, generating potential business opportunities. The effect is boosted by zero-waste communities' tendency to form associations, hold flea markets, or other occasions to swap things people no longer need. They also educate each other on what is and what is not environmentally friendly. Thus, zero waste is an opportunity for many new business models and initiates a specific type of innovation, open innovation. These innovations are based on the exchange of knowledge and collaboration to obtain solutions to limit waste generation at resource sourcing, production, product distribution, use, and disposal.

According to Fortunati *et al.* (2020), cosmetic businesses also strive to protect the environment and biodiversity through such efforts as the commitment to reduce CO2 emissions, waste, and water and/or plastic consumption (Fortunati *et al.*, 2020). The organisations declare further that their future goal is to improve the share of natural or organic resources to 80%-100%. They also believe that the reduction of the volume, weight, packaging, and materials used in products can be an important step towards environmental protection. Therefore, they are involved in sourcing reusable containers and using recycled materials (Fortunati *et al.*, 2020). Studies by Diaczek and Gardula (2019) and Firek and Dziadkowiec (2020) on the Polish cosmetics market also identified good practices regarding environmental-friendly solutions and methods for inspiring consumers to recover used packaging (Diaczek & Garduła, 2019; Firek & Dziadkowiec, 2020). The examples above show that the cosmetics industry strives to propose a more sustainable cosmetic product by changing production, packing, and waste disposal. Rocca *et al.* (2022) and Suphasomboon and Vassanadumrongdee (2022) concluded that a

growing demand for sustainable products is one of the drivers of this effort (Rocca *et al.*, 2022; Suphasomboon & Vassanadumrongdee, 2022).

Many researchers (Askadilla & Krisjanti, 2017; Ghazali *et al.*, 2017; Sheehan, 2013; Yeon Kim & Chung, 2011) stressed that motivation to purchase sustainable products depends on attitudes, values, and sociocultural factors. The natural cosmetics market is growing dynamically in Poland. The compound annual growth rate (CAGR) for the natural cosmetics market is forecast to exceed 10% from 2021 to 2026 (Industry Report, 2021). Such strong market growth opens ample opportunities. Nevertheless, there is still a need for multifaceted research in this specific cosmetics and care product sector in Poland, especially in the context of the circular economy. For example, there is virtually no research on what drives consumers to buy natural cosmetic products in Poland. We noted a particular gap regarding the impact of zero waste on the motivation to purchase sustainable cosmetic products.

Therefore, considering the above, we aimed to identify factors affecting zero-waste intentions and behaviour among consumers of cosmetic and personal care products in Poland. We pose the following research question:

Research Question: What factors affect zero-waste intentions and behaviour regarding cosmetics and personal care products in Poland?

The novelty of the article is founded on the following:

1. It fills the research gap regarding the impact of zero waste on the implementation of the circular economy. Similar studies have been conducted in foreign literature (Zaman & Ahsan, 2019; Zaman & Newman, 2021)
2. It identifies factors that affect zero-waste intentions and behaviour in the cosmetics industry in Poland. This will be an extension of research into intentions to buy green cosmetics conducted by researchers such as Askadilla and Krisjanti (2017), Chin *et al.* (2018), Fatoki (2020), and Hsu *et al.* (2017).
3. It proposes recommendations for improving the acceptance of zero-waste-inspired innovation. Our recommendation can strengthen efforts to build environmentally friendly attitudes in organisations, including the promotion of the Zero Waste concept in Poland. As it happens on the international stage (Askadilla & Krisjanti, 2017; Bilal *et al.*, 2020; Fortunati *et al.*, 2020).

The main means for answering the research question and achieving the aim was a quantitative survey of 344 people conducted in February and March 2022 in Poland. The theoretical background was the theory of planned behaviour (TPB). The data were analysed with structural equation modelling.

The article is structured as follows. Section two discusses zero waste as an external source of innovation opportunities and presents natural cosmetics as an innovation to foster sustainable development. We then present the development of the research hypotheses using TPB. Section three introduces the research method. Results and discussion are recorded in section four. There are then conclusions in section five together with theoretical and practical implications, limitations and further research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Zero Waste as an External Source of Innovation Opportunities

Innovation can be a product, process, service, or method that should satisfy the needs of its users and improve business competitiveness. Taking the environmental aspect into consideration, one can discuss innovation for sustainable development or, in broader terms, eco-innovation. Innovation for sustainable development is the commercialisation of a new product or service, a system of product services, or a pure service that yields environmental, social, or economic benefits (Charina *et al.*, 2022; Love & Roper, 2015; Pichlak & Szromek, 2021). The majority of definitions of eco-innovation emphasize that the implementation of new solutions takes into account curbing negative environmental impact. Note that literature on eco-innovation has yet to work out a unified terminology. Most researchers use environmental innovations, green innovations, sustainable innovations, or innovations for sustainable development as equivalents of eco-innovations (Cecere *et al.*, 2014; Forsman *et al.*, 2013; Javeed *et al.*, 2022). Pichlak and Szromek (2021) consider eco-innovation to be a new solution in a business that leads to removing or limiting adverse environmental impact (Pichlak & Szromek, 2021). Note here

that what is commonplace for one organisation at a given point in time and space may be an innovation in another business (Carrillo-Hermosilla *et al.*, 2010).

We may also perceive eco-innovation as the creation of new knowledge and combination of the existing knowledge in a novel way. In this context, knowledge used to generate eco-innovation can be created inside the organisation or come from its environment. This approach is consistent with the open innovation concept considered a critical paradigm in innovation management (Pichlak & Szromek, 2021). Open innovation is a holistic approach to innovation management by 'systematically encouraging and exploring a wide range of internal and external sources for innovation opportunities, consciously integrating that exploration with firm capabilities and resources, and broadly exploiting those opportunities through multiple channels' (West & Gallagher, 2006). The open innovation process consists of three subprocesses: outside-in, inside-out, and mixed processes. Each type requires different stakeholders (Cecere *et al.*, 2014; Charina *et al.*, 2022). Doran and Ryan (2016) indicated that access to knowledge and information from the market was particularly important in generating and implementing eco-innovations. Therefore, broad collaboration and interactions with customers and suppliers, research institutes, universities, and other businesses are very important (Doran & Ryan, 2016).

Hence, we may consider eco-innovations an important tool for sustainable development, and zero waste can be a significant external source of innovation opportunities, leading to a new business model open to innovations. Many cosmetics and personal care businesses have already implemented new business models founded on zero waste. Fortunati and colleagues investigated cosmetics companies in the context of this concept (L'Orèal Group, Clarins Group, Guerlain Group, Shisei-do Group, Lush Group, Yves Rocher Group, Pierre Fabre Group, and Chanel Group) (Fortunati *et al.*, 2020). Their results demonstrated that international corporations perceived the design phase as crucial and that eco-design, that is the use of sustainable materials in production, was already popular. Research by Diaczek and Gardula (2019) and Firek and Dziadkowiec (2020) on the Polish market also shows interest in zero waste (Diaczek & Garduła, 2019; Firek & Dziadkowiec, 2020). For instance, Lush Botanicals offers discounts for sending back five used product bottles or a new product of the customer's choice for ten bottles. Yope allowed its customers to refill plastic bottles with cosmetics at refilling stations. Therefore, one of the leading focal areas for the cosmetics industry is to replace the existing packaging materials with sustainable alternatives and raise customer awareness of packaging recycling and reuse.

Natural Cosmetics as an Innovation to Foster Sustainable Development

Cosmetics consumers and their everchanging expectations drive the need for new, better ingredients that are safer for people and the environment (Chin *et al.*, 2018; Ghazali *et al.*, 2017). Various research and development programmes cover all possible aspects of the industry: consumer behaviour and cosmetics aspirations, the biology of the skin, hair, teeth, and oral cavity, and new innovative technologies and improved models of sustainable development. Innovations follow various directions in the cosmetics industry. Some researchers create new products with traditional materials (such as ginseng). Others use molecular-level materials (nanotechnologies) to invent a completely new generation of ingredients. Some examples include stem-cell research to help in skincare at the molecular level by protecting the DNA or oral cavity hygiene research to find a new generation of products against plaque (Cosmetics Europe, 2022). Cosmetics industry innovations are all but short-lived because it may take over five years of innovative research and recipes to market a new product. The European cosmetics and personal care industry is a leader in the sector. It provides about 28 800 jobs for researchers representing diversified fields, like physics, microbiology, biology, dermatology, oral medicine, toxicology, rheology, analytical chemistry, or genetics. There are at least 77 innovative research centres in Europe investigating cosmetics (Cosmetics Europe, 2022).

The growing consumer environmental awareness pushes a business towards innovation and promotion of green cosmetics, also referred to as natural or organic cosmetics (Limbu *et al*., 2022). Such cosmetics are free of chemicals or non-natural admixtures and additions. Their ingredients are natural and fruit-derived. Moreover, their objective is to protect the environment and animal well-being. Therefore, they are made with no pesticides, synthetic chemicals, or tests on animals (Shimul *et al.*, 2022). Green cosmetics cover a broad array of personal care products, such as environmentally-friendly creams, make-

up, and beauty products. The demand for green cosmetics has been growing worldwide. The global green cosmetics market was estimated at USD 34.5 billion in 2018 and is expected to reach USD 54.5 billion by 2027 at a compound annual growth rate of 5.2% from 2018 to 2027 (Statista, 2020).

Determinants of Acceptance of Zero-Waste-Inspired Innovation in the Cosmetics Industry in the Framework of the Theory of Planned Behaviour

The theory of planned behaviour (TPB) is based on the theory of reasoned action (TRA) (Ajzen & Fishbein, 1977; Ajzen & Fishbein, 1980). It helps better understand relationships among attitudes, intentions, and behaviour and defines the impact of an individual's subjective norms and attitudes on the intention. The TPB adds one more factor, perceived behavioural control (Ajzen, 1991a; Ajzen & Driver, 1991), affecting intentions and behaviour. The TPB is successfully employed in environment management (Fielding *et al.*, 2005; Grilli & Notaro, 2019; Wach & Wojciechowski, 2016). It is a well-founded theory applicable to accounting for ethical and environmentally motivated behaviour among consumers (Han & Stoel, 2017; Han, 2020; Onwezen *et al.*, 2013; Han, 2021). It is applied to behaviour connected with recycling (Aguilar-Luzón *et al.*, 2012; Chan & Bishop, 2013; Khan *et al.*, 2019), green shopping (Arvola *et al.*, 2008; Albayrak *et al.*, 2013), water and energy conservation, public transport, and avoidance of disposable products (Untaru *et al.*, 2016; Paiano *et al.*, 2020; Moon, 2021).

Although the TPB is generally believed to be an effective tool for behavioural studies, some researchers do mention its limitations. One of them is that it fails to ensure sufficient accuracy in predicting intentions and behaviour (Ogden, 2003). Some research with the TPB demonstrated no influence or very low influence of the disposition or subjective norms on intention and behaviour. Nevertheless, Ajzen and Fishbein (2004) explained that the predictive value of the three main predictors may differ depending on the type of behaviour and population (Ajzen & Fishbein, 2004). Moreover, the model can be expanded with other predictors if they improve the model's predictive power, considering the current variables of the theory (Ajzen, 1991b; Han & Stoel, 2017).

The central concept of the TPB is a behavioural intention, the intention to perform a certain behaviour. It is a strong predictor of actual behaviour. In TPB, the behavioural intention defines the motivation to perform a given behaviour with three conceptually independent factors: attitudes, subjective norms, and perceived behavioural control related to the specific behaviour (Ajzen, 1991a; Ajzen & Driver, 1991; Ajzen & Fishbein, 1977).

Perceived behavioural control affects both the intentions and the actual behaviour. The first construct determining behavioural intention is attitude. It is defined as the disposition and belief about a behaviour (Ajzen, 1991a). In the context of zero-waste behaviour, it will be beliefs and dispositions towards such behaviour. According to recycling researchers (Botetzagias *et al.*, 2015; Chu & Chiu, 2003), attitude is a significant predictor of behavioural intention concerning recycling. Moreover, research by Askadilla and Krisjanti (2017), Chin *et al.* (2018), Fatoki (2020), Hsu *et al.* (2017), Yeon Kim and Chung (2011) demonstrated that attitude is the key factor in intentions to purchase green cosmetics (Askadilla & Krisjanti, 2017; Chin *et al.,* 2018; Fatoki, 2020; Hsu *et al.*, 2017; Yeon Kim & Chung, 2011). Therefore, we may expect attitude to have a significant effect on zero-waste behaviour (ZWB) in general, including in the context of cosmetics and personal care products.

According to Arvola *et al.* (2008), attitude covers cognitive and emotional components. Therefore, the zero-waste attitude will be determined by the knowledge of this behaviour and emotions towards it (Arvola *et al.*, 2008). Hence, attitudes towards ZWB regarding cosmetics and personal care products will hinge on the individual's knowledge of the benefits of this behaviour, that is health, environmental, and economic benefits, and emotions regarding the behaviour. The attitudes can be positive or negative. The individual may perceive ZWB positively or, on the contrary, as a tool for greenwashing. This is the foundation for the first research hypothesis:

H1: Attitudes towards zero waste significantly affect zero-waste behaviour intentions regarding cosmetics and personal care products.

Considering that the TPB can be expanded with additional constructs, we decided to use 'awareness of consequences' as an additional determinant of behavioural intention following the example

of (Khan *et al.*, 2019). It is important for investigating human behaviour according to Schwartz's altruistic behaviour model (Schwartz, 1977). People more readily exhibit behaviour that brings better results. According to Bianchi and Birtwistle (2012), people who care about the environment tend towards more environmentally friendly behaviour and exhibit behaviour that does not harm the environment (Bianchi & Birtwistle, 2012). The awareness of the consequences of ZWB will be connected to the prevention of the effects of excessive consumerism and the health, environmental, and economic benefits of that prevention. This leads to the second hypothesis:

H2: The awareness of the consequences of zero-waste activities significantly affects zero waste-behaviour intentions regarding cosmetics and personal care products.

Another construct to determine behavioural intention is subjective norms. It is defined as the social pressure perceived by the individual when performing a behaviour (Ajzen, 1991a). The pressure comes from family and friends. The individual leans towards behaviour preferred by their closest circle. Many recycling researchers believe subjective norms to be an important behaviour predictor (Chen & Tung, 2010; Wan *et al.*, 2014). Moreover, research by Hsu *et al.* (2017) on green skin-care products also demonstrated that subjective norms are an important factor in accounting for intentions to purchase green cosmetics (Hsu *et al.*, 2017). It can be assumed to be a significant predictor for zero-waste behaviour related to cosmetics.

However, some authors (Fatoki, 2020; Suphasomboon & Vassanadumrongdee, 2022) demonstrated that subjective norms may not be a significant predictor of intentions to purchase green cosmetics. Thus, we hypothesised further to investigate the issue:

H3: Subjective norms significantly affect zero-waste behaviour intentions regarding cosmetics and personal care products.

The next construct that determines behavioural intention under the TPB is perceived behavioural control. It is the degree of control the individual has over their behaviour. Research by Hsu *et al.* (2017) lists perceived behavioural control as a significant predictor of intentions to purchase green products (Hsu *et al.*, 2017). Oom Do Valle *et al.* (2005) determined that the degree of control depends on external and internal conditions (Oom Do Valle *et al*., 2005). External conditions are defined as the ease and convenience of performing a behaviour. External conditions refer to the individual's perceived abilities, including their understanding and familiarity with the behaviour. Therefore, perceived behavioural control hinges on the capabilities and resources available to the individual and their sense of effectiveness. Hence, the decision regarding a behaviour depends on the associated ease and difficulties (Ajzen, 1985). Considering that perceived behavioural control determines both intentions and actual behaviour, we posed the fourth and fifth research hypotheses:

H4: Perceived behavioural control significantly affects zero-waste behaviour intentions regarding cosmetics and personal care products.

H5: Perceived behavioural control significantly affects zero-waste behaviour regarding cosmetics and personal care products.

As mentioned above, behavioural intention is a strong predictor of actual behaviour (Ajzen, 1991a; Ajzen & Driver, 1991; Ajzen & Fishbein, 1977). The greater the intention to engage in a behaviour, the greater the probability of performing it. Consequently, an intention regarding a specific behaviour is a reliable predictor of whether or not it will be performed. In the case of zero-waste behaviour, a greater intention of a consumer to perform a zero-waste behaviour is expected to result in a greater chance of the behaviour. This led us to the sixth research hypothesis:

H6: Zero-waste behaviour intentions concerning cosmetics and personal care products significantly affect zero-waste behaviour.

RESEARCH METHODOLOGY

Research Model

The analyses employed structural equation modelling (SEM). The SEM involved a series of such tests as factor, discriminant, and regression analyses to investigate the dependencies among the constructs defined herein. They are shown in Figure 1. Such constructs as attitudes, awareness of consequences, subjective norms, and perceived behavioural control account for the construct of zero-waste behaviour intention. Consequently, zero-waste behaviour intention and perceived behavioural control are predictors for zero-waste behaviour. The specific type of SEM used here is PLS-SEM, which is SEM based on variance. We used SmartPLS for this purpose.

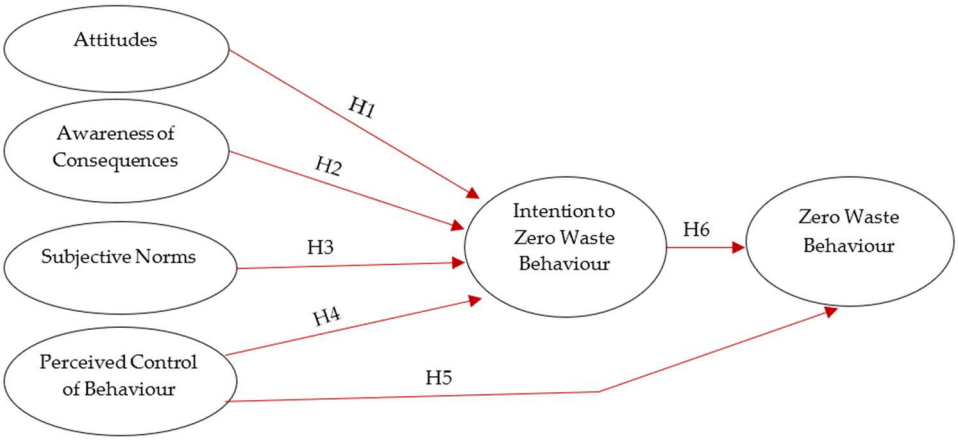

Figure 1. Research model for determining the factors of zero-waste behaviour among Polish consumers of cosmetics and care products

Source: own elaboration.

