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Public Health and Sustainable Development: Assessing SDG3 across the Countries of the European Union

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ABSTRACT

Objective: To classify EU countries by their degree of implementation of Sustainable Development Goal 3 – good health and well-being; to identify the changes which have occurred in two years, 2016 and 2020.

Research Design & Methods: The study used methods of multivariate statistical analysis with a particular emphasis on cluster analysis methods, including Ward's method and *k*-means. Using Ward's hierarchical clustering, a preliminary determination of the number of EU country groups was made using a dendrogram of linkages, integration distances, and classification steps. The Calinski-Harabasz index was used for the final selection of the optimal number of classes.

Findings: In both 2016 and 2020, two classes of the EU countries emerged, differing significantly in terms of their SDG3 implementation levels. The class presenting a higher level of public health and well-being included the Member States of the EU prior to its expansion eastward. Greece

(a country with longer term EU membership), Cyprus, Malta and Slovenia (of the EU's new enlargement) were among the other class.

Implications/Recommendations: The changes that occurred in SDG3 implementation in EU countries from 2016 to 2020 are positive. Most of the indicators we tracked changed for the better, indicating that the actions taken by EU Member State governments effectively improve public health and well-being. Future efforts should focus on improving preventable mortality, reducing obesity, and extending healthy life.

Contribution: The article is intended to broaden the knowledge on sustainable development implementation levels for good health and well-being and to identify the changes which occurred in this area between 2016 and 2020, the two years examined.

Article type: original article.

Keywords: public health, good health and well-being, sustainable development, European Union.

JEL Classification: Q56, C38.

1. Introduction

Sustainable development is based on the concept of progressive, harmonious change across three dimensions – economic, social and environmental. Public health is a key dimension of the social sphere (Zalewska, 2015). Life expectancy is the main determinant of public health, and positive trends can be noted in many countries, especially highly developed ones. Extending the human lifespan has become possible thanks to effective control of infectious diseases, improved sanitation, better food quality and greater availability, increasingly healthy eating habits, improved road safety and other preventive public health measures (Cianciara, 2018).

On the other hand, there continue to be significant risks to human health and life, including unbalanced diet, a lack of or very little physical activity, being overweight or obese, excessive alcohol consumption, and smoking (Johnson *et al*., 2016; Azzopardi-Muscat *et al*., 2017), air pollution, climate change, poverty, inadequate living conditions, human activity-related accidents and disasters (Wojteczek, 2019). These factors often lead to chronic diseases – and consequently premature death – and many of them are associated with modern lifestyles.

Lalonde (1974) observed that human health depends largely (53%) on lifestyle. Physical environment (21%), genetic factors (16%) and, most importantly, the healthcare system (10%) have much less influence. Two studies have confirmed these general conclusions (Wysocki, 2007; Cianciara, 2018), as did a 2002 report by the World Health Organization (WHO, 2002), which found that the key to public health is not treatment, but prevention of disease by eliminating environmental, socioeconomic and cultural risks, including those related to lifestyle (Zalewska, 2015).

An appropriate framework for debate on the factors that shape public health can be found in the 2030 Agenda for Sustainable Development. With regard to this framework, the present research pursues answers to two questions:

1. What changes occurred in the level of SDG3 implementation in EU countries between 2016 and 2020, and can they be assessed positively?

2. What differences in the level of SDG3 implementation existed between EU countries in 2016 and 2020?

Our overarching purpose is to understand the diversity and classification of EU countries regarding the implementation level of SDG3 as it applies to good health and well-being in the years 2016 and 2020. It is also to identify changes which have occurred in this regard in the five years under consideration.

2. Health, Public Health and Sustainable Development: A Literature Review

Health is not mere the opposite of disease or disability, but a state of physical, mental and social well-being (Bickenbach, 2015; Eckermann, 2018). Within this triad of subjective well-being, physical health is manifest in the proper functioning of the body; mental health is expressed in the ability to think logically, articulate and perceive feelings, and overcome anxiety and stress; social health takes the form of an individual's proper existence in society. The protection of holistic well-being is addressed by the field known as public health (WHO, 2023).

According to Acheson's (1988, p. 24) definition, which has been adopted by the WHO European Region, public health is "the science and art of preventing disease, prolonging life and promoting health through the organized efforts of society." In pragmatic terms, public health as framed and addressed by health policies and programmes plays a crucial role. They include measures aimed at controlling and preventing disease, protecting the environment, promoting education and health, and making healthcare universally accessible (Wysocki, 2007).

Health is important for both the individual and society as a whole. It should be perceived in terms of (Korporowicz, 2011; Michaluk-Mazurek, 2019):

– value enabling an individual or a specific community to fulfil aspirations and the need to achieve satisfaction,

– a resource conditioning social and economic development,

– a means to everyday life determining its quality.

The importance of health was uniquely emphasised in the Rio Declaration on Environment and Development. The document accepts that "human beings are at the centre of the sustainable development process; they have the right to live healthy and creative lives in harmony with nature" (ONZ, 1992). This rule, upheld in the global programme *Transforming Our World: Agenda for Sustainable Develop-*

ment 2030 (Agenda 2030), indicates not only the high importance of health, but also its connection to sustainable and harmonised shaping of progressive change (Mazur-Wierzbicka, 2017). Among the 17 Sustainable Development Goals (SDGs) eligible for implementation by 2030, the objective need to *strive for a healthy life for all people of all ages and promote well-being* has been recognised (SDG3). Success in this regard conditions the implementation of the global development agenda in each of its three pillars – environmental, economic and social (Peña-Sánchez, Ruiz-Chico & Jiménez-García, 2021), and these correlations are not one-sided. That there is a feedback loop between sustainability and public health has been widely accepted (Macassa, 2021). Sustainable development is not possible in the absence of healthy lives and well-being (Davis *et al*., 2015; Le Blanc, 2015; Pereira *et al*., 2021), and conversely, without sustainable development humanity will not achieve a favourable state of health (Nunes, Lee & O'Riordan, 2016; Aftab *et al*., 2020). This correlation makes the implementation of SDG3 a major challenge in today's world (Sachs *et al*., 2021; AbuShihab *et al*., 2024).

Assuming that sustainable development is grounded in a moderately anthropocentric value system, its core objective can be understood as the pursuit of enhanced physical, mental, and social well-being for individuals and the global population. This is achieved through the creation of a high quality of life that does not compromise the ability of future generations to meet their own needs (Pluye, Potvin & Denis, 2004; Porritt, 2005). In this perspective, health becomes a specific, aggregate measure of successful sustainable development (Kickbusch, 2013).

The correlation between health and sustainable development is clearly visible in the links between the goals specified in the 2030 Agenda. These links take on particular significance when the goal of *ensuring a healthy life for all at all ages and promoting well-being* (SDG3) is viewed in relation to the other 16 goals of sustainable and harmonised change. There are synergies between SDG3 and the other SDGs (Kickbusch, 2013; Becerra-Posada, 2015). Health conditions the implementation of the overall social, economic and environmental goals. In any case, all of the SDGs are interconnected by the principle of indivisibility – the 17 SDGs are equally important and can only be achieved through their comprehensive implementation (Kostetckaia & Hametner, 2022).

3. Statistical Data and Research Methods

The 17 SDGs elaborated in Agenda 2030 are oriented toward people, the planet, prosperity, peace and partnership (Lipiec, 2019; Adamowicz, 2021; Firlej, 2021; Perkowski, Kosicki & Chrzanowski, 2023). It lists 169 tasks which are measured using 231 indicators, with national governments responsible for observing the progress made on the orders. EU Member States have adopted their own set of

indicators (including a group of measures for SDG3), which are reported by Eurostat (Eurostat, 2021; Szymańska, 2021; Gavurova & Megyesiova, 2022). This study assesses the differentiation and classification of EU countries in terms of the extent to which they have implemented sustainable development in the category of good health and well-being (SDG3). It also identifies the changes that have occurred in this area from 2016 to 2020, the two years under analysis. The following set of 11 indicators, adopted by the EU for monitoring the implementation of SDG3, was used as the basis for formulating value judgments:

– H_1 – healthy life years at birth (years),
– H_2 – share of people with good or very good perceived health (%),
– H_3 – smoking prevalence (%),
– H_4 – standardised death rate due to tuberculosis, HIV and hepatitis (rate),
– H_5 – standardised preventable and treatable mortality (rate),
– H_6 – self-reported unmet need for medical examination and care (%),
– H_7 – obesity rate by body mass index (%),
– H_8 – fatal accidents at work per 100,000 workers,
– H_9 – population living in households reporting suffering from noise (%),
– H_{10} – road traffic deaths per 100,000 persons,
– H_{11} – years of life lost due to PM2.5 exposure (rate).

Statistical information was retrieved from the Eurostat database (sustainability indicators – good health and well-being) (Eurostat, 2023). 2016 and 2020 were chosen for analysis of the implementation of SDG3 in EU countries as data for those years were fully available, thus allowing for a precise and reliable examination of progress and the identification of key trends in SDG3 implementation. It is also an appropriate period for observing changes. The year 2016 is the first full year after the adoption of the 2030 Agenda, making it a crucial starting point. The year 2020 is significant as it represents the point just before the outbreak of the COVID-19 pandemic, allowing for the assessment of progress before the pandemic's impact. Additionally, 2020 is the latest year for which complete data is available for all 11 SDG3 indicators adopted by the EU, enabling a comprehensive and consistent analysis. For 2021, statistical information is not available for three indicators: smoking prevalence (%) (H_3), obesity rate by body mass index (%) (H_7), and population living in households that report suffering from noise (%) (H_9). Finally, observing significant differences in SDG3 implementation levels over the five years is crucial for assessing the effectiveness of actions taken by individual countries.

Choosing different years would likely have yielded different results, especially if years with significant events, such as the COVID-19 pandemic, were included, as these could significantly impact health indicator outcomes. This should be the scope of further research on the degree of SDG3 implementation by EU countries.

The present study used methods of multivariate statistical analysis with particular emphasis on cluster analysis methods, including Ward's method and *k*-means method. More on cluster analysis methods can be found in the work of Ward (1963) and Hartigan (1975). The research was carried out in according to the following procedure.

Step 1. Assess the changes in the indicators used to monitor the implementation of SDG3 in the EU and the diversification of Member States in this respect in 2016 and 2020.

Step 2. Construct matrices that form the basis for classifying the EU countries in terms of the implementation level of SDG3 in 2016 and 2020:

$$\mathbf{X}^t = \left[x_{ij}^t \right]_{(nxm)}, \tag{1}$$

$$\mathbf{Z}^t = \left[z_{ij}^t \right]_{(nxm)}, \tag{2}$$

where:

$\mathbf{X}^t$ – the matrix of values of $H_1 – H_{11}$ indicators monitoring the implementation of SDG3 in *t*-th period,

$\mathbf{Z}^t$ – the matrix of normalised values of $H_1 – H_{11}$ indicators monitoring the implementation of SDG3 in *t*-th period,

$t = 1, 2$ – the number of the analysed period, for 2016 and 2020, respectively,

$i = 1, \ldots, n$ ($n = 27$) – the number of the analysed period (country),

$j = 1, \ldots, m$ ($m = 11$) – the number of the indicator monitoring the implementation of SDG3,

x_{ij}^t – value of *j*-th SDG3 indicator in *i*-th object and *t*-th period,

z_{ij}^t – normalised value of *j*-th SDG3 indicator in *i*-th object and *t*-th period.

Before the classification methods were applied, transformation of the indicators monitoring SDG3 was normalised. The characteristics of the formulas for normalising variables and their properties have been presented elsewhere (Kukuła, 2000; Zeliaś, 2002; Sobczak, 2010).

In the present analysis, the indicators H_1 and H_2 play the role of stimulants, making their high values desirable for the realisation of SDG3. All other indicators monitoring SDG3 are destimulants, but their low values are favourable for achieving SDG3.

Zero unitarisation (Kukuła, 2000) was used to normalise the SGD3 indicators. It is expressed by formula (3) for SDG3 indicators acting as stimulants and formula (4) for destimulants:

$$z_{ij}^t = \frac{x_{ij}^t - \min\limits_i x_{ij}^t}{R_j^t} \qquad \text{for } j = 1, 2, \tag{3}$$

$$z_{ij}^t = \frac{\max\limits_i x_{ij}^t - x_{ij}^t}{R_j^t} \qquad \text{for } j = 3, 4, \ldots, 11, \tag{4}$$

where R_j^t is the range of values of *j*-th indicator monitoring the implementation of SDG3 in *t*-th period.

Step 3. A preliminary classification of EU countries based on their level of SDG3 implementation was conducted using Ward's hierarchical clustering method (Ward, 1963). This analysis, covering 27 EU countries in 2016 and 2020, was guided by a dendrogram of linkages, integration distances, and classification steps. Prior to applying Ward's method, squared Euclidean distances between the countries were calculated based on their SDG3 indicators.

Step 4. The EU countries were grouped into relatively homogeneous classes based on their level of SDG3 implementation in 2016 and 2020 using *k*-means clustering method developed by Dalenius and Gurney (1951).

The Calinski-Harabasz index was used to select the optimal number of classes (Caliński & Harabasz, 1974).

Step 5. A typology and characteristics of the classes of EU countries in terms of their level of SDG3 implementation in 2016 and 2020.

The applied research procedure made it possible to assess the degree of diversification among the EU countries in SDG3 implementation, as well as the changes that occurred between 2016 and 2020.

4. Research Results

The degree and direction of changes occurring in the scale of sustainable development implementation in good health and well-being in the EU were assessed. To this end, the relative changes of indicators monitoring the implementation of SDG3 in 2020 compared to 2016 were used. The coefficients of variation were used to assess the differentiation in the EU countries and the changes which occurred during the period under study. Results of calculations are presented in Table 1 and Figure 1.

Table 1. Relative Changes in the Values of Indicators Monitoring Sustainable Development in Terms of SDG3 in the EU in 2020 Compared to 2016

SDG3 Indicator	Preference Direction	Relative Change (%) 2020/2016	Direction of Indicator Change	Coefficient of Variation (%)	
				2016	2020
H_1	S	0.00	no change	8.0	7.3
H_2	S	2.96	positive	14.9	13.8
H_3	D	–7.41	positive	25.2	31.5
H_4	D	–31.54	positive	89.5	92.0
H_5	D	6.28	negative	40.6	43.3
H_6	D	–32.14	positive	120.0	119.7
H_7	D	1.74	negative	9.5	9.0

Table 1 cnt'd

SDG3 Indicator	Preference Direction	Relative Change (%) 2020/2016	Direction of Indicator Change	Coefficient of Variation (%)	
				2016	2020
H_8	D	–3.80	positive	54.8	50.0
H_9	D	–2.76	positive	31.0	35.8
H_{10}	D	–20.75	positive	31.6	34.9
H_{11}	D	–25.34	positive	69.3	76.0

Notes: S – stimulant, D – destimulant.

Source: the authors, based on Eurostat database.

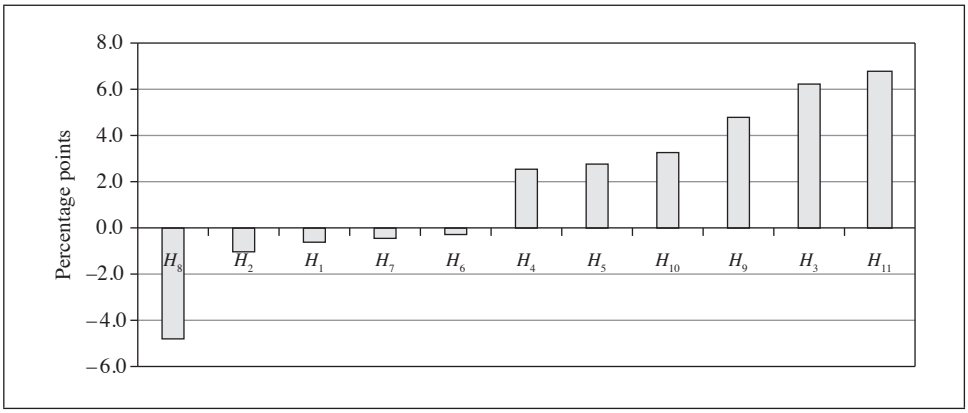

Fig. 1. Absolute Changes in the Coefficients of Variation for the Indicators Monitoring the Implementation of SDG3 in the EU in 2020 Compared to 2016 (Percentage Points) Arranged in Ascending Order

Source: the authors, based on Eurostat database.

Analysis of Table 1 and Figure 1 shows that both the dispersion of the EU countries in terms of their level of SDG3 implementation and the changes that occurred to that level in 2020 varied significantly from that observed in 2016 for the individual monitoring indicators.

Ward's method was used to determine a preliminary proposal for dividing the EU countries into relatively homogeneous classes based on the level of SDG3 implementation. Figure 2 shows the steps of hierarchical classification in the form of a dendrogram of connections and node distances in 2016 and 2020. Based on these, a variant division of the EU27 countries, using *k*-means method, into two and three classes for both years, was proposed. In order to select the optimal number of classes, Calinski-Harabasz quality index of classification results CH(*k*)*t* was

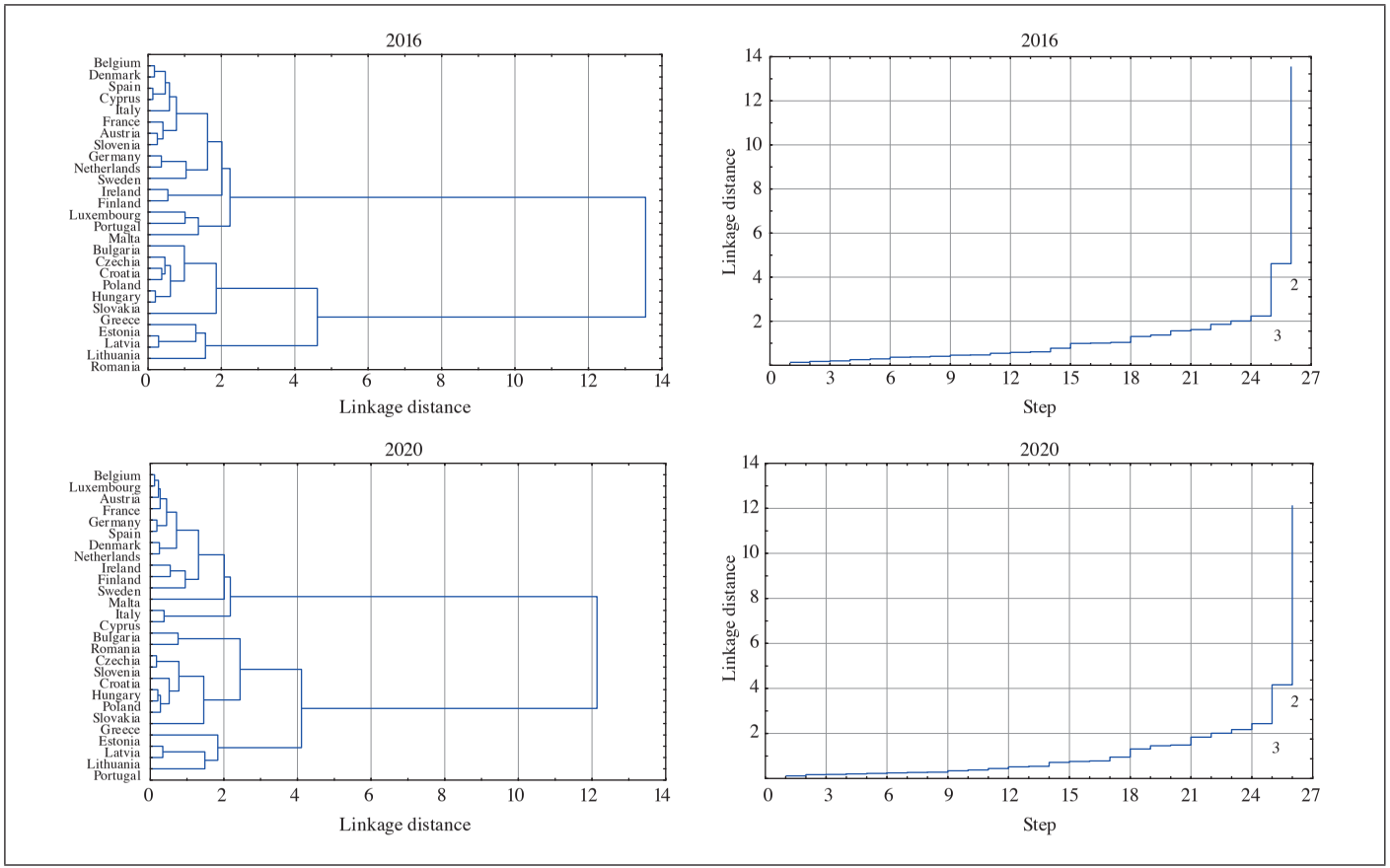

Fig. 2. Dendrogram of Connections Using Ward's Method, Node Distances and Classification Steps of 27 EU Countries in 2016 and 2020
Source: the authors (using Statistica 13.3 software), based on Eurostat database.

used (where: k – number of classes, $t = 1, 2$ for 2016 and 2020, respectively), which took the following values: $CH(2)_1 = 13.41$, $CH(3)_1 = 10.56$, $CH(2)_2 = 14.61$, $CH(3)_2 = 10.34$. More favourable, maximum values of the quality index for the classification results were obtained when the EU countries were divided into two relatively diverse classes in 2016 and 2020.

Classification results of the EU countries for implementation level of SDG3 (good health and well-being) in 2016 and 2020 are summarised in Table 2.

Table 2. Classification Results of the EU Countries into Relatively Uniform Classes in Terms of SDG3 Implementation Level in 2016 and 2020 Using *k*-means Method

Class Number	Class Name	Class Composition (Distance from the Middle of the Class)	Class Size	Average Distance from the Middle of the Class
2016				
1	Lower level of SDG3 implementation	Bulgaria (0.24), Czechia (0.20), Estonia (0.30), Greece (0.30), Croatia (0.15), Latvia (0.28), Lithuania (0.22), Hungary (0.15), Poland (0.13), Romania (0.24), Slovakia (0.18)	11	0.22
2	Higher level of SDG3 implementation	Belgium (0.11), Denmark (0.11), Germany (0.16), Ireland (0.24), Spain (0.09), France (0.17), Italy (0.19), Cyprus (0.13), Luxembourg (0.24), Malta (0.27), Netherlands (0.20), Austria (0.13), Portugal (0.25), Slovenia (0.17), Finland (0.23), Sweden (0.26)	16	0.18
2020				
1	Lower level of SDG3 implementation	Bulgaria (0.24), Czechia (0.17), Estonia (0.32), Croatia (0.16), Latvia (0.26), Lithuania (0.20), Hungary (0.14), Poland (0.13), Romania (0.23), Slovakia (0.15)	10	0.20
2	Higher level of SDG3 implementation	Belgium (0.10), Denmark (0.14), Germany (0.12), Ireland (0.17), Greece (0.27), Spain (0.08), France (0.13), Italy (0.22), Cyprus (0.23), Luxembourg (0.10), Malta (0.29), Netherlands (0.20), Austria (0.11), Portugal (0.25), Slovenia (0.13), Finland (0.21), Sweden (0.24)	17	0.18

Source: the authors (using Statistica 13.3 software), based on Eurostat database.

Figure 3 shows average values of the normalised SDG3 indicators in separated classes of EU countries in 2016 and 2020.

Table 3 lists the profiles of the separated classes of the EU countries in 2016 and 2020, providing the basis for detailed characterisation and assessment of the differences existing between them in the implementation of SDG3.

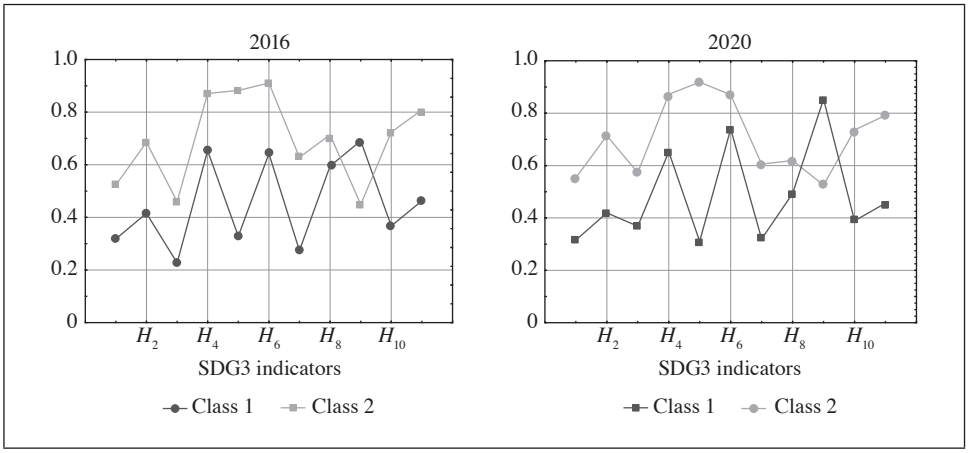

Fig. 3. Mean Values of the Normalised SDG3 Indicators in the EU Countries in 2016 and 2020
Source: the authors (using Statistica 13.3 software), based on Eurostat database.

Table 3. Mean Values of Indicators Monitoring the Implementation of SDG3 for the Identified Types of Classes of the EU Countries in 2016 and 2020

Indicators Monitoring SDG3	Mean Value of the Indicator			
	2016		2020	
	Class 1	Class 2	Class 1	Class 2
H_1 – healthy life years at birth (years) – S	59.84	63.84	59.49	64.08
H_2 – share of people with good or very good perceived health (%) – S	59.82	70.48	60.82	72.43
H_3 – smoking prevalence (%) – D	30.18	23.19	29.10	21.94
H_4 – standardised death rate due to tuberculosis, HIV and hepatitis by type of disease (rate) – D	4.11	1.97	3.02	1.38
H_5 – standardised preventable and treatable mortality (rate) – D	419.94	214.66	465.62	216.00
H_6 – self-reported unmet need for medical examination and care (%) – D	5.60	1.55	3.38	1.69
H_7 – obesity rate by body mass index (%) – D	58.08	51.84	58.69	53.23
H_8 – fatal accidents at work per 100,000 workers – D	2.86	2.16	2.40	1.88
H_9 – population living in households that report suffering from noise (%) – D	13.42	17.89	11.33	18.82
H_{10} – road traffic deaths per 100,000 persons – D	7.25	4.69	5.97	3.72
H_{11} – years of life lost due to PM2.5 exposure (rate) – D	1,109.45	424.5	850.2	333.24

Notes: S – stimulant, D – destimulant.

Source: the authors, based on Eurostat database.

The research results allow for a detailed assessment of the differentiation level among the EU countries regarding their implementation of the SDG3 and the changes which occurred in 2020 compared to 2016.

5. Discussion and Conclusions of the Research

Research on the implementation of sustainable development goals has focused on a wide range of issues, including:

– monitoring the achievement of SDGs (Hametner & Kostetckaia, 2020; Lafortune *et al*., 2020; Sachs *et al*., 2021),

– seeking harmony (synergies) or conflict (trade-offs) between the Agenda 2030 goals (Hickel & Kallis, 2020; Linnerud, Holden & Simonsen, 2021; Warchold, Pradhan & Kropp, 2021),

– integrating these research areas (Biggeri *et al*., 2019; Hametner & Kostetckaia, 2020).

Monitoring the achievement of SDGs usually involves constructing aggregate indices based on normalised values of selected indicators. Studying the relationships between the goals (harmony, conflict), on the other hand, typically relies on analysing the correlations between the variables (e.g., using Spearman's rank correlation method). The literature does not report on attempts to assess the degree of implementation of individual sustainable development goals or to classify countries in this regard.

The study has analysed the values of 11 indicators monitoring the implementation of SDG3 in the countries of the EU in two years, 2016 and 2020. In 2020, only healthy life years at birth (H_1) remained unchanged, and in both years the average score for the EU was 64 years of age. Standardised preventable and treatable mortality deteriorated (H_5) – the value increased by 6.28%, while the obesity rate by body mass index (H_7) increased by 1.73%. In 2016, 51.80% of the EU population was overweight, a share that had risen to 52.70% by 2020. A positive direction of change was observed for the remaining eight SDG3 indicators all improved from 2016 to 2020. The most favourable changes in SDG3 occurred for self-reported unmet need for medical examination and care (H_6) – a decrease of 32.14%, and standardised death rate due to tuberculosis, HIV and hepatitis (H_4) – a decline of 31.54%. Significant improvement was also recorded for the years of life lost due to PM2.5 exposure (H_{11}) – down by 25.34% and the rate for road traffic deaths (H_{10}) – lower by 20.75%.

The differentiation levels among EU countries in 2016 and 2020, based on individual indicators monitoring SDG3 implementation, varied considerably. The coefficient of variation ranged from 7.30% in 2020 for H_1 indicator (healthy life years) to 120.00% in 2016 for the H_6 indicator (self-reported unmet need for medical examination and care).

In both 2016 and 2020, EU countries exhibited very high – though slightly decreasing – levels of disparity for the H_6 indicator, which showed by far the greatest variation. The coefficient of variation amounted to 120.00% in 2016 and dropped slightly to 119.70% in 2020. It is worth noting that this indicator showed the greatest improvement during the analysed period.

EU Member States varied little (the coefficient of variation was lower than 15.00%) with regard to three goals: the share of people with good or very good perceived health (H_2), obesity rate by body mass index (H_7) and healthy life years at birth (H_1), all of which decreased from 2016 to 2020.

The variation among the EU countries declined for 5 of the 11 SDG3 indicators (healthy life years at birth, share of people with good or very good perceived health, self-reported unmet need for medical examination and care, obesity rate by body mass index and fatal accidents at work – H_1, H_2, H_6, H_7, H_8). But it was higher for the other indicators. While the variation among EU countries for indicators including H_4 – standardised death rate due to tuberculosis and HIV and hepatitis and H_{11} – years of life lost due to PM2.5 exposure was very high in 2016 (with coefficient values reaching 89.50% and 69.30%, respectively), it had worryingly increased even further by 2020 – to 92.00% and 76.00%, respectively.

Dividing the EU countries by their level of SDG3 implementation into two relatively homogeneous classes was optimal for both years. In both years the first class, comprising the countries characterised by lower levels of SDG3 implementation (11 and 10 countries, respectively), was less numerous. In 2016, the first class included the 11 countries: Bulgaria, Czechia, Estonia, Greece, Croatia, Latvia, Lithuania, Hungary, Poland, Romania and Slovakia. The second class (for which SDG3 implementation was higher) included the other 16 countries. The division of countries into homogeneous groups in 2016 and 2020 turned out to be relatively stable. The only change in the composition of the classes concerned Greece, which in 2020 was characterised by a higher level of SDG3 implementation. In 2016 and 2020, only three countries of the "new EU enlargement" (Cyprus, Malta and Slovenia) were listed in the class 2 grouping (those countries with higher SDG3 implementation). All countries of the "post-socialist block," with the exception of Slovenia, had significantly worse health and well-being.

The differences in the degree of SDG3 implementation in the identified classes of EU countries can be caused by a variety of factors, including (Küfeoğlu, 2022):

– lifestyle,
– dietary habits and access to healthy food,
– healthcare systems and expenditures on health services,
– state of the natural environment,
– historical neglect in public health in former Eastern Bloc countries.

Identifying the causes of the observed differences in the degree of SDG3 implementation in EU countries is a significant research challenge, as the conclusions drawn can serve as a basis for addressing these disparities.

The countries presenting higher levels of SDG3 implementation were characterised by a greater clustering around the centre of gravity. In class 1, average distances from the centres of gravity in 2016 and 2020 were 0.22 and 0.20, while in class 2 they were 0.18 and 0.18, respectively. In class 1, Estonia and Greece were the most distant from the centre of class gravity in 2016, as were Estonia and Latvia in 2020, while in class 2 Malta and Portugal were the furthest from the centre in 2016, as were Malta and Greece in 2020.

In both years, the first class, which grouped the EU countries characterised by a lower level of SDG3 implementation, showed significantly more favourable values for the H_9 indicator (population living in households reporting suffering from noise). In 2016 in the first class, 13.42% of the population reported being exposed to noise at home, while in 2020 the number fell to 11.33%. In the second class, the H_9 indicator reached 17.89% in 2016 and increased to 18.82% in 2020.

In both 2016 and 2020, the second class of countries was characterised by greater SDG3 implementation for the other 10 indicators. At the same time, the EU countries differed the most for the H_5 indicator (standardised preventable and treatable mortality). In 2020, it deteriorated in both classes of countries, largely due to the COVID-19 pandemic. However, the increase in the rate of standardised preventable and treatable mortality was much higher in the class of countries featuring a lower level of SDG3 implementation. Without diminishing the importance of the other indicators monitoring public health and well-being, it should be noted that preventable mortality is among the most severe impacts, requiring urgent and prioritised action by the governments of the EU Member States classified in class 1.

The changes in disparities between the identified classes in the years under study are also noteworthy. In 2020, the disproportions increased over 2016 levels for the following indicators: H_1, H_2, H_5, H_8, H_9, while decreasing for: $H_3, H_6, H_7, H_{10}, H_{11}$. Only for one indicator, H_4, did no change occur.

A detailed comparative analysis between classes of countries with different levels of SDG3 implementation makes it possible to evaluate the effectiveness of actions taken within each group of countries. Countries with lower SDG3 implementation levels exhibit higher preventable and treatable mortality rates (H_5), suggesting significant gaps in their healthcare systems. Large investments are necessary in health infrastructure, medical personnel training, and improving the accessibility and quality of healthcare services. The lower percentage of individuals reporting good or very good health (H_2) indicates a need for intensive educational campaigns promoting a healthy lifestyle and health prevention measures. The high percentage of smokers (H_3) in this group highlights the need for intensified anti-

smoking efforts, including educational campaigns, stricter regulations on the sale and consumption of tobacco products, increased tobacco taxes, and support for smoking cessation programmes. The higher rate of road traffic deaths (H_{10}) suggests the need for modernising road infrastructure, redoubling efforts to improve road safety, and conducting educational campaigns on road safety. The high percentage of individuals reporting unmet health needs (H_6) indicates problems with access to healthcare. Improving the accessibility and quality of healthcare services are urgently needed, and could be achieved by developing a network of medical facilities and implementing innovative solutions such as telemedicine. The high number of years of life lost due to PM2.5 exposure (H_{11}) suggests the need to improve air quality. Reducing pollutant emissions and promoting clean energy sources would be advisable steps forward.

Countries with higher SDG3 implementation levels have lower preventable mortality rates (H_5), reflecting the efficiency of their healthcare systems. They should continue investing in medical innovations and further improve their healthcare systems. The higher percentage of individuals reporting good or very good health (H_2) may result from better access to healthcare, effective health campaigns, and strong awareness of public health issues. These countries should continue educational and preventive campaigns to promote healthy lifestyles and increase public health awareness. Lower smoking rates (H_3) suggest the effectiveness of anti-smoking measures such as strict regulations on smoking in public places, educational campaigns, and support for the cessation of smoking. These countries should maintain strict smoking regulations and support smoking cessation programmes. Lower road traffic death rates (H_{10}) indicate the effectiveness of road safety improvement measures, such as modernising road infrastructure, strengthening regulations, and public education on road safety, and the need for their continuation. A low percentage of individuals reporting unmet health needs (H_6) reflects good accessibility and quality of healthcare services, resulting from effective health policies and investments in the health sector. These countries should continue their current actions and support and develop innovative solutions. Fewer years of life lost due to PM2.5 exposure (H_{11}) suggests that environmental protection measures and air quality improvements are effective. Countries with higher SDG3 implementation levels should continue promoting clean energy sources and reducing pollutant emissions.

In conclusion, the detailed analysis presented here shows that EU countries have had varying degrees of success in implementing SDG3 measures. Countries with lower SDG3 implementation levels require intensified actions in many areas, while countries with higher levels should continue their effective strategies while introducing innovations and further improvements.

The research has three main limitations:

1. The study was based on 11 health and well-being indicators adopted by the EU. While these indicators are crucial, they may not reflect the full picture of public health and quality of life. There are many other aspects of health and well-being that were not included.

2. The research was conducted for the years 2016 and 2020, which may not fully capture long-term trends and changes. Analysing data over a longer period could provide a more comprehensive view of SDG3 implementation.

3. The research was based on quantitative data, which limits the understanding of the context and qualitative aspects of SDG3 implementation. Qualitative data could provide valuable insights into the causes and effects of the phenomena observed.

These limitations suggest the results should be interpreted cautiously and that there is a need to consider these limitations when formulating conclusions and policy recommendations. The limitations form the basis for determining the further research perspective, primarily focused on expanding the subject and temporal scope of the research and undertaking qualitative studies.

Based on the foregoing research, the following general conclusions can be formulated:

1. From 2016 to 2020, the countries of the European Union (EU27) showed progress in implementing SDG3 goals. Progress was recorded for 8 of the 11 indicators analysed, suggesting that activities taken by the EU and its Member States improved public health and well-being. Further efforts should be focused on improving preventable mortality, reducing obesity, and extending health. This will primarily require promoting a healthy lifestyle, including physical activity and a proper diet, as well as expanding preventive health screenings and improving the quality of medical care. These goals can be achieved by increasing spending on comprehensive health protection for residents, as well as enhancing the organisation of the healthcare system. It also seems important to intensify efforts in implementing other SDGs that are highly correlated with health security, such as poverty eradication, green energy, and improving the state of the natural environment.

2. A significant increase in the value of the standardised preventable and treatable mortality indicator should be considered alarming. Its source certainly lies in the effects of the COVID-19 pandemic, but it also points to unhealthy lifestyle practices and deficiencies in the public health system. This only further suggests the need to promote healthy lifestyles and increase investment in the healthcare system.

3. The countries of the European Union, in 2016 and 2020, varied significantly in their SDG3 implementation levels. The largest variation occurred for self-reported unmet need for medical examination and care (H_6) and standardised death rate due to tuberculosis, HIV and hepatitis (H_4). Changes in the degree of variation among EU countries were bidirectional: dispersion increased for six indicators and

decreased for five. Addressing these disparities should be a priority for EU policy and the actions of Member States governments.

4. In both years, two classes of the EU countries emerged, one consisting of older EU Member States, which had a higher level of public health and well--being (Greece, which in 2016 was classified among the lower-rated countries, was an exception). Then there were Cyprus, Malta and Slovenia from among the countries of the so-called new enlargement. As can be seen, the former Eastern Bloc countries (except Slovenia) require special support from the EU and the intensification of national efforts to implement SDG3.

5. SDG3 indicators should be constantly monitored so changes in the implementation of SDG3 can be identified and assessed, solutions improved, and actions developed to bring about better public health and well-being.

Further research should examine drivers and inhibitors of progress in SDG3 implementation, model solutions, and methods to improve the effectiveness of measures taken by both the EU and the individual Member States. Incorporating a temporal perspective in further research will allow for a better understanding of the changes and the effectiveness of actions taken, which is crucial for achieving long-term health goals and quality of life across the entire EU.

Authors' Contribution

The authors' individual contribution is as follows: Each contributed 50%.

Conflict of Interest

The authors declare no conflict of interest.

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Coordination, Comprehensiveness and Continuity as the Quality Measures of Remote Primary Healthcare in Poland

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ABSTRACT

Objective: The purpose of this article is to examine the quality of remote primary healthcare in Poland measured through three dimensions: coordination, comprehensiveness, and continuity (3Cs) and examine the relationship between them.

Research Design & Methods: The 3Cs were measured using a proprietary questionnaire to measure the quality of primary healthcare in a teleconsultation setting. The survey was conducted among 98 patients in primary healthcare facilities nationwide in 2021. Structural equation modelling was used in the data analysis.

Findings: The survey results showed that coordination and continuity are one common dimension of quality of primary healthcare. In Poland, patients distinguish only between continuity of care and comprehensiveness. Coordination can be considered part of continuity because it requires a long-term relationship between the patient and the general practitioners. We found that continuity positively affects the comprehensiveness of primary healthcare.

Implications/Recommendations: This study is the first of its kind in primary healthcare in Poland, and its results may be of particular value to general practitioners and healthcare managers wishing to improve the quality of teleconsultation services.

Contribution: The evidence can help develop appropriate strategies for improving the quality of 3Cs-based care. Validated research tools provide basic metrics that can be used for future research to see to what extent the development of the telehealth system improves the continuity, coordination and comprehensiveness of remote primary healthcare.

Article type: original article.

Keywords: comprehensiveness, continuity, coordination, quality of primary healthcare.

JEL Classification: I10.

1. Introduction

During the COVID-19 pandemic, many individuals were reluctant to visit healthcare facilities due to concerns about potential exposure to the virus. In response, the adoption of remote primary healthcare to support patients in managing non-emergency procedures became a widely accepted solution (Latifi & Doarn, 2020; Maria, Serra & Heleno, 2022). Remote primary healthcare, a key technology, enables healthcare professionals – particularly general practitioners (GPs) – to deliver health services remotely (Garattini, Badinella Martini & Mannucci, 2021). GPs play a critical role in maintaining patient health (Hu *et al*., 1999). This approach leverages information and communication technology (ICT) to facilitate the exchange of information for diagnosis, treatment, and disease prevention, as well as for testing, assessment, and the ongoing education of healthcare professionals (Bokolo, 2020). Remote primary healthcare offers several benefits, including convenience, affordability, and improved access to health-related information via the Internet and related

technologies (Kalaivani *et al*., 2015). The integration of ICT in primary healthcare can empower patients by promoting greater involvement in their healthcare plans and fostering enhanced autonomy. Moreover, remote primary healthcare has the potential to significantly improve health outcomes, particularly in areas with limited access to primary and specialist care (Mold *et al*., 2019). This technology seeks to expand healthcare access for all individuals, irrespective of geographic location, while minimising the need for face-to-face consultations (Khairat *et al*., 2019). Given the pivotal role of remote primary healthcare in improving healthcare delivery, particularly during the COVID-19 pandemic, it is essential to assess the quality of these services. Poor-quality remote primary healthcare is widely recognised as a major barrier to achieving effective healthcare across many systems globally. Evaluation of remote primary healthcare quality (QPHC) from the patient's perspective should focus on three core dimensions: coordination, comprehensiveness, and continuity (3Cs) (Bodenheimer *et al*., 2014; Hashemi *et al*., 2020). These dimensions are rooted in the definition of primary healthcare, which is described as first-contact, coordinated, comprehensive, and continuous care provided to individuals and populations, regardless of age, gender, disease, or organ system (Peckham, 2006). The 3Cs form the foundation of many frameworks for primary healthcare. In the context of QPHC, these critical elements are associated with improved service quality, reduced healthcare disparities, and better health outcomes for populations. Previous studies have confirmed that remote healthcare facilitates the initial contact between a GP and a patient by improving availability (Kludacz-Alessandri *et al*., 2021). Moreover, effective communication between patients and GPs is linked to positive health outcomes, with evidence suggesting that in select cases, teleconsultations are not inferior to in-person consultations in terms of patient satisfaction and clinical results (Orlandoni *et al*., 2016). However, for telemedicine services to become a sustainable option, further research is needed on patient experiences with this technology across other dimensions of primary healthcare quality. To date, the quality of primary healthcare has not been thoroughly examined in relation to the three core pillars of care – coordination, comprehensiveness, and continuity. Thus, this article seeks to explore this important issue.

2. Literature Background

Coordination is one of the most recognisable dimensions of primary healthcare quality, and its features have been highlighted in several reviews, particularly in relation to the healthcare of patients with chronic diseases. In the current health context, characterised by specialisation and an overload of information, coordination refers to the ability of GPs to coordinate the use of other levels of healthcare and to the extent to which information from various sources is taken into account by the GP in the care of the patient (Starfield, Shi & Macinko, 2005). Coordination for this

study was defined as the extent to which the GP collaborates with other physicians, health professionals, and healthcare providers to provide remote primary healthcare for optimising patient health. Comprehensiveness is the direct or indirect provision of a full range of services to meet patients' healthcare needs. This includes health promotion, prevention, diagnosis and treatment of common conditions, referral to other clinicians, management of chronic diseases, rehabilitation, palliative care and, in some models, social services (Donelan *et al*., 2019). This study defines comprehensiveness as the direct or indirect provision of a full range of health services to meet the patient's needs. Continuity refers to long-term patient-centred care over time (Macinko, Starfield & Shi, 2003). Continuity is often viewed as a sequence of visits to the same GP. Continuity was defined for the study as a lasting relationship between the patient and the GP, providing the patient with a sense of treatment consistency, which enables the gathering of more and more knowledge about the patient and the use of information about past medical events in order to adapt ongoing care to the patient's needs. The continuity of care has already been a subject of many studies, with many scholars highlighting its significant role in QPHC and the whole healthcare system. Shin *et al*. (2014) added that continuity of care leads to faster recognition of health problems and that the patients who have continuity of care with the same physician tend to adopt better self-management behaviours and increase adherence to medication recommendations. Maarsingh *et al*. (2016) noted that the old patients are the ones who benefit the most from continuity of primary healthcare, as they are likely to have multiple chronic conditions. Finally, we shall note that the results obtained by several scholars indicate lower mortality rates associated with increased continuity of primary healthcare.

During the literature review, we encountered a problem with the broad conceptualisation of the 3Cs (Jimenez *et al*., 2021). While conceptually, each dimension of the 3Cs should be fully considered in the analysis of the QPHC, there are inherent trade-offs and complementarities between them. Some dimensions may be an element of others, depending on the organisation and capabilities of primary care facilities and the needs of patients. For example, the possibilities resulting from comprehensiveness also relate to the GP's ability to coordinate care with other providers (coordination), thanks to which they can take care of patients throughout their lives (continuity) (O'Malley *et al*., 2015). The literature analysis shows that coordination, comprehensiveness and continuity do not work independently and that several overlapping elements exist between them. Coordination and continuity have the potential to be tightly linked if the patient's experience of coordination is that it is personal. The patient may see coordination as enhancing continuity. Thus, when designing interventions for strengthening primary healthcare, it may be helpful to focus on ensuring that the person or team members know the patient personally (Jimenez *et al*., 2021). While studying the interrelationship between coordination,

comprehensiveness and continuity, arguments about the ability to compensate for the lower efficiency of some features with the high efficiency of others (substitution effect) occur. In contrast, other features must coexist at high levels to achieve the goals of each function (i.e., synergistic effect) (Jimenez *et al*., 2021). In some cases, one feature may replace another, and in others, they may have a combined or synergistic effect. That is why it is important to consider the interrelationship of these dimensions (Jimenez *et al*., 2021).