Research Process

The analyses were divided into two stages (Figure 2). Firstly, we built and verified the measurement model (outer model) and then the structural model (inner model) (Hair Jr *et al.*, 2014; Hair, 2014; Hair *et al.*, 2019; Hair *et al.*, 2011; Ramli *et al.*, 2019).

The measurement model (outer model) encompassed variables and constructs. We built it by assigning variables measured in the survey to the constructs identified in the literature search. We verified the model with reliability and validity tests for each construct. We calculated factor loadings for variables constituting each construct. We assumed that factor loadings should be greater than 0.5. The internal consistency of the constructs was investigated with Cronbach's alpha and composite reliability (CR). Both should exceed the cut-off value of 0.7. The convergent validity was measured with the average variance extracted (AVE). The AVE should exceed the cut-off value of 0.5. We measured the discriminant validity with the Fornell-Larcker criterion and the Heterotrait-Monotrait Ratio (HTMT).

We built the inner model by calculating path coefficients (β) for constructs that are predictors. The coefficients' significance was verified with t-test statistics and p-values. The significance level was set at $\alpha = 0.05$. We computed R^2, Q^2, and f^2 for the model. R^2 specifies the variance of the endogenous variable accounted for by predictors. Q^2 specifies the predictive power of the model. Finally, f^2 specifies the effect of predictors on the endogenous variable.

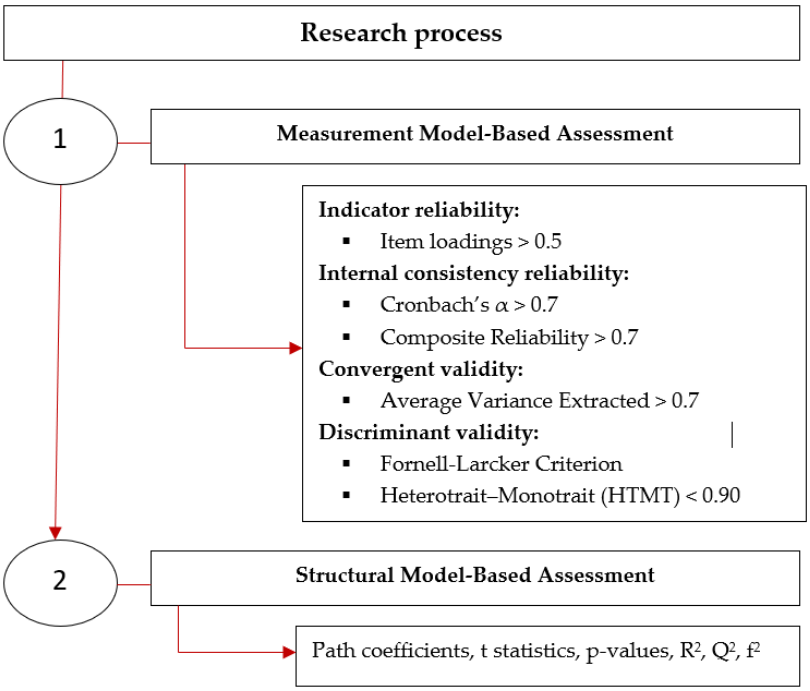

Figure 2. Research process in structural equation modelling for data collected during surveys
Source: own elaboration.

Structure of the Questionnaire

Table 1 presents questions from the questionnaire. These were five-point Likert scale questions ('Strongly agree,' 'Agree,' 'Don't know,' 'Disagree,' 'Strongly disagree').

Table 1. A survey questionnaire used to examine the factors determining zero waste behaviour among Polish consumers of cosmetics and care products

Construct	Question	Reference
Attitudes	Att_1. Zero-waste activities pay off	(Khan *et al.*, 2019)
	Att_2. Zero-waste activities are good	
	Att_3. Zero-waste activities are useful	
	Att_4. Zero-waste activities are gratifying	
	Att_5. We must follow zero-waste principles	
	Att_6. Zero-waste activities make me feel a better person	
Subjective Norms	SbN_1. Most of my family would engage in zero-waste activities	(Khan *et al.*, 2019)
	SbN_2. Most of my friends would engage in zero-waste activities	
	SbN_3. Most of my family believe I should engage in zero-waste activities	
	SbN_4. Most of my friends believe I should engage in zero-waste activities	
	Sbn_5. Most of my friends and family would consider zero-waste activities as good	
Awareness of Conse-quences	Awarn_1. Zero-waste activities are the primary method for reducing environmental pollution	(Khan *et al.*, 2019)
	Awarn_2. Zero-waste activities create a better environment for posterity	
	Awarn_3. Zero-waste activities are the primary method for reducing landfills	
	Awarn_4. Zero-waste activities are the primary method for conserving natural re-sources	
	Awarn_5. Zero-waste activities save money	
Zero Waste-Behaviour Intention	Int_Cosm_1. I would like to buy cosmetics and personal care products in packaging limiting plastic use (such as compostable, returnable, and recyclable)	Original work
	Int_Cosm_2. I would like to buy solid cosmetics to limit the use of plastic (such as soap/shampoo bars or toothpaste tablets)	

Construct	Question	Reference
Zero Waste-Behaviour Intention	Int_Cosm_3. I would like to buy reusable products (electric shaver, diapers, personal care products)	Original work
	Int_Cosm_4. I would like to buy products made of biodegradable ingredients with no plastic	
Zero-Waste Behaviour (ZWB)	Beh_Cosm_1. I often buy cosmetics and personal care products in packaging limiting plastic use (such as compostable, returnable, and recyclable)	Original work
	Beh_Cosm_2. I often buy solid cosmetics to limit the use of plastic (such as soap/shampoo bars or toothpaste tablets)	
	Beh_Cosm_3. I often buy reusable products (electric shavers, diapers, personal care products)	
	Beh_Cosm_4. I often buy products made of biodegradable ingredients with no plastic	
Perceived Behavioural Control	Control_1. It is convenient to buy cosmetics and personal care products in packaging limiting plastic use (such as compostable, returnable, and recyclable)	Original work
	Control_2. It is convenient to buy solid cosmetics to limit the use of plastic (such as soap/shampoo bars or toothpaste tablets)	
	Control_3. It is convenient to buy reusable products (electric shaver, diapers, personal care products)	
	Control_4. It is convenient to buy products made of biodegradable ingredients with no plastic	

Source: own study.

Sample

We conducted the research in February and March 2022. We surveyed 344 participants. The survey questionnaire was prepared in electronic version and distributed using the snowball method. The sample size was estimated so that the maximum error does not exceed 5%. Table 2 summarizes the sample details.

Table 2. Profile of the sample of survey participants in Poland, n=344

Sex	Percentage	Age	Percentage	Residence	Percentage
Female	60%	20 years and less	22%	Village	19%
Male	40%	21-30 years	52%	Town	9%
–	–	31-40 years	6%	Small city	23%
–	–	41-50 years	13%	Large city	48%
–	–	Over 50 years	7%	–	–

Source: own study.

RESULTS AND DISCUSSION

Measurement Model-Based Assessment

Table 3 shows the results of the measurement model. It demonstrates that the constructs meet the posed criteria. This means that each construct contains variables for which factor loadings exceed 0.5. Cronbach's α and CR exceed 0.7 and the average variance extracted exceeds 0.5 for each construct. Some variables had to be excluded to obtain this model. The removed variables are not listed in the item column (Table 3).

We tested the discriminant validity of the measurement model as well. Tables 4 and 5 show the results of this analysis. Both the Fornell-Larcker and Heterotrait-Monotrait criteria indicated good discriminant validity of the measurement model.

Table 3. Statistical measures used to evaluate the reliability and convergent validity of the measurement model applied in the research process

Variables	Item	Loadings	Cronbach's alpha	CR	AVE
Attitudes	Att_1	0.658	0.870	0.902	0.607
	Att_2	0.789			
	Att_3	0.849			
	Att_4	0.814			
	Att_5	0.777			
	Att_6	0.776			
Awareness of Consequences	Awarn_1	0.836	0.901	0.931	0.771
	Awarn_2	0.875			
	Awarn_3	0.917			
	Awarn_4	0.883			
ZW Cosm Behaviour	Beh_Cosm_1	0.802	0.723	0.829	0.550
	Beh_Cosm_2	0.710			
	Beh_Cosm_3	0.644			
	Beh_Cosm_4	0.798			
Perceived Behavioural Control	Control_1	0.833	0.790	0.864	0.612
	Control_2	0.801			
	Control_3	0.751			
	Control_4	0.746			
ZW Cosm Behaviour Intention	Int_Cosm_1	0.790	0.770	0.853	0.593
	Int_Cosm_2	0.712			
	Int_Cosm_3	0.737			
	Int_Cosm_4	0.836			
Subjective Norms	SbN_1	0.783	0.824	0.876	0.585
	SbN_2	0.758			
	SbN_3	0.777			
	SbN_4	0.791			
	SbN_5	0.713			

Source: own study.

Table 4. Fornell-Larcker criterion used to evaluate the discriminant validity of the measurement model applied in the research process

Variables	Attitudes	Awareness of Consequences	ZW Cosm Behaviour	ZW Cosm Intention	Perceived Behavioural Control	Subjective Norms
Attitudes	0.779	–	–	–	–	–
Awareness of Consequences	0.663	0.878	–	–	–	–
ZW Cosm Behaviour	0.322	0.315	0.741	–	–	–
ZW Cosm Intention	0.557	0.454	0.519	0.770	–	–
Perceived Behavioural Control	0.276	0.221	0.548	0.378	0.784	–
Subjective Norms	0.553	0.399	0.331	0.331	0.253	0.765

Source: own study.

Structural Model-Based Assessment

Figure 3 presents the structural model. The constructed structural model accounted for 41.1% (R^2 = 0.414) of the variability of the zero-waste behaviour construct for cosmetics and personal care products. The predictive power of the model was Q^2 = 0.220. The model's significance was confirmed by SRMR = 0.078, which was lower than the assumed cut-off value of 0.09.

Table 5. Heterotrait-Monotrait criterion used to evaluate the discriminant validity of the measurement model applied in the research process

Variables	Attitudes	Awareness of Consequences	ZW Cosm Behaviour	ZW Cosm Intention	Perceived Behavioural Control
Awareness of Consequences	0.743	–	–	–	–
ZW Cosm Behaviour	0.405	0.386	–	–	–
ZW Cosm Intention	0.666	0.529	0.702	–	–
Perceived Behavioural Control	0.329	0.258	0.722	0.488	–
Subjective Norms	0.642	0.451	0.430	0.401	0.309

Source: own study.

Table 6 shows which hypotheses were confirmed under the present research model. Therefore, the significant predictors of zero-waste behaviour regarding cosmetics and personal care products were intentions of the behaviour (p-value < 0.001) and perceived behavioural control over this behaviour (p-value < 0.001). In this way, we confirmed hypotheses H5 and H6. Factors connected with the awareness of consequences and subjective norms turned out to be insignificant predictors of zero-waste behaviour intentions regarding cosmetics and personal care products. Therefore, hypotheses H2 and H3 have not been proven true. Attitudes towards ZWB (p-value < 0.001) and perceived behavioural control (p-value < 0.001) turned out to be significant predictors of zero-waste behaviour regarding cosmetics and personal care products, which confirmed hypotheses H1 and H4.

Table 6. Results of hypothesis testing in the structural model applied in the research process

Variables	β	Standard Deviation	t	p-value	f^2	Verification of the hypothesis
H1. Attitudes -> ZW Cosm Intention	0.405	0.088	4.580	0.000	0.119	positive
H2. Awareness of Consequences -> ZW Cosm Intention	0.136	0.096	1.417	0.157	0.016	negative
H3. Subjective Norms -> ZW Cosm Intention	-0.008	0.064	0.118	0.906	0.000	negative
H4. Perceived Behavioural Control -> ZW Cosm Intention	0.238	0.053	4.460	0.000	0.082	positive
H5. Perceived Behavioural Control -> ZW Cosm Behaviour	0.410	0.049	8.325	0.000	0.246	positive
H6. ZW Cosm Intention -> ZW Cosm Behaviour	0.364	0.050	7.231	0.000	0.194	positive

Note: statistically significant values are in red.
Source: own study.

Discussion

The results confirming the significance of attitudes and perceived behavioural control were consistent with other studies (Askadilla & Krisjanti, 2017; Chin *et al.*, 2018; Fatoki, 2020; Hsu *et al.*, 2017; Yeon Kim & Chung, 2011). Both attitudes and perceived behavioural control affected purchase intentions positively. Research by Firek and Dziadkowiec (2020) offers an interesting comment on attitudes (Firek & Dziadkowiec, 2020). Of course, knowledge of a product shapes attitudes with rational arguments for positive and negative dispositions towards it. Still, Firek and Dziadkowiec (2020) indicate that the low level of knowledge about green cosmetics in Poland is the main reason why people tend not to buy them. Moreover, according to Firek and Dziadkowiec (2020), green cosmetics are available mainly online. Their availability in brick-and-mortar chemists is believed to be low. This means the perceived behavioural control concerning access to green cosmetics among Polish consumers is low. Therefore, in light of the model proposed here, low perceived behavioural control will be detrimental to the purchase of green cosmetics. However, we hope that global trends such as increasing concern for the environment, development of ecological certifications, the influence of social media and global pro-ecological initiatives, and increased awareness of health and safety will contribute to improving the knowledge and availability of ecological cosmetics in Poland.

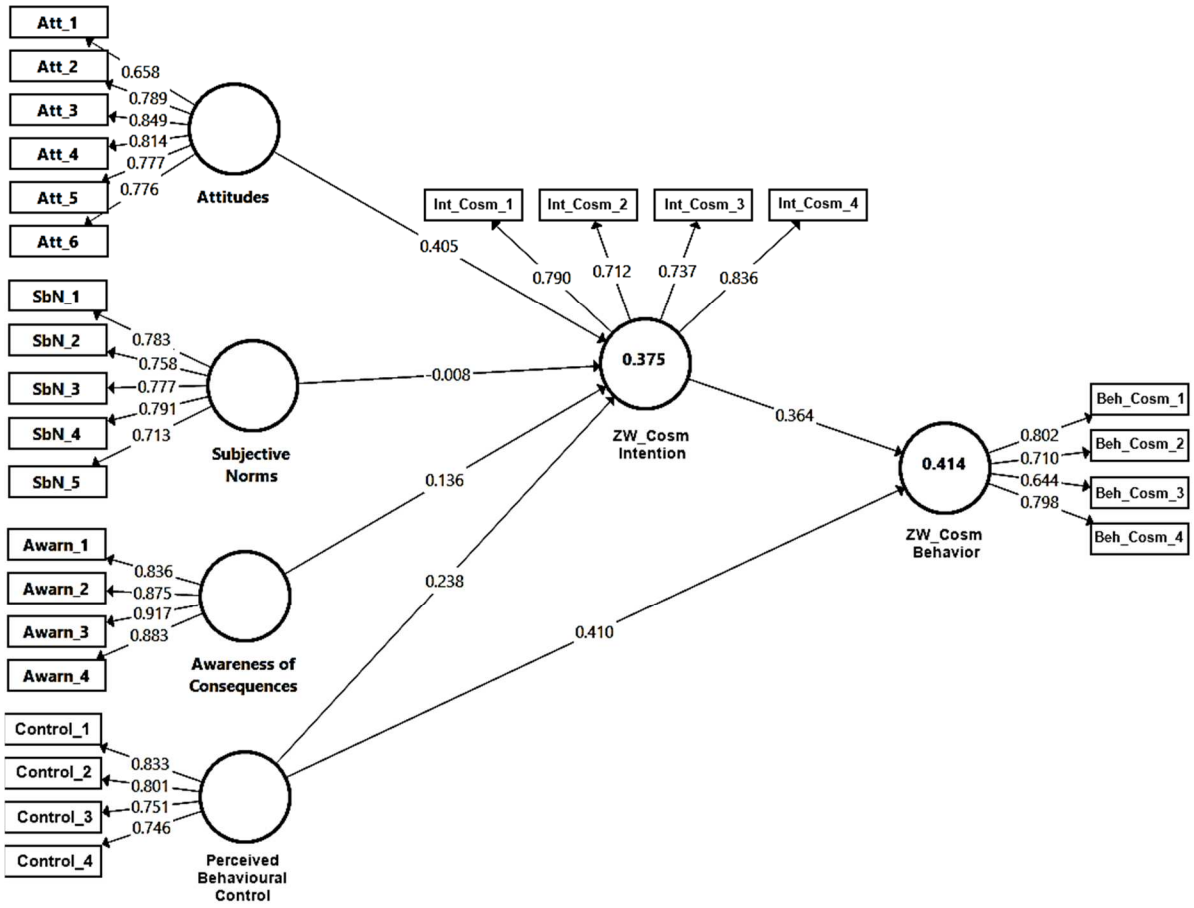

Figure 3. Structural model of the factors determining zero waste behaviour among Polish consumers of cosmetics and care products

Source: own elaboration.

The most surprising result was that subjective norms were not confirmed as a significant factor. In research by Askadilla and Krisjanti (2017), Chin *et al.* (2018), Hsu *et al.* (2017), Yeon Kim and Chung (2011), this factor is identified as a significant determinant of behavioural intentions. We argue that as social beings, humans consider the opinions of their closest circles when making decisions. However, subjective norms turned out to be insignificantly affecting intentions to purchase green cosmetics in the present study. Nevertheless, other authors also presented similar results. Suphasomboon and Vassanadumrongdee (2022) used the perceived value theory and established that social value does not affect the intention to purchase sustainable cosmetics. Similarly, a ranked list of motivators to purchase green cosmetics proposed by Firek and Dziadkowiec (2020) puts opinions and recommendations of friends among the least significant factors (seventh out of ten).

Fatoki (2020) identified the insignificance of subjective norms in the framework of TPB. This may be because Fatoki conducted the study among communities with no significant traditions of environmental awareness and no strong regard for environmental values. They were dominated by other values. Firek and Dziadkowiec (2020) provide more details by placing green cosmetics' ingredients and health impact as the primary purchase motivators in their ranking list. In light of the above, the insignificance of the subjective norm factor observed in our model is easier to understand. It also demonstrates that the green cosmetics market in Poland is at an initial stage of growth. The public pressure towards environmentally-friendly behaviour can be expected to increase as environmental trends grow more popular. Subjective norms may then become more relevant. We also assume that the increase in marketing and educational activities of organic cosmetics producers will have a positive impact on the significance of subjective norms.

Another factor found to be insignificant in the present study is the awareness of the consequences of zero-waste behaviour. It is absent in the original theory of planned behaviour. Perhaps, it is one of the reasons why it has no significant impact on zero-waste behaviour intentions towards green cosmetics. However, it seems more probable that the factor is connected with poor environmental awareness. Especially considering that ecological awareness was in the sixth position out of ten in the ranking list of motivators to purchase green cosmetics proposed by Firek and Dziadkowiec (2020). The situation is even more complicated as regulations concerning extended producer responsibility are yet to be implemented in Poland even though they are anticipated. Therefore, consumers expect manufacturers to first take responsibility for environmental issues, and only then can the zero-waste effort reach its full potential.

CONCLUSIONS

General Summary of Results

In search of the answer to the research question, we verified six hypotheses and confirmed four of them. The research question looked for factors affecting zero-waste behaviour regarding cosmetics in Poland. We indicated zero-waste behaviour intentions and perceived behavioural control as potential factors. We confirmed both hypotheses. As behaviour intentions are a complex construct determined by multiple factors according to TPB, we proposed further potential predictors during the study. The indicated factors were related to attitudes towards zero waste, factors referred to as the awareness of consequences of zero-waste activities, factors referred to as subjective norms and factors related to perceived behavioural control. Attitudes and perceived behavioural control turned out to be significant, while awareness of consequences and subjective norms were insignificant for zero-waste behaviour intentions regarding cosmetics in Poland.

Theoretical and Practical Implications

The results significantly contribute to the state of the art of research on the impact of zero waste on the implementation of the circular economy. Note particularly that the survey was conducted in Poland, where such environmentally-involved movements as zero waste are budding and just catching the eyes of consumers and manufacturers. Although the problem has grown in popularity in the literature, it has yet to gain footing in Eastern-European countries. In light of the above, the model based on the theory of planned behaviour identified attitudes and perceived behavioural control as significant factors affecting zero-waste intentions and behaviour.

We expanded the TPB model for the current analysis to identify factors affecting zero-waste intentions and behaviour regarding cosmetics and personal care products with an additional construct awareness of consequences. Even though this factor turned out to be insignificant (hypothesis falsified) in the study among Polish consumers, it can potentially be significant in the case of other European populations with longer environmental traditions and greater awareness. The proposed new construct in the TPB model can be useful for juxtaposing other European countries, where the circular economy model is more popular. Being aware of the consequences of zero waste behaviour is linked to preventing the negative effects of excessive consumerism and the associated health, environmental and economic benefits.

Moreover, the analyses investigated the significance of subjective norms, which was assigned various, also opposite, significance levels across other studies in the literature (Askadilla & Krisjanti, 2017; Chin *et al.*, 2018; Hsu *et al.*, 2017; Suphasomboon & Vassanadumrongdee, 2022; Yeon Kim & Chung, 2011). The insignificance of subjective norms in the present study could be attributed to the fact that the Polish cosmetics industry just started its green cosmetics journey.

The study is also a practical contribution to manufacturers and sellers of green cosmetics and personal care products in Poland. It is recommended that the entrepreneur makes sure to give the consumer a sense of greater control over ZWB regarding cosmetics and personal care products when introducing such innovations. It is advisable to improve the availability of green products so that they can be purchased in brick-and-mortar stores as well as online. As the present research shows, per-

ceived behavioural control does affect purchase intentions and the purchase itself. Another recommendation is to intensify the effort to build environmentally friendly attitudes, including the promotion of the zero-waste concept. The significant role of attitudes demonstrated in our model affects intentions to purchase green cosmetics, which, in turn, affects purchase directly. We suggest that the educational and marketing activities of ecological cosmetics producers take advantage of the strong tradition of herbalism and natural cosmetics among older generations in Poland. In our opinion, younger generations will expect education and marketing activities in social media and the involvement of influencers. However, we emphasize that all marketing activities should be combined with the anti-plastic revolution in packaging, so as not to lose credibility for sustainable development.

Limitations of the Study and Further Research

The primary limitation of the deliberations and analyses presented here is their spatial extent limited to Polish consumers. In particular, Poland's cultural and economic differences should be emphasized, which may significantly impact consumer behaviour. Nevertheless, the conclusions and recommendations can still be employed in other European countries, especially those with still developing environmental awareness of consumers and manufacturers.

Moreover, the research did not analyse the impact of demographic factors (age, sex) on zero-waste intentions and behaviour. It might be particularly interesting to investigate determinants of zero waste across generations to make comparisons with the period before Poland's economic transformation. Therefore, future research will be international and will include analyses of intergenerational differences. Moreover, considering the ubiquity of the Internet and social media communication, it may be a substantial future research direction to investigate the role of social media in shaping consumer awareness regarding purchasing green products and zero-waste behaviour.

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Authors

The contribution share of authors is equal and amounted to one-third for each of them. Conceptualization: I.Z., B.H., D.Z; methodology: I.Z.; formal analysis, I.Z.; investigation: IZ.; writing—original draft preparation: I.Z B.H. D.Z; writing—review and editing: I.Z., B.H., D.Z.; visualization: I.Z.; funding acquisition: I.Z., B.H., D.Z.

Iwona Zdonek
PhD, Assistant Professor of Silesian University of Technology, Department of Economics and Informatics, Faculty of Organization and Management. Her research interests include sustainable development. She has conducted research in CSR, technology of photovoltaic systems, sustainable tourism, and sustainable fashion. She also deals with issues of combining sustainable development with data science and project-based learning.
Correspondence to: Silesian University of Technology, Department of Economics and Informatics, Faculty of Organization and Management, ul. Akademicka 2A, 44-100 Gliwice, Poland, e-mail: iwona.zdonek@polsl.pl
ORCID http://orcid.org/0000-0002-3377-0904

Beata Hysa
PhD, Assistant Professor of Silesian University of Technology, Department of Economics and Informatics, Faculty of Organization and Management. Her research interests include modern information technologies in Human Resource Management, social media, and methods of communication. She also deals with issues of combining sustainable development with digital technology.
Correspondence to: Silesian University of Technology, Department of Economics and Informatics, Faculty of Organization and Management, ul. Akademicka 2A, 44-100 Gliwice, Poland, e-mail: beata.hysa@polsl.pl
ORCID http://orcid.org/0000-0003-1192-9395

Dariusz Zdonek
PhD, Assistant Professor at the Silesian University of Technology in Poland. His research interests include information and communication technologies (ICT). He has conducted research in digital maturity, internet technologies, quality of websites and motivation. He also deals with issues of combining sustainable development with ICT.
Correspondence to: Silesian University of Technology, Department of Economics and Informatics, Faculty of Organization and Management, ul. Akademicka 2A, 44-100 Gliwice, Poland, e-mail: dariusz.zdonek@polsl.pl
ORCID http://orcid.org/0000-0002-6190-9643

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In search of a benchmark for the quick ratio: The Polish-German setting

Piotr Wójtowicz

ABSTRACT

Objective: The objective of the article is to empirically assess the benchmarks for the quick ratio (QR) commonly provided in the Polish literature. The article challenges the suggestion of a single benchmark despite a country's and industry's uniqueness. It concentrates on the Polish-German setting because of the intensive cooperation between the two countries.

Research Design & Methods: Apart from reviewing and critiquing the existing literature, the article presents the results of empirical analysis. The research sample comprised 998 710 Polish firm-years and 1 579 619 German ones. Data was retrieved from the Orbis Database for going concern, non-financial firms from 2013 to 2022. Research methods comprised analyses of distributions, including descriptive statistics and histograms, parametric and nonparametric ANOVA, and trend analysis.

Findings: The analysis shows that the benchmark for the quick ratio depends on the country, industry, period, and firm size. Standards should be drawn from quartiles instead of the arithmetic mean because of the high variability of QR. The range for QR is respectively wide. For Poland, it ranges from 0.6 (the first quartile) to 2.7 (the third quartile), with a median of 1.2 for the total sample. For Germany, it ranges from 0.7 (the first quartile) to 3.9 (the third quartile), with a median of 1.6. Benchmarks vary annually in Poland and Germany. Medians and third quartiles increase over time. They grow faster in Germany. There are substantial between-industry differences in both countries. The pattern of these differences is unique to a country. The size of the firm negatively influences the desired liquidity level in both countries.

Implications & Recommendations: Because of substantive between-country, industry, period, and firm size differences in benchmarks, analysts and investors must be sensitive to the standards they use in assessing investment opportunities. A shock in the economy increases risk and, hence, benchmarks.

Contribution & Value Added: The article's main contribution is the empirical verification of benchmarks for the quick ratio provided in the Polish literature. Analysts should not trust theoretical concepts when looking for benchmarks. They must compare the firm's financial standing with that of other firms from the same country, industry, period, and of a similar size.

Article type: research article

Keywords: liquidity ratios; quick ratio; financial analysis; Poland; Germany

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INTRODUCTION

Perhaps the easiest way to assess the financial health of a business is to compare it with its counterparts in the same country, region, or industry. This simple idea requires a high-quality benchmark that stems from sound theory and is verified by empirical analysis.

The article aims to empirically assess the quick ratio (QR) benchmarks commonly provided in the Polish literature. It also analyses the suggestion of a single benchmark despite a country's, period's,

industry's, and firm size uniqueness. I concentrate on the Polish-German setting because of the intensive cooperation between these two countries.

The quick ratio measures a company's short-term liquidity and describes its ability to pay short-term obligations using the most liquid assets. Despite some differences between accounting systems worldwide, liquid assets are current assets that can be easily converted into cash with a minimal price decrease. Current liabilities are company debts due to be paid within one year. Wójtowicz (2022) extensively analyses benchmarks for the current ratio. In this article, I concentrate exclusively on the benchmarks for the quick ratio.

A theoretical approach suggests that 1 is the *standard* of a QR. This means a business is equipped with enough liquid assets to pay off its current liabilities instantly. A well-known accounting-rooted relationship suggests that a quick ratio of less than 1 may signal problems with the ability to pay off current liabilities in the short run. A value above 1 suggests that a business is furnished with enough current assets to pay its creditors. A ratio that aligns with the industry average or is higher is acceptable. On the other hand, a current ratio lower than the industry average may signal an increased risk of bankruptcy.

The aforementioned point of view stems from understanding the meaning and nature of accounting concepts. Unfortunately, these general rules and conclusions are not necessarily valid in practice, and I am going to challenge them empirically. The average of the distribution is exposed to outliers; hence, the benchmark may be biased towards the right tail of the distribution. The differences between industries' ratios are supposed to be significant. In some industries, high current asset turnovers result in a low balance sheet value. At the same time, extended maturity of liabilities increases their amount.

I suspect between-country differences in the average level of liquidity powered by country-related factors. Unusual circumstances, such as the COVID-19 pandemic, increase business risk and the expected liquidity level. In the next section, these issues are formulated as hypotheses.

The novelty of my article is the empirical verification of the benchmark for the QR provided in the literature. I empirically test benchmarks and identify patterns they follow for Polish and German firms. My empirical approach permits the verification of premises stemming from the theoretical first step. Furthermore, a between-country comparison of the two European economies sheds light on the size of a firm as an anticipated factor influencing liquidity levels.

The remainder of the article is organised as follows. The next section contains a literature review and develops the hypotheses. Next, I will include the sample selection process and the description of the data, followed by results and discussion. The last section will conclude the study and explain the limitations and avenues for further research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Liquidity ratios describe a firm's ability to pay off current debts without raising extra capital. Failure in that respect may quickly result in the company's bankruptcy. Liquidity ratios include the current ratio, quick ratio (QR), and cash ratio. Although these ratios are commonly known, QR is defined in the next section for clarity. The QR builds on accrual items; hence, it may be impacted by accrual and real earnings management. Comporek (2023) shows that the scope of the former practices for listed companies is the largest in industrial companies in the growth and maturity phase. Such firms constitute a small fraction of my sample.

Surprisingly, international accounting and finance literature concerning benchmarks for liquidity ratios is very scant, although it dates back to the 1960s (Lev, 1969). Building on the existing literature, one may conclude that universal, internationally recognised benchmarks do not exist or are useless in practice. Furthermore, benchmarks and, broadly speaking, liquidity-related relationships are industry-specific. Tóth *et al.* (2013) find that in the Slovak Republic, the liquidity level in agriculture is much lower than in other industries. Similarly, Lesiak and Sajnóg (2018) report a significant positive relationship between net working capital and liquidity ratios. There exists a considerable and industry-specific correlation between liquidity ratios and the Return on Assets (ROA) both in family farms (Bereżnicka, 2014) and in meat processing (Szymańska & Lukoszová, 2021). Hence, authors try to assess the financial situation of firms searching for industry-related benchmarks (Maślach *et al.*, 2019), (Lisek *et al.*, 2019).

Several Poland-related articles and monographs suggest theoretical benchmarks for the quick ratio. Generally, the recommended benchmark is about 1 (Sierpińska & Jachna, 2006). Other authors, *e.g.* Michalski (2005), propose a benchmark of above 1. Finally, some authors suggest a benchmark in the specific range, *e.g.* 0.7-1.5 (Kreczmańska-Gigol, 2020). Unfortunately, cited authors do not reference the literature or research behind their proposed standards. Furthermore, they often quote one another, so the reader does not know if the benchmarks are based on empirical analysis or whether they represent the authors' beliefs. Niemiec (2014) provides a comprehensive review of the proposed benchmarks for liquidity ratios.

I am aware of only one research article empirically analysing benchmarks for the liquidity ratio in the Polish context. Niemiec (2014) provides a framework based on extensive trend analysis. His suggested benchmarks are asymptotes of the arctangent function. Specifically, he claims QR above 0.7, preferably from 0.7 (first quartile) to 2.6 (third quartile), with a median of 1.3. The above conclusion is drawn from the entire sample provided by the Financial Analysis Committee of the Scientific Council of the Accountants Association in Poland (Komisja ds. Analizy Finansowej Rady Naukowej Stowarzyszenia Księgowych w Polsce) for the period 2002-2012. The Financial Analysis Committee has analysed distributions of yearly values of financial ratios by industry in Poland since 2002. All companies included are obliged to (Dudycz & Skoczylas, 2023):

- prepare financial statements in line with the Polish Accounting Act,
- provide financial statements for two consecutive years for comparison,
- have a fiscal year equal to 12 months,
- have a nonnegative value of the owner's equity.

Due to the sample selection process, the overall sample comprises a considerable number of companies, and the number of firms is increasing over time. They range from small sole proprietorships to blue chips listed on the Warsaw Stock Exchange (Dudycz & Skoczylas, 2023).

A detailed analysis of the Financial Analysis Committee's data shows that the ratios' average and median values vary considerably. Means are much higher than medians; hence, the distributions are asymmetric, with substantial outliers. The analysis shows significant differences between industry ratios. Sestanj-Peric *et al.* (2019) point out that even after removing outliers, arithmetic means' informativeness remains weak. They suggest using medians and interquartile ranges instead.

Analysts may regard the diversity of the sample as an opportunity but also as a threat. The size of the business entails different institutional conditions, so it may encapsulate the outcome of various risks influencing the liquidity level. On the other hand, the breakdown by industry follows the Classification of Business Activities in Poland (Polska Klasyfikacja Działalności – PKD); hence, an international comparison of these ratios is impossible. Only intra-industry trend analysis and a between-industry comparison is feasible. The economic behaviour of a firm is influenced by many formal and informal institutions, which may establish different economic conditions and risk factors.

Furthermore, the impact of culture is conditional on the level of regulation and monitoring in a country (Kanagaretnam *et al.*, 2011). In such circumstances, benchmarks established for one country are not helpful for another. Between-countries differences may also stem from the accounting profession (de)regulation (Hońko *et al.*, 2023).

I decided to compare Poland and Germany for several reasons. Firstly, both countries are members of the European Union, and firms follow the same European legal regulations. Secondly, Germany is the biggest EU economy measured by total GDP, while Poland is the sixth. In other words, differences in liquidity levels resulting from macroeconomic conditions may exist. Thirdly, both countries are neighbours involved in intensive mutual international trade; hence, such a comparison may be meaningful to managers and analysts from both countries. In 2021, Germany exported USD 84.2 billion to Poland. Germany's exports to Poland have increased at an annualised rate of 9.2%, from USD 8.55 billion in 1995 to USD 84.2 billion in 2021 (OEC, 2023). In 2022, Poland exported USD 95.22 billion and remains the fifth trade partner of Germany (Trading Economics, 2023).

I conjecture that the QR benchmarks may differ from those suggested in the literature quoted above. Furthermore, benchmarks may vary over time between industries and countries and may

depend on the firm size. Finally, the average industry and yearly quick ratio values differ from medians.

The hypotheses address these issues as follows:

- H1: Mean values of QR differ from medians;
- H2: Mean values of QR differ from the benchmarks most commonly provided in the literature;
- H3: Medians of QR differ from the benchmarks most widely offered in the literature;
- H4: Mean values and medians of QR differ between Poland and Germany;
- H5: Mean values and medians of QR vary over time in Poland and Germany;
- H6: Mean values and medians of QR differ between industries in Poland and Germany;
- H7: Benchmarks for the liquidity ratio depend on the size of the firm.

RESEARCH METHODOLOGY

The size of the business and its legal form entail different institutional conditions. Wanting to present a broad picture and capture factors influencing the quick ratio, I included all firms meeting some of the general criteria described below. I concentrated on the period 2013-2022. I started with 2013 because the earlier the period, the lower the data availability in the database. Data availability for the last period, 2022, is also limited. Nonetheless, I aimed to capture the impact of the COVID-19 pandemic.

I retrieved data from the Orbis Database. The sample consisted of Polish and German going concern firms. I excluded firms with incomplete data on quick ratios and firms with negative owner's equity.

The definition of the quick ratio (QR), *i.e.* the LIQR field in the Orbis Database, is the following:

$$QR = \frac{TCA - TI}{TCL} \tag{1}$$

in wchich:

TCA - Total Current Assets (field 13061);
TI - Total Net Inventories (field 20010);
TCL - Total Current Liabilities (field 14011).

The reason for retrieving ready-made QR, *i.e.* the LIQR field, is twofold. Firstly, the database is incomplete regarding current assets, total inventories, and current liabilities. However, it contains calculated QR even if it lacks the mentioned elements; hence, I can significantly increase the sample. Secondly, building on ratios provided by the professional service, I can be certain of its high quality and limited or non-existent inconsistencies in my between-country analysis.