The aim of this article is to examine the quality of remote primary healthcare in Poland measured by three dimensions: coordination, comprehensiveness, and continuity and investigate the relationship between them. In order to achieve the objective of the study, we employ a literature review and empirical studies. The article is organised as follows. This section presents the literature review, focusing on three core dimensions of primary healthcare: coordination, comprehensiveness and continuity. The second section presents the research methodology. The third section gives the results obtained in a study on coordination, comprehensiveness and continuity of primary healthcare. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are used to select the final variables for measuring the analysed 3Cs factors of QPHC. The third section also comments on the impact of healthcare continuity on its comprehensiveness. The fourth section includes a discussion of the results taking into account the restrictions of this study. The article ends with conclusions.

3. Methods

3.1. Questionnaire Preparation

The research conducted in this study is a part of the project aimed at creating a model for assessment of remote work for healthcare facilities ensuring continuous healthcare in conditions of limited social mobility. This research consisted of the development and application of a questionnaire in a survey of primary care patients. The questionnaire and procedure for conducting the research were assessed from an ethical perspective by the Warsaw University of Technology Senate Committee for Professional Ethics that has issued a Certificate of Ethics Approval (certificate dated January 15, 2021).

The questionnaire consisted of two parts: a part regarding the dimensions of QPHC and an informative part with questions characterising the respondents. The aim was to obtain patients' opinions regarding the QPHC provided by GPs during remote consultations. Each question was scored on a five-point Likert scale. Based on the analysis of the literature six indicators have been proposed to measure the coordination of primary healthcare, seven to measure comprehensiveness, and five to measure continuity. Data was collected in 2021, and the research

was conducted using the computer assisted telephone interview method. From the database provided by the PHC clinics, patients over 18 years of age who had had at least two prior teleconsultations since November 2020 were selected randomly. As care coordination is usually considered the most appropriate for patients who receive medical care more than once and in more than one location, we included in our analyses only patients who had two medical appointments and had authorised referrals issued after the first visit to the electronic data system. We assumed that patients who were referred for diagnostic tests or to a specialist at the first visit and required repeated teleconsultations are better equipped to assess the coordination, continuity and comprehensiveness of medical care. A total of 105 responses were collected; only 98 records were used for analysis, as the others were incomplete and unsuitable for valid statistical analysis.

3.2. Data Analysis

The number of observations was sufficient for further EFA and CFA. Based on the EFA, the preliminary factor model has been prepared. Then the CFA method confirmed the reliability and validity of the model. This study uses the structural equation modelling method (SEM). All analyses were conducted using Statistica v. 13.3, SPSS v. 27, AMOS v. 27 and Excel v. 365.

4. Results

4.1. Descriptive Statistics

The descriptive statistics regarding the *KR*1–*KR*6 variables used to assess the coordination dimension are shown in Table 1.

Table 1. Descriptive Statistics of Coordination Dimension Variables

Variable	Mean	Median	Standard Deviation	Variance	Skewness	Kurtosis
*KR*1	4.337	5	0.994	0.989	–1.366	1.174
*KR*2	2.878	3	1.229	1.511	–0.034	–0.616
*KR*3	4.510	5	0.790	0.624	–1.316	0.362
*KR*4	3.735	4	1.297	1.681	–0.648	–0.651
*KR*5	3.816	4	1.246	1.554	–0.785	–0.453
*KR*6	3.051	3	1.509	2.276	0.004	–1.441

Source: the authors.

Patients most appreciate their GPs taking into account the results of their diagnostic tests (*KR*3: $\bar{x} = 4.5$) and the diagnoses of specialist doctors (*KR*1: $\bar{x} = 4.3$). Coordination of medical care from other doctors and institutions (*KR*4: $\bar{x} = 3.7$)

and continuous monitoring of health during and after treatment (*KR*5: $\bar{x} = 3.8$) were perceived worse. The worst perception was GPs' willingness to consult other specialists about patients' health status (*KR*2: $\bar{x} = 2.9$). Respondents believe that remote healthcare coordination should be improved. The distribution of answers is presented in Figure 1.

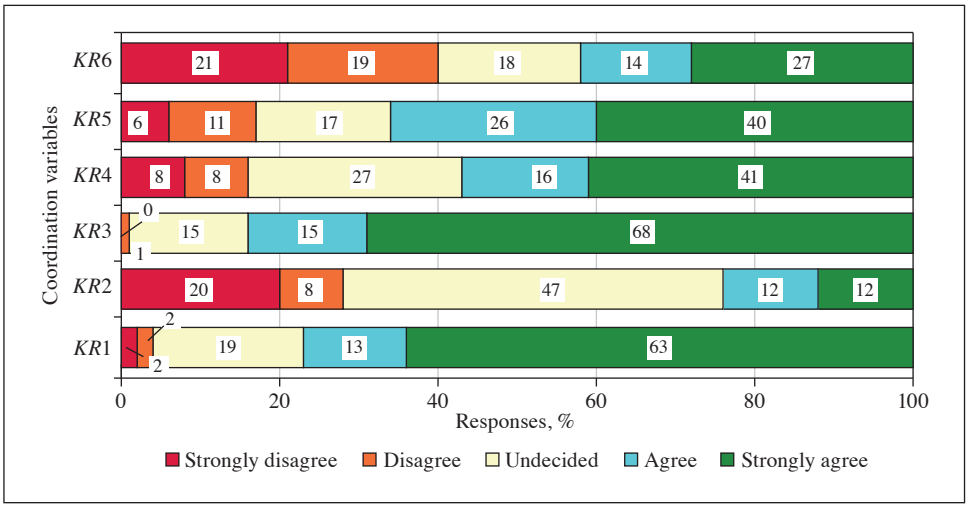

Fig. 1. Distribution of Coordination Responses

Source: the authors.

Descriptive statistics of comprehensiveness variables *KP*1–*KP*7 are presented in Table 2.

Table 2. Descriptive Statistics of Comprehensiveness Dimension Variables

Variable	Mean	Median	Standard Deviation	Variance	Skewness	Kurtosis
*KP*1	3.888	4	1.291	1.668	–0.960	–0.198
*KP*2	4.582	5	0.836	0.699	–2.315	5.769
*KP*3	4.786	5	0.542	0.294	–2.492	5.114
*KP*4	4.561	5	0.813	0.661	–1.964	3.760
*KP*5	3.969	5	1.388	1.927	–1.054	–0.268
*KP*6	3.520	4	1.480	2.190	–0.567	–1.152
*KP*7	4.133	5	1.172	1.374	–1.361	0.898

Source: the authors.

Most patients rate teleconsultations very highly in terms of their comprehensiveness. Patients rating highest the possibility of getting prescriptions for the medications they need (*KP*3: $\bar{x} = 4.8$), getting referrals to the appropriate specialist doctor (*KP*2: $\bar{x} = 4.6$) and getting referrals for the diagnostic tests (*KP*4: $\bar{x} = 4.6$). GPs' advice on how to get specialised treatment (*KP*1: $\bar{x} = 3.9$), GPs' recommendations for preventive tests (*KP*5: $\bar{x} = 4.0$), and GPs' advising what to do to prevent future health problems (*KP*7: $\bar{x} = 4.1$) were rated as average. The worst opinion was given to the possibility of dealing with the patient's health requirements (*KP*6: $\bar{x} = 3.5$). Unfortunately, almost 30% of respondents disagreed with the statement that the healthcare facility is able to meet all their health needs. The distribution of answers is presented in Figure 2.

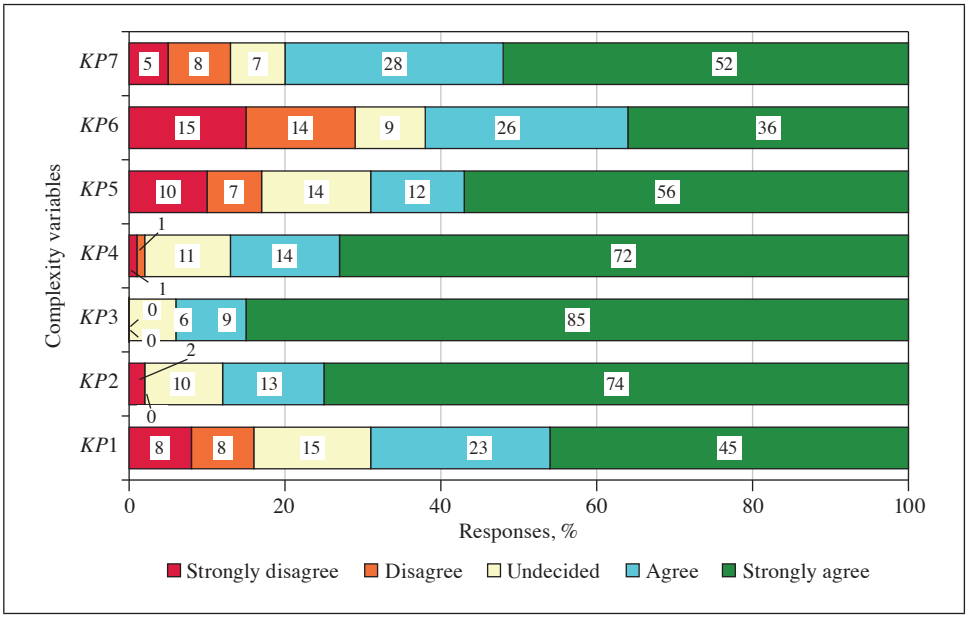

Fig. 2. Distribution of Comprehensiveness Responses

Source: the authors.

The continuity dimension got the worst marks of all presented in this study. Descriptive statistics of continuity variables *C*1–*C*5 are shown in Table 3.

Patients rated the continuity of information best. Patients agree that their GPs have access to information on their entire treatment history (*C*2: $\bar{x} = 4.5$). It is compulsory to enter data regarding patients' treatment into the system. 2% of respondents said during the interview that they had not provided complete documentation to their current primary healthcare facility. Therefore, these persons

Table 3. Descriptive Statistics of Continuity Dimension Variables

Variable	Mean	Median	Standard Deviation	Variance	Skewness	Kurtosis
*C*1	3.765	5	1.604	2.573	–0.862	–0.950
*C*2	4.469	5	0.922	0.850	–1.884	3.310
*C*3	3.939	4	1.283	1.646	–1.080	0.045
*C*4	2.980	3	1.705	2.907	–0.057	–1.720
*C*5	2.755	2	1.805	3.259	0.257	–1.781

Source: the authors.

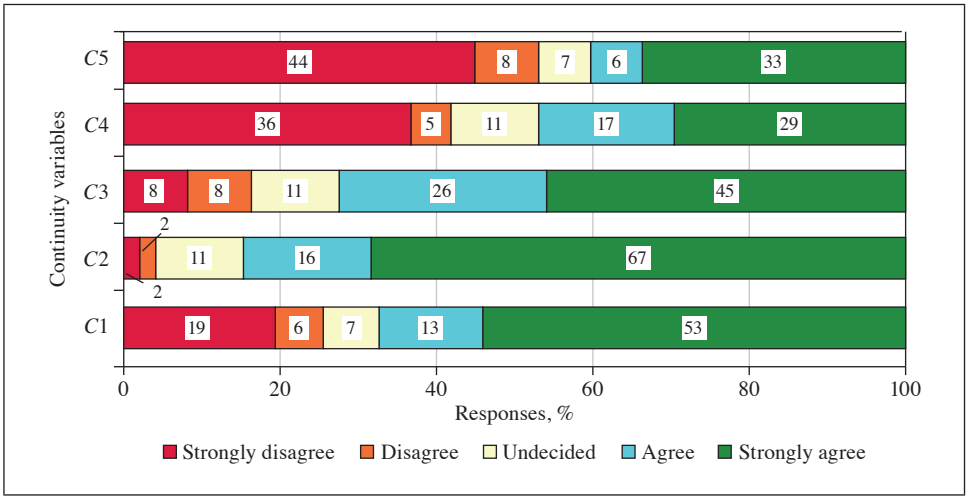

Fig. 3. Distribution of Continuity Responses

Source: the authors.

reported that the lack of information continuity was their own fault. Longitudinal and relational continuity were assessed at an average level. Patients rated as medium the possibility of consulting the same doctor during their treatment (*C*1: $\bar{x} = 3.8$) and the GP's understanding of the patient's needs (*C*3: $\bar{x} = 3.9$). 25% of the respondents had remote consultations with different GPs. When assessing relational continuity, the patients adopted two contradictory attitudes. Some of them believed that they did not feel the need for constant contact with the same GP. Others, on the other hand, complained that the facility, due to staff turnover, could not ensure the continuity of their relationship with one GP and emphasised that it was an inconvenience for them. Family continuity was assessed as worst by the respondents. Patients are not convinced that doctors know their families (*C*4: $\bar{x} = 3.0$). They also do not think

it is possible for all family members to be treated by the same doctor (*C*5: $\bar{x} = 2.8$). The distribution of answers is presented in Figure 3.

4.2. Exploratory Factor Analysis

Each construct: continuity, comprehensiveness, and coordination, were measured with multiple survey statements prepared based on literature analysis. However, assessing whether they are reliable measures of each dimension's factor is required. The variables are eligible for factor analysis because the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) equals 0.854 > 0.6. The result of Bartlett's test of sphericity is significant (Table 4).

Table 4. KMO and Bartlett's Test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.854
Bartlett's test of sphericity	approx. chi-square	751.042
	df	153
	Sig.	< 0.0001

Source: the authors.

In order to prepare the final dimensions and variables for analysis, EFA was performed. EFA was performed several times, assuming 2–3 factors. Finally, we identified the two-factor solution as the best approximation of the data. Both factors in Figure 4 explain 59.8% of the variance (Table 5).

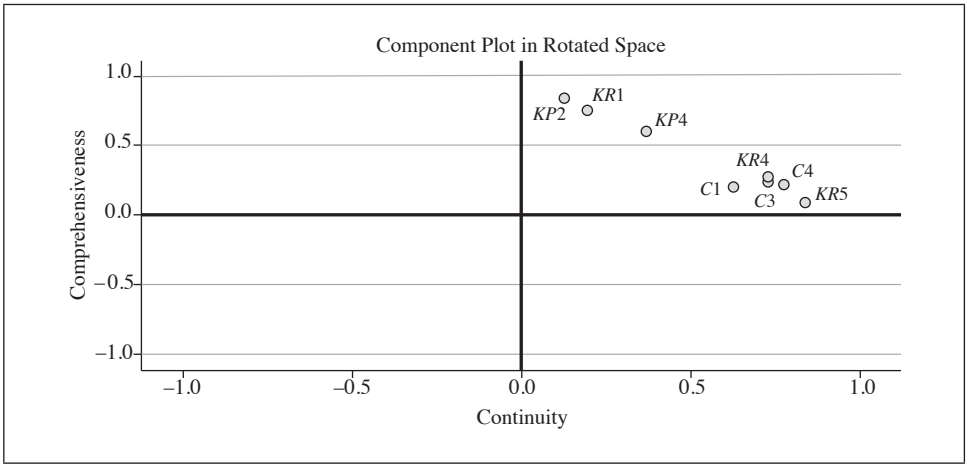

Fig. 4. Continuity and Comprehensiveness Factors Identified as a Result of the EFA Analysis
Source: the authors.

Table 5. Total Variance Explained. Extraction Method: Principal Component Analysis

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.726	46.572	46.572	3.726	46.572	46.572	2.911	36.383	36.383
2	1.057	13.211	59.784	1.057	13.211	59.784	1.872	23.401	59.784
3	0.749	9.362	69.146	–	–	–	–	–	–
4	0.691	8.635	77.781	–	–	–	–	–	–
5	0.623	7.786	85.568	–	–	–	–	–	–
6	0.449	5.614	91.182	–	–	–	–	–	–
7	0.408	5.098	96.280	–	–	–	–	–	–
8	0.298	3.720	100.000	–	–	–	–	–	–

Source: the authors.

Finally eight variables clearly load on only two factors: continuity (Cronbach's alpha = 0.817 > 0.7) and comprehensiveness (Cronbach's alpha = 0.655 > 0.6). The remaining variables were removed from the final factors due to low factor loadings or a lack of fit to the model. The results of EFA are presented in Table 6.

Table 6. Rotated Component Matrix. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation

Variable	Factor	
	1	2
*KR*1	–	0.767
*KR*4	0.725	–
*KR*5	0.834	–
*KP*2	–	0.834
*KP*4	–	0.586
*C*1	0.618	–
*C*3	0.724	–
*C*4	0.772	–

Source: the authors.

EFA indicated that factor continuity covers five variables *C*1, *C*3, *C*4, *KR*4 and *KR*5. *KR*4 and *KR*5 could be included in variable continuity since they relate to the uninterrupted medical care from the GP. The remaining variables (*KR*1, *KP*2, *KP*4)

reflect the scope of medical care by the GP. They were therefore included in the dimension of comprehensiveness.

4.3. Confirmatory Factor Analysis

CFA confirmed the EFA model with eight variables. Model fit indices are presented in Table 7.

Table 7. Model Fit Indices

Measure	Estimate
CMIN	26.197
df	19
X^2/df	$1.379 \in \langle 1, 3 \rangle$
CFI	$0.969 > 0.95$
SRMR	$0.056 < 0.08$
RMSEA	$0.062 \in \langle 0.05, 0.08 \rangle$
pClose	$0.332 > 0.05$

Source: the authors.

Model fit values are excellent. $X^2 = 26.197$; $df = 19$; $\frac{X^2}{df} = 1.379 \in \langle 1, 3 \rangle$. Absolute model fit values $SRMR = 0.056 < 0.08$ (excellent), $RMSEA = 0.062 \in \langle 0.06, 0.08 \rangle$ which is acceptable. However, $pClose = 0.332 > 0.05$ is insignificant, which means excellent. The relative fit measure, $CFI = 0.969 > 0.95$ is also excellent. Model validity measures are presented in Table 8.

Table 8. Model Validity Measures

Factor	*CR*	AVE	MSV	MaxR(H)	*C*	*KP*
C	0.828	0.493	0.507	0.837	Square root of AVE 0.702	*HTMT* 0.722
KP	0.661	0.393	0.507	0.661	0.712	Square root of AVE 0.627

Notes: *C* – continuity, *KP* – comprehensiveness.

Source: the authors.

Convergent validity and factor reliability is supported based on the composite reliability measure $CR = 0.828 > 0.7$ for the continuity factor and $CR = 0.661 > 0.6$ for the comprehensiveness factor. Discriminant validity, the correlative distance

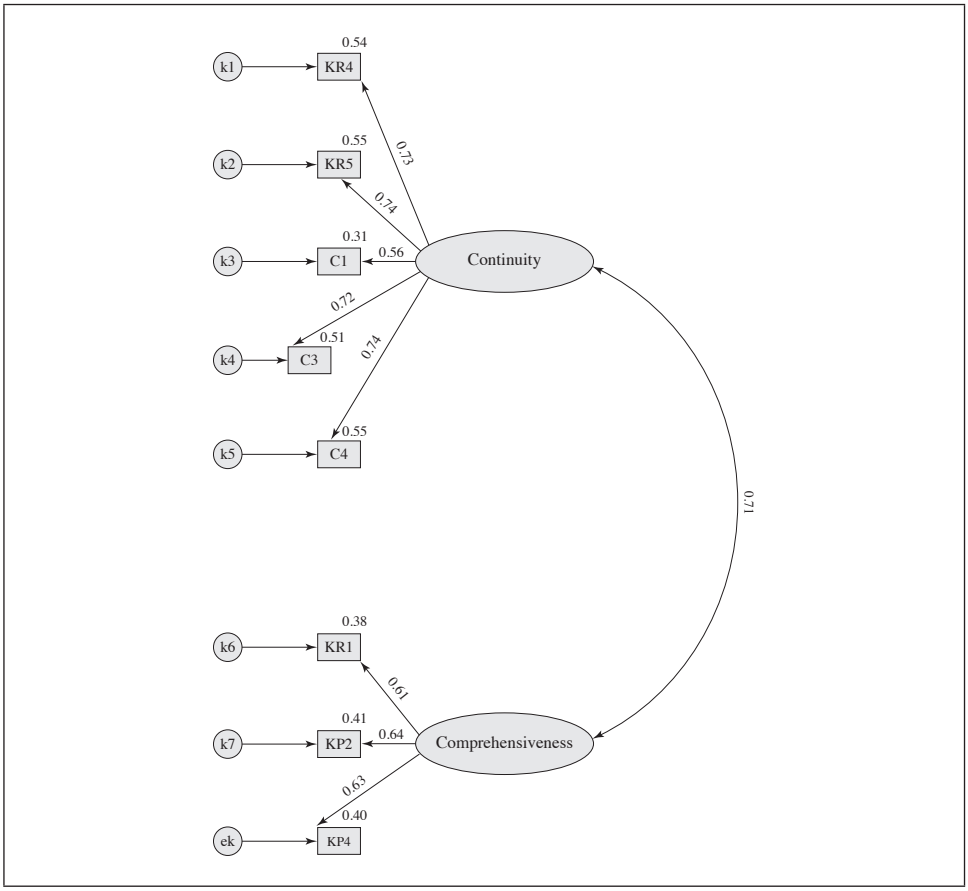

Fig. 5. Standardised Solution of the CFA Model

Source: the authors.

between factors is also established since the square roots of the AVEs are greater than correlation between factors and heterotrait measure *HTMT* = = 0.722 < 0.85. In Figure 5 a standardised solution of the CFA model is presented.

4.4. Regression Analysis

Aside from the CFA model, a regression analysis was also conducted (Fig. 6). Two dimensions were calculated based on the CFA model. Two hypotheses were proposed:

H0. Continuity does not affect comprehensiveness.

H1. Continuity affects comprehensiveness.

Standardised and unstandardised regression model path loadings are presented in Table 9.

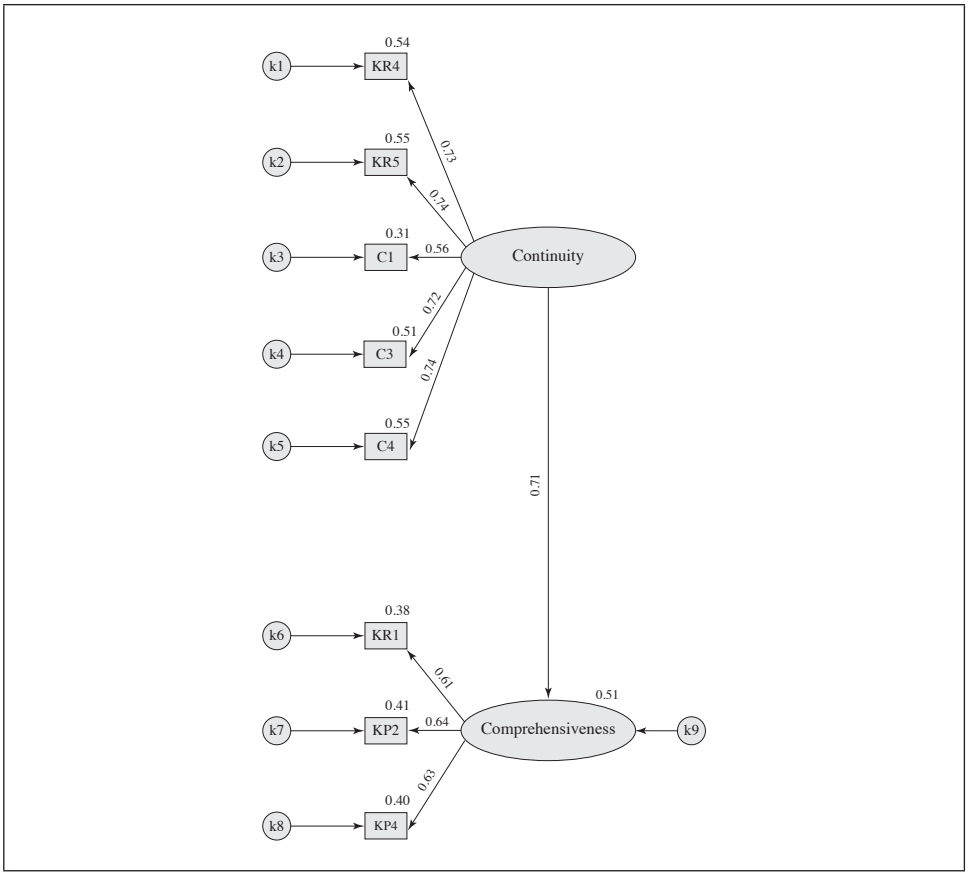

Fig. 6. Regression Model for the Continuity and Comprehensiveness Dimensions (Standardised Estimates)

Source: the authors.