My preliminary selection process stems from the NACE Rev. 2 classification and legal form of the business.

Firstly, I used the NACE Rev. 2 classification, a statistical classification of economic activities in the European Community, to break down firms between industries (Eurostat, 2023). I concentrated on the broad structure of NACE Rev. 2, which breaks industry classification into sections marked with capital letters of the Latin alphabet. I included firms assigned to sections from A to J and M in my database. I excluded: financial and insurance activities (K); real estate activities (L); administrative and support service activities (N); public administration and defence (O); education (P); human health and social work activities (Q); arts, entertainment, and recreation (R); other service activities (S); activities of households as employers (T); and activities of extraterritorial organisations and bodies (U). Some firms assigned to these sections face unique regulations and are monitored by specialised national supervisory authorities. For some firms, the measurement of liquidity with QR may be meaningless.

Secondly, the Orbis Database classifies business units according to categories of standard legal forms. I excluded firms classified as branches (of foreign companies), companies with unknown legal forms, foreign companies, non-profit organisations, other legal forms, and public authorities. I included sole proprietorships, partnerships, private limited companies, and public limited companies.

For Poland, the initial sample consisted of 998 717 observations, *i.e.* going concern firms-years meeting the first and second general criteria. I excluded seven firms with negative total assets, so the final sample consisted of 998 710 firm-years. For Germany, the sample consisted of 1 579 619 observations. Tables 1 and 2 show the distribution according to NACE Rev. 2 section and year.

Table 1. Number of observations per year and the NACE Rev. 2 section, Poland

Year / Section	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
A	2219	2356	2506	2325	3367	3099	3171	3258	3193	2141	27 635
B	321	362	386	401	620	598	599	611	601	415	4914
C	13 666	14 524	15 685	16 141	22 342	22 694	23 824	24 561	24 670	16 661	194 768
D	886	982	1059	1076	1903	1930	2082	2234	2339	1699	16 190
E	1323	1405	1461	1515	2144	2140	2181	2238	2265	1788	18 460
F	6531	7218	8242	8835	16 120	16 923	18 803	20 259	21 398	13 984	138 313
G	19 450	21 003	22 801	23 361	34 636	34 401	35 747	36 892	37 150	24 721	290 162
H	2644	2960	3396	4166	6851	7219	7879	8468	8746	5764	58 093
I	1675	1922	2117	2163	4575	4696	5058	5280	5197	3040	35 723
J	3840	4310	4650	4874	10 027	9611	10 216	10 910	11 122	7251	76 811
M	6453	7033	7854	8313	18 626	17 837	18 868	19 765	19 955	12 937	137 641
Total	59 008	64 075	70 157	73 170	121 211	121 148	128 428	134 476	136 636	90 401	998 710

Description of sections: A: agriculture, forestry, and fishing; B: mining and quarrying; C: manufacturing; D: electricity, gas, steam, and air conditioning supply; E: water supply; sewerage, waste management, and remediation activities; F: construction; G: wholesale and retail trade; repair of motor vehicles and motorcycles; H: transportation and storage; I: accommodation and food service activities; J: information and communication; M: professional, scientific, and technical activities.
Source: own study in Stata.

Table 2. Number of observations per year and the NACE Rev. 2 section, Germany

Year/ Section	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
A	1390	1838	2252	2595	2743	3025	3523	3909	3849	1187	26 311
B	240	317	465	543	509	681	792	864	847	73	5 331
C	14 925	18 639	28 437	33 219	32 500	42 241	49 144	52 787	53 412	6 868	332 172
D	2798	3728	4819	5524	5531	6670	8 008	8314	7780	1100	54 272
E	893	1132	1566	1830	1793	2346	2790	3055	3079	339	18 823
F	8 236	11 161	20 431	24 562	23 646	32 892	39 466	45 094	46 045	4580	256 113
G	16 658	21 682	34 298	40 544	40 330	52 257	61 469	66 985	67 693	8621	410 537
H	3508	4614	7048	8374	8423	11 431	13 541	14 668	14 791	616	88 014
I	2052	2826	4349	5382	5579	7480	8997	9440	8963	597	55 665
J	4366	5697	8052	9470	9897	12 526	14 854	16 231	16 585	2411	100 089
M	8747	12 397	18 813	23 159	22 735	30 143	35 937	37 928	37 488	4945	232 292
Total	63 813	84 031	130 530	155 202	153 686	201 692	238 521	259 275	260 532	32 337	1 579 619

Source: own study in Stata.

My research methods comprised analysis of distributions, including descriptive statistics and histograms, parametric and nonparametric ANOVA, and trend analysis.

RESULTS AND DISCUSSION

Figures 1 and 2 show the histograms for QR for the sample in both countries. Both Figures show histograms truncated at QR equal to 8.0 because each distribution has a long right tail.

Bar width equals 0.2. For Poland and Germany, the percentage of observations presented in Figures 1 and 2 is calculated for QRs truncated at 8.0. For Poland, five bars from 0.2 to 1.2 include a similar percentage of observations. Taken together, they equal about 45%. However rough this assessment is, it estimates a benchmark range for QR for the total sample. This range differs substantially from the ranges provided in the literature. For Germany, only three bars, from 0.2 to 0.8, include a similar percentage of observations. These bars contain about 25% of the truncated sample. This provisional verification supports hypotheses H3-H6.

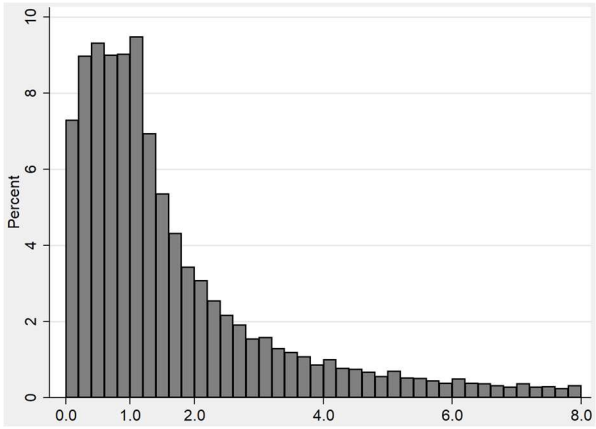

Figure 1. Histogram for the quick ratio, Poland
Source: own elaboration based on QR calculation.

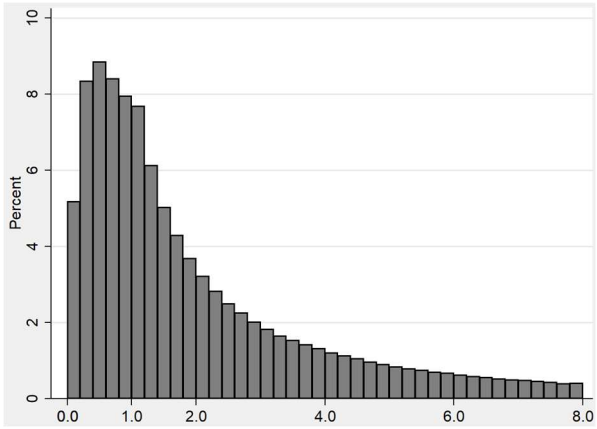

Figure 2. Histogram for the quick ratio, Germany
Source: own elaboration based on QR calculation.

Table 3. Descriptive statistics of the quick ratio (QR) per year in Poland

Year / Parameter	No. of Obs.	Mean	Std. Dev.	25%	Median	75%	Skewness	Kurtosis
2013	59 008	2.9	7.1	0.6	1.1	2.3	7.1	67.1
2014	64 075	2.9	6.9	0.6	1.1	2.3	7.0	65.8
2015	70 157	3.0	7.2	0.6	1.2	2.4	7.0	64.6
2016	73 170	2.9	7.0	0.6	1.2	2.3	7.3	70.4
2017	121 211	3.3	7.8	0.6	1.2	2.5	6.4	55.4
2018	121 148	3.3	7.8	0.6	1.2	2.6	6.4	55.3
2019	128 428	3.5	8.3	0.6	1.3	2.8	6.1	49.7
2020	134 476	3.7	8.6	0.7	1.4	3.0	5.9	45.9
2021	136 636	3.8	8.7	0.7	1.3	3.0	5.8	44.8
2022	90 401	4.1	9.1	0.7	1.4	3.3	5.5	40.5
Total	998 710	3.4	8.0	0.6	1.2	2.7	6.3	52.1

Source: own study in Stata.

Tables 3 and 4 show descriptive statistics of the QR per year for the total sample in both countries. Distributions of QR are highly asymmetric, with skewness equalling, respectively, 6.3 and 5.2 in the sample. I do not include the Min and Max of the distributions in the Tables, but in every country and year, Min equals zero, and Max equals 100. Hence, both distributions are heavily skewed to the right. Kurtosis is a measure of the heaviness of the tails of a distribution. In the Poland (Germany) sample, kurtosis of 52.1 (36.5) signals extremely tailed distribution.

Table 4. Descriptive statistics of the quick ratio (QR) per year in Germany

Year / Parameter	No. of Obs.	Mean	Std. Dev.	25%	Median	75%	Skewness	Kurtosis
2013	63 813	3.8	9.0	0.6	1.2	2.9	5.7	42.8
2014	84 031	4.9	11.7	0.6	1.3	3.5	4.8	29.0
2015	130 530	4.5	10.0	0.7	1.5	3.7	5.2	36.0
2016	155 202	4.4	9.6	0.7	1.5	3.7	5.4	38.2
2017	153 686	4.6	10.1	0.7	1.5	3.8	5.2	34.9
2018	201 692	4.5	9.8	0.7	1.5	3.8	5.2	36.2
2019	238 521	4.5	9.6	0.7	1.6	3.9	5.3	37.6
2020	259 275	4.8	9.7	0.9	1.8	4.4	5.1	35.0
2021	260 532	4.5	9.2	0.8	1.7	4.2	5.4	39.6
2022	32 337	5.0	9.9	0.9	1.9	4.7	5.0	33.6
Total	1 579 619	4.5	9.8	0.7	1.6	3.9	5.2	36.5

Source: own study in Stata.

For Poland (Germany), an arithmetic mean equals 3.8 (4.5) and differs from the median equal 1.2 (1.6). The observed differences between the arithmetic mean and medians stem from the asymmetry of the distributions. For analysts, this means that they should use the median as a benchmark; the mean seems useless because of the high asymmetry and variability of distributions. The Polish sample and yearly medians are close to the benchmarks suggested in the abovementioned literature. For Germany, the yearly and sample medians are higher.

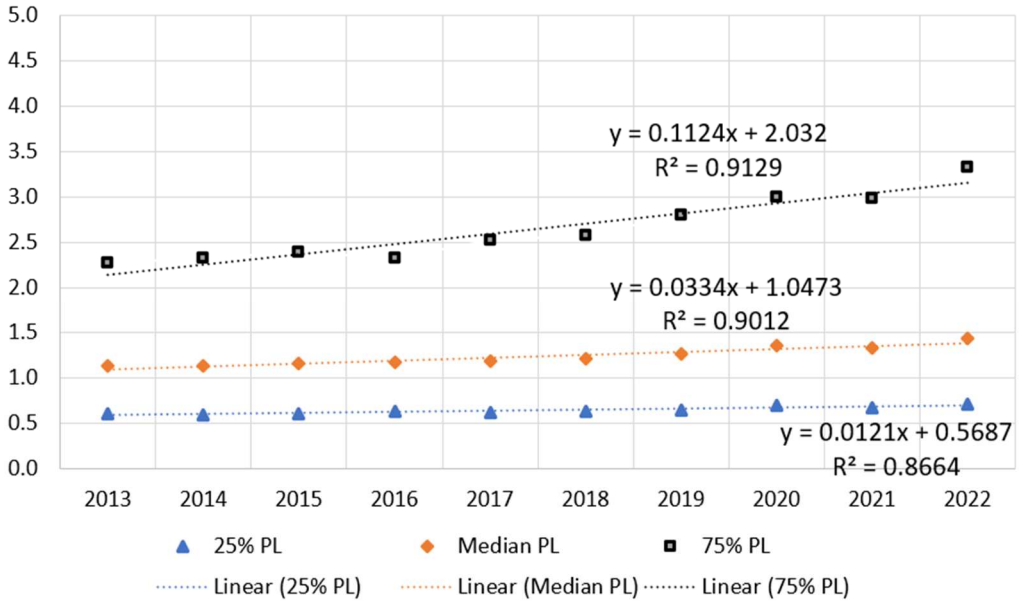

Figure 3. Median, first (25%), and third (75%) quartile of QR per year, Poland
Source: own elaboration based on a quick ratio calculation.

Interpreting the interquartile ranges (Tables 3 and 4) for total samples is inspiring. The range for Poland says that 50% of firm-years have a value of QR from 0.6 to 2.7, with a median of 1.2. Firms included in the sample are going concern units; hence, I interpret this range as empirical verification of the benchmarks suggested in the literature. The first (25%) and the third (75%) quartile are far removed from the theoretical standards. Moreover, the first quartile is respectively stable over time, but the third quartile increases in 2013-2022, especially in 2020-2022. Therefore, I fit linear trend lines to quartiles to verify my temporary conclusions. Figure 3 shows the yearly quartiles of QR and regression results.

The intercept for the first quartile linear model (Figure 3) says that its estimated value in 2012 was 0.57 and is increasing yearly by 0.0121 on average; hence, it is very stable. The intercept for the third quartile linear model says its estimated value in 2012 was 2.03 and is increasing annually at a fast pace, by

0.1124 on average. In other words, the quartile range is, on average, becoming increasingly wider year by year because of the increase in the third quartile. The first quartile (close to 0.6) is reasonably stable over time. It may be interpreted as an empirically verified minimum of the benchmark for the QR. I conjecture that the increase in QR is due to the increased risk of business activity, especially during the COVID-19 pandemic season and the war in Ukraine. The median also grows over time at a rate of 0.0334 per year, from 1.05 in 2012. All R^2 coefficients are high, so linear models fit the data in the research period.

Table 4 and Figure 4 tell a corresponding story for Germany. The main similarity between the Polish and German settings is in the general pattern, *i.e.* an increase in quartiles over time. However, there are also substantial differences. The third quartile and median in 2012 were higher in Germany than in Poland, *i.e.* 3.01 and 1.21, respectively. They grow yearly at an average rate of 0.1519 and 0.0627. Hence, median QR grows almost two times faster in Germany than in Poland. The total interquartile range says that 50% of firm-years have a value of QR from 0.7 to 3.9, with a median of 1.6.

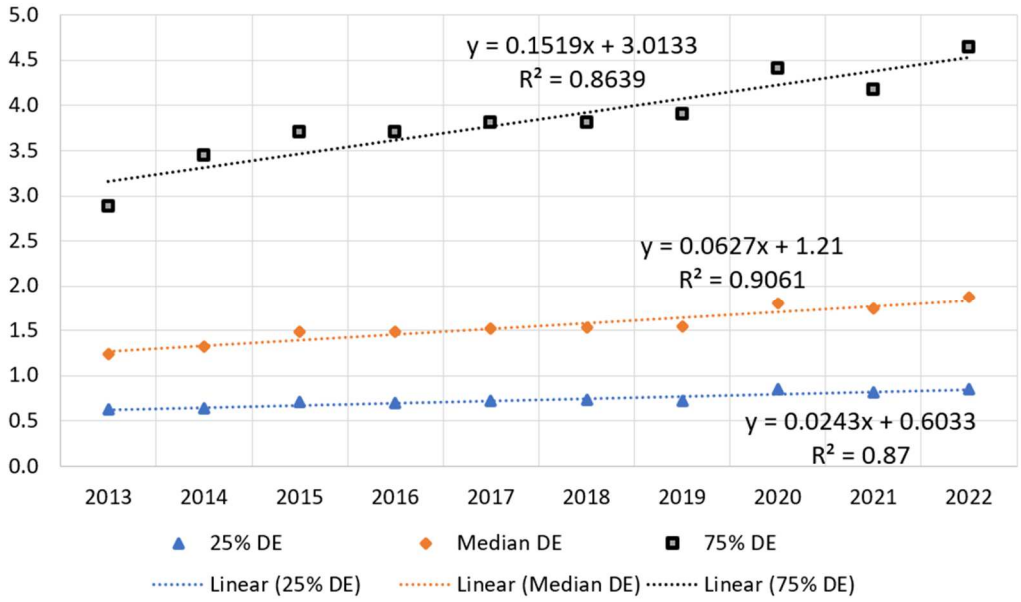

Figure 4. Median, first (25%), and third (75%) quartile of QR per year, Germany
Source: own elaboration based on a quick ratio calculation.

I ran a Student's two-group mean-comparison t-test to verify whether there are any statistically significant differences between the means of the QR for Poland and Germany. The hypotheses for the test are H_0: population means are equal; H_1: Germany's population mean is greater than Poland's population mean. The p-value <0.0001; hence, the null hypothesis should be rejected. Unfortunately, QR is not normally distributed, and the p-value<0.0001 in Bartlett's test for equal variances. In other words, the underlying assumptions for the Student's t-test are broken. To verify these results, I ran the nonparametric equality-of-medians test. The hypotheses for the test are: H_0: population medians are equal; H_1: population medians are not equal. The p-value<0.0001. Statistic tests show that QR country medians differ, so hypothesis H4 should not be rejected. In other words, there are significant between-country differences in QR. For analysts, it is a premise for using country-related benchmarks. In my opinion, there is a substantive difference between medians for Poland and Germany: 1.2 vs 1.6. Furthermore, the direction of the difference suggests that German managers run their businesses with greater caution than their Polish counterparts.

The differences between quartiles and means presented in Tables 3 and 4 provisionally support hypothesis H5. Wanting to strengthen my tests, I run ANOVA for Polish and German firms to verify whether there are statistically significant differences between the yearly means and medians of the QR. The p-value<0.0001, so the null hypothesis (means are equal) should be rejected in both countries. As mentioned above, QR is not normally distributed, and the p-value in Bartlett's test for equal vari-

ances is p<0.0001, so the ANOVA assumptions are again broken. To verify my results, I ran the nonparametric Kruskal-Wallis ANOVA. Similarly, the p-value<0.001 for both countries. Statistic tests showed that QR medians vary yearly, so hypothesis H5 should not be rejected.

The above analysis and discussion verify some of my research hypotheses. Hypothesis H1 is supported, *i.e.* arithmetic means differ significantly from medians. Hypothesis H2 is supported, *i.e.* the mean values of the distributions are far from the literature benchmarks. The conclusion about H3 is unclear. From one point of view, H3 should be rejected because the literature benchmarks implicitly refer to medians. From another point of view, the authors do not consider changes over time. Hence, building on medians, one may conclude that the benchmark is about 1.2 and, on average, is growing year by year. Hypothesis H4 is supported, so analysts must be cautious in the case of the Poland-Germany analysis and perhaps in every international setting. In the same vein, means and medians vary over time in both countries. Furthermore, they grow yearly at country-specific rates. Hypothesis H5 is supported.

The following analysis stage goes deeper into assessing QR benchmarks for industries and the firm size.

Table 5. Descriptive statistics of the quick ratio (QR) per NACE Rev. 2 section in Poland

Section / Parameter	No. of Obs.	Mean	Std. Dev.	25%	Median	75%	Skewness	Kurtosis
A	27 635	5.4	11.5	0.6	1.4	4.3	4.3	25.0
B	4914	3.5	7.9	0.6	1.3	3.0	6.2	53.5
C	194 768	2.7	6.4	0.6	1.1	2.3	7.6	78.5
D	16 190	4.0	10.6	0.4	1.0	2.4	5.1	32.6
E	18 460	2.5	6.0	0.5	1.2	2.4	8.5	97.3
F	138 313	3.8	8.8	0.7	1.4	2.9	5.8	45.0
G	290 162	2.6	6.9	0.5	1.0	1.9	7.4	72.8
H	58 093	2.9	6.4	0.9	1.3	2.4	7.6	77.1
I	35 723	3.2	7.9	0.4	1.1	2.5	6.5	55.8
J	76 811	4.5	9.1	0.9	1.8	4.0	5.4	39.9
M	137 641	5.1	10.1	1.0	2.0	4.6	4.8	31.8
Total	998 710	3.4	8.0	0.6	1.2	2.7	6.3	52.1

Source: own study in Stata.

Table 6. Descriptive statistics of the quick ratio (QR) per NACE Rev. 2 section in Germany

Section / Parameter	No. of Obs.	Mean	Std. Dev.	25%	Median	75%	Skewness	Kurtosis
A	26 311	5.7	12.4	0.7	1.7	4.5	4.3	23.8
B	5331	4.8	9.4	0.7	1.6	4.6	4.5	29.5
C	332 172	4.2	8.4	0.7	1.6	4.0	5.5	42.7
D	54 272	4.8	11.7	0.6	1.3	2.9	4.6	27.2
E	18 823	4.4	9.2	0.9	1.7	3.9	5.5	40.6
F	256 113	3.3	7.0	0.6	1.4	3.2	7.0	67.6
G	410 537	3.8	8.8	0.6	1.3	3.1	5.8	45.2
H	88 014	3.8	8.4	0.9	1.6	3.2	70.1	50.5
I	55 665	4.4	9.6	0.8	1.6	3.8	5.3	37.5
J	100 089	6.1	11.0	1.2	2.5	5.9	4.4	26.8
M	232 292	7.2	13.7	1.1	2.4	6.4	3.8	19.0
Total	1 579 619	4.5	9.8	0.7	1.6	3.9	5.2	36.5

Source: own study in Stata.

Tables 5 and 6 show descriptive statistics of QR per NACE Rev. 2 section in Poland and Germany, respectively. The results show that distributions differ between industries proxied by NACE sections. For Poland, the lowest median of 1.0 is for sections D and G. The highest median of 2.0 is for section M. Arithmetic means and standard deviations also differ. Although parametric ANOVA assumptions are broken, I ran parametric and nonparametric analyses for Poland and Germany. Not surprisingly, in all tests, p-value<0.0001. For analysts, benchmarks vary between industries in both countries. Moreover, differences in benchmarks proxied by medians are substantial. The above results support

hypothesis H6. Their practical consequences are hard to overestimate. One may ask a question about the *proper* value of the QR; however, the answer is not simple. It depends on the business's country of origin, period, and industry.

Tables 5 and 6 also show that the pattern of the between-industry differences is unique to a country. For instance, the highest median in Poland is for section M (2.0). In Germany, the highest median is for J (2.5), and the median for M (2.4) is second in this ranking.

The last hypothesis – H7 – addresses the impact of the firm size on the liquidity level. I proxy the size of the firm following general EU regulations. Small and medium-sized enterprises (SMEs) represent 99% of all businesses in the EU. The main factors determining whether an enterprise is a Micro/Small/Medium/Big unit are staff headcount and either turnover or balance sheet total assets (European Commission, 2023). SMEs are essential European creators of jobs and development (Pichler, 2018).

Due to the scant availability of data on turnover and total assets, especially for Germany, I concentrate on headcount only. Following the EU regulations, I classify a business as *micro* if the staff headcount<10; *small* if headcount>=10 and headcount<50; *medium* if headcount>=50 and headcount<250; and *big* otherwise.

Table 7 shows descriptive statistics per company size category for Poland and Germany. The total number of observations differs from the totals presented in Tables 3 and 4 because of the missing data in the Orbis database. I use 47.7% of the data set for Poland and 73.1% for Germany.

Table 7. Descriptive statistics of the quick ratio (QR) per company size in Poland and Germany

Size / Parameter	No. of Obs.	Mean	Std. Dev.	25%	Median	75%
Poland						
Micro	227 487	3.79	8.44	0.70	1.36	3.14
Small	160 591	2.31	4.31	0.68	1.24	2.35
Medium	69 101	1.61	2.49	0.55	1.02	1.81
Big	18 995	1.34	1.70	0.58	0.97	1.53
Total	**476 174**	**2.88**	**6.49**	**0.65**	**1.23**	**2.50**
Germany						
Micro	344 358	5.73	11.63	0.79	1.77	5.04
Small	556 405	3.86	7.71	0.75	1.60	3.78
Medium	199 341	2.97	6.10	0.73	1.38	2.97
Big	53 840	2.48	4.78	0.80	1.36	2.48
Total	**1 153 944**	**4.20**	**8.81**	**0.76**	**1.57**	**3.80**

Source: own study in Stata.

I ran parametric and nonparametric ANOVA for Poland and Germany for the last time. Again, in all tests, p-value<0.0001. Table 7 and ANOVA results generate several important conclusions. Firstly, the size of the business matters. I find the negative impact of the size on the average liquidity level proxied by various measures. Secondly, there is a negative relationship between the size of the business and the variability of QR proxied by the standard deviation of the distribution. For analysts, it is a signal that benchmarking for small firms is more complex than for big ones. These relationships apply to Poland and Germany. Thirdly, the observed excess of the median liquidity for German firms over their Polish counterparts remains relatively stable and, in each group, equals about 0.4. Fourthly, the total descriptive statistics reported in Table 7 are close to those reported in Tables 3 and 4. In my opinion, the existing differences have no substantial significance for analysts. In other words, I performed a robustness test of the results using the subsample. Hence, hypothesis H7 is supported.

CONCLUSIONS

The article aimed to empirically verify the benchmarks for the quick ratio – QR – commonly provided in the Polish literature. It also challenged the suggestion of a single benchmark despite a country's,

period's, industry's, and firm size uniqueness. The article concentrated on the Polish-German setting because of the intensive cooperation between the two countries.

The analysis shows that the benchmark depends on the country, industry, period, and firm size. Benchmarks must be drawn from quartiles instead of the arithmetic mean. The high variability of QR renders the mean useless for analysts. The commonly proposed theoretical benchmark for QR of about 1 may be used only as a rough suggestion. The findings show that the range for QR is much broader. For Poland, it ranges from 0.6 (the first quartile) to 2.7 (the third quartile), with a median of 1.2 for the total sample. It is close to the range empirically established by Niemiec (2014). For Germany, it ranges from 0.7 (the first quartile) to 3.9 (the third quartile), with a median of 1.6.

Tests indicate that benchmarks vary annually in Poland and Germany. Trend analysis permits the identification of the pattern and magnitude of the change in the benchmark. Medians and third quartiles increase over time and grow faster in Germany.

There are substantial between-industry differences in both countries. Furthermore, the pattern of these differences is unique to a country.

Finally, the size of the firm negatively influences the desired liquidity level. In both countries, the same relationship holds. The bigger the firm, the lower the liquidity level.

My research, as any other, has its limitations, but it provides an opportunity for future inquiry. Firstly, further research may extend to between-country settings. Secondly, the benchmarks for the cash ratio may be analysed. Thirdly, the question of techniques useful in benchmark identification remains open.

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Author

Piotr Wójtowicz

PhD, Associate Professor at the Krakow University of Economics (Poland). His research interests include financial reporting, earnings management, and the impact of cultural factors on earnings quality.

Correspondence to: Prof. UEK, dr hab. Piotr Wójtowicz, Uniwersytet Ekonomiczny w Krakowie, Katedra Rachunkowości, 31-510 Kraków, ul. Rakowicka 27, Polska, e-mail: piotr.wojtowicz@uek.krakow.pl

ORCID http://orcid.org/0000-0001-5054-9964

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Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Entrepreneurial intentions among female senior high school students in Ghana

Kwaku Amofah, Michael Gameli Dziwornu, Tomasz Rachwał, Ramon Saladrigues, Fred Fosu Agyarko

ABSTRACT

Objective: The objective of the article is to understand entrepreneurial intentions among female high school students in Ghana using the theory of planned behaviour. Moreover, it investigates differences based on parental entrepreneurship background and academic specialization.

Research Design & Methods: We selected a sample of 1286 senior high school females across 20 schools in Ghana via convenience sampling. We gathered data through a structured questionnaire by Liñán and Chen (2009) and analysed it using confirmatory factor analysis (CFA) and structural equation modelling (SEM) post-screening.

Findings: The results revealed strengthened entrepreneurial intentions for females with parent role models compared to those without. Although all programs significantly impacted intentions, the business track exhibited the largest effect. Hypothesis testing confirmed the theory of planned behaviour's core antecedents as significant drivers.

Implications & Recommendations: The findings can guide education policies and interventions aimed at strengthening female entrepreneurial intentions. However, future studies may consider more senior high or secondary schools in Ghana and other countries.

Contribution & Value Added: This research makes key contributions. For instance, it provides greater clarity on the motivational factors shaping Ghanaian female students' orientations toward future entrepreneurship.

Article type:	research article
Keywords:	entrepreneurial intentions; Ghana; theory of planned behaviour; senior high school students; females
JEL codes:	I21, L26

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INTRODUCTION

The role of women in the economic advancement of nations cannot be overstated as they constitute nearly half of the employed population. However, in certain sectors, such as entrepreneurship, their participation remains inadequate (Strawser *et al.*, 2021). Ghana is positioned as the second country in Africa concerning female entrepreneurs and occupies the 46th spot in the global rankings among Middle East and North Africa (MENA) economies. However, despite this ranking, female business proprietors in Ghana exhibit inferior performance compared to their male counterparts, as indicated by decreased productivity and sales reported by businesswomen (Owoo *et al.,* 2019; Agyire-Tettey *et al.,* 2018). In terms of value, the disparity in productivity between females and males falls within the bracket of 11% to 19%, varying based on the metric of productivity employed, which is a figure similar to assessments made for other nations in Africa (Aterido *et al.,* 2011). Moreover, women's involvement in decision-making processes in Ghana remains limited, with only 15% of national parliament members being women, and 27% of management positions in the private sector being held

by women (Caulker *et al.,* 2023). Despite their significant contribution to economic growth, women continue to face disparities in treatment, exemplified by lower remuneration compared to their male counterparts (Jha *et al.*, 2018).

In developing and emerging nations, women are often burdened with domestic responsibilities and household commitments, which hinder their participation in the workforce (Yousafzai *et al.*, 2015). Although societal advancements have led to improvements in the socioeconomic status of women, certain challenges persist, including issues of fair treatment, egalitarianism, prejudice, and the perpetuation of violent acts against women (Fauzi *et al.*, 2023).

Furthermore, the labour market poses greater vulnerability for women in Ghana, as they are more likely to hold precarious employment. A significant proportion of women (77%) are engaged in vulnerable jobs, compared to 58% of men (Caulker *et al.*, 2023). This highlights the need for targeted interventions aimed at addressing the disparities faced by women in the workforce, particularly in the entrepreneurial sector.

The Millennium Development Goal 3, which aims to promote gender equality and empower women, is a vital strategy adopted by governments and development partners to bridge the gender gap in the business sector (Buame *et al.*, 2013). Despite Ghana's leadership in promoting gender equality in the West and Central Africa region (Caulker *et al.*, 2023), deeply ingrained gendered social norms continue to marginalize women from crucial opportunities throughout their lives. The challenges posed by climate change, the COVID-19 pandemic, and high inflation further exacerbate gender disparities across all sectors (Caulker *et al.*, 2023). Nonetheless, empowering women in entrepreneurship is recognized as a key driver of economic growth and societal advancement. In Ghana, Buame *et al.* (2013) argue that significant progress in gender equity, either through human capital accumulation or increased economic participation among women, can result in an annual economic growth rate of 2.5%. Fauzi *et al.* (2023) emphasize the importance of women's entrepreneurial endeavours in achieving sustainable development goals (SDGs), particularly SDG 1, which aims to eradicate poverty in all its forms globally.

The significance of women's roles in economic development, personal health, and societal advancement has been acknowledged by various organizations and governmental entities (ILO 2020; UN Women, 2020; Bullough *et al.* 2019). Elsayed *et al.* (2021) highlight the low levels of economic and social empowerment experienced by women in many developing nations, which pose significant challenges. According to the World Bank's development indicators for 2022, Ghana's female population represents 50.13% of the total population (World Bank, 2007; Doepke *et al.*, 2012). Women in developing nations continue to lack social and economic influence compared to their counterparts in developed countries (World Bank, 2007; Doepke *et al.*, 2012). Kariv (2013) identifies several limitations and barriers that prevent women from pursuing entrepreneurial careers, including institutional, regulatory, sociological, and skill-related constraints, as well as attitude and resource-related barriers.

The effectiveness of entrepreneurial education at the secondary school level has garnered increasing attention in recent years, particularly considering the growing recognition of the importance of fostering entrepreneurial intentions among young people (Martínez-Gregorio & Oliver, 2022; Kilar & Rachwał, 2019; Rachwał *et al.,* 2016). While most empirical research on entrepreneurship has focused on university students (*e.g.* Amofah *et al*., 2023; 2024; Andrade *et al.,* 2023; Korpysa, & Waluyohadi, 2022; Reissová *et al.,* 2020; Wach & Wojciechowski, 2016; Zamrudi & Yulianti, 2020), a significant knowledge gap remain regarding the entrepreneurial intentions of secondary school students (Escolar-Llamazares *et al.*, 2019). This is despite the fact that secondary school students have expressed an interest in educational initiatives that align with their interests (Xu *et al.*, 2016). The early years of life and adolescence are widely considered to be critical periods for acquiring knowledge and cultivating favourable attitudes towards entrepreneurship (Fayolle & Liñán, 2014). However, research on entrepreneurial education has been largely limited to university students, with a scarcity of studies involving adolescents (Schaub & Tokar, 2005). These limitations in the ability to generalize findings to the broader population of prospective non-university entrepreneurs.

Notwithstanding, researchers have studied the efficacy of entrepreneurial education for secondary pupils, albeit infrequently (Athayde, 2009; Peterman & Kennedy, 2003; Sánchez, 2013). These studies have the potential to enhance the development of more efficient education initiatives (Fayolle & Liñán, 2014).

Moreover, the overreliance on university students and the scarcity of research involving adolescents have imposed limitations on the ability to generalize the findings to the broader population of prospective non-university entrepreneurs (Schaub & Tokar, 2005). Noteworthy, women entrepreneurs play a crucial role in generating new jobs and advancing the social and economic development of their societies (Brush *et al.*, 2019; Hechavarria *et al.*, 2019). However, the interplay and complexities of women's entrepreneurship, growth, and culture are understudied (Escolar-Llamazares *et al.*, 2019; Sidi Ali, 2016).

We aimed to investigate the entrepreneurial intentions of senior high school students (SHSS) in Ghana, with a particular focus on female students. We employed the theory of planned behaviour (TPB) and a survey questionnaire to gather data. The TPB model has been widely used in research on entrepreneurial intentions and studies have shown that it provides a reliable framework for understanding the factors that influence entrepreneurial behaviour (Ajzen, 1991; La Barbera & Ajzen, 2020). However, there is a need for further research to validate the TPB model among secondary school students, particularly among female students (Sara Martínez-Gregorio & Oliver, 2022). The study's motivation is rooted in the pressing issue of youth unemployment, particularly among females, which poses significant socio-economic challenges for national governments (Padi *et al.*, 2022). Entrepreneurial education in secondary schools has been identified as a crucial tool for fostering innovative systems and entrepreneurial endeavours (Martínez-Gregorio & Oliver, 2022; Rachwał *et al.* 2016). Furthermore, there is a need for more diverse and inclusive samples in research studies to enhance the generalizability of findings (Khan *et al.*, 2020). To the best of our knowledge, this study is one of the pioneering studies on female entrepreneurial intentions in Ghana, which can be classified as a novelty.

The study addresses the following research questions: To what extent do female secondary school students aspire to be entrepreneurs?, What are the differences in entrepreneurial intentions between various disciplines (programs of study)?, What are the differences in entrepreneurial intentions between students with and without entrepreneurial role models? The study's findings have important implications for promoting entrepreneurship in early education and addressing the challenges of youth unemployment. The article is structured as follows. The next section will present a literature review and conceptual framework followed by a description of the methodology, results, and discussion. Finally, we will discuss the conclusion, implications, and study limitations.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Theory of Planned Behaviour and Entrepreneurial Intentions

Aside the criticisms (its sole concentration on logical reasoning, its static explanatory character, and whether or not these are simply commonsense claims that are unfalsifiable) of the theory of planned behaviour (TPB) (McEachan *et al.*, 2011; Ogden, 2003; Sheeran *et al.*, 2013), it is a widely used framework for modelling entrepreneurial intentions and their precursors, including attitudes towards entrepreneurship, subjective norms, and perceived behavioural control (Amofah *et al*., 2023, 2024; Martínez-Gregorio & Oliver, 2022; Wach & Wojciechowski, 2016). The theory of planned behaviour posits that intentions serve as the best predictor of future behaviour (Ajzen, 2001). Entrepreneurial intention refers to the deliberate cognitive state that precedes and focuses attention on venturing actions like starting a business or adopting an entrepreneurial role (Moriano *et al.*, 2012). Scholars see it as the conscious intent preceding entrepreneurial behaviour and a strong marker of eventual conduct (Martínez-Gregorio & Oliver, 2022). Moreover, TPB proposes three drivers of intentions: perceived control, subjective norms, and attitudes about the behaviour. Other factors are considered to influence intentions via these components (Entrialgo & Iglesias, 2016). Attitudes relate to personal evaluations regarding the expected consequences of the behaviour grounded in beliefs about how it will impact oneself and others. Subjective norms encompass perceived social pressures to perform the behaviour based on perceptions that relevant others endorse engagement. Perceived behavioural control denotes the belief in having the necessary skills, experiences, and resources to successfully execute the behaviour (Bouarir *et al.*, 2023).