Table 9. Standardised and Unstandardised Regression Model Path Loadings

Variable		Dimensions	Unstandardised Estimate	Standard Error	Critical Ratio	*P*	Standardised Estimate
C	←	*KP*	0.456	0.108	4.212	< 0.001	0.712
*KR*4	←	*C*	1.000	–	–	–	0.734
*KR*5	←	*C*	0.967	0.146	6.627	< 0.001	0.739
*C*1	←	*C*	0.939	0.190	4.948	< 0.001	0.558

Table 9 cnt'd

Variable		Dimensions	Unstandardised Estimate	Standard Error	Critical Ratio	*P*	Standardised Estimate
*C*3	←	*C*	0.967	0.154	6.296	< 0.001	0.718
*C*4	←	*C*	1.330	0.199	6.696	< 0.001	0.743
*KR*1	←	*KP*	1.000	–	–	–	0.613
*KP*2	←	*KP*	0.874	0.199	4.398	< 0.001	0.637
*KP*4	←	*KP*	0.843	0.214	3.950	< 0.001	0.632

Notes: C – continuity, KP – comprehensiveness.

Source: the authors.

The null hypothesis H0 was rejected in favour of the alternative hypothesis H1. The latent factor continuity had a significant influence on comprehensiveness. The structural coefficient on the path between both variables (0.71) points out the rate of change of the dependent variable from the independent variable. The model explained 50.7% of the comprehensiveness variance.

5. Discussion

This article investigates the relationship between coordination, comprehensiveness and continuity of primary healthcare delivered via teleconsultations in Poland. The literature research was aimed at proposing appropriate initial sets of indicators for their evaluation. Then they were used in the primary healthcare quality survey.

Patients gave an average rating regarding the coordination dimension. Most of the patients expressed their confidence that their GPs take into account the results of their diagnostic tests and the diagnosis of specialist doctors. Almost 60% of patients also believe that their GPs coordinate the care they receive from other doctors or in other institutions. However, many patients complain that their GPs do not monitor their health during or after treatment. In studies conducted in other countries, coordination did not receive the best assessment. For example, in the studies conducted among GPs from 31 European countries, Australia, New Zealand and Canada, coordination was considered the poorest dimension of the QPHC (Pavlič *et al*., 2015). Comprehensiveness was the best-assessed element of the three analysed dimensions (3Cs) of the QPHC. Most of the patients rated teleconsultations very highly in terms of comprehensiveness. More than 70% of patients did not experience problems with being referred for diagnostic tests, to specialists and receiving recommendations for prevention. Some patients, however, complained that the healthcare facility could not meet all their health needs. An excellent assessment of comprehensiveness was also made in studies conducted among family doctors from Sweden, New Zealand,

England, Norway and the Netherlands. The reverse was the case in Cyprus, Slovakia, the Czech Republic, Turkey and Italy (Pavlič *et al*., 2015).

The research shows that the assessment regarding the continuity of medical care is low. Family continuity was rated the worst. Over 50% of patients declare that their family members are under the supervision of another doctor or belong to another primary healthcare facility. Over 40% of patients believe their GP does not know their family situation. The highest-rated type of continuity was information continuity. More than 80% of patients assess as good or very good the access of the GP to information on their entire treatment history.

Relational and longitudinal continuity was evaluated at an average level. Different results were obtained in international studies where GPs perceived continuity of care as the essential quality dimension (Pavlič *et al*., 2015). The best continuity results were obtained in New Zealand and England. Also, Belgium, Germany, Norway, Slovenia, Sweden, Switzerland, and Australia are distinguished by excellent continuity of care, with high results for all indicators used to measure it. Conversely, unfavourable results for continuity of care were obtained in Turkey, Greece, Malta, Cyprus and Slovakia (Schäfer *et al*., 2015).

When comparing the overall average score for each of the three 3C dimensions of primary healthcare, the patients reported the highest score regarding comprehensiveness, then coordination and the lowest for continuity. A similar ranking was obtained in studies conducted in India (Faujdar *et al*., 2020). The reverse results were obtained in China, where continuity was the best-assessed dimension and comprehensiveness was the worst-assessed (Kuang *et al*., 2015). In studies conducted in Hungarian PHC clinics, all 3C dimensions – continuity, comprehensiveness and coordination – were assessed at a similar satisfactory level (Rurik *et al*., 2021). In turn, Greece obtained low results in all assessed dimensions (Lionis *et al*., 2017). Differences between countries in terms of coordination and continuity of care, as well as, to a lesser extent, comprehensiveness of care, can be partially explained by the scope of GP services. This means that in some countries, patients perceive a better quality of care as GPs in these countries offer a more comprehensive range of services (Schäfer *et al*., 2018).

The second goal of our study was to investigate the relationship between the analysed 3Cs dimensions of the QPHC. As a result of the EFA and CFA, a 2-factor model was created, containing the dimension of continuity and comprehensiveness. The continuity dimension in our model includes three variables regarding relational and longitudinal continuity, which means continuity with the same practice over time and interpersonal continuity with the same clinician over time (Haggerty *et al*., 2003). In addition, two more variables previously assigned to the coordination dimension have been loaded into the continuity dimension. They concern the coordination by a GP of medical care which patients receive from other doctors

or in other institutions, and the monitoring of their health. It has already been noted in previous studies that care coordination is an element of continuity without which there is no responsible provider that coordinates care (O'Malley *et al*., 2015). The second dimension of QPHC in our model is comprehensiveness, which includes meeting the patient's health needs by providing diagnostic and specialised care. Such a definition of this dimension is also justified by other studies, in which most of the measures of complexity focused on the scope of services provided in practice and paid less attention to the depth and scope of the conditions treated (Starfield, Shi & Macinko, 2005; Kringos *et al*., 2013).

The relationship between the various dimensions of the 3Cs, and especially between continuity and comprehensiveness of care, has already been analysed in previous studies (Cabana & Jee, 2004). The literature review showed that the continuity of care might be associated with improving preventive benefits, health promotion and diagnostics (Worrall & Knight, 2006). Previous research has shown that more comprehensive care can increase patient continuity and facilitate care coordination while reducing care fragmentation (Kringos *et al*., 2013). In this way, a wide range of medical services can be provided, which can positively influence maintaining the continuity of the relationship (Freeman & Hughes, 2010). However, the question arises of whether a very comprehensive primary healthcare clinic with many service providers will not reduce the patient's sense of continuity of care (Kringos *et al*., 2010). Because of these doubts, we examined the inverse relationship assuming that comprehensive primary care requires a GP capable of dealing with the broad problems of patients. This study explored the direct impact of continuity on the comprehensiveness of medical care. It was found that continuity of care positively influences comprehensiveness and that this relationship is statistically significant. The analysed structural model explained 50.7% of the variance. In our opinion, the comprehensiveness of care depends on its continuity because the constant, intense relationship between the patient and the GP means that the doctor can better understand the patient's health problems, which is conducive to issuing appropriate referrals to specialists and diagnostic tests.

6. Conclusions

In this study, we considered a teleconsultation-based approach to QPHC assessment. We focused on three dimensions of the QPHC (3Cs). According to our results, Polish patients rated the quality of care high in terms of comprehensiveness, on average in terms of coordination and the lowest in terms of continuity. The key conclusion from the literature analysis was that, to a large extent, the 3Cs do not function independently and that several overlapping elements exist between them. Our results suggest that continuity and coordination constitute one common dimension. Coordination can be regarded as an element of continuity as it requires the

patient to have a long-term trust-based relationship with their GP. Exploratory factor analysis showed that the final 2-factor model adopted for further research was correct. We also found that continuity of care positively influences comprehensiveness and this relationship is statistically significant. The results of this study show the significance of a long-term, lasting, trust-based relationship between GP and patient in comprehensive treatment.

The combination of coordination and continuity in one dimension that affects the comprehensiveness of medical care indicates the need for a holistic approach to the primary healthcare system. The study develops a patient-based framework for assessing primary care continuity, coordination and comprehensiveness. Taking into account patients' opinions on the quality of medical services when receiving healthcare remotely can contribute to improving the overall healthcare provision in primary healthcare facilities responsible for most health needs. It is worth adding that the very concept of QPHC based on the 3Cs is oriented towards practical activities. This knowledge should constitute a significant push for the further digital transformation of primary healthcare entities.

Authors' Contribution

The authors' individual contribution is as follows: Each contributed a sixth.

Conflict of Interest

The authors declare no conflict of interest.

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Education Quality and Technological Progress in the Business Sector at Different Stages of Economic Development

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ABSTRACT

Objective: To empirically investigate the relationship between education quality and technological progress in the business sector at different stages of economic development.
Research Design & Methods: We divided 160 countries into four groups by GDP *per capita*. The research period was 2007–2021. We use Spearman's correlation analysis to verify associations between nine indicators for education quality and ten indicators for technological progress.
Findings: Our outcomes show that if education quality does not improve, countries do not move up the economic development ladder. Adult literacy, primary education quality, adult skills, and women's average years in school have the strongest influence on technological progress.
Implications/Recommendations: Our paper contains many implications for those seeking to improve social well-being. For example, governments should ensure that women have access to

education on equal terms with men. Otherwise, they lose an important source of technological progress and impede the development of human capital. Greater emphasis should be placed on learning how to write and describe reality, read with comprehension, perform simple calculations without a calculator, and teach various learning methods. In the absence of these, the skills of primary, secondary and higher education graduates will not improve.

Contribution: The outcomes of our research, both theoretical and empirical, create a multi-faceted approach to the issue of the mutual influence of education and technological progress. They allow us to look at this problem from the perspective of subsequent stages of economic development.

Article type: original article.

Keywords: education quality, technological progress, stages of economic development, business sector.

JEL Classification: I25, O32, O33.

1. Introduction

The education system should facilitate technological progress, a directional process that may occur linearly or stepwise. Romer (1990, 1996), a key progenitor of new growth theories, has emphasised that technological progress is the outcome of a shift from less to more productive ways of combining things into different configurations. This is usually the result of knowledge accumulation by the carriers of human capital. Main methods of knowledge accumulation include self-acquisition of knowledge, education in schools, vocational training, learning by doing, learning by mimicking, learning by doing innovation, learning through teamwork, and learning by imitating social groups.

Technology in new growth theories concerns how to transform knowledge into a more productive arrangement of things – in other words, innovation. Innovations are new approaches to technical, organisational, scientific, economic and social problems (e.g., Mazur-Wierzbicka, 2018; Valdivieso, Uribe Gómez & Ordóñez-Matamoros, 2021; Ober, 2022; Grabowski & Stawasz, 2023).

Technological capabilities are understood as those of a given entity, organisation or country in locating, acquiring, developing and using knowledge. Such capabilities determine the quality of decision-making, facilitate problem-solving and form the foundation for introducing innovations in current activities (e.g., Rudny, 2009; Song & Thieme, 2009; Hamdoun, Chiappetta Jabbour & Ben Othman, 2018; Ode & Ayavoo, 2020).

If a person learns and shares knowledge with others, he or she develops knowledge absorptive capacity – the ability to acquire knowledge from various sources in order to develop and use it in action (e.g., Kogut & Zander, 1992; Delfmann

& Koster, 2012; Heitor, Horta & Mendonça, 2014; Fernández-Esquinas *et al*., 2016; Majewska, 2017).

The aim of this paper is to empirically investigate the relationship between education quality and technological progress in the business sector at different stages of economic development. It consists of a theoretical introduction, a description of the research methodology, a presentation and discussion of research results and conclusions.

The research was conducted on 160 countries in years 2007–2021. According to United Nations, there are 195 countries in the world. Thus our research covers 82% of the general population. Countries were divided into four groups consisting of 40 economies according to their GDP per capita in US dollars in 2022. We studied the relationships between nine indicators of education quality and ten of technological progress.

2. A Theoretical Framework

A pioneer in the field of operations research, systems thinking and management sciences, Ackoff (1986) stressed that an underdeveloped country flooded with money temporarily becomes richer, but not necessarily more developed in the long run. That is because economic development is more about good quality teaching and a willingness to learn than about earning money. Hence, a developed country with a large number of skilled employees is able to increase the prosperity of its society more effectively than a less developed country that does not invest sufficiently in educating its future and current workforce.

In countries at the first stage of development, the formal labour market does not exist and human capital is only beginning to develop. The country's internal institutions and infrastructure are just beginning to take shape and most of its citizens are poor. For these reasons, technology has not accumulated locally. The country has created only a small number of assets, which are performing as endogenous advantages. The dominant sectors of the economy are agriculture and mining.

These countries start investing in human capital by creating a primary education system and teaching people to work systematically. The main goal is to increase the resources of semi-skilled workers and prepare staff who can teach children and young people in primary schools and various institutions of elementary education. Particular attention should be paid to increasing literacy and numeracy skills. In the meantime, secondary education should be developed and the teaching staff expanded to ensure continuity of education. UNCTAD emphasises that at this stage there is still a need to ensure that all girls and boys complete free, equitable and quality primary and secondary education. It is worth taking advantage of UNICEF programmes because the organisation has extensive experience in education

(Porter, 1991; Dunning & Lundan, 2009, 2010; Majewska & Buszkowska, 2014; UNCTAD, 2021b).

At the second stage, faster development of the country depends on achieving threshold levels for socio-economic infrastructure, innovative activity accumulated outcomes and knowledge absorption capacity. Without it, the country cannot "take off." This means that success can only be achieved by countries whose governments invest in technological capabilities and help companies imitate foreign technologies. This leads to the creation of incremental innovations, which take the form of adaptive, modernising or improving changes. Good examples include: subsidies for domestic enterprises engaged in innovative activities, subsidies for the acquisition of more advanced technology, clusters and technology centers (Porter, 1991; Valdivieso, Uribe Gómez & Ordóñez-Matamoros, 2021; Grabowski & Stawasz, 2023).

The task of the education system at this stage is to transform low-skilled workers into highly-skilled ones. Investments in education and learning from the rest of the world enable better-skilled employees to work with more advanced capital goods. As a result, the share of more highly processed labour- and capital-intensive production is growing. Then the quality of exports increases that means higher profits from foreign trade. Production is more and more technologically complex, which increases demand for better-skilled workers (Porter, 1991; Dunning & Lundan, 2009, 2010; Zaitseva *et al*., 2017).

Drucker (2002) emphasises that in order to move from the second to the third stage of economic development, enough technicians must be educated. Such technicians include laboratory workers, rehabilitators, mechanics, medical staff, teachers, programmers, installers of various devices, and operators of specialised equipment, among others. He believes that every country is able to achieve this goal and thus accelerate technological progress – provided the vocational sector of secondary education increased to boost the number of trained technicians. Kamens and Benavot (2007) noted that the vocational sector of secondary education often includes multiple tracks and timetables, meaning that education, in such cases, is professionalised.

At the third stage, new domestic technologies have been developed and foreign technologies improved thanks to enterprises' innovative efforts. Government here seeks to maintain competitiveness in mature industries while supporting the development of innovations in emerging sectors. Endogenous advantages grow thanks to increased expenditure on innovative activities and education, in particular the development of higher education institutions. The share of products produced by medium- and high-skill workers grows.

Toffler and Toffler (1995) point out that the education system should be more individualised, i.e. adapted to a wider variety of student aspirations and abilities.

If this has not been done before, the structure of education system should be based on the results of forecasts regarding types of professions and activities needed in the future, changes in technical tools and systems and transformations in organisational structures of tomorrow's institutions. There should also be more emphasis on civil rights and the education of democratic institutions. Unfortunately, governments may be reluctant to do this because power is strongly centralised in a traditional industrial society.

The state should promote entrepreneurship and help develop institutional and technological environments, as they boost enterprise competitiveness by implementing the outcomes of innovative activities. In other words, government is advised to build a national innovation system to become a knowledge-based economy (Porter, 1991; Dunning & Lundan 2009, 2010; Majewska & Buszkowska, 2014; Majewska & Rawińska, 2018).

The father of the concept of post-industrial society, Bell (1976) wrote that knowledge and intellectual technology are at the center of post-industrial society and scientists should constitute a key social stratum that decides on future development trajectories. In such a society, the educational and scientific research base is developed but its size and quality are still growing.

To transform their societies into post-industrial ones, as Majewska and Nieżurawska-Zając (2021) write, governments must guarantee everyone free access to education and the opportunity to work in a profession – that is, they must guarantee an equal start in life. The education system should be improved so that it can help reduce social inequalities and prepare for life in a modern democracy.

At the fourth stage, companies' greater ownership advantages are increasingly dependent on the development of endogenous knowledge-intensive assets. This is accompanied by a gradual withdrawal from outdated production industries, especially those that harm the natural environment. As a result, domestic enterprises have competitive advantages in green manufacturing and technologically advanced products with a high content of embedded knowledge (Porter, 1991; Dunning & Lundan, 2009, 2010; Majewska, 2022; Mayenberger & Perez-Castillo, 2022; Bendig, Kleine-Stegemann & Gisa, 2023).

3. Materials and Research Methods

Before we begin, a word on the main limitations of our research. Technological progress and education quality are highly complex and multi-faceted phenomena. In the study of such phenomena, there is a high risk of endogeneity. The probability of omitting an important explanatory variable is particularly high in economic research because many factors co-occur and influence each other. Additionally, the choice of indicators by a researcher of economic phenomena is often limited by the availability of data.

Gross domestic product *per capita* in current prices (GDP pc) denominated in USD is the national measure of wealth we have used. GDP pc is a commonly used indicator of economic development and overall well-being. According to the World Bank, GDP pc provides a basic measure of the value of output per person, an indirect indicator of *per capita* income. The World Bank divides economies into four income groups: low income, lower middle income, upper middle income and high income. We have grouped the 160 countries in this study using the same division. Countries were divided into four groups of 40 according to their GDP pc in 2022: low GDP pc countries, 350 to 2,101; lower middle GDP pc countries, 2,122 to 6,568; upper middle GDP pc countries 6,639 to 20,107; and high GDP pc countries, 21,149 to 128,481.

Table 1. Description of Indicators for Education Quality

Variable	Code	Description
Primary education quality	PEQ	The mean score of harmonised learning outcomes at the primary level
Adult literacy	ADL	The percentage of people ages 15 and above who can both read and write to such a degree that they are able to understand a short simple statement about their everyday life
Secondary education quality	SEQ	The average of learning outcomes across math, reading, and science at both the primary and secondary level of education
Average quality of higher education institutions	HEQ	A composite measure, made from the score given to the top 1,000 universities in the QS World University Rankings and TES Higher Education World University Rankings, normalised by number of higher education institutions in the country
Skillset of university graduates needed by businesses	SUG	In your country, to what extent do graduating students from university possess the skills needed by businesses?
Women's average years in school	WSH	The average number of years of primary, secondary or tertiary education attended by women aged between 25 and 34 years old
Adult skills	ASK	The skill-base of the existing working-age population, which is a reflection of the historic quality of education as well as providing a base level for the short-term potential of the economy
Digital skills among population	DIS	In your country, to what extent does the active population possess sufficient digital skills (e.g. computer skills, basic coding, digital reading)?
Quality of vocational training	QVT	In your country, how do you assess the quality of vocational training?

Source: Legatum Institute (2019).

Following the literature, we assume that low GDP pc countries are at pre-agricultural and agricultural stage of economic development. Below average GDP pc countries are agricultural economies that have begun to industrialise. Upper average GDP pc countries are industrialised economies. High-income countries have entered a post-industrial stage and are building out their knowledge economy.

Table 2. Description of Indicators for Technological Progress

Variable	Code	Description
Human capital	HC	Captures the education, skills and health conditions possessed by population, and the overall research and development integration in society through the number of researchers and expenditure on research activities
Labour productivity	LPR	GDP output per worker in the workforce (population in employment)
Information and communication technology	ICT	Estimates the accessibility and integration of communication systems in the population
New business density	NBD	The number of newly registered limited liability corporations created per calendar year
Building quality control index by enterprises	QCI	A composite measure of the quality control and safety mechanisms in the construction regulatory system: a) quality of building regulations, b) quality control before, during, and after construction, c) liability and insurance regimes, and d) professional certifications
Structural change	SCH	Refers to the movement of labour and other productive resources from low-productivity to high-productivity economic activities
Patent applications	PA	The rate of applications for the exclusive rights to an invention, covering both products and processes as inventions
Export quality	EXQ	A composite measure estimating a country's export quality, based on both the a) value and b) quantity, of bilateral trades
High-tech manufactured exports	THE	The value of manufactured exports with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery, expressed as a percentage of the value of all manufactured exports
Gross domestic product *per capita*	GDP pc	An indicator of economic productivity

Source: Legatum Institute (2019), UNCTAD (2021a).

Tables 1 and 2 present the variable definitions and symbols. The main source of data was The Legatum Prosperity Index, an annual ranking developed by the

Legatum Institute. For GDP pc and such indicators as human capital, information and communication technology, structural change, data were also taken from UNCTAD. These four indicators are components of the Productive Capacities Index developed by UNCTAD. The indicator values sourced from UNCTAD and the Legatum Institute underwent standardisation. Only GDP pc is expressed in absolute values, which were transformed into natural logarithms.

The study adopted the same research method that UNCTAD (2021a) used to examine the interdependence between the Productive Capacities Index and key macroeconomic indicators, including the Sustainable Development Goals. It uses correlation analysis with Spearman's rank correlation analysis, a nonparametric measure of any monotonic relationship that exists between two variables. When calculating Spearman's correlation coefficient ρ, the mean rank is assigned in case of ties. There are two methods of calculating Spearman's correlation. Which you choose depends on whether the data does or does not have tied ranks. Our data is not rank-aligned, hence we used the following calculation formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)},$$

where:

d_i – difference in paired ranks,

n – number of cases.

The potential impact of outliers can be mitigated by using Spearman's correlation instead of Pearson's correlation. Outliers are extreme values that stand out significantly from the overall pattern of values in a dataset. They can distort statistical analyses and violate the assumptions used in the analyses.

The *p*-value is the probability of observing a non-zero correlation coefficient in our sample data when the null hypothesis is true. In our study, Spearman's correlation coefficient was significant if the *p*-value is less than 0.05. In the case of correlation analysis, the null hypothesis is typically that the relationship observed between the variables is the result of pure chance – the correlation coefficient is really zero. The alternative hypothesis is that the correlation we have measured is legitimately present in our data – the coefficient is other than zero. Therefore, if you have a *p*-value less than 0.05, you would reject the null hypothesis. In other words, there is enough evidence to conclude that the relationship between the variables is statistically significant.

Correlation coefficients were calculated for all of the countries studied and the four GDP pc groups of countries. Because the interpretation of correlation coefficients differs according to the number of observations, we assumed the GDP pc groups of countries to be of the same size.

We also used a time-lag study method to estimate the correlation between the indicators of the quality of education in year t_0 and the proxies of technological progress in t_{+2}. For all of the countries studied, the number of observations in the period t_{+0} was 2,400 and in t_{+2} 2,080. For each of the four groups of countries, the number of observations in the period t_{+0} was 600 and in t_{+2} 520.

We adopted the following scale in interpreting the results of correlation analysis:

– the value lies below 0.19: a very weak/low correlation,

– the value lies between 0.20 and 0.39: a weak/low correlation,

– the value lies between 0.40 and 0.59: a medium correlation,

– the value lies between 0.60 and 0.79: a strong/high correlation,

– the value lies between 0.80 and 1: a very strong/high correlation,

The statistical analysis was carried out to verify the following hypotheses:

H1: The importance of higher education quality increases with economic development, while the importance of primary and secondary education quality decreases.

H2: Reducing educational inequalities between women and men helps speed up technological progress.

H3: Investing in quality adult qualifications is an important determinant of technological progress regardless of the stage of economic development.

4. Results

Table 3 shows that for all the countries studied, the interdependency between an increase in education quality and technological progress has been confirmed by Spearman's correlation in 2007–2021. At a level of 0.05, all correlation coefficients are positive and statistically significant. The strength of these correlational relationships persists over time.

Table 3. Spearman's Correlation Coefficients for All Researched Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.84	0.74	0.79	0.64	0.43	0.70	0.80	0.70	0.53	0.77
ADL	0.85	0.76	0.82	0.67	0.40	0.68	0.79	0.68	0.52	0.79
SEQ	0.78	0.75	0.75	0.61	0.42	0.70	0.78	0.65	0.53	0.76
HEQ	0.76	0.75	0.74	0.48	0.44	0.68	0.72	0.60	0.49	0.76
SUG	0.53	0.55	0.55	0.40	0.23	0.48	0.51	0.47	0.38	0.60
WSH	0.87	0.78	0.86	0.69	0.43	0.67	0.80	0.69	0.50	0.80
ASK	0.87	0.78	0.86	0.69	0.46	0.68	0.81	0.70	0.52	0.81
DIS	0.68	0.70	0.70	0.52	0.45	0.60	0.70	0.55	0.42	0.70
QVT	0.55	0.57	0.57	0.42	0.29	0.51	0.56	0.46	0.41	0.62

Table 3 cnt'd

Indicator	HCt_2	LPRt_2	ICTt_2	NBDt_2	QCIt_2	SCHt_2	PAt_2	PSt_2	HTEt_2	GDPt_2
PEQ	0.84	0.75	0.80	0.63	0.43	0.69	0.80	0.70	0.54	0.77
ADL	0.81	0.74	0.80	0.67	0.36	0.64	0.76	0.66	0.50	0.76
SEQ	0.77	0.73	0.75	0.62	0.40	0.68	0.76	0.64	0.53	0.75
HEQ	0.75	0.75	0.74	0.47	0.43	0.67	0.72	0.60	0.49	0.76
SUG	0.53	0.54	0.55	0.41	0.23	0.48	0.51	0.47	0.38	0.60
WSH	0.86	0.78	0.86	0.68	0.42	0.67	0.79	0.70	0.51	0.80
ASK	0.80	0.73	0.81	0.66	0.41	0.62	0.75	0.65	0.48	0.75
DIS	0.69	0.70	0.72	0.53	0.45	0.60	0.70	0.56	0.42	0.71
QVT	0.55	0.57	0.57	0.42	0.28	0.51	0.57	0.46	0.40	0.63

Notes: All correlations are statistically significant at $p < 0.05$.

Source: the authors' calculations.

12 correlation coefficients are very strong. In the case of women's average years in school and adult skills, there is a very strong correlation with the same four indicators of technological progress (human capital, ICT, patent application and GDP pc). A very strong correlation also holds for associations between human capital and primary education quality and adult literacy.

In addition, there is a very strong interdependency between primary education quality and patent application as well as between adult literacy and ICT. We can thus conclude that adult literacy, primary education quality, adult skills, and women's average years in school have the strongest influence on technological progress in the countries studied.

Table 4 presents the results for countries at the pre-agricultural or agricultural development stage with low GDP pc. The highest positive correlation coefficients are observed for associations between human capital and indicators for technological progress. A strongest interdependency (0.61) occurs between human capital and adult skills. Adult literacy and women's average years in school share second place (0.55), while primary education is in third place (0.37) and digital skills among population in fourth place (0.32).

As might be expected, correlations with indicators for technological progress are stronger in most cases for primary education quality than for higher education quality. However, secondary education quality has a twice stronger impact on labour productivity than higher education and primary education quality. This has not yet translated into a structural change, which should appear at stage 2.

Table 4. Spearman's Correlation Coefficients for Low GDP pc Countries, 2007–2021

Indicator	HCt_0	$LPRt_0$	$ICTt_0$	$NBDt_0$	$QCIt_0$	$SCHt_0$	PAt_0	$EXQt_0$	$HTEt_0$	$GDPt_0$
PEQ	0.37*	0.14*	0.21*	0.27*	0.36*	0.24*	0.11*	–0.02	–0.09*	0.22*
ADL	0.55*	0.25*	0.38*	0.35*	0.16*	0.45*	0.05	0.12*	–0.05	0.29*
SEQ	0.13*	0.30*	0.19*	0.20*	0.16*	0.06	0.06	–0.05	0.06	0.32*
HEQ	–0.05	0.13*	0.10*	0.04	0.28*	0.15*	0.09*	0.12*	–0.02	0.11*
SUG	0.16*	0.15*	0.28*	0.22*	0.17*	0.24*	0.05	0.18*	–0.21*	0.24*
WSH	0.55*	0.30*	0.39*	0.39*	0.13*	0.44*	0.09*	0.10*	0.09*	0.41*
ASK	0.61*	0.31*	0.42*	0.44*	0.17*	0.48*	0.07	0.19*	–0.03	0.39*
DIS	0.32*	0.42*	0.39*	0.18*	0.29*	0.26*	0.22*	0.19*	–0.08	0.33*
QVT	–0.01	0.08*	0.17*	0.24*	0.29*	0.18*	0.17*	0.06	0.06	0.15*
Indicator	HCt_2	$LPRt_2$	$ICTt_2$	$NBDt_2$	$QCIt_2$	$SCHt_2$	PAt_2	PSt_2	$HTEt_2$	$GDPt_2$
PEQ	0.36*	0.13*	0.23*	0.24*	0.34*	0.24*	0.10*	–0.04	–0.08	0.23*
ADL	0.53*	0.25*	0.39*	0.35*	0.16*	0.44*	0.03	0.15*	–0.05	0.31*
SEQ	0.12*	0.31*	0.23*	0.19*	0.16*	0.06	0.04	–0.04	0.05	0.34*
HEQ	–0.08	0.13*	0.10*	0.02	0.28*	0.12*	0.08	0.12*	–0.05	0.11*
SUG	0.16*	0.15*	0.30*	0.23*	0.14*	0.25*	0.01	0.19*	–0.19*	0.25*
WSH	0.54*	0.30*	0.40*	0.38*	0.13*	0.44*	0.08	0.11*	0.10*	0.43*
ASK	0.60*	0.31*	0.44*	0.44*	0.17*	0.48*	0.05	0.21*	–0.02	0.41*
DIS	0.30*	0.41*	0.42*	0.19*	0.29*	0.26*	0.20*	0.22*	–0.09*	0.35*
QVT	–0.02	0.10*	0.19*	0.26*	0.30*	0.21*	0.16*	0.04	0.06	0.16*

* $p < 0.05$.

Source: the authors' calculations.

The correlation coefficients between indicators for education quality and patent applications, export quality and the value of manufactured exports with high R&D intensity are statistically insignificant or weak at this stage. This is because low GDP pc countries have the majority of advantages in natural resources. Labour- and resource-intensive goods dominate their production structure.

Table 5 presents the outcomes obtained for lower middle GDP *per capita* countries. The values of three correlation coefficients exceed 0.6. There are associations between adult skills with human capital (0.63) and ICT (0.63) as well as between women's average years in school and ICT (0.61). A medium correlation occurred in 12 cases, and for 5 of them the coefficients are higher than 0.5. There are correlations of adult literacy with human capital and ICT, women's average years in school with human capital and patent application, adult skills with patent applications.

Table 5. Spearman's Correlation Coefficients for Lower Middle GDP pc Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.41*	0.16*	0.43*	0.35*	0.06	0.10*	0.35*	0.29*	0.11*	0.18*
ADL	0.54*	0.32*	0.59*	0.33*	0.16*	0.10*	0.41*	0.41*	0.31*	0.40*
SEQ	0.22*	0.27*	0.24*	0.42*	0.39*	0.26*	0.45*	0.19*	–0.06	0.15*
HEQ	0.16*	0.22*	0.15*	–0.15*	0.14*	0.13*	0.29*	0.03	0.17*	0.08
SUG	0.01	–0.03	0.06	0.02	–0.03	0.10*	0.01	–0.01	0.26*	0.15*
WSH	0.58*	0.38*	0.61*	0.29*	0.16*	–0.03	0.57*	0.46*	0.20*	0.39*
ASK	0.63*	0.35*	0.63*	0.27*	0.20*	0.07	0.53*	0.48*	0.29*	0.38*
DIS	0.13*	0.01	0.09*	–0.02	0.39*	0.34*	0.39*	0.14*	0.10*	–0.16*
QVT	0.02	0.02	0.09*	0.03	0.00	0.21*	0.07	0.05	0.23*	0.17*
Indicator	HCt_2	LPRt_2	ICTt_2	NBDt_2	QCIt_2	SCHt_2	PAt_2	PSt_2	HTEt_2	GDPt_2
PEQ	0.39*	0.16*	0.44*	0.34*	0.05	0.07	0.33*	0.28*	0.12*	0.19*
ADL	0.53*	0.32*	0.62*	0.33*	0.15*	0.08	0.38*	0.40*	0.32*	0.42*
SEQ	0.20*	0.29*	0.26*	0.43*	0.40*	0.24*	0.44*	0.19*	–0.08	0.14*
HEQ	0.14*	0.24*	0.12*	–0.16*	0.12*	0.13*	0.30	0.02	0.16*	0.08
SUG	0.01	–0.05	0.06	0.00	0.00	0.12*	0.04	–0.02	0.29*	0.14*
WSH	0.56*	0.39*	0.62*	0.29*	0.16*	–0.04	0.56*	0.45*	0.20*	0.38*
ASK	0.61*	0.36*	0.65*	0.27*	0.19*	0.06	0.51*	0.47*	0.30*	0.38*
DIS	0.14*	0.02	0.12*	–0.01	0.40*	0.33*	0.39*	0.13*	0.12*	–0.15*
QVT	0.01	0.01	0.07	0.02	–0.01	0.23*	0.07	0.03	0.23*	0.16*

* $p < 0.05$.

Source: the authors' calculations.

Compared to countries with lower GDP *per capita*, the strength of interdependence between primary education quality and ICT and between patent application and export quality has increased significantly. In these cases correlations are still stronger than those for higher education quality. However, there is a statistically significant and positive correlation between higher education quality with human capital and high-tech manufactured export. The correlation between higher education quality and labour productivity, ICT and patent application is also strengthening.

As we suggested earlier, the largest changes in the values of correlation coefficients are observed for secondary education quality compared to primary and higher education quality. This applies especially to structural change (by 0.20), new business density (by 0.22), building quality control index by enterprises (by 0.23), export quality, and patent applications (0.39).

Table 6 shows the results obtained for upper middle GDP pc countries. There is neither a strong nor a very strong correlation, though a medium correlation occurs six times. The highest positive correlation coefficients are again observed for associations between human capital and indicators for technological progress. There are four other medium correlations, including ones for ICT with women's average years in school and adult skills as well as patent applications with primary and secondary quality education.

Table 6. Spearman's Correlation Coefficients for Upper Middle GDP pc Countries, 2007–2021

Indicator	HCt_0	$LPRt_0$	$ICTt_0$	$NBDt_0$	$QCIt_0$	$SCHt_0$	PAt_0	$EXQt_0$	$HTEt_0$	$GDPt_0$
PEQ	0.53*	0.25*	0.38*	0.04	0.34*	0.25*	0.41*	0.29*	0.27*	0.23*
ADL	0.44*	0.07	0.36*	–0.05	0.05	0.01	0.31*	0.11*	0.21*	0.17*
SEQ	0.47*	0.35*	0.33*	–0.12*	0.15*	0.38*	0.50*	0.25*	0.32*	0.30*
HEQ	0.47*	0.19*	0.33*	–0.10*	0.41*	0.35*	0.24*	0.26*	0.37*	0.27*
SUG	–0.08	–0.07	–0.04	–0.07	0.01	–0.08	–0.13*	–0.12*	0.14*	0.14*
WSH	0.42*	0.16*	0.57*	0.11*	0.22*	0.05	0.23*	0.14*	0.09*	0.22*
ASK	0.43*	0.08	0.53*	0.09*	0.28*	0.03	0.28*	0.15*	0.15*	0.16*
DIS	0.13*	–0.02	0.21*	–0.05	0.23*	–0.06	0.20*	–0.03	0.17*	0.14*
QVT	–0.07	–0.10*	0.00	–0.03	–0.05	–0.21*	–0.06	–0.22*	0.11*	0.16*
Indicator	HCt_2	$LPRt_2$	$ICTt_2$	$NBDt_2$	$QCIt_2$	$SCHt_2$	PAt_2	PSt_2	$HTEt_2$	$GDPt_2$
PEQ	0.54*	0.24*	0.40*	0.02	0.33*	0.25*	0.40*	0.31*	0.29*	0.21*
ADL	0.43*	0.07	0.39*	–0.03	0.04	0.02	0.29*	0.12*	0.24*	0.16*
SEQ	0.51*	0.34*	0.35*	–0.11*	0.15*	0.39*	0.50*	0.26*	0.34*	0.28*
HEQ	0.48*	0.18*	0.33*	–0.12*	0.43*	0.35*	0.25*	0.25*	0.38*	0.27*
SUG	–0.09	–0.08	–0.05	–0.08	0.00	–0.08	–0.12*	–0.15*	0.12*	0.15*
WSH	0.39*	0.16*	0.57*	0.12*	0.22*	0.06	0.20*	0.14*	0.11*	0.21*
ASK	0.40*	0.07	0.54*	0.10*	0.27*	0.03	0.25*	0.15*	0.16*	0.15*
DIS	0.13*	–0.03	0.23*	–0.06	0.22*	–0.07	0.19*	–0.04	0.16*	0.15*
QVT	–0.08	–0.09*	0.00	–0.03	–0.04	–0.19*	–0.05	–0.23*	0.10*	0.18*

* $p < 0.05$.

Source: the authors' calculations.

From among all levels of education, primary education quality is most closely related to changes in human capital, ICT, and export quality. Secondary education quality is most closely related to changes in labour productivity, structural change, patent applications and GDP pc. Higher education quality is most closely related to changes in the quality control index and high-tech manufactured exports.

Only in this group of countries is there such a weak positive correlation or such a strong negative correlation between the skillset of university graduates and vocational training quality with indicators for technological progress. Furthermore, the strength of the correlation decreased in 58 cases. We can therefore conclude that the worst situation occurs in industrialised countries. This will be explained in the results discussion section.

Table 7 presents the findings obtained for the highest GDP pc countries. Almost all correlation coefficients are statistically significant and positive, with the exception of associations between indicators for education quality and new business density.

Table 7. Spearman's Correlation Coefficients for High GDP pc Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.51*	0.11*	0.43*	0.11*	–0.07	0.52*	0.62*	0.68*	0.45*	0.24*
ADL	0.69*	0.29*	0.50*	0.27*	–0.12*	0.41*	0.69*	0.54*	0.41*	0.56*
SEQ	0.63*	0.07	0.46*	0.15*	–0.06	0.50*	0.59*	0.54*	0.52*	0.28*
HEQ	0.51*	0.47*	0.48*	0.27*	–0.10*	0.42*	0.46*	0.38*	0.32*	0.57*
SUG	0.52*	0.54*	0.49*	0.31*	–0.11*	0.26*	0.55*	0.43*	0.41*	0.73*
WSH	0.65*	0.02	0.60*	0.27*	–0.05	0.31*	0.56*	0.37*	0.43*	0.34*
ASK	0.68*	0.10*	0.60*	0.30*	–0.02	0.31*	0.62*	0.42*	0.49*	0.43*
DIS	0.38*	0.25*	0.37*	0.35*	–0.20*	0.04	0.39*	0.19*	0.40*	0.47*
QVT	0.60*	0.53*	0.53*	0.15*	–0.07	0.49*	0.67*	0.53*	0.38*	0.72*
Indicator	HCt_2	LPRt_2	ICTt_2	NBDt_2	QCIt_2	SCHt_2	PAt_2	PSt_2	HTEt_2	GDPt_2
PEQ	0.57*	0.15*	0.41*	0.10*	0.02	0.53*	0.61*	0.64*	0.43*	0.32*
ADL	0.50*	0.25*	0.45*	0.27*	–0.27*	0.31*	0.61*	0.49*	0.38*	0.41*
SEQ	0.62*	0.05	0.46*	0.25*	–0.08	0.44*	0.54*	0.47*	0.53*	0.28*
HEQ	0.54*	0.50*	0.46*	0.20*	–0.10*	0.47*	0.47*	0.41*	0.32*	0.58*
SUG	0.54*	0.54*	0.48*	0.35*	–0.11*	0.26*	0.53*	0.40*	0.42*	0.76*
WSH	0.59*	0.03	0.53*	0.24*	–0.10*	0.33*	0.55*	0.37*	0.42*	0.31*
ASK	0.53*	0.09*	0.51*	0.25*	–0.12*	0.26*	0.56*	0.39*	0.43*	0.33*
DIS	0.40*	0.25*	0.38*	0.36*	–0.19*	0.05	0.39*	0.18*	0.41*	0.49*
QVT	0.60*	0.54*	0.53*	0.15*	–0.08	0.50*	0.67*	0.53*	0.36*	0.72*

* $p < 0.05$.

Source: the authors' calculations.

The correlation coefficient values exceed 0.70 only in two cases – GDP pc with skillset of university graduates and vocational training quality. Furthermore, these two education quality indicators are the strongest correlated with labour productivity among other indicators for technological progress.

Taking into account all levels of education, primary education quality is the most strongly correlated with patent applications and export quality, secondary education quality with human capital and high-tech manufactured exports, higher education quality with labour productivity, building quality control index and GDP pc. The outcomes also show that the importance of literacy, adult skills and women's average years in school in stimulating technological progress are not decreasing. We can therefore conclude that the mutual interaction of higher education quality and skillset of university graduates with indicators of technological progress is the strongest in countries with the highest GDP pc.

5. Discussion

The research results confirm that the increase in education quality translates into technological progress. They are consistent with the findings of a number of other researchers (Saviotti, Pyka & Jun, 2016; Volchik, Oganesyan & Olejarz, 2018; Agasisti & Bertoletti, 2022; Karabayev *et al*., 2023).

The findings do not confirm H1 as true. They indicate that the importance of higher education quality increases alongside economic development, but the importance of primary and secondary education quality does not decrease. This is because primary education quality influences secondary education quality and this is ultimately reflected in the skills of university graduates.

The research results do confirm H2. In our study, women's average years in school are one of five education quality indicators most strongly correlated with technological progress in 160 of the countries studied. The validity of H2 is also confirmed by Global Gender Gap Reports.

As for H3, the findings prove that investing in the quality of adult skills is an important determinant of technological progress regardless of the stage of economic development (e.g., Kamprath & Mietzner, 2015; Grenčíková, Kordoš & Navickas, 2021; Spöttl & Windelband, 2021). For example, the OECD (2018) indicates that future-ready students will need a broad range of skills, including cognitive and meta-cognitive skills (e.g. critical thinking, creative thinking, learning to learn and self-regulation); social and emotional skills (e.g. empathy, self-efficacy and collaboration); and practical and physical skills (e.g. using new information and communication technology devices).

As one might expect, industrialised countries are lagging. There are likely reasons for this. One is the significant concentration of power in the hands of a small number of men who do not want to change the prevailing situation. They may prefer autocratic management and for various types of schools to function as factories churning out appropriately trained graduates (e.g., Costa, Pádua & Moreira, 2023; Khosravi, Yahyazadehfar & Sani, 2023). Another reason is that some industrialised countries seek to forcefully maintain the competitive advantage in resources-,

labour-, and capital-intensive commodities that are easy to imitate instead of investing in education and innovative activities. In the case of these competitive advantages, price competition rules the day, making entrepreneurs reluctant to introduce labour-saving innovations (e.g., Majewska & Rawińska, 2018; Kwon, 2019).

6. Conclusions

Our findings have confirmed that without improving education quality it is impossible to move to more advanced stages of economic development. They also suggest that greater prosperity can be achieved by providing women with the same educational opportunities as men and creating better educational conditions for children. Taking these measures leads to a greater majority of society being able to read and write, a necessary condition for social development since the beginning of human history. Literacy in our study also opens the door to ICT and is strongly correlated with improving human capital at every stage of economic development.

The research results also suggest that countries at the second stage must exceed the threshold level for knowledge absorption capacity, which ultimately widens technological capabilities. This cannot be achieved without investing in education quality.

These outcomes allow us to conclude that improving skillset of university graduates and increasing higher education and vocational training quality are the primary conditions for becoming a post-industrial society with a knowledge economy, where the professionalisation of management, democracy and human rights reign.

In future work, we intend to deepen the analysis of the links between the indicators of education quality and technological progress separately for each stage of economic development.

Authors' Contribution

The authors' individual contribution is as follows: Maria Majewska 40%, Ewa Mazur-Wierzbicka 40%, Nelson Duarte 20%.

Conflict of Interest

The authors declare no conflict of interest.

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Digital Competences in the Economy 4.0 and Their Determinants

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ABSTRACT

Objective: The article aims to assess the differentiation of the level of digital competences of young adults and identification of factors influencing the level of these competences among respondents disadvantaged by the digital divide.

Research Design & Methods: The article discusses the differences in the level of digital competences among young adults in Poland. The determinants of the level of digital competences among respondents at risk of digital exclusion were identified and, based on a regression tree analysis, it was indicated which of them best predict a low level of digital competences. Material from our own research conducted on a nationwide sample of 1,000 respondents was used. The catalogue of digital competences was taken from The European Digital Competence Framework (DigComp). Radar plots, box-plot plots, and regression trees were used to analyse the data.

Findings: As a result of the research, determinants of the low level of digital competences were identified, such as the type of place of residence, the level of education, and the level of social and cognitive competences. Moreover, it has been shown that the level of digital competences of people at risk of digital exclusion is only slightly differentiated by gender.

Implications/Recommendations: Reducing digital competence deficits is possible by participating in the education process. While competence gaps among young people can be reduced through formal education, in the case of professionally active people this is possible mainly through participation in informal and non-formal education. In the light of the research results, the development of digital competences requires the simultaneous development of cognitive and social competences.

Contribution: The article fills a research gap in the field of digital competences of young adults in Poland. Individual digital skills were measured and factors that differentiate their level were identified. It was also indicated which of the identified determinants best predict the risk of digital divide among young adults in Poland, which is the novel factor in the paper.