Entrepreneurship is often conceptualized as the outcome of a deliberate, planned decision that can be cultivated through educational methods and real-world experience (Liñán & Chen, 2009; İyigün,

2015). While approximately 90% of Norwegian secondary schools offer entrepreneurial education, its presence in Ghana remains limited (Johansen & Schanke, 2013). However, promoting such training in high schools is a vital tool for strengthening innovation systems and entrepreneurship overall (Fagerberg & Srholec, 2008). Early entrepreneurial education can facilitate the development of venture skills, underscoring its importance (Huber *et al.*, 2014). Effectiveness is typically gauged through enhanced entrepreneurial attitudes, self-efficacy, or intentions (Athayde, 2012; Bergman *et al.*, 2011; Sánchez, 2013; Schröder & Schmitt-Rodermund, 2006). Of these, entrepreneurial intention is the most widely used variable for assessing educational impact (Bae *et al.*, 2014; Longva & Foss, 2018).

For instance, a study in South Korea found that perceived behavioural control, social norms, and favourability of attitudes positively predicted entrepreneurial intentions among high schoolers (Kim *et al.*, 2022). Global surveys revealed relatively high 3-year entrepreneurial intention rates of 29% for young women and 35% for young men (Schott *et al.*, 2015). Introducing entrepreneurship through formal schooling is expected to raise women's participation levels (Jones, 2014). Analyses likewise show a strong inclination and openness to entrepreneurial paths among female university students in Ghana, highlighting the need for comprehensive social and financial support mechanisms for this group (Padi *et al.*, 2022).

Women are less likely than men to launch a business in many developed and developing nations (Kelley *et al.*, 2010). Furthermore, according to Ackah *et al.* (2024), female-founded enterprises typically have lower success rates than their male counterparts. Prior research on entrepreneurial intentions has frequently utilized mixed-gender, with a limited focus exclusively on women (Anwar & Saleem, 2019; Bazan *et al.*, 2019; Sidi Ali, 2016). One study of female business undergraduates in India established attitudes, social norms, and perceived behavioural control as positive drivers of women's venturing intentions (Khan *et al.*, 2020). However, few studies have concentrated specifically on secondary school females' intentions as this article does.

University analyses reveal entrepreneurial self-efficacy and positive attitudes boost intentions, yet this examines high school students (Matsheke & Dhurup, 2017). Entrepreneurial attitudes directly and significantly influence venturing intentions for Ghanaian youth as well (Nunfam *et al.*, 2022). Personal attitudes play a pivotal role in explaining intentions more broadly (do Paço *et al.*, 2011). According to TPB, attitudes constitute a key cognitive foundation shaping behavioural intentions and actions (Ajzen, 1991; Vamvaka *et al.*, 2020). Specifically, optimistic perspectives on entrepreneurship cultivate favourable views toward entrepreneurship intentions (Ajzen, 1991). Empirical evidence verifies the attitudinal-intentions linkage among various groups (Amofah & Saladrigues, 2022; Amofah *et al.* 2020; Esfandiar *et al.*, 2019; Vamvaka *et al.*, 2020). However, one study found subjective norms and perceived control unrelated to women's venturing aims (Amofah & Saladrigues, 2022). From the foregoing, we hypothesised that:

H1: Attitude towards entrepreneurship positively impacts entrepreneurial intention.

H2: Perceived behavioural control or self-efficacy positively impacts entrepreneurial intention.

H3: Subjective norm positively impacts entrepreneurial intention.

Entrepreneurial Intentions, Prior Entrepreneurial Exposure/Role Models and Study Programme

Prior research has revealed that role models and early exposure shape youth entrepreneurial intentions. An entrepreneurship program for Australian female high school students increased venturing aims through nurturing soft skills, connections, and positive mentors (Shahin *et al.*, 2021). However, past participation exhibited negative links with attitudes, perceived control, norms, and intentions in one study, warranting further inquiry (Malebana & Mahlaole, 2023). This contrasts with findings by Malebana and Mothibi (2023), who reported that prior start-up experience and knowledge of successful entrepreneurs had a significant positive relationship with entrepreneurial intention, attitude towards entrepreneurship, subjective norms, and perceived behavioural control among secondary school learners in South Africa.

Role models also influence critical perceptual factors. Female exemplars boosted women's confidence and competitiveness compared to male demonstrations (Schier, 2020). Parents' entrepreneurship is associated with higher career expectations, motivations, and preparedness (Scherer *et al.*, 1989). Indeed, business students with family business backgrounds are likely to display higher intentions and talent (Looi & Khoo-Lattimore, 2015). Abbasianchavari and Moritz (2021) further emphasize the importance of considering different types of role models, sociocultural contexts, and life cycle stages when structuring entrepreneurship education programs, as role models play a vital role in shaping entrepreneurial intentions and behaviour (Edigbo *et al.*, 2021). Meanwhile, Ghanaian female mentorship initiatives improved various educational outcomes (Asiegbor *et al.*, 2016).

Furthermore, previous studies also show that students' academic specialization relates to entrepreneurial intentions. Business programs exhibit higher venturing aims versus other majors (Looi & Khoo-lattimore, 2015). Indeed, more entrepreneurship coursework fosters greater intentions (Fallatah & Ayed, 2023). Thus, positive links exist between entrepreneurship education and intentions (Martin *et al.*, 2013; Rauch & Hulsink, 2015). However, the impact of the antecedents of the TPB on intentions may differ for secondary school students pursuing different programme options, hence this study. Le *et al.* (2023) further contribute to this discourse by exploring the relationship between entrepreneurial education and intentions to become an entrepreneur among master's students, finding that entrepreneurial education positively correlates with entrepreneurial perceived feasibility, perceived desirability, and intention to enter entrepreneurial activities.

Broader curricula expanding women's access to education simultaneously enable female entrepreneurship by elevating skills and judgements around work options (Ahn & Winters, 2023). However, subjects aligned with industries like biotechnology or software provide targeted competencies for those venturing paths (Ahn & Winters, 2023). Thus, while arts programs are associated with lower incomes in self- or paid employment, STEM disciplines promise higher salaries for venturing. As entrepreneurial requirements differ by sector, tailored postsecondary training likely proves most salient (Ahn & Winters, 2023).

Still, basic education access indirectly spurs startups at a macro-level by lifting human capital (Rostam-Afschar, 2014). However, heightened secondary school mandates may not replicate higher education's enablement since they compel some unwilling prospective founders (Rostam-Afschar, 2014). Voluntary tertiary schooling optimizes skills for the motivated.

In the light of the above, we proposed that:

H4: Female students with prior entrepreneurial exposure or role models display favourable entrepreneurial intentions than those without.

H5: Differences in entrepreneurial intentions differ on a programme basis.

RESEARCH METHODOLOGY

Research Design and Analytical Approach

We aimed to analyse entrepreneurial intentions among female high school students in Ghana. We applied a survey questionnaire developed by Liñán and Chen (2009) grounded in the TBP encompassing four subscales: perceived behavioural control, attitudes towards entrepreneurship, subjective norms, and intentions. We selected this measurement scale to enable a valid, reliable assessment of venture perceptions and aims that address prior gaps.

We built the subscales on validated items from earlier works. We tested the scale validity plus the conceptual model and hypotheses statistically using Cronbach's alpha, confirmatory factor analysis, and structural equation modelling in SmartPLS software. Specifically, Cronbach's alpha evaluates internal reliability among subscale items. Confirmatory factor analysis checks if the data fits the hypothesized factor structure. Finally, structural equation modelling analyses the causal pathways within the conceptual framework.

Measurement

We used a 5-point Likert scale to evaluate all constructs, with 1 representing 'strongly disagree' and 5 indicating 'strongly agree.' Adapting Liñán and Chen's (2009) methodology, the survey measured attitudes towards entrepreneurship, subjective norms, perceived behavioural control/self-efficacy, and entrepreneurial intentions among students.

Sampling and Data Collection

We administered closed-ended self-report questionnaires to assess the variables hypothesized to shape startup intentions. After obtaining teacher approval, research team members distributed surveys with voluntary participation briefed to classes. We maintained anonymity by keeping responses anonymous. Only graduating secondary school students across 20 schools in Ghana's Bono region partook (a total of 2178 respondents, of which 1286 females were included in this study). We employed convenience sampling per precedents in entrepreneurship intention literature (Amofah & Saladrigues, 2022; Amofah *et al.*, 2020). The average respondent age was 19 years old. Table 1 displays the demographic details of respondents relating to their study program and their entrepreneurial family background, which are crucial for the research analysis.

Table 1. Characteristics of respondents

Variable	***Percentage***
Program of Study	
General Science	11.9
Business	14.3
General Arts	34.5
Visual Arts	23.0
Home Economics	6.7
Other	9.6
Entrepreneurial family background	
Yes	70.1
No	29.9

Source: own elaboration based on survey.

RESULTS AND DISCUSSION

Measurement Model

In the realm of structural equation modelling (SEM), this facet of the paradigm assesses the relationships between latent variables and their various indicators. Thus, we evaluated. the reliability and validity of constructs. We gauged the reliability and validity of constructs through Cronbach's alpha and average variance extracted (AVE), respectively. As Table 2 shows, the second and third columns delineate the standardized factor loadings and the associated p-values of the CFA model. All items were statistically significant (*i.e.*, p-value < 0.05), indicating that they accurately reflect their underlying latent constructs.

Furthermore, we observed that Cronbach's alpha and composite reliability values reported for all factors exceed the threshold of 0.70 (Hair *et al.,* 2010). This suggests that the measurement model was reliable. Furthermore, our measurement model achieved convergent validity, as evidenced by the average variance extracted (AVE) values recorded for each construct being greater than 0.05 (Table 3).

Structural model

To evaluate the hypothesized relationships in the structural model, assessing model fit is prudent first. We examined fit statistics for the model including standardized root mean square residual (SRMR), squared Euclidean distance (SED), geodesic distance (GD), chi-square and normed fit index (NFI). The values indicated an acceptable fitting model overall.

Specifically, the SRMR value of 0.064 was under the 0.08 threshold for good fit (Henseler *et al.*, 2014). Moreover, SED and GD exceeded the minimum 0.05 level as well. The NFI approached 1, denoting a better fit. Moreover, all items showed variance inflation factors under 2, signifying no multicollinearity concerns.

With adequate model fit confirmed, we tested the hypotheses. The first hypothesis predicted students' attitudes towards entrepreneurship positively influence entrepreneurial intentions across all specializations and the full sample. Results consistently supported this hypothesis (see Table 5 and Figure 1), agreeing with prior work (Khan *et al.*, 2020; Nunfam *et al.*, 2022). This underscores the need to foster favourable attitudes through education, rather than just technical skills (do Paço *et al.*, 2011).

Table 2. Measurement items, their reliability, and VIF's

Constructs and their respective items	Factor loadings	P-Values	VIF
Attitude towards entrepreneurship (ATE)			
Being an entrepreneur implies more advantages than disadvantages to me (ATE1)	0.663	0.00	1.350
A career as an entrepreneur is attractive to me (ATE2)	0.776	0.00	1.520
If I had the opportunity and resources, I'd like to start a firm (ATE3)	0.739	0.00	1.407
Being an entrepreneur would entail great satisfaction for me (ATE4)	0.707	0.00	1.352
Among various career options, I'd rather be an entrepreneur (ATE5)	0.563 (dropped)	0.00	1.160
Entrepreneurial intentions (EI)			
I am ready to do anything to be an entrepreneur (EI1)	0.751	0.00	1.637
My professional goal is to be an entrepreneur (EI2)	0.708	0.00	1.546
I will make every effort to start my own enterprise (EI3)	0.682	0.00	1.444
I am determined to create a firm in the future (EI4)	0.747	0.00	1.653
I have very seriously thought of starting a firm (EI5)	0.731	0.00	1.596
I have the firm intention to start a company someday (EI6)	0.712	0.00	1.532
Perceived behavioural control (PBC)			
Start a firm and keeping it working would be easy for me (PBC1)	0.605	0.00	1.238
I am prepared to start a viable firm (PBC2)	0.687	0.00	1.336
I can control the creation process of a new firm (PBC3)	0.685	0.00	1.357
I know the necessary practical details to start a firm (PBC4)	0.649	0.00	1.415
I know how to develop an entrepreneurial project (PBC5)	0.637	0.00	1.38
If I tried to start a firm, I would have a high probability of succeeding (PBC6)	0.656	0.00	1.245
Subjective norm (SN)			
My closest family members think that I should pursue a career as an entrepreneur (SN1)	0.814	0.00	1.602
My closest friends members think that I should pursue a career as an entrepreneur (SN2)	0.848	0.00	1.740
People who are important to me think that I should pursue a career as an entrepreneur (SN3)	0.842	0.00	1.582

Note: *VIF - Variance Inflation Factor

Source: own study based on survey data.

Table 3. Constructs reliability and validity

Constructs	Cronbach's alpha	Composite reliability	Average variance extracted
ATE	0.727	0.741	0.511
EI	0.816	0.819	0.521
PBC	0.733	0.735	0.520
SN	0.783	0.787	0.697

Source: own study based on survey data.

Table 4. Model fit

Indicators	Saturated model	Estimated model
Standardized root mean square residual (SRMR)	0.064	0.064
Squared Euclidean distance (SED)	0.857	0.857
Geodesic distance (GD)	0.192	0.192
Chi-square	2408.840	2408.840
Normed fit index (NFI)	0.822	0.822

Source: own study based on survey data.

The second hypothesis stated that perceived behavioural control positively impacts intentions. We found confirmation for it across all student groups and the combined sample. However, this directionally contrasts with some previous studies (Amofah & Saladrigues &, 2022) while aligning with others (Linan & Chen, 2009; Khan *et al.*, 2020).

Table 5. Regression [estimates of the structural model]

Hypotheses	Estimate	Standard error	Remarks	P-Values
Complete				
ATE -> EI	0.327	0.024	Supported	0.000
PBC -> EI	0.327	0.023	Supported	0.000
SN -> EI	0.213	0.022	Supported	0.000
Arts				
ATE -> EI	0.260	0.038	Supported	0.000
PBC -> EI	0.304	0.037	Supported	0.000
SN -> EI	0.269	0.033	Supported	0.000
Science				
ATE -> EI	0.321	0.055	Supported	0.000
PBC -> EI	0.354	0.065	Supported	0.000
SN -> EI	0.219	0.047	Supported	0.000
Business				
ATE -> EI	0.407	0.071	Supported	0.000
PBC -> EI	0.266	0.063	Supported	0.000
SN -> EI	0.237	0.07	Supported	0.000
Home economics				
ATE -> EI	0.394	0.047	Supported	0.000
PBC -> EI	0.245	0.051	Supported	0.000
SN -> EI	0.186	0.05	Supported	0.000
Visual arts				
ATE -> EI	0.386	0.082	Supported	0.000
PBC -> EI	0.466	0.081	Supported	0.000
SN -> EI	0.058	0.081	Not Supported	0.250
Others				
ATE -> EI	0.295	0.067	Supported	0.000
PBC -> EI	0.577	0.069	Supported	0.000
SN -> EI	-0.011	0.07	Not Supported	0.397

Source: own study based on survey data.

The third hypothesis aimed to investigate the impact of students' subjective norms on their entrepreneurial intentions. The complete sample model supported the hypothesis with a positive and statistically significant estimate for the SN variable. This suggests that students' subjective norm plays a

significant role in shaping their entrepreneurial intentions. Further analysis revealed that the results were consistent across different fields of study, including general arts, science, business, and home economics. However, the narrative differed for students who offered visual arts and others, as their estimates for the SN variable, although positive, were not statistically significant at 5%. This suggests that the subjective norm of students offering visual arts and others did not significantly influence their entrepreneurial intentions. Interestingly, the subjective norm construct is considered one of the weakest among the three determinants of the TPB in many studies, according to Andrade and Carvalho (2023). This is because African students, for instance, have been found to have a more entrepreneurial attitude, while Asian and American students perceive themselves as having more behavioural control. Moreover, Andrade and Carvalho (2023) noted that African students demonstrated a stronger subjective norm than their counterparts.