Article type: original article.

Keywords: digital competences, digital divide, labour market, survey data.

JEL Classification: I25, J24, J29, O15.

1. Introduction

The ongoing technological changes are one of the most important factors influencing the functioning of the modern digital economy. Digitalisation is universal and global, and concerns both social and economic processes, creating new challenges for a wide range of entities. The consequences of the dynamic development of technology include, among others: changing requirements in the labour market. They concern both employers, who must use these technologies on an increasingly wider scale to remain competitive, and employees, who must have the skills to work in a digital environment. Therefore, the requirements for employees in terms of the ability to use, manage and work with new technologies are increasing (Butler-Adam, 2018). Hence, in the Economy 4.0, employees must have not only skills related to the use of digital information and data, communication and cooperation in the digital world but also the creation of digital content, cybersecurity, and solving problems arising from working in a digital environment. It is also worth emphasising that the issue of digital competences is important not only in the aspect of Economy 4.0 but also in 5.0. The approach presented within this concept places people at the centre of the production process and uses progress for sustainable, intelligent development while respecting the environment (Atif, 2023; Raja Santhi & Muthuswamy, 2023).

Bearing in mind the above premises, the aim of the article is to assess differentiation of the level of digital competences of young adults and identification of factors influencing the level of these competences among respondents threatened by a digital divide. To achieve the goal, the following research questions were formulated: 1) What is the level of individual digital skills among respondents declaring different levels of general digital competences? 2) What are the determi-

nants of the level of digital competences among respondents threatened by a digital divide? 3) Which of the identified determinants best predict a low level of digital competences? To carry out the research planned in this way, material from our own research conducted on a nationwide sample of 1,000 respondents was analysed. The catalogue of digital competences was taken from The European Digital Competence Framework (DigComp). Radar plots, box-plot plots, and regression trees were used to analyse the data.

2. Literature Review

The digital transformation poses a challenge for a number of areas in modern society, including the labour market, education system, healthcare, and public administration. The consequences of digitalisation on the labour market are expressed, among other things, in employers' expectations of both the existing employees and individuals who are just entering the labour market. In the wake of the new digital world, globalisation and automation have reduced the number of routine, low-skilled jobs. Employees are required to have greater flexibility since much of the work which they have performed thus far has been automated. This implies a need for constant adaptation to shifting trends in the labour market, as well as lifelong learning and readiness to change occupations. Digital technologies accelerate the meaningful transformation of business activities, processes, competence, and models while allowing full leverage of the changes and opportunities brought about by their impact across society in a strategic and prioritised manner (Demirkan, Spohrer & Welser, 2016; Firlej, 2016).

Digital technologies allow us to obtain large data streams that require further research to create value which could provide a competitive edge for enterprises (Kraus *et al*., 2021). Big data (BD) is universal and therefore it is suitable for extensive use – both to identify customer needs and risk management, to design products and services, as well as to manage quality. Data analysis can also serve as a source of information about internal corporate processes and a starting point for their improvement (Urbinati *et al*., 2019). Hence, now more than ever enterprises have a growing need for people with specialist knowledge of information and communications technology (ICT). Debortoli, Müller and vom Brocke (2014) have distinguished between BD and traditional business analysis and developed a competency classification for BD and business intelligence (BI). The authors are certain that BI mainly requires skills associated with the use of appropriate software while working with BD which must go hand in hand with coding skills and knowledge of statistics. Research into this trend has also been conducted by Dubey and Gunasekaran (2015), who demonstrated the potential to enhance organisational value by possessing the appropriate hard and soft skills necessary to use BD and business analytics.

In turn, the consequences of BD or other megatrends (artificial intelligence, blockchain, advanced robotisation) for the education system imply a need for a new perspective on the competences transferred as part of the education process (Ćwiek & Maj-Waśniowska, 2020). This indicates several reasons to justify the inclusion of ICT in education. The first concerns the potential benefits of ICT in teaching and learning, which should result in better achievement and higher levels of student motivation (Pettersson, 2018). Secondly, digital competences are absolutely necessary for the modern knowledge-based society (Maj-Serwatka & Stabryła-Chudzio, 2023). Finally, digital competences, which enable active participation in social and economic life, prevent the digital divide. The term "digital divide" originally denoted inequality of access to ICT and the Internet (Irving *et al*., 1999). The evolution of ICT infrastructure brought with it a change in the perception of the digital divide and the focus shifted from the hardware aspect to the ability to use digital resources and competences (Ćwiek, 2018).

Changes and reforms of education systems as stipulated by technological progress are a prerequisite for people graduating and starting their working lives in order to meet work-related challenges of the digital future in the era of Economy 4.0 (Schwab, 2016). Gartner (2017) observes that new technologies (mixed reality, cognitive computing, blockchain, artificial intelligence), through their impact on the labour market, force companies to look for employees with the required digital skills (Bughin *et al*., 2018).

The digital competences that employees must acquire vary depending on the nature of the work. Murawski and Bick (2017) indicate that this acquisition is conditioned by properly designed curricula and training. A dual approach to digital competences, specifically from the demand and supply sides, may be helpful in this context. In both instances, the analyses use text mining techniques, among many other methods. The former case concerns the use of job advertisements to examine the required competences for a given position and the accompanying level of remuneration. The supply-side approach, on the other hand, means an analysis of the skills declared by employees in given jobs. Regarding the competences required for individual jobs, the difference between demand and supply indicates a gap between the currently existing vs. actually required digital competences of the labour force (Oberländer, Beinicke & Bipp, 2020; Bilan, Mishchuk & Samoliuk, 2023).

However, it should be noted that digital competences are also very important not only in the context of the functioning of the private sector but also from the point of view of public administration. Research in this area was conducted by Androniceanu *et al*. (2023). The authors looked for factors that most determine human resources digital competences and identified social factors, extrinsic motivation factors, and administrative and managerial factors as the most important. Moreover, research results indicate that the main reason for the development of

digital competences is the need to ensure data security and the need to ensure the continuity of the organisation's operations through consistent application of technological tools. In turn, Andronicеanu and Georgescu (2023) studied the correlations between human development and the digital competences of citizens and employees of a public administration office in Romania. The research results indicate two interesting relationships. Firstly, a negative relationship between Internet use and human development was observed. At the same time, a positive correlation was found between human development and digital skills. What is more, digitalisation of public administration has reduced employment in this area.

Economy 4.0 means the analysis of big data, related to the continuous acquisition of information, automation of production processes, the use of blockchain technology, machine learning, and finally – artificial intelligence. Therefore, active participation in socio-economic life requires the ability to understand and use digital content. These skills include both digital as well as social and cognitive competences that are used to operate in the digital age (Martzoukou *et al*., 2020). Digital competences also support interaction and communication in personal and social life (Bughin *et al*., 2018). These are increasingly referred to as essential soft skills (Kovacs & Vamosi Zarandne, 2022). According to the European Commission (2022), in the future nine out of ten jobs will require digital skills. This means that these skills will be necessary in both your private and professional life. The importance of social competences for an individual results from the fact that they allow for building social capital and determine the ability to work in an international environment (PwC, 2017). Cognitive competences, in turn, become particularly important in the era of the Internet due to information chaos. Thanks to logical reasoning it is possible to critically select information and assess its credibility. Changes in the labour market and the growing number of jobs requiring social and cognitive skills indicate the increasing importance of soft skills in relation to analytical skills (Varga *et al*., 2017).

The triad of competences, i.e. social, cognitive and digital competences, are referred to as the competences of the future or meta-competences (Śledziewska & Włoch, 2020). Hence, it should be stated that digital competences are necessary to counteract the digital divide, but not all tasks performed can be automated. Flexible perception, creativity, and emotional intelligence are necessary for effective problem solving (McKinsey Global Institute, 2017). The requirements regarding these competences, which are key from the employer's perspective regardless of the field of business activity, are a source of challenges for employees in the digital economy.

Considering digitalisation and technological changes and their impact on the labour market in the era of the 4.0 Economy, numerous studies have been conducted. Hetmańczyk (2024) pointed out that due to the ongoing digitalisation processes,

multidimensional professional training of employees is necessary. Adapting employee skills to new challenges ensures the competitiveness of the economy. They are also essential to achieving the sustainable development goals. In this context, according to Bugowski and Trzaska (2023), employees' digital competences are of particular importance. Threats and challenges for the labour market due to increasing digitalisation were discussed by Kolokytha *et al*. (2018). They pointed out that technological changes intensify structural maladjustment in the labour market. On the one hand, in some countries there is a high level of unemployment, and on the other, enterprises report problems with finding employees with appropriate competences. In turn, Chinoracký and Čorejova (2019), and Sârbu *et al*. (2020) investigated the possible labour market consequences of the widespread use of new technologies.

All of the studies mentioned above point to the need to develop competences, particularly digital ones, among employees in connection with ongoing technological changes. However, these studies did not characterise employees who are most at risk of marginalisation in the labour market due to low levels of digital competences. Hence, this article fills the research gap by identifying the factors that differentiate the level of digital competences of young adults and identifying those that best predict the risk of the digital divide.

3. Data and Research Method

The assessment of the level of digital competences and the identification of the determinants of their low level were evaluated based on primary data obtained in the course of our own research. A nationwide survey using computer assisted web interview (CAWI) on an online panel was conducted by the Public Opinion Research Center in the fourth quarter of 2020. The survey covered 1,000 respondents aged 18–30, with at least secondary education, selected by quotas from panel participants. The sample is representative in terms of age, sex, and education level (Table 1).

The catalogue of competences examined in the study was taken from The European Digital Competence Framework (DigComp) (Ferrari, 2013). The digital competence survey covered 21 skills grouped in five areas: 1) information and data literacy, 2) communication and collaboration, 3) digital content creation, 4) safety, 5) problem solving.

The respondents evaluated individual skills on a Likert scale (from 1 to 5); additionally, a possible answer was that one is unable to self-assess the level of a given competence. According to the DigComp methodology, an individual fluent in these five areas who is able to use the functions of digital technologies is considered a person with digital competence.

Table 1. Characteristics of Respondents Participating in the Study

Variable	Number	Percentage
Sex		
Male	476	47.6
Female	524	52.4
Age		
18–24	399	39.9
25–30	601	60.1
Level of education		
Secondary	575	57.5
Tertiary	425	42.5

Source: the authors.

The competence level assessment is presented in the form of a radar chart. It presents the results for all respondents, as well as the results for people who assessed their general digital competences as average at best (score 3 or lower), and those who assessed their competences at a good or very good level (score 4 or 5). Due to the purpose of the article, further analysis was carried out only for people at risk of digital divide. The criterion for this risk was an assessment of general digital competences of at most level 3.

Among persons with average or low digital competences, 57% are female. 37% of people in the study group are aged 18–24, the remaining 63% are aged 25–30. Nearly 60% of all respondents threatened by the digital divide have secondary education (Table 2). The smallest number of such people is in the group of respondents with higher education who have a PhD or postgraduate studies.

Table 2. The Number of Respondents with a Low Level of Digital Competence According to the Level of Education

Level of Education	Number	Cumulative Number	Percentage	Cumulative Percentage
Vocational secondary schools	96	96	24.00	24.00
General secondary	80	176	20.00	44.00
Post-secondary	56	232	14.00	58.00
Incomplete tertiary	18	250	4.50	62.50
Bachelor's degree or equivalent	69	319	17.25	79.75
Master's degree or equivalent	73	392	18.25	98.00
PhD or postgraduate studies	8	400	2.00	100.00

Source: the authors.

The last element of the characteristics of people at risk of digital divide is their place of residence. The largest groups are residents of rural areas (42.25%), small towns with a population of up to 20,000, and towns with 20,000–49,000 inhabitants (12.25% and 11.25% respectively).

During the analysis, first of all, for the indicated group, it was checked whether variables such as sex, age, level of education, and size of place of residence affect the level of digital competences. The analysis used a synthetic variable, which is the arithmetic mean of the ratings of 21 competences included in The European Digital Competence Framework. This variable is a stimulant. Then, the direction and strength of the correlation between the examined digital competences and cognitive and social competences was checked. The inclusion of cognitive and social competences in the model results from the belief in the literature on the complementarity of these three types of skills (Śledziewska & Włoch, 2020). Finally, a regression tree was developed, which is one of the methods of data mining. They allow a recursive division of the set of observations into disjoint subsets based on a dependent variable. The condition for using this method is an appropriate scale for measuring the dependent variable (at least an interval scale). The purpose of its use is to separate high and low values of the dependent variable at each stage of division while minimising leaf variability (Łapczyński, 2010).

The model for regression trees is created locally by submitting models built in disjoint segments of multidimensional space:

$$f(x_i) = \sum_{k=1}^{K} \alpha_k I(x_i \in R_k), \tag{1}$$

where:

R_k – segments of space X^m,

α_k – model parameters,

m – the number of explanatory variables,

I – the indicator variable expressed as:

$$I(x_i \in R_k) = \prod_{l=1}^{L} I\left(v_{kl}^{(d)} \le x_{il} \le v_{kl}^{(g)}\right), \tag{2}$$

where: $v_{kl}^{(d)}$ and $v_{kl}^{(g)}$ are respectively the lower and upper limits in the l dimension of space.

Model parameters α_k are determined according to the formula:

$$\alpha_k = \frac{1}{N(k)} \sum\nolimits_{x_i \in R_k} y_i, \tag{3}$$

where: $N_{(k)}$ – the number of observations that belong to R_k segment.

In the next step, using the appropriate quality functions of division, the R segment is divided into subsequence segments. The final form of the model is selected using one of the edge trimming methods (Walesiak & Gatnar, 2012). The C&RT algo-

rithm with the minimum cost of a cross-check was used to build regression trees. The explanatory variables include: cognitive competences, social competences, size of place of residence, level of education, age and sex. Statistical analysis of the data was performed using the Statistica 13 software.

4. Results and Discussion

To achieve the research goal, the analysis was carried out in two variants. In the first variant, the opinions of all respondents were taken into account (G1), while in the second variant, the respondents were divided into two groups (G2–G3) according to the self-assessment of general digital skills. In the second variant, the first group includes people who assess their digital skills as average at best (G2 – score 1–3) and the second – people who assess their digital skills as high or very high (G3 – score 4–5). Group G2 are people threatened by the digital divide. The average ratings of 21 individual digital competences for each group are shown in Figure 1.

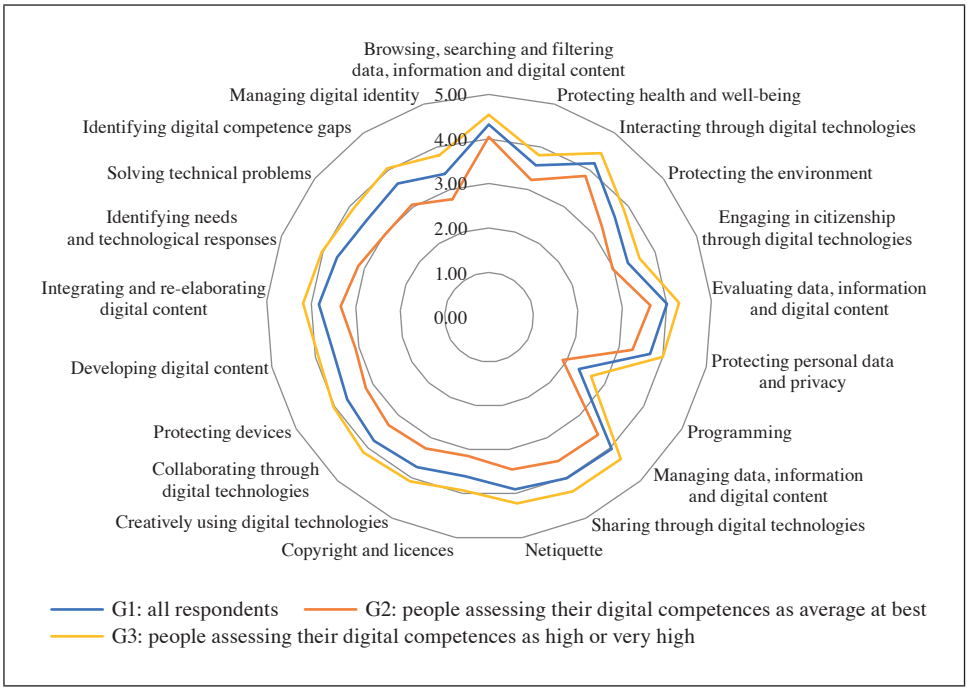

Fig. 1. Radar Chart of Average Ratings of Digital Competences in the Surveyed Groups of Respondents

Source: the authors.

Analysing the presented radar chart, it can be noticed that regardless of group affiliation, respondents rate the same competences as the highest and lowest, which results in a similar arrangement of lines on the chart, but with the difference that the assessment of people threatened by the digital divide is shifted towards the middle of the chart. If we compare the self-assessment of competences by respondents from the first and second groups, the smallest differences are visible for 1) browsing, searching and filtering data, information and digital content and 2) protecting health and well-being (0.28 and 0.34, respectively). The largest differences were observed for managing digital identity and identifying digital competence gaps (0.60 and 0.57, respectively). It is worth emphasising that in the case of people in the G1 group, only one digital skill was rated at a level below 3 (programming). The vast majority of other competences were rated above 3.5. In the G2 group, however, respondents rated the vast majority of skills as less than 3.5. Interestingly, if we compare the average competence ratings of respondents from the G2 and G3 groups, the smallest and largest differences were noted in the case of the same skills as when comparing G1 and G2 groups. However, this time the discrepancies in assessments are much greater. The smallest differences for the previously mentioned competences were 0.50 and 0.58, respectively, while the largest were 1.03 and 0.99, respectively. This means that the differences mentioned are almost twice as large, which demonstrates a wide range in the respondents' level of competences.

The conclusions reached by van Laar *et al*. (2020) and De Haan (2010) seem important in this context. The authors indicate that the differences in the level of digital skills in knowledge-based societies are one of the causes of social inequality. Moreover, the progressive development of new technologies and the information society deepens these gaps. Professionally inactive people with lower education, as well as the elderly and members of ethnic minorities are particularly vulnerable to the risk of digital divide (De Haan, 2010).

In the next step, it was checked whether the digital competences of people threatened by digital divide depend on features such as gender, level of education and the size of the respondents' place of residence. For this purpose, a synthetic variable was introduced to describe the respondents' digital competences, which is the arithmetic mean of the assessments of individual 21 competences. The distribution of the synthetic variable in the mentioned cross-sections is shown in Figure 2.

Analysing the obtained distributions, it can be seen that women and men rated their digital skills at a similar level. Opinions on the impact of gender on the level of digital competences are divided in the literature on the subject. Its absence was pointed out by, among others, Guillén Gámez and Perrino Peña (2020) and Rodríguez, Cantabrana and Cervera (2021).

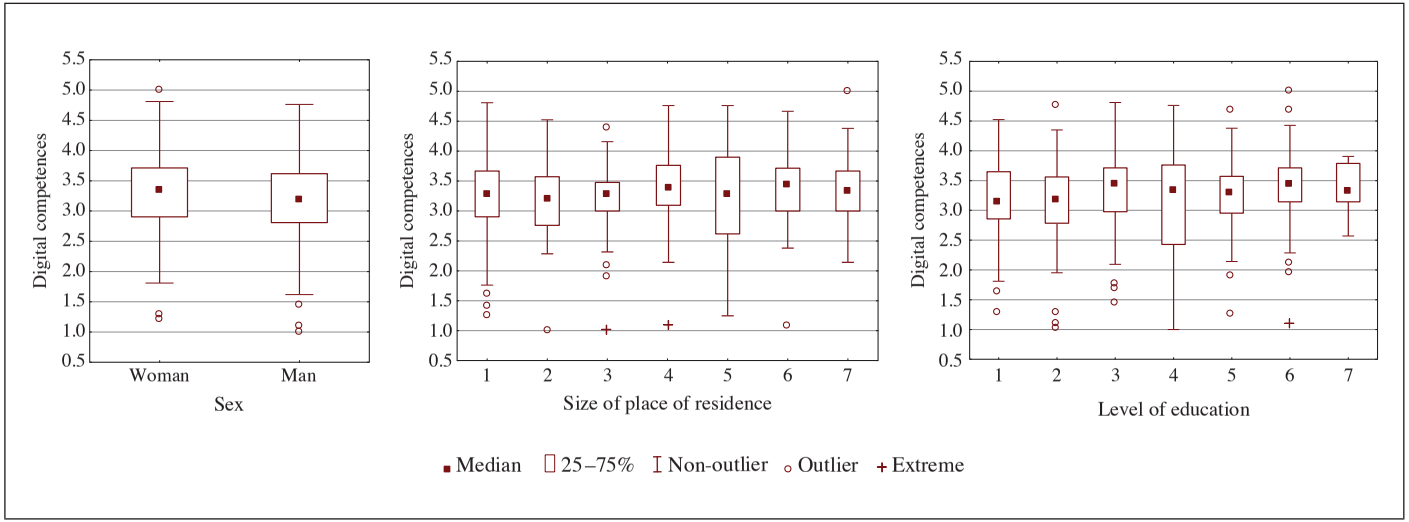

Fig. 2. Distributions of the Synthetic Variable Describing Digital Competences by Gender, Size of Place of Residence and Level of Education

Notes: Size of place of residence: 1 – village, 2 – town up to 20,000 inhabitants, 3 – town with 20,000–49,000 inhabitants, 4 – city with 50,000–99,000 inhabitants, 5 – city with 100,000–199,000 inhabitants, 6 – city with 200,000–500,000 inhabitants, 7 – city with over 500,000 inhabitants. Level of education: 1 – vocational secondary schools, 2 – general secondary, 3 – post-secondary, 4 – incomplete tertiary, 5 – bachelor's degree or equivalent, 6 – master's degree or equivalent, 7 – PhD or postgraduate studies.

Source: the authors.

Slightly greater differences are visible in the case of respondents' assessment of the size of their place of residence. The highest median rating is observed for residents of the cities with 50,000–99,000 and 200,000–500,000 inhabitants. However, for residents of villages and cities with 100,000–199,000 inhabitants, the greatest range of answers is visible, which means the greatest differences in the assessment of the level of digital competences. It is also worth emphasising that the self-assessment of competences of residents of the largest cities, i.e. those with more than 500,000 inhabitants, does not differ significantly from the assessment of competences of residents of smaller cities. This result is different from the results of Eurostat research, which indicate that urban residents have a higher average level of digital competences (Eurostat, 2023). However, it should be remembered that the results of our own research concern only the group of people under threat from the digital divide, while the results of Eurostat research concern the general public.

Taking into account the level of education, it is clearly visible that the discrepancies in the self-assessment of digital competences are the largest. The highest median grade was recorded for respondents with post-secondary education and a master's degree or equivalent. The greatest differences in the assessment of skills occurred in the case of people with incomplete tertiary education (the range of non-outlier values ranges from 1 to 4.7). However, the smallest difference is visible in the case of respondents with PhD or postgraduate studies. It should be noted, however, that the maximum self-assessment is much lower than in the case of other respondents and is below 4.0. Research by Rozkrut (2018) indicates greater activity of people with higher education in the context of using ICT. Eurostat research also shows a clearly higher level of digital competences among people with higher education (Eurostat, 2022).

Due to the purpose of the research, it was necessary to take into account the level of social and cognitive competences of the respondents in the analyses. The relationship between the level of digital competences and social and cognitive competences is presented in Table 3.

Table 3. Correlation Matrix between the Assessment of Digital Competences and Social and Cognitive Competences

Variable	Social Competences	Cognitive Competences	Digital Competences
Social competences	1.0000	0.5821*	0.4064*
Cognitive competences	0.5821*	1.0000	0.4815*
Digital competences	0.4064*	0.4815*	1.0000

*$p < 0.05$.

Source: the authors.

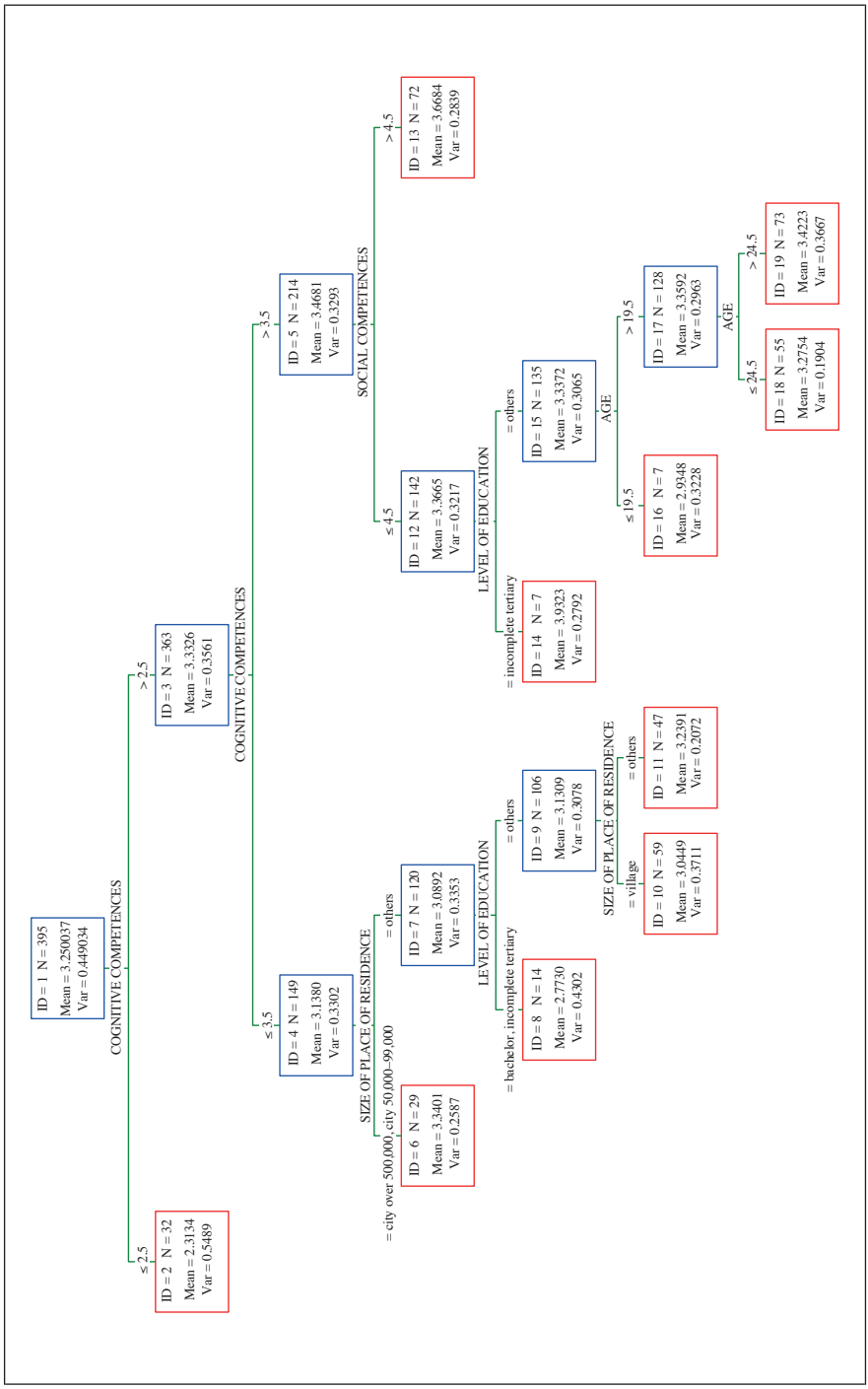

Fig. 3. Regression Tree for the Synthetic Variable Describing the Level of Digital Competences of Respondents at Risk of Digital Divide

Source: the authors.

The analysis of the results contained in Table 3 confirms the existence of a relationship between digital competences measured by the synthetic variable and cognitive and social competences. This is a moderate but statistically significant relationship, and the strength of the relationship between digital and cognitive competences is slightly greater than in the case of the correlation between digital and social competences.

To study the impact of all specified variables together on the digital competences, regression trees were used. The explained variable is a synthetic variable of digital competences. The explanatory variables include: cognitive competences, social competences, size of place of residence, level of education, age and sex. The regression tree obtained consists of nine split nodes and ten terminal nodes (Fig. 3). They were prepared for people who defined their general digital competences as level 3 at most, i.e. people threatened by the digital divide.

In the analysed tree, the first division line indicates that people with cognitive competences at a level less than or equal to 2.5 have on average 31% lower digital competences than people with cognitive competences above 2.5.

The cognitive competence level also determines the second division line. In this case, the limit value is 3.5. People with the above-mentioned competences at a level less than or equal to 3.5 have an average level of digital competence at a level of 3.14. Further dividing lines indicate that residents of cities with over 500,000 inhabitants and cities with between 50,000 and 99,000 inhabitants have higher digital competences than respondents living in smaller towns. Another division criterion is the level of education. A higher average level of the examined variable was observed in respondents who had completed master's studies and also in those with secondary education. The difference in relation to people with a bachelor's degree and incomplete higher education is 12.9%. The last dividing line in this part of the tree is related to the size of the place of residence. People living in rural areas have, on average, a lower level of digital competences than residents of other types of towns.

Returning to the second division line of the tree, it can be noticed that people with cognitive competences at a level higher than 3.5 have digital competences at a level of 3.47. In the case of these respondents, the differentiating feature is the level of social competences. Thus, people with these competences at a level of 4.5 or less have digital competences at a lower level. Among these people, the lowest level of digital competence is for people aged 19.5 or younger (average 2.93) and the highest for people aged 24.5 (average level 3.42).

What makes it disconcerting is that the age group 24 and above are people entering the labour market (often with higher education) who should possess skills that are desired by employers. Shortcomings in this area may be limited along with the acquisition of professional experience, however, they demonstrate that the education system is maladapted to the contemporary realities of socio-economic life.

This is confirmed by the results of research conducted by Google and the Polish Development Fund Group at the turn of 2018 and 2019 among 1,128 students and graduates of various universities (Włoch & Śledziewska, 2019). 31% of respondents indicated that they did not acquire digital competences at all during their studies, and 48% declared that they acquired them at a basic level. Respondents assessed the level of acquired social competences even less positively. In the case of some manifestations of these competences, such as people management, as many as 52% indicated that they had not acquired this competence at all. The respondents rated the level of their cognitive competences the best. In this case, most people indicated that they had them at a very high level (depending on individual skills, it was from 19% to 26%) (Śledziewska & Włoch, 2020). As a consequence, a significant group of employees entering the labour market, despite higher education, will require specialised training to improve their professional qualifications. According to the World Economic Forum (2018) report, this will be over 50% of employees. In the case of as many as 10%, thorough training lasting over a year will be necessary. The situation of people who do not have higher education on the labour market may be even more difficult, especially those faced with automation of their work (OECD, 2018).

Weak competences that do not meet the requirements of the labour market are a problem especially in the countries of Central and Eastern Europe, including Poland. According to Eurostat research, in 2023 only 44.3% of individuals aged 25 to 64 who are employees, self-employed or family workers have digital competences at least at the basic level. Nearly 4% of them do not have digital competences and 20% assess their skills as low (Eurostat, 2024). The issue of differences in the level of digital competences in European Union countries was also examined by Maj-Serwatka and Stabryła-Chudzio (2023).

In this context, it is worth mentioning that the crisis caused by the COVID-19 pandemic has unveiled new threats, which are related to the differences in the level of competences among young people who, as a whole, are perceived as the "owners" of high-level digital skills. The discrepancy between the belief of young adults in their exceptional digital competences and their actual digital skills has become especially prominent. At the same time, it is difficult to pinpoint the reasons for this difference. This is due to insufficient evidence of a relationship between the self-assessment of the level of digital competences and factors such as age, gender or level of education (Hecker & Loprest, 2019). It is, moreover, equally important to pinpoint that high self-assessment of digital competences may be rooted in the fact that young adults assess these competences through the prism of the ability to use social media, communicate, send information and photos, or use Internet resources, which merely encompasses skills that are part of information and data literacy and communication and collaboration (López-Meneses *et al*., 2020).

Young adults, as employees, should be aware of their digital skills, but also their shortcomings, and employers should clearly formulate expectations regarding the type and level of digital competences of employees. Such guidelines are important in the context of employee motivation and their desire to develop their skills, which in turn should be reflected in financial recognition (Bassi & Nansamba, 2019).

In the case of people with low digital competences threatened by the digital divide, it is necessary to develop them in the process of lifelong learning. In the era of digitalisation, digital competences and the need for the constant development thereof are necessary in order to counteract the digital divide, which may further become a source of social exclusion. All this is taking place in a situation where, due to lack of knowledge, individuals are unable to take advantage of the opportunities offered by the information society (Calderón, Sanmartín Ortí & Kuric, 2022). Although the work of machines will complement and support the work of people, rather than replace it (Daugherty & Wilson, 2018), the prevailing view is that advancing automation processes are skill biased (Brynjolfsson & McAfee, 2014).

5. Conclusions

The digital competence deficits identified in the article pose a particular threat to the construction and development of the digital economy. Although the formal education process and curricula increasingly pay attention to the need to develop digital skills, research results clearly indicate that these activities are insufficient. The research conducted indicates that mere graduation from studies does not guarantee the acquisition of digital competences in all five areas included in the European Digital Competence Framework methodology. However, education is mentioned as a vital element in reducing deficits in digital competence. Lythreatis *et al*. (2021) indicate that among the many factors influencing digital divide, such as: socio-demographic and socio-economic factors, social support, personal predispositions, type of technology, it is precisely education that is most closely related to the digital divide. Undoubtedly, the educational process carried out during working life is also an opportunity to reduce the competence gap and increase the level of competences, among others in the form of courses or training. Hence, formal, informal and non-formal education will largely contribute to reducing the risk of digital divide. While the competence gaps in young individuals can be limited or eliminated through formal education, in the case of the professionally active this is possible mainly through participation in informal and non-formal education.

The execution of digital development programmes and training should take into account that these measures must include competences from all five researched areas. This is due to the fact that a digitally competent person is fluent in all these areas, rather than merely being able to use digital technologies.

The conducted research allowed for the identification of practical implications. Technological changes, affecting the labour market, force a redefinition of educational policy, both in terms of its subjects, goals and content of teaching and recipients. It becomes necessary to include, in addition to traditional knowledge, new skills that will enable active participation in socio-economic life. First of all, the education system should develop digital competences, with particular emphasis on managing digital identity, which is necessary in the context of cybersecurity. In the light of the research results, the development of digital competences requires the simultaneous development of cognitive and social competences. Thanks to them, it is possible to build social capital and function in an international environment, as well as critical verification of information necessary in connection with the information noise in the era of new technologies and growing threats resulting from cybercrime.

Finally, it is also worth noting that the research conducted may constitute the basis for further in-depth analysis related to the issues raised. Particularly interesting is the issue of digital competences according to the modified DigComp 2.2, which contains examples of knowledge, skills and attitudes applicable to each of the 21 competences (Vuorikari, Kluzer & Punie, 2022). The new approach is particularly important for people who are responsible for preparing both school curricula and training programmes and courses. When it comes to the subject range, DigComp 2.2 covers topics including: disinformation in social media and news websites, datafication of Internet services and applications, interaction of people with AI systems and new technologies such as the Internet of Things and, finally sustainable growth. This last issue seems to be particularly important in the concept of Economy 5.0, which puts humans at the centre of the production process and uses progress for sustainable, intelligent development while respecting the environment (Atif, 2023; Raja Santhi & Muthuswamy, 2023). Hence, future research should take into account the issue of digital competences in Economy 5.0.

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Authors' Contribution

The authors' individual contribution is as follows: Each contributed 50%.

Conflict of Interest

The authors declare no conflict of interest.

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Micro, Small and Medium-sized Enterprises in the Digital Economy: Barriers to Digitalisation

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ABSTRACT

Objective: To identify the barriers to digitalisation micro, small and medium-sized enterprises (SME) in Poland face, using enterprises in Dolnośląskie voivodeship as an example.

Research Design & Methods: A review of the subject literature on the essence, level and importance of the digitalisation of enterprises, as well as on the limitations in the use of digital technologies by SMEs. The review is complemented by empirical research conducted in June and July 2023 on a sample of 50 enterprises. The research was preceded by field observation. A questionnaire was administered in electronic (Microsoft Forms) and paper form among clients of an accounting office in the Dolnośląskie voivodeship.

Findings: The results confirm that the level of digitalisation among micro, small and medium-sized enterprises in Poland is low. The owners of enterprises point to a range of barriers that discourage them from implementing digital solutions. The research showed that, among the micro, small, and medium-sized enterprises surveyed, the most frequent barriers to implementing digital solutions were a successfully functioning business, a lack of knowledge on available digital solutions, and a lack of clarity regarding the benefits that such solutions may bring. Meanwhile, firms that have already begun digital transformation indicated a range of barriers to further implementation of digital solutions, including a lack of suitable competences, high investment

costs, and concerns about leaving traces in the digital world and being exposed to various types of inspections.

Implications/Recommendations: There is a need for education and support of digital competences, as well as to increase awareness among the owners of small firms as to the benefits digitalisation promises. At the same time, data and privacy must be protected in order to encourage entrepreneurs to safely implement digital solutions.

Contribution: The research conclusions fill a research gap and can be used by both practitioners and theoreticians. Understanding both the level of digitalisation in SMEs and the barriers hindering the use of digital technologies should help the field develop.

Article type: original article.

Keywords: digital economy, micro, small and medium-sized enterprises (SMEs), digitalisation barriers, digital competencies.

JEL Classification: D22, O33.

1. Introduction

Digital transformation is today considered to be a leading way for a company to build competitive advantage, improve its products and services, and broaden its market. As such, the development of the digital economy commands widespread interest among researchers. Applied digital solutions can help firms survive rising energy prices, disruptions to supply chains, the increasing costs of servicing credit, and the continuing fallout from the COVID-19 pandemic.

It is widely believed that economic entities using information and communication technology (ICT) solutions is the foundation upon which the digital economy will develop. Given that the micro, small and medium-sized enterprise (SME) sector constitutes 99.8% of all enterprises in Poland, it has a key role to play in developing the digital economy (PARP, 2023). It is therefore crucial to monitor the sector's push into digitalisation, identify the barriers to their digitalisation, and work to streamline and accelerate the implementation of digital solutions. At the same time, SMEs in Poland have largely failed to digitalise, making research on barriers to the implementation of digital solutions all the more important. This is even more relevant as digital transformation is expected to have an increasing impact on enterprise survival and growth opportunities. The digitisation of SMEs in Poland faces multiple barriers, including financial constraints, lack of competences, organisational challenges (Marcysiak & Pleskacz, 2021; Szwajca & Rydzewska, 2022; Brink & Packmohr, 2023) as well as a lack of skilled personnel and human capacity (Mohamad *et al*., 2022; Le-Dain *et al*., 2023). Most of the solutions Polish SMEs use are limited to the most basic forms of digitalisation, such as online financial and telecommunications services and having a website (Chaber, 2017), while they

have used advanced solutions to only a minimal extent. With a view to developing the digital economy, it is important to determine which factors cause micro, small and medium-sized enterprises not to make use of digital solutions, as well as those that limit such digital transformation once it has begun. The aim of the paper is to identify and understand the principle barriers that keep SMEs in Poland from moving forward with digitalisation, and to fill the research gap in this regard.

2. Literature Review

Numerous contemporary scientific studies have shown that global socio--economic changes have forced digital transformation upon small and medium--sized enterprises (Su *et al*., 2022). This changes their traditional business model and the process of creating value for customers (Matarazzo *et al*., 2021). The traditional approach to digitalisation involves "using computer and internet technologies to provide a more efficient and more effective process of creating economic value" (Reddy & Reinartz, 2017). Digital transformation also entails changing one's approach to the customer, as well as the organisation comprehensively changing to new ways of functioning with the use of the latest digital technologies (Gajewski, Paprocki & Pieriegud, 2016). It involves making significant changes to the existing principles by which enterprises operate. A good example of this came about as a result of the COVID-19 pandemic, which vastly accelerated the pace of digital transformation, including among small and medium-sized enterprises (Papadopoulos, Baltas & Balta, 2020; Skare, de las Mercedes de Obesso & Ribeiro--Navarrete, 2023).

Digital transformation can boost sales and productivity, as well as in innovation in the creation of value and interaction with the customer (Matt, Hess & Benlian, 2015; Węgrzyn, 2023). It can facilitate and streamline financial management and payments, thus increasing digital integration (Shofawati, 2019). Digital technologies cover a range of tools, devices and electronic resources, as well as systems used to generate, store, process and transform data (GUS, 2022b). Relatively cheap and simple digital solutions make it possible to easily communicate with potential clients, as well as gather data on consumer preferences and analyse such data based on the artificial intelligence used in cloud-based solutions (Marr & Ward, 2019). Digitalisation also provides greater flexibility and dynamics when implementing innovative solutions (Yoo, Henfridsson & Lyvtinen, 2010; Kowalczyk, 2017).

Thanks to digital solutions, enterprises obtain access not only to their home market, but also to global markets, and at a relatively low cost. It is equally important that thanks to global platforms, small and medium-sized enterprises are also able to expand globally. At the same time, consumers in local markets gain access to global products (Chądrzyński *et al*., 2021). Thanks to the popularisation of cloud services and the development of software, such changes can occur both in large as

well as the smallest economic entities. A dozen or so years ago, only large enterprises could afford advanced stock management systems and accounting software. Today, every shop can track sales and inventory using suitable dedicated applications. The owners of small entities can manage their own accounting using software solutions or online services. The digitalisation of enterprises provides the impetus to employ innovation and change across multiple sectors. It can bring about countless benefits for small and medium-sized enterprises, but requires the appropriate knowledge and resources in order for its potential to be exploited and threats avoided.

Research on digitalisation in micro, small and medium-sized enterprises has focused mainly on the benefits achieved by implementing new technologies, innovations and new business models. However, many authors have also addressed barriers to digitalisation, especially among small and medium-sized enterprises (Peillon & Dubruc, 2019). The barriers to development SMEs face are usually divided into internal (microeconomic) and external (macroeconomic) ones. The former are those on which the enterprise has an influence, and include factors related to the enterprise itself, including its competences, weaknesses in management and production. External barriers, or elements in an enterprise's surroundings, threaten the process of founding enterprises and their operation on the market. "External barriers are the product of an enterprise's surroundings, and are related to its low potential, high complexity and the uncertainty of operating in a changing economic environment" (Klimek, 2017, p. 97).

SMEs are decidedly less well-prepared to adapt new technologies than large firms (Moeuf *et al*., 2020). The literature describes numerous classifications of the barriers and limitations affecting SMEs seeking to implement ICT. One of the most frequently mentioned is the lack of resources, both financial and personnel-related (Orłowska & Żołądkiewicz, 2018). The lack of financial resources can significantly hamper SMEs in realising developmental projects (Kocsis, 2012; Mittal *et al*., 2018). According to von Leipzig *et al*. (2017), typical barriers indicated by SMEs themselves include insufficient IT structures, lack of technical skills, unsuitable business processes, the high risk of implementation and costs. Other issues raised, by both the owners and employees of SMEs, concern competences and skills. According to Lerch and Gotsch (2015), the principal barrier to digitalisation is the lack of qualified employees for developing and providing such services.

3. The Essence of SMEs and the Level of Digital Advancement

SMEs are those that employ fewer than 250 employees, and whose annual turnover does not exceed 50 million euros, and/or whose total annual balance sheet does not exceed 43 million euros (Ustawa z dnia 6 marca 2018 r. Prawo przedsiębiorców). The basis for classification is most commonly the number of employees according

to the following division: micro firms: 1 to 9 employees, small firms: 10 to 49 employees, medium-sized firms: 50 to 249 employees, large firms: 250+ employees.

SMEs make up over 99% of all enterprises in the European Union, are the greatest employer in the EU economy, and make the greatest contribution to its development. In Poland, SMEs are even more common, constituting 99.8% of all enterprises in 2021, with the most numerous group being microenterprises (97.2%; 2.3 million) (PARP, 2023). In the years 2013–2021 in Poland the number of microenterprises increased by 351,600, or 17.5%. What is more, the greatest average annual pace of growth was in entities employing one person, with an increase of 4.4% compared to an average annual increase of 3.3% for microenterprises as a whole. According to ZUS data, the tendency to opt for self-employment (B2B agreements) over more traditional employment contracts has been on the rise, especially as a result of the coronavirus pandemic. In 2021, the proportion of those who were self-employed among all professionally active individuals in Poland was 15.5%, placing the country third in the European Union, behind Greece and Italy. At the same time, only one in five of the self-employed was an employer (ranking the country fifth in the EU alongside Lithuania), while the EU average was almost one in three (Lasocki, 2021). Table 1 presents the main features of microenterprises in Poland in 2021.

Table 1. Features of Microenterprises in Poland in 2021

Feature	2021
Total number of microenterprises	2,355,639
Including the number of microenterprises with 1 employee	1,748,074
Working (as of 31.12)	4,445,189
According to type of accounting records (in %)	
Accounting books	11.5
Tax book of income and expenses	65.6
Revenue records	19.7
Tax card	3.2
Microenterprises by business activity (PKD) section (in %)	
Agriculture, forestry, hunting and fishing	0.4
Industry (sections B–E)	8.8
Construction	15.2
Trade, vehicle repairs	20.1
Services (sections H–S)	55.5

Source: GUS (2022a, pp. 16–17, 22).

In Poland, microenterprises create over 4.4 million jobs, and mainly operate in services and trade (75.6%), construction (15.2%) and industry (8.8%). A vast majority (88.5%) maintain accounting records in simplified form, with most using a tax book of income and expenses (65.5% of all microenterprises). Such a preponderance of microenterprises in the economy is worrying, as the power of the economy is, as a rule, built by larger firms, which are also more innovative and more often make use of digital solutions. This may threaten a wider rollout of digitalisation in the Polish economy, a problem noted by the European Commission, which made support for micro, small and medium-sized enterprises in their digital development a main political priority for the years 2019–2024 (European Union, n.d.). The Digital Single Market Strategy for Europe DSM (European Union, n.d.), the Digital Compass 2030: The European Digital Decade (European Commission, 2021) and the SME Strategy for a Sustainable and Digital Europe assume, among others, a considerable increase in the number of SMEs using digital technologies (European Commission, 2020).

Digitalisation figures prominently in economic policy throughout the world, and many institutions and firms create their own sets of digital indicators in order to make international comparisons (Święcicki, 2022). Analysis of the maturity of the digital economy usually takes into account how digitalisation – the process of using technology and digital tools to conduct economic activity – spreads in individual sectors of the economy (Adamczewski, 2018).