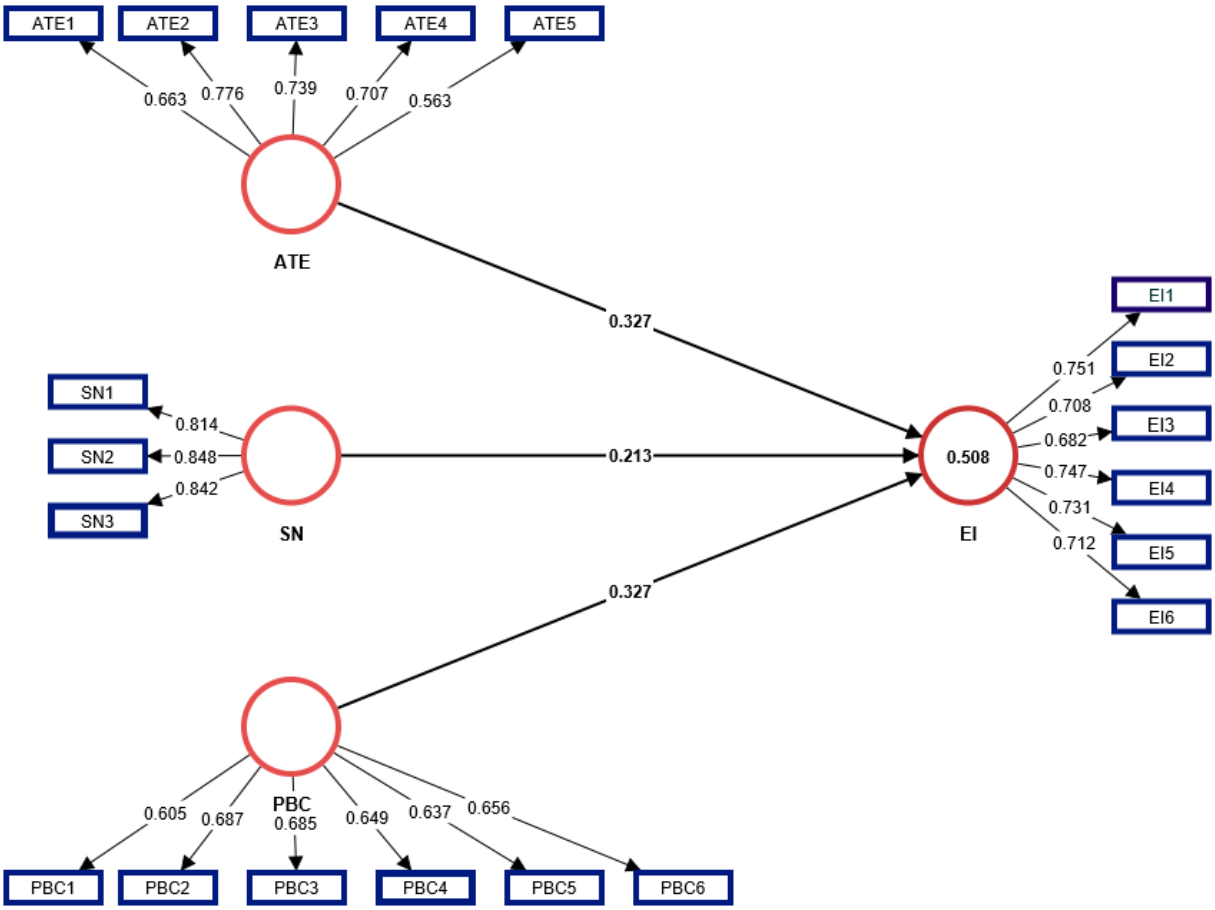

Figure 1. The estimated structural equation model

SEM model – fit: **χ2** (P-Value) = 0.00, NFI = 0.822, SED = 0.857, GD = 0.192, SRMR = 0.07, R2= 0.508

Source: own elaboration using SmartPLS.

According to the findings of Khan *et al.* (2020), the predictive power of PBC on entrepreneurial intention (EI) is deemed the most considerable, followed by the influence of ATE. Previous studies have consistently demonstrated that PBC is a significant predictor of EI (Bazan *et al.*, 2019; Roy *et al.*, 2017; Anwar & Saleem, 2019a; Maresch *et al.*, 2016; Liñán & Chen, 2009; Souitaris *et al.*, 2007). This lends support to the notion that PBC plays a vital role in shaping EI among female university students. Noteworthy, scholars have identified ATE as the strongest predictor of EI in earlier research (Souitaris *et al.*, 2007; Roy *et al.*, 2017; Bazan *et al.*, 2019; Maresch *et al.*, 2016).

In relation to Hypothesis 4, we aimed to investigate whether entrepreneurial exposure has a significant impact on the entrepreneurial intentions of female students. Our findings indicate that the attitude towards entrepreneurship among female students who have been exposed to entrepreneurship is positive and statistically significant. Similarly, the attitude towards entrepreneurship among

female students without entrepreneurial exposure is also positive and statistically significant. Although both groups display positive attitudes towards entrepreneurship, female students with prior entrepreneurial exposure exhibit more favourable entrepreneurial intentions than those without, as evidenced by the higher estimate (0.301) recorded for the former group compared to the latter (Table 6).

Table 6. Female students with and without prior entrepreneurial exposure

Hypotheses	Exposure	P-values (Exposure)	None	P-values (None)
ATE -> EI	0.301	0.000	0.295	0.000
PBC -> EI	0.341	0.000	0.349	0.000
SN -> EI	0.227	0.000	0.220	0.000

Source: own study based on survey data.

The study's findings suggest that female students with prior entrepreneurial exposure display more favourable entrepreneurial intentions than those without, in terms of both ATE and SN. Conversely, female students without prior entrepreneurial exposure display more favourable entrepreneurial intentions than those with exposure in terms of PBC. These findings support the notion that exposure to entrepreneurship can positively influence an individual's entrepreneurial intentions.

The study also explores the impact of role models on entrepreneurial intentions. According to research by Asiegbor *et al.* (2016), gender equality in Adaklu junior high schools has improved due to role models, and female students are influenced by role models in developing entrepreneurial attitudes and self-efficacy. Similarly, Moreno-Gómez *et al.* (2020) argue that having parental role models can boost an individual's desire to pursue entrepreneurship.

Moreover, we conducted a multigroup analysis to examine differences in entrepreneurial intentions among students enrolled in different programs (H5). While the majority of pairwise comparisons revealed no significant differences in entrepreneurial intentions based on programs offered, some comparisons showed significant differences (Table 7). Notably, entrepreneurship programs have been found to positively impact students' entrepreneurial intentions, engagement, and career ambitions (Liu *et al.*, 2023). However, the study notes that secondary schools in Ghana lack deliberate and systematic entrepreneurial course content, which may limit the impact of such programs on entrepreneurial intentions.

CONCLUSIONS

The findings carry important implications for entrepreneurship education policy in Ghana. At the secondary level, entrepreneurial skills modules should systematically cultivate positive attitudes by fostering self-efficacy through hands-on learning. Moreover, extracurricular programs can boost exposure through mentors and competitions. Furthermore, higher education curricula must balance hard skills with opportunities to support perceived behavioural control. Next, community outreach promoting local role models could inspire underrepresented groups through shared learning platforms. It is imperative that policymakers, school administrators, and entrepreneurship educators eagerly promote student entrepreneurial activities and implement teaching policies focused on learner-centric methods, skills development, and cultivating positive entrepreneurial attitudes. The practical actions taken in entrepreneurial education are crucial for effectively spurring students' desires to launch ventures, thereby creating jobs and wealth to drive growth. Hence, adapting teaching approaches and aligning course content to shape enterprising mindsets is vital.

The findings also highlight the potential of entrepreneurship development for positive social impact in Ghana. Widening access to entrepreneurial exposure and role models especially benefits women and students. Such interventions inspire marginalized groups while strengthening socioeconomic ties. Moreover, recognizing the influence of subjective norms also affords opportunities for targeted community engagement. Interactive platforms celebrating success stories resonate with values that sustain aspiring entrepreneurs through challenges.

Table 7. Multigroup analysis

Program 1 vs Program 2	Hypothesis	Program 1	Program 2	Invariant	Differences (1-2)
Arts vs business	ATE -> EI	0.309***	0.402***	Yes	-0.093
	PBC -> EI	0.303***	0.266***	Yes	0.037
	SN -> EI	0.271***	0.239***	Yes	0.032
Arts vs home economics	ATE -> EI	0.309***	0.390***	Yes	-0.081
	PBC -> EI	0.303***	0.245***	Yes	0.058
	SN -> EI	0.271***	0.185***	Yes	0.086
Arts vs science	ATE -> EI	0.309***	0.319***	Yes	-0.010
	PBC -> EI	0.303***	0.346***	Yes	-0.042
	SN -> EI	0.271***	0.225***	Yes	0.046
Arts vs visual	ATE -> EI	0.309***	0.390***	Yes	-0.081
	PBC -> EI	0.303***	0.460	No	-0.157**
	SN -> EI	0.271***	0.055	No	0.216*
Arts vs others	ATE -> EI	0.309***	0.293***	Yes	0.016
	PBC -> EI	0.303***	0.578	No	-0.275*
	SN -> EI	0.271***	-0.018	No	0.289*
Business vs home economics	ATE -> EI	0.402***	0.390***	Yes	0.012
	PBC -> EI	0.266***	0.245***	Yes	0.021
	SN -> EI	0.239***	0.185***	Yes	0.054
Business vs science	ATE -> EI	0.402***	0.319***	Yes	0.083
	PBC -> EI	0.266***	0.346***	Yes	-0.079
	SN -> EI	0.239***	0.225***	Yes	0.014
Business vs visual	ATE -> EI	0.402***	0.390***	Yes	0.012
	PBC -> EI	0.266***	0.460	No	-0.194**
	SN -> EI	0.239***	0.055	No	0.184*
Business vs others	ATE -> EI	0.402***	0.293***	Yes	0.109
	PBC -> EI	0.266***	0.578	No	-0.312*
	SN -> EI	0.239***	-0.018	No	0.257**
Home economics vs science	ATE -> EI	0.390***	0.319***	Yes	0.071
	PBC -> EI	0.245***	0.346***	Yes	-0.100
	SN -> EI	0.185***	0.225***	Yes	-0.039
Home economics vs visual	ATE -> EI	0.390***	0.390***	Yes	0
	PBC -> EI	0.245***	0.460	No	-0.215**
	SN -> EI	0.185***	0.055	No	0.130
Home economics vs others	ATE -> EI	0.390***	0.293***	Yes	0.097
	PBC -> EI	0.245***	0.578	No	-0.333**
	SN -> EI	0.185***	-0.018	No	0.204***
Science vs visual	ATE -> EI	0.319***	0.390***	Yes	-0.071
	PBC -> EI	0.346***	0.460***	Yes	-0.115
	SN -> EI	0.225***	0.001	No	0.170*
Science vs others	ATE -> EI	0.319***	0.293***	Yes	0.026
	PBC -> EI	0.346***	0.578	No	-0.233**
	SN -> EI	0.225***	-0.018	No	0.243**
Visual vs others	ATE -> EI	0.39***	0.293***	Yes	0.097
	PBC -> EI	0.460***	0.578***	Yes	-0.118
	SN -> EI	0.055	-0.018	Yes	0.073

Note: ***P < 0.001, **P < 0.01, *P < 0.05.
Source: own study.

Women entrepreneurs often confront low self-confidence due to systemic disadvantages, socio-cultural biases, and financial barriers. Increasing female participation in entrepreneurship carries both prospects and difficulties needing redress (Moreira *et al.*, 2019). Policy reforms are critically

required to transform frameworks inhibiting women's workforce involvement, especially in emerging economies (Cho *et al.*, 2020). Examining women's startup intentions would strengthen overall entrepreneurship understanding while spotlighting institutional and cultural dimensions alongside gender equality issues in developing contexts like Ghana.

Validating the TPB model among high school students provides a reliable tool to evaluate entrepreneurial intentions. It can assess education program efficacy and benchmark secondary school orientation levels. The attitudes and self-efficacy factors importantly predicted venturing aims, signalling the need to prioritize confidence and positivity cultivation in curricula. Indeed, many advocate that entrepreneurial schooling builds knowledge and competencies across genders (European Commission, 2008; Jones, 2014; Kuratko, 2005). Moreover, the attention to increasing women's participation is urged (Council of the European Union, 2014).

The confirmed TPB forecasts carry implications for female students in Ghana's secondary institutions including focusing less on rote examination, building student entrepreneurial capability beliefs to make founding seem achievable, and bridging curricular gaps between secondary and tertiary entrepreneurship education.

Nonetheless, there are limitations to the study. We validated the model solely on Ghanaian students, constraining generalizability. We omitted other potential theories. We did not examine cultural and contextual aspects influencing entrepreneurial intentions, limiting applicability in diverse settings. Furthermore, we did not establish predictive validity regarding actual entrepreneurial behaviours. We relied on self-reported data from a questionnaire, which may be subject to response biases and may not fully capture the complexity of the factors influencing entrepreneurial intentions. Finally, the convenience sampling method may diminish the findings' generalizability.

Future studies may use other models such as the entrepreneurial event model (EEM) or self-efficacy theory and an extension of the study in other countries.

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Authors

The contribution share of authors is as follows: Kwaku Amofah – 25%, Michael Gameli Dziwornu – 25%, Tomasz Rachwał – 20%; Ramon Solé Saladrigues – 10%, Fred Fosu Agyarko – 20%.

Kwaku Amofah

Kwaku Amofah holds a PhD in Law and Business Administration from the University of Lleida, Spain. He is a Senior Lecturer and Head of the Distance Learning Centre at Sunyani Technical University, Ghana. His research interest include entrepreneurship, management, and strategic management.

Correspondence to: Kwaku Amofah, Distance Learning Centre, Sunyani Technical University, P.O. BOX 206, Sunyani, Ghana, e-mail: email: kwaku-amofah@stu.edu.gh

ORCID http://orcid.org/0000-0002-3944-5504

Michael Gameli Dziwornu

Michael Gameli Dziwornu holds a PhD in Urban Studies from the University of Milan-Bicocca, Italy. He is a Research Scientist at the Institute for Scientific and Technological Information (INSTI) of the Council for Scientific and Industrial Research (CSIR), Accra, Ghana. His research interests include economic geography, sustainable development, crime geography, and entrepreneurship.

Correspondence to: Michael Gameli Dziwornu, Institute for Scientific and Technological Information (INSTI) of the Council for Scientific and Industrial Research (CSIR), P.O. BOX M.32, Accra, Ghana, e-mail: m.dziwornu@campus.unimib.it

ORCID http://orcid.org/0000-0001-5004-5344

Tomasz Rachwał

Tomasz Rachwał, PhD, is a Professor of Economics and Economic Geography at the Department of International Trade of the Krakow University of Economics (KUE), Poland. He is also affiliated with the Centre for Strategic and International Entrepreneurship of KUE. He is a member of the editorial board of journals in the field of entrepreneurship and economic geography. His research interests include entrepreneurship education, entrepreneurial intentions of young people, the role of entrepreneurship in the development of local and regional systems, and socio-economic geography.

Correspondence to: Tomasz Rachwał, Department of International Trade, Krakow University of Economics, ul.Rakowicka 27, 31-510 Kraków, Poland, e-mail: Tomasz.Rachwal@uek.krakow.pl

ORCID http://orcid.org/0000-0002-2232-591X

Ramon Solé Saladrigues

Ramon Solé Saladrigues, PhD, is an Associate Professor of Financial Economy and Accounting at the University of Lleida, Spain. His research interests include economic and financial indicators, European convergence international accounting and accounting reform, entrepreneurship and business creation and university analytical accounting.

Correspondence to: Ramon Solé Saladrigues, University of Lleida, c/Jaume II, 73, 25001 Lleida, Spain, e-mail: ramon.saladrigues@udl.cat

ORCID http://orcid.org/0000-0003-3987-2511

Fred Fosu Agyarko

Fred Fosu Agyarko is a doctoral student in Statistics at the University of Ghana, Legon. He is also a Statistician at the Institute for Scientific and Technological Information (INSTI) of the Council for Scientific and Industrial Research (CSIR), Accra, Ghana. His research interests include statistics of extremes, longitudinal data/repeated measures, and mixed models/random-effects models.

Correspondence to: Fred Fosu Agyarko, Institute for Scientific and Technological Information (INSTI) of the Council for Scientific and Industrial Research (CSIR), P.O. BOX M.32, Accra, Ghana, e-mail: ffagyarko@st.ug.edu.gh

ORCID http://orcid.org/0000-0002-6733-5409

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Conflict of Interest

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Power distance, uncertainty avoidance, and students' entrepreneurial intentions

Krystian Bigos, Paweł Milka

ABSTRACT

Objective: The objective of the article is to verify the relationship between power distance, uncertainty avoidance, and entrepreneurial intentions among university students according to Hofstede's national culture dimensions.

Research Design & Methods: The study sample comprised 226 Polish students, whom we asked questions related to two of Hofstede's cultural dimensions, i.e. power distance and uncertainty avoidance. We developed binomial logistic regression models and tested the hypothesis based on the estimated parameters of these models in the subsequent step.

Findings: The study showed that individuals with weak uncertainty avoidance are more likely to start their own businesses compared to those with strong uncertainty avoidance.

Implications & Recommendations: The research findings indicated that traits associated with a culture of weak uncertainty avoidance promote the emergence and growth of entrepreneurial intentions. Therefore, in terms of education aimed at fostering entrepreneurial behaviour, we recommend cultivating these attributes within society by focusing the educational process on training creative leaders, individuals with strong mental resilience, and those willing to compete and enhance the world around them.

Contribution & Value Added: The article addresses the research gap concerning cultural factors influencing entrepreneurial development, emphasizing the necessity for further research using larger and internationally comparative samples.

Article type: research article

Keywords: entrepreneurial intentions; Hofstede; entrepreneurial determinants; power distance; uncertainty avoidance; entrepreneurship education

JEL codes: I23, L26

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INTRODUCTION

National culture, including organizational culture, is an important aspect of countries' economic development. Values passed from father to son result in the formation of appropriate behaviours (Wach & Wojciechowski, 2016; Hayton & Cacciotti, 2013; Wardana *et al.*, 2021; Bigos *et al.* 2023). Research regarding cultural determinants of internationalization, innovativeness, and firms' networking is based on the concept of national culture dimensions by Geert Hofstede. Hofstede distinguished four basic dimensions of culture: power distance (PD), collectivism vs. individualism (IDV), masculinity vs. femininity (MSC), and uncertainty avoidance (UA). In further scientific works from 1991 and 2010, he added two more dimensions: the long-term orientation (LTO) and the indulgence vs restraint dimension (IND). Hofstede investigated the correlations between the above dimensions and indicated that in most cases, researchers should use two or three dimensions to describe the relationship between them (Hofstede, 2001; Szymura-Tyc & Kucia, 2016).

In the literature of the course, we can find works related to the analysis of Hofstede's dimensions in relation to the organizational culture of companies or global corporations. In the article, we want to

verify how the dimensions of power distance and avoidance of uncertainty relate to the Gen-Z generation and their propensity to start businesses, so-called 'entrepreneurial intention,' which, in turn, is intensively studied topic within international business research (*e.g.* Bigos *et al.*, 2023; Ngoc Tuan & Pham, 2022; Widjaja *et al.*, 2022; Korpysa, & Waluyohadi, 2022; Gill *et al.*, 2021; Edigbo *et al.*, 2021).

We aimed to verify the relationship between power distance, uncertainty avoidance, and entrepreneurial intentions among university students according to Hofstede's national culture dimensions. We surveyed a sample of 226 students studying at Krakow University of Economics, trying to link the mentioned cultural dimensions proposed by Hofstede with the declared entrepreneurial intentions of the students. The undertaken subject is part of current research on entrepreneurship education, which draws particular attention to the fact that a comprehensive educational process aims at shaping appropriate entrepreneurial attitudes.

The article consists of a theoretical part and an empirical part. In the theoretical part based on critical literature analysis, we will present a relationship between Hofstede's power distance, uncertainty avoidance and prospective entrepreneurial intentions. Finally, we will formulate a research hypothesis which was tested in the empirical part of the article. The results are based on the primary data obtained from the survey.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Entrepreneurship among young people is a very important phenomenon because of its economic and social dimensions (Holienka, 2014; Holienka *et al.*, 2016). The macroeconomic aspect of youth unemployment is a pressing and important topic across the EU. The increase in the unemployment rate among people under 30 can be slowed or stopped by the issue of youth self-employment. The increase in entrepreneurship among people under 30 can also result in the creation of new places – as a result of the increase in self-employment. An additional aspect is the change in young people's attitude to work. If a person under 30 becomes independent of an employer (self-employment instead of a full-time job) he or she will become self-sufficient. Such a decision at a young age will cause these individuals to follow self-sufficiency and self-employment throughout their working life and thus the development of the qualitative side of entrepreneurship (Holienka *et al.*, 2016).

However, according to Thompson (2009), entrepreneurial intent is a person's belief that he or she will set up a business venture and plans to do so. Young people who want to start a business must consider certain factors (*e.g*. the ability to make sacrifices and commitments) and, most importantly, personality traits such as feasibility or effectiveness (Byabashaija & Katono, 2011). These traits promote intentions and their transformation to concrete behaviour – *i.e.* to open one's own business (Wach & Wojciechowski, 2016). The aforementioned personality traits and attitudes toward entrepreneurship and self-employment result mainly from the cultural conditions in which these individuals grow up.

The theoretical background of our study focuses on the analysis of two dimensions of Hofstede's culture: power distance and uncertainty avoidance concerning the entrepreneurial intentions of students (representatives of the GEN-Z generation).

The first dimension of Hofstede's culture that the authors of this article will highlight is the dimension of power distance. In analyzing this dimension, Hofstede found that low power distance is characterized by the following values: the desire for decentralization, small differences in pay between low and high positions, subordinates wanting to be taken into account when making key decisions, reducing inequality in the company, the superior is a democrat, everyone should have equal rights.

The research result associated with high power distance is on the opposite side of the spectrum. It entails strong centralization, large differences in pay between positions of different levels, subordinates expect a list of tasks from superiors, the superior is an autocrat, and those with positions should have due privileges.

The second analysed dimension was the uncertainty avoidance dimension, a dimension that describes the extent to which a country's citizens are willing to accept the uncertainty of tomorrow. Hofstede divided this dimension in two ways. The features characterizing weak uncertainty are low-stress

levels, recognizing uncertainty as a natural part of life, acceptance of life as it is, acceptance of innovations in actions and ideas, minimal laws and regulations, and the statement that hard work is a necessity.

Uncertainty avoidance is in opposition to these traits. It involves high levels of stress, recognizing uncertainty as a threat that must be fought against, rejection of innovative activities and ideas, a high need to frame everything in a framework and laws, and the statement that hard work is an internal need (Hofstede *et al.*, 2010; Szymura-Tyc & Kucia, 2016).

Boonghee *et al*. (2011) conclude that at the individual level, Hofstede's above dimensions of culture (power distance and uncertainty avoidance) do not yield realistic results for the overall global consumer level. They conclude that these measures of national culture do not perform as well as multidimensional measures and that additional work is needed in this area. Blodgett *et al.* (2008) also examined Hofstede's cultural framework at the individual consumer level. Their results were unsatisfactory and their factor analyses did not yield a consistent framework. They raised the need to develop a reliable and valid measure of Hofstede's cultural dimensions at the individual level. They indicated why individuals from different regions respond differently to different business strategies (Boonghee *et al.*, 2011).

Given that the results of previous scientific studies have not provided clear answers in the context of the influence of power distance and uncertainty avoidance on students' entrepreneurial intentions, we decided to verify the following hypotheses:

H1: Individuals who have a high-power distance manifest higher entrepreneurial intentions than those with a lower distance.

H2: Individuals who weakly avoid uncertainty manifest higher entrepreneurial intentions than those with strong uncertainty avoidance.

Based on the above considerations, we conducted an empirical study verifying the above hypothesis in the later stages of the work.

RESEARCH METHODOLOGY

Sample and Data Collection

The study employs a post-positivist framework typical of quantitative research (Creswell & Creswell, 2022). Our analysis utilizes primary data collected from a survey of 226 students in Poland (Table 1). The majority of respondents were women, comprising 64.6% of the sample, while men made up 35.4%. We conducted the survey in January 2023 and included questions addressing Hofstede's cultural dimensions. For this article, we focused on two specific dimensions: power distance and uncertainty avoidance.

Table 1. Sample structure

Variables	Characteristics	Frequency	Per cent
Gender	Male	80	35.4%
	Female	146	64.6%
Family Entrepreneurial Experience	Yes	162	71.7%
	No	64	28.3%

Source: own study in PQStat.

Variables in the Analysis

The study included a single dependent variable related to entrepreneurial intentions, specifically students' declarations regarding their plans to start a business in the near future (*e.g.* 'Are you considering starting your own business during or after your studies?'). This variable aligns with the frameworks established by Liñán and Chen (2009) and Amofah *et al.* (2024). The dependent variable was dichotomous. We coded a 'yes' response to the question as 1, while a 'no' – as 0.

In the study, we included four independent variables in total, with the first two relating to power distance: (1) low power distance and (2) high power distance. The remaining two pertain to the level of uncertainty avoidance: (3) weak uncertainty avoidance, and (4) strong uncertainty avoidance. We calculated the value of the independent variable describing low power as the arithmetic mean of

three 5-level Likert scale questions: (1a) 'I believe that at work, the boss, and employee should treat each other as partners – without a clear division between superior and subordinate,' (1b) 'I believe that everyone should have an equal share in decision-making at work, regardless of their job position,' (1c) 'I believe that a supervisors should not have special privileges due to their position.' Conversely, high power distance was determined based on the arithmetic mean of three questions: (2a) 'I believe that hierarchy at work is important, so subordinates should be dependent on superiors and show them absolute respect,' (2b) 'I believe that decisions at work should be made by superiors, and employees should be supervised while performing assigned tasks,' (2c) 'I believe that supervisors should have special privileges due to their position.' Similarly, the values of the variables related to uncertainty avoidance were calculated as the arithmetic mean of 5-level Likert scale questions: for weak uncertainty avoidance: (3a) 'When working in a group/at work, I usually feel confident – I do not feel negative emotions,' (3b) 'Competing among colleagues at university/work is highly motivating and builds character,' (3c) 'Rules are meant to be broken – without this, breakthrough solutions would not emerge;' and for strong uncertainty avoidance: (4a) 'When working in a group/at work, I usually feel nervous/stressed,' (4b) 'Competing among colleagues at university/work usually does more harm than good,' (4c) 'Rules should not be broken in a company/university, even if the student/employee believes it is in the best interest of the company/university.'

The study also included two control variables, *i.e. gender* and *family entrepreneurial experience*. We measured gender dichotomously, with a value of 1 assigned to male respondents and 0 to female respondents. This choice reflects findings from previous research, *e.g.* Zhang *et al.* (2014), who suggest that men generally exhibit a higher propensity to start businesses than women. The final control variable pertained to *family entrepreneurial experience*, specifically regarding the business activities of relatives. If the surveyed student indicated that any of their relatives currently or previously conducted business, we assigned a value of 1; otherwise, a value of 0. This approach aligns with the studies by Gubik (2021) and Bigos and Michalik (2020).

Research Model and Statistical Tests

The inferences in this study are derived from the estimated parameters of a binomial logistic regression model, which is suitable for variables on a weak scale. We assessed the reliability of these models using two statistical tests:

1. the likelihood ratio test, which seeks statistical significance, and
2. the Hosmer-Lemeshow test, which aims for a lack of statistical significance.

Moreover, we computed pseudo-*R*-squared coefficients using the Cox-Snell and Nagelkerke methods. Given the weak scale of the variables, we also calculated *V*-Cramer coefficients to examine the interdependence among the analysed variables. Figure 1 illustrates the proposed research model.

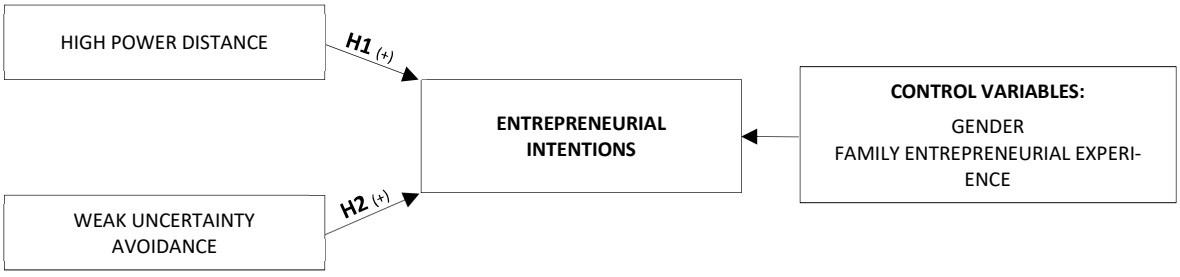

Figure 1. Proposed research model
Source: own elaboration.

RESULTS AND DISCUSSION

Given that the variables in the analysis are expressed on a weak scale, we calculated the *V*-Cramer coefficient (refer to Table 2). We can observe that the variables *WEAK UNCERTAINTY AVOIDANCE* and *STRONG UNCERTAINTY AVOIDANCE* exhibit relatively the highest degree of association (v=0.385, p<0.001). This is

followed by the relationship between *LOW POWER DISTANCE* and *HIGH POWER DISTANCE* (*v*=0.317, p<0.001), and between *GENDER* and *STRONG UNCERTAINTY AVOIDANCE* (*v*=0.316, *p*<0.05). The association between *GENDER* and *FAMILY ENTREPRENEURIAL EXPERIENCE* was relatively the weakest (*v*=0.096).

Table 2. V-Cramer coefficient

Variable	1	2	3	4	5	6	7
1. ENTREPRENEURIAL INTENTIONS	1	–	–	–	–	–	–
2. GENDER	**0.155***	1	–	–	–	–	–
3. FAMILY ENTREPRENEURIAL EXPERIENCE	**0.178****	0.096	1	–	–	–	–
4. LOW POWER DISTANCE	0.275	**0.300+**	0.147	1	–	–	–
5. HIGH POWER DISTANCE	0.215	0.231	0.201	**0.317*****	1	–	–
6. WEAK UNCERTAINTY AVOIDANCE	0.255	0.238	0.270	0.232	0.221	1	–
7. STRONG UNCERTAINTY AVOIDANCE	**0.304+**	**0.316***	0.180	0.220	**0.285*****	**0.385*****	1

Note: Significant codes: + p<0.1, * p<0.05, ** p<0.01, ***p<0.001.
Source: own study in PQStat.

We verified the hypothesis using the parameter estimation results in the econometric models presented in Table 3. We measured their reliability using the likelihood ratio test and the Hosmer-Lemeshow test. In all models, the likelihood ratio test showed statistical significance (model 1: chi-square=17.885, *p*<0.01; model 2: chi-square=17.193, *p*<0.001; model 3: chi-square=13.829, *p*<0.01; model 4: chi-square=17.554, *p*<0.01; model 5: chi-square=17.448, *p*<0.001; model 6: chi-square=12.047, *p*<0.01), while the Hosmer-Lemeshow test indicated statistical insignificance (model 1: chi-square=5.584, *p*=0.694; model 2: chi-square=7.335, *p*=0.501; model 3: chi-square=6.841, *p*=0.554; model 4: chi-square=6.112, *p*=0.635; model 5: chi-square=9.738, *p*<0.284; model 6: chi-square=13.059, *p*<0.110).

In terms of the Akaike Information Criterion, model 5 demonstrated a better fit, while model 6 showed a relatively poorer fit. Moreover, we determined pseudo *R*-square values, calculated using the Nagelkerke and Cox-Snell methods, for the created binomial logistic regression models (Smith & McKenna, 2013). For the first econometric model, Nagelkerke's pseudo *R*-square (NPRsq) was 0.105, and Cox-Snell's Pseudo *R*-square (CSsq) was 0.076. We observed higher values for models 2, 4, and 5, with Nagelkerke's Pseudo *R*-square at 0.101, 0.103, and 0.102, respectively, and Cox-Snell's pseudo *R*-square at 0.073, 0.075, and 0.074, respectively (see Table 3). We observed relatively poorer results for models 3 and 6 (model 3: NPRsq=0.082, CSsq=0.059; model 6: NPRsq=0.072, CSsq=0.052).

Based on the estimated parameters in all econometric models, we could observe that both variables *FAMILY* ENTREPRENEURIAL *EXPERIENCE* and *GENDER* were statistically significant among the control variables. Based on this, we can conclude that conducting business activity in the past and currently by relatives promotes higher entrepreneurial intentions (slightly twice as often). However, in the context of *GENDER*, men manifest slightly less than twice the propensity to start a business than women. Nevertheless, in the following regression models, the estimated parameter demonstrates statistical significance at the level of *p*<0.1.

Regarding the first research hypothesis, which posited that individuals with a higher power distance exhibit a greater tendency to establish firms than those with a lower power distance, we tested the hypothesis based on the interpretation of estimated logistic regression parameters in models 1, 2, and 3. The results show a negative relationship between low power distance and entrepreneurial intentions (model 1: odds ratio=0.676, *p*<0.05; model 2: odds ratio=0.643, *p*<0.05). However, for high power distance, the parameter was statistically insignificant in both model 1 and model 3. Therefore, there was no basis to either reject or accept H1.

The situation differs for the second hypothesis, where model 4 shows that the estimated logistic regression parameter for WEAK UNCERTAINTY AVOIDANCE is statistically significant (*p*<0.05), with an odds ratio of 1.703. This indicates that individuals characterized by weak uncertainty avoidance have a higher tendency to start a business compared to those with strong uncertainty avoidance.

The results of model 5 confirmed it, as the tendency was 1.653 times higher than for other individuals (model 5: odds ratio=1.653, $p<0.05$). Thus, we accepted hypothesis 2.

Table 3. The list of estimated models (odd ratios)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
const.	1.609 (0.967)	**3.054+ (0.590)**	0.376 (0.632)	**0.149+ (1.137)**	**0.200* (0.683)**	1.329 (0.634)
GENDER	**1.752+ (0.319)**	**1.776+ (0.318)**	**1.849+ (0.315)**	**1.793+ (0.326)**	**1.751+ (0.318)**	**1.822+ (0.323)**
FAMILY ENTREPRENEURIAL EXPERIENCE	**2.160* (0.314)**	**2.086* (0.311)**	**2.251** (0.312)**	**1.976* (0.313)**	**1.975* (0.312)**	**2.101* (0.308)**
LOW POWER DISTANCE	**0.676* (0.197)**	**0.643* (0.188)**	–	–	–	–
HIGH POWER DISTANCE	1.178 (0.197)	–	1.322 (0.186)	–	–	–
WEAK UNCERTAINTY AVOIDANCE	–	–	–	**1.703* (0.229)**	**1.653* (0.210)**	-
STRONG UNCERTAINTY AVOIDANCE	–	–	–	1.073 (0.217)	–	0.872 (0.195)
Likelihood ratio test	17.885**	17.193***	13.829**	17.554**	17.448***	12.047**
Hosmer-Lemeshow test	5.584 (p=0.694)	7.335 (p=0.501)	6.841 (p=0.554)	6.112 (p=0.635)	9.738 (p=0.284)	13.059 (p=0.110)
Akaike Information Criterion	282.637	281.329	284.693	282.968	281.074	286.475
Pseudo R-square (Negelkerke)	0.105	0.101	0.082	0.103	0.102	0.072
Pseudo R-square (Cox-Snell)	0.076	0.073	0.059	0.075	0.074	0.052
N	226	226	226	226	226	226

Note: Significant codes: + p<0.1, * p<0.05, ** p<0.01, ***p<0.001. Standard errors in parentheses.
Source: own study in PQStat.

We observed that our research findings regarding power distance are indirectly consistent with the findings of other researchers, such as Miao *et al.* (2018). The study by Samydevan *et al.* (2021) showed that power distance had an insignificant relationship with entrepreneurial intentions. On the other hand, regarding weak uncertainty avoidance, Jung *et al.* (2001) and Beliaeva *et al.* (2017) reached similar conclusions.

CONCLUSIONS

From an economic perspective, supporting business activities is particularly important. The presented research results support the hypothesis that in cultures with low uncertainty avoidance, entrepreneurial intentions are higher than in cultures with high uncertainty avoidance. We neither confirmed nor rejected the hypothesis related to the degree of power distance. Therefore, it is advisable to extend research to a larger sample in various countries. This finding is consistent with previously cited research by other authors.

We must also note the research limitations concerning the obtained results. First of all, the sample was relatively small and limited to students from one university, which may not necessarily translate to the studies' replicability as it pertains to a narrow cultural context. Future research should also focus on other countries and cultural contexts. In the context of studies on entrepreneurial intentions, there remains a profound need for further research in this area. Therefore, entrepreneurial education policies need to consider the cultural contexts of the young generation's personality traits, which differ from the behaviour models of the elder generations. Moreover, it is necessary to recognize the implications for promoting traits oriented towards risk-taking from the early stages of education, as risk

aversion can effectively discourage the business establishment. Policymakers also play a crucial role in this regard. They should support the development of entrepreneurship in their country by designing programs and promoting the idea of entrepreneurship among young citizens.

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Authors

The contribution share of authors is equal and amounted to 50% for each of them.

Krystian Bigos
Assistant Professor at Krakow University of Economics, Department of International Trade at College of Economics, Finance and Law. His research interests include early and rapid internationalisation, international start-ups, and international entrepreneurship.
Correspondence to: Krystian Bigos, PhD, Department of International Trade, Krakow University of Economics, ul. Rakowicka 27, 31-510 Kraków, Poland, e-mail: bigosk@uek.krakow.pl
ORCID http://orcid.org/0000-0001-6030-4119

Paweł Milka
Teaching Assistant at Krakow University of Economics, College of Economics, Finance and Law. His research interests include international financial markets, investments, hedging instruments, international transport, international e-business.
Correspondence to: Mgr Paweł Milka, Krakow University of Economics, ul. Rakowicka 27, 31-510 Kraków, Poland, e-mail: milkap@uek.krakow.pl
ORCID http://orcid.org/0000-0002-6276-7587

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Department of International Trade
Centre for Strategic and International Entrepreneurship
Krakow Uniwersity of Economics
ul. Rakowicka 27, 31-510 Krakow, Poland
phone +12 293 5929, -5376, fax +12 293 5037
e-mail: ier@uek.krakow.pl
http://ier.uek.krakow.pl

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