Among the numerous studies that have measured the extent of economic digitalisation, the most frequently cited tool is the Digital Economy and Society Index (DESI), which has been prepared periodically since 2014 by the European Commission. The index focuses on five key dimensions of digital transformation: connectivity, human capital, use of internet services, integration of digital technologies, and digital public services. Alongside Romania, Bulgaria and Greece, Poland ranks poorly on the DESI index. In 2022 (as in 2021), it ranked 24th from among the 27 EU Member States. The overall 2022 DESI index for Poland was 40.5, against an EU average of 52.3 (in 2021, the figures were 41 and 50.7).

The statistics published as a part of DESI regarding the use of ICTs in enterprises contain a great deal of detailed information on various aspects of economic activity. SMEs in Poland are considerably below the EU average for use of digital technology in business. Digital intensity in enterprises is categorised into four levels based on the number of digital technologies implemented, with each technology contributing one point to the overall score: 0 to 3 points: very low digital intensity, 4 to 6 points: low digital intensity, 7 to 9 points: high digital intensity, 10 to 12 points: very high digital intensity. Table 2 presents the results for the digital economy index for Poland and the European Union in the field of integration of digital technologies by enterprises.

Table 2. DESI Integration of Digital Technologies for 2022 – Poland and the European Union (Data from 2021)

Specification	Poland	EU
Integration of digital technology indicators in DESI 2022	22.9	36.1
SMEs with at least a basic level of digital intensity (% SMEs)	40	55
SMEs selling online (% SMEs)	14	18
Selling online cross-border (% SMEs)	5	9
Electronic information sharing (% enterprises)	32	38
Social media (% enterprises)	18	29
Big data (% enterprises)	8	14
Cloud (% enterprises)	19	34
AI (% enterprises)	3	8
E-invoices (% enterprises)	13	32

Source: European Commission (2023).

Around 40% of Polish SMEs achieved at least a low level of the indicator for the use of digital technologies. This came in well below the EU average of 55%. In Poland in 2021, 14% of firms in the SME sector conducted internet sales (13% in 2020), while 5% conducted cross-border sales to other EU countries. The averages for the European Union were higher, at 18% and 9%, respectively. That said, advanced technologies are slowly but steadily becoming popular among Polish enterprises, 19% of which use cloud solutions (*versus* 15% in 2021, and 34% on average for the EU as a whole). Electronic information sharing was used by 32% of Polish firms, while the EU average was 38%. However, only 18% of Polish enterprises actively use social media, and only 3% use artificial intelligence technology in their activity. E-invoices and large datasets are not used widely. In Poland in 2021, 13% of enterprises used e-invoices (the EU average was 32%), and only 8% of enterprises used large datasets, while the European Union average was 14%. This shows that there are gaps in the adoption of new digital technologies, and there is untapped potential among Polish SMEs. Greater effort should be made to increase the use of cloud services, large datasets and artificial intelligence.

The second popular indicator that is used to assess digital advancement is the Digital Intensity Index (DII) developed by the European Investment Bank. This index has a somewhat narrower scope and describes firms' use of digital technologies (digital intensity), access to industrial infrastructure, investment in software and the organisation of digital business processes, the use of strategic digital monitoring systems, and perspectives for further digitalisation. It reflects the degree to which enterprises make use of various digital technologies, as well as the level of economic integration in various sectors of the economy, such as production, financial services, healthcare and retail. As such, the DII can be used to compare the digital strengths

of various countries. It can also identify areas in which further investment in digital technologies is necessary.

The composition of the DII varies in each year the study is conducted depending on the questions used in the research, and thus its comparability over time is limited. The basic level assumes the use of at least 4 of 12 selected digital technologies (e.g. any AI technology, e-commerce at the level of at least 1% of total turnover). The basic level covers entities that have a low, high and very high level, while excluding those with a very low level. In Poland, 55% of micro, small and medium-sized enterprises had a basic level of digital intensity, compared to 88% of large enterprises. Research shows that this discrepancy causes a slowing of digital transformation in the economy (Rückert, Weiss & Revoltella, 2020). Data from 2022 shows that Polish firms are above the EU average in terms of using augmented and virtual reality, artificial intelligence and big data analysis, at the EU average in the use of drones and advanced robots, and below average for 3D printing, the Internet of Things and digital platforms (European Investment Bank, 2023).

4. Research Methodology

Based on a review of the subject literature on the essence and level of the use of digital tools among SMEs in Poland compared to the EU as a whole, empirical research was conducted in order to complement the theoretical considerations. The qualitative research was preceded by field observation in order to understand the real-life circumstances in which selected SMEs operate. The empirical research was conducted in June and July 2023 among 50 firms that were clients of an accounting office. The characteristics of the research sample are presented in Table 3. The qualitative research made use of a study questionnaire prepared in Microsoft Forms, as well as in paper form.

Table 3. Research Sample Characteristics

Entrepreneur Characteristics	Number of Indications $N = 50$	Percentage
Owner's gender		
Female	13	26
Male	37	74
Owner's age		
Up to 25	2	4
From 26 to 35	18	36
From 36 to 45	9	18
From 46 to 60	13	26
Above 61	8	16

Table 3 cnt'd

Entrepreneur Characteristics	Number of Indications $N = 50$	Percentage
Business experience in years		
Up to 10	41	82
From 11 to 15	2	4
From 16 to 19	1	2
20 or more	6	12
Area of activity		
Production	2	4
Construction	10	20
Services	38	76
Legal form		
Self-employed	39	78
Partnership	2	4
Private limited company	9	18
Number of employees		
Sole proprietorship	30	60
Up to 9	9	18
From 10 to 49	10	20
From 50 to 249	1	2

Source: the author.

The link to the questionnaire was sent to 55 enterprises – clients of the accounting office – and an additional eight questionnaires were completed by company owners. A total of 42 entrepreneurs answered the electronic questionnaire, which together with the paper versions gave a total of 50 correctly completed questionnaires.

The enterprises in the study were dominated by microenterprises (78%) conducting activity in the services sector (76%) in the form of a sole proprietorship (78%).

5. Research Results

The results of the survey into the barriers to the digitalisation of SMEs in the surveyed sample are presented in Figures 1–5. In their responses to the first question, the enterprise owners defined their firm's level of digitalisation. Among the study sample, nine firms reported that digital solutions had been implemented in almost every area of the firm's operations, while eight firms indicated that digital

solutions are present in the firm, but that there are still areas that require digitalisation. Of all the firms in the study, 44% (22 firms) had not yet undertaken digitalisation, while 22% (11 firms) had only begun the process (Fig. 1).

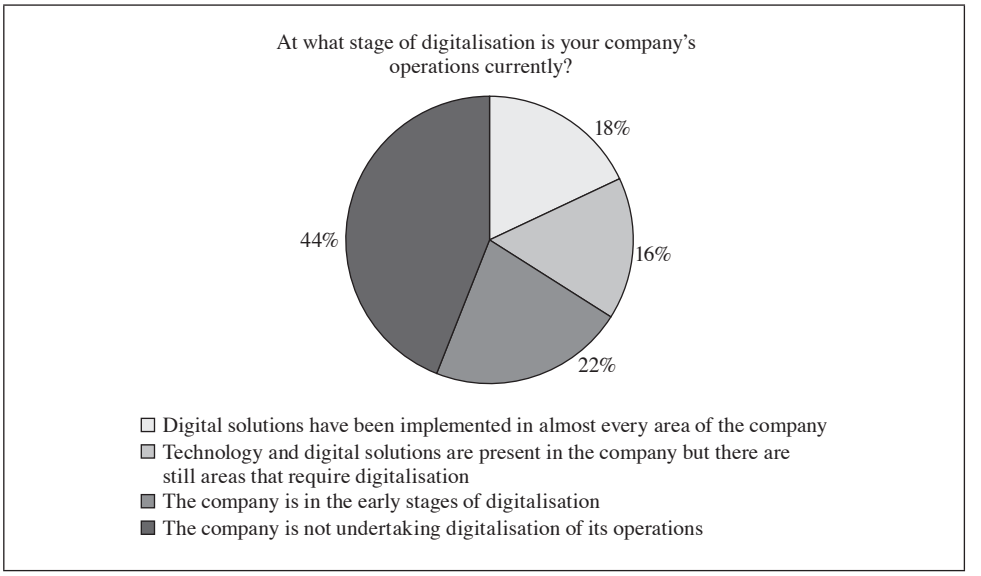

Fig. 1. Stage of Advancement of Digitalisation in Operations
Source: the author.

At this stage of the questionnaire, depending on the answer provided to the first question, the enterprise representatives answered the subsequent sections of the survey, which contained different questions. Those who indicated that they were not undertaking digitalisation were asked to indicate the key factors that had influenced their decision not to do so (Fig. 2).

This part of the questionnaire was completed by 22 enterprises. Among the most common reasons was the belief that the firm functions well without digital solutions (45.6%), lack of orientation of the available solutions on the market and the opportunities they offer (40.9%), the need to investment a great deal of time (36.4%) and lack of competency needed to implement digital solutions (27.3%). These were the key factors influencing the decision not to undertake digitalisation. Such answers were provided respectively by 15, 9, 8 and 6 of 22 firm owners. Five firms, or 22.7% of the study sample, indicated concerns about leaving traces in the digital world as the reason for not using digital tools. These entrepreneurs avoid using digital tools so as not to attract the attention of various administrative bodies and not expose

themselves to inspections. None reported concerns about the low return of investment as a reason for not undertaking digitalisation.

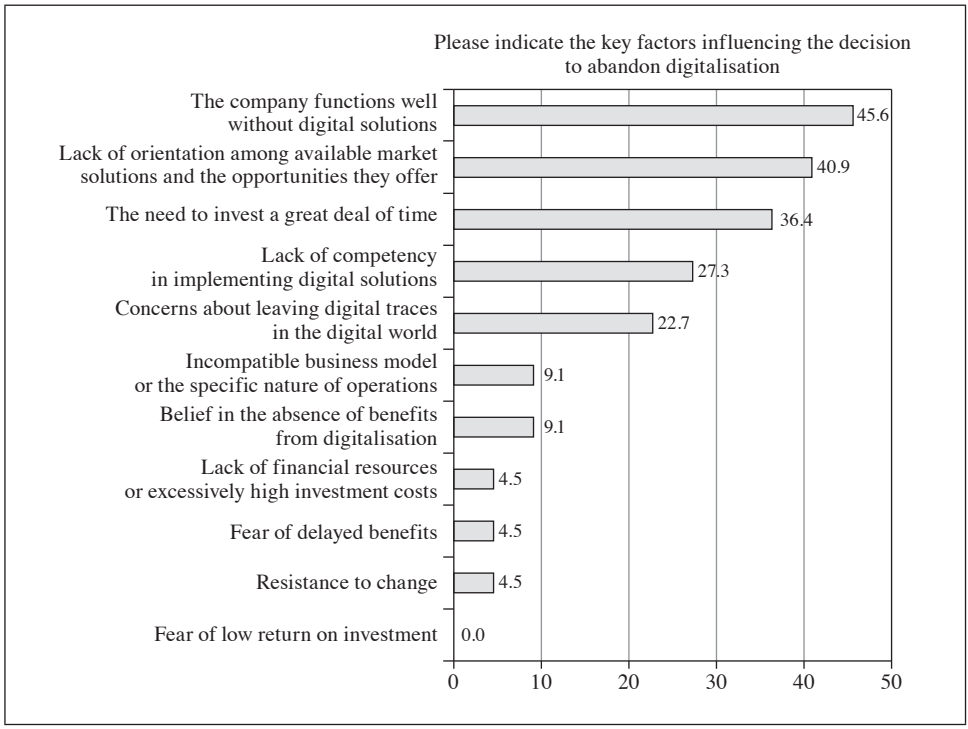

Fig. 2. Factors Influencing the Decision Not to Undertake Digitalisation (in %)
Source: the author.

The next part of the questionnaire was addressed to the 28 entrepreneurs who were undertaking digitalisation (56% of all the firms in the study). The questions related to areas in the firm in which digital technologies were used. Here more than one answer could be chosen. Almost 90% of the entrepreneurs indicated that digital technologies were used in their firm mainly for marketing and customer relations (Fig. 3).

Interaction with suppliers (46.4%), accounting (35.7%) and sales (32.1%) were somewhat less popular in the digitalisation of operations. Only 10.7% of the respondents (three firms) indicated employee communication as an area in which digital technologies were used.

The next question asked the entrepreneurs to indicate specific digital solutions they had implemented. The purchase and use of digital equipment and infrastructure

to equip the firm at a basic level (including computers, photocopiers and scanners) was the most common response. 100% of firms selected this answer (Fig. 4).

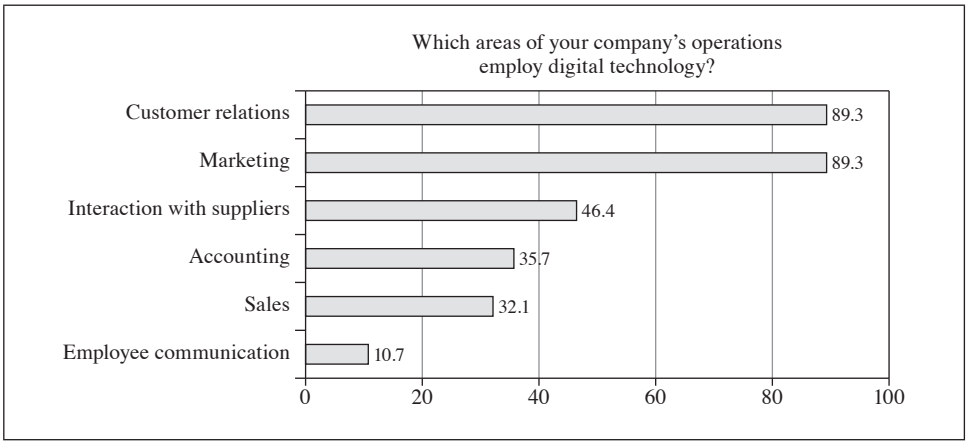

Fig. 3. Areas of the Firm's Operations in Which Digital Technologies Are Used (in %)
Source: the author.

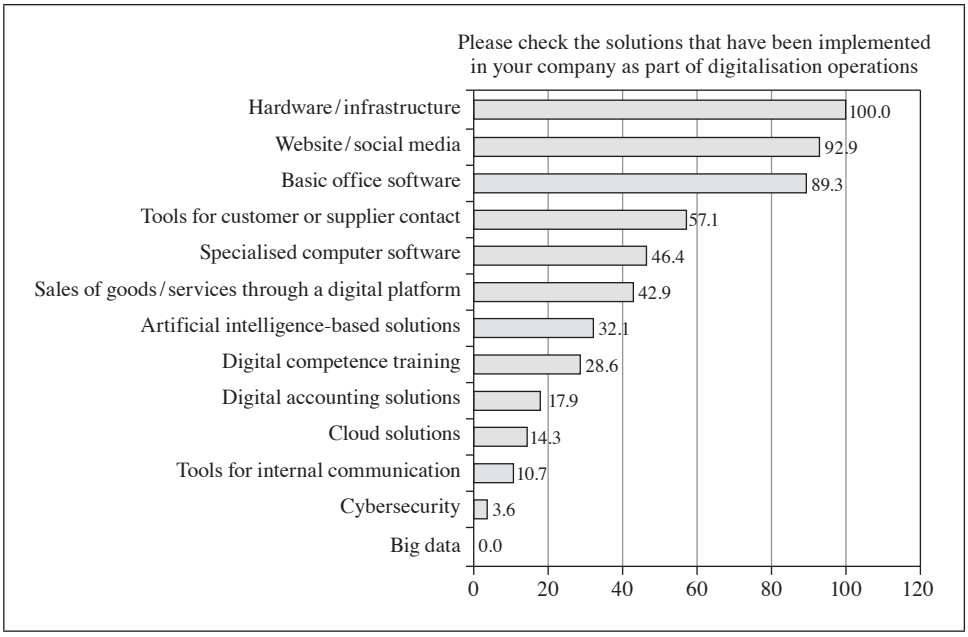

Fig. 4. Digital Solutions Implemented in the Firm (in %)
Source: the author.

92.9% indicated that their firm has its own website, social media feed, or information in browsers. Almost 90% indicated that they use basic office software. 57.1% use digital technologies for contacting customers, while 42.9% sell goods and services via a digital platform. A large gap was noted between these solutions and more advanced ones. Nine firms (32.1%), mainly in the real estate sector, use solutions based on artificial intelligence. Real estate firms also use various applications that employ augmented and virtual reality to generate graphic material such as visualisations, virtual walks and 3D models. Advanced digital solutions including big data were not used in the firms involved in the study.

As regards the most significant barriers to firms implementing digital solutions, four firms (14.3%) indicated that they had no barriers to implementing such solutions (Fig. 5).

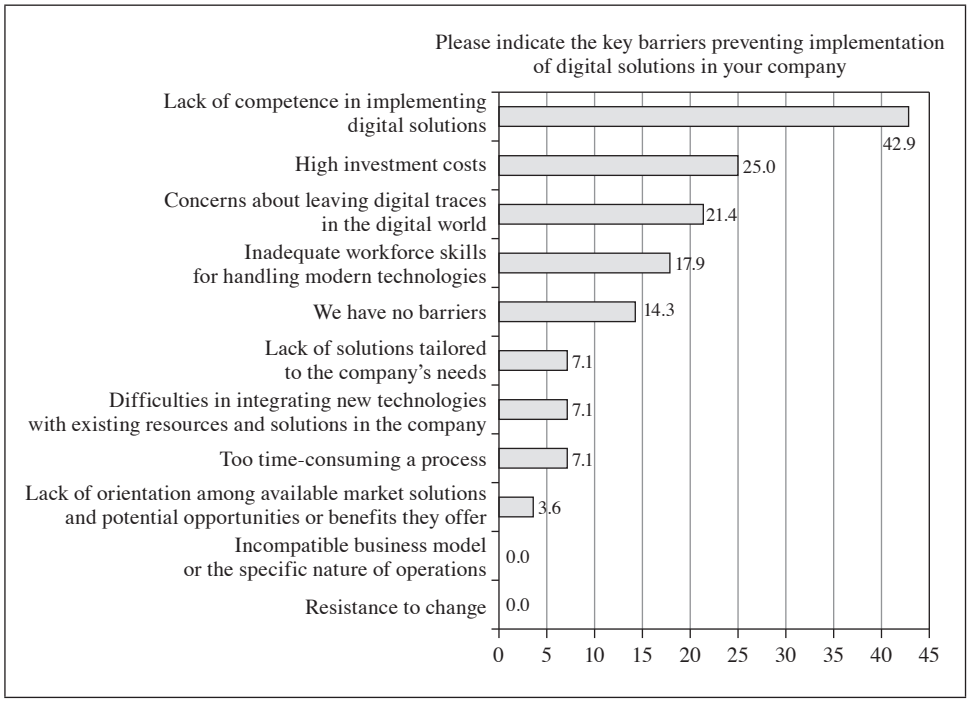

Fig. 5. Barriers Hindering Firms' Implementation of Digital Solutions (in %)
Source: the author.

42.9% lack the competence to implement digital solutions. 25% of the firms saw excessive investment costs as the main barrier to digitalisation, while six firms (21.4%) indicated concerns about leaving traces about the firm's operations

in the digital world. Among the remaining answers were inadequate workforce skills for handling modern technologies (17.9%), excessively time-consuming process, difficulties in integrating new technologies with existing company resources and solutions, and lack of solutions tailored to the needs of the firm. None of the entrepreneurs indicated resistance to change, or an incompatible business model or specificity of operations as barriers hindering the implementation of digital solutions. The research covered only a small percentage of the enterprises in the Dolnośląskie voivodeship; however, it can serve as an example of the general state of digitalisation in Poland and its prospects for development.

6. Conclusions

Digitalisation is changing the world and people's lives. Micro, small and medium-sized enterprises are of key importance, as such firms are numerous and, as a whole, provide employment to huge numbers of people. That said, the research results presented here are based on a purposive sample of 50 SMEs, and therefore cannot be generalised to the entire population of Polish SMEs.

Research analyses of the DESI indicator results and the digital advancement Digital Intensity Index developed by the European Investment Bank paint a picture of digitalisation among micro, small and medium-sized enterprises in Poland. Unfortunately, digitalisation in this sector remains low, which is a serious challenge for the development of the digital economy in the country. Polish SMEs use digital solutions less than the EU average. Moreover, the use of advanced solutions has not been encouraged, leaving basic equipment and software for supporting daily tasks and duties the main area of digitalisation addressed.

The integration of digital technologies with marketing practices is essential for SMEs to improve customer relations, enhance marketing effectiveness, and boost business performance (Pergelova *et al*., 2018). Nearly 90% of enterprise owners in our study sample indicated that they use digital technologies primarily for marketing and customer relations. This is supported by the literature, where digital platforms play a crucial role in enhancing customer interactions, facilitating marketing activities, and expanding market reach for SMEs (Nazaruddin, Utami & Rahmawati, 2024). Adopting digital marketing channels, such as search engine marketing and social media marketing, can optimise business performance among SMEs (Kurniawan, Logaiswari & Umar, 2023).

The research provides valuable conclusions both on the reasons digitalisation has not been undertaken and the factors hindering the further development of digital solutions once they have been implemented. A main takeaway is that many owners felt their firms functioned well without digital solutions, so existing business processes can be said to be effective in their current form. Firms have opted not to

undertake digitalisation due to a lack of knowledge of the digital solutions available on the market, the fact that implementing digital solutions is time-consuming, and the lack of clarity as to how such solutions may benefit users.

The main barriers to digitisation among the Polish SMEs surveyed include a lack of competence (42.9%), high investment costs (25%), and concerns about leaving digital traces (21.4%). These findings are consistent with those of Uzule and Verina (2023), who also emphasised the importance of digital competence gaps and the challenges of integrating new technologies as major obstacles in the transformation of businesses. Additionally, our research confirms the observations of Pergelova *et al*. (2018) and Nazaruddin, Utami and Rahmawati (2024), who highlight the crucial role that education and support in data security play in overcoming barriers to digitalisation.

It is surprising but important that 14.3% of the firms that had already started their digital transformation declared that they had not faced any barriers in the process of implementing digital solutions. This indicates that some enterprises are already well prepared for digitalisation. However, 85.7% of the firms recognise clear barriers to further digitalisation, a fact which must be addressed. As barriers hindering further progress in the digitalisation of their operations, enterprises indicate a lack of suitable competences, high investment costs, as well as concerns about leaving traces in the digital world and being exposed to various types of inspection. The latter is of key importance, as it reveals a need to ensure an appropriate level of data security and privacy protection in the digitalisation process. There is also a need for education and support in the field of digital competencies, as well as education among the owners of the surveyed small firms as to the benefits stemming from digitalisation. At the same time, appropriate data and privacy protection must be ensured so as to encourage entrepreneurs to safely implement digital solutions.

In conclusion, the main barriers preventing SMEs from digitalising include financial constraints, organisational barriers, lack of skilled personnel, reluctance to invest in digital technologies, and challenges in measuring the return on digital investments. Overcoming these barriers is crucial for SMEs to successfully navigate the digital transformation process and leverage the benefits of digital technologies for their growth and competitiveness. This study underscores the importance of providing targeted support and training for SMEs to enhance their digital capabilities. Future research could focus on developing specific strategies and frameworks to assist SMEs in overcoming these obstacles and fully embracing digitalisation. The results, while informative for the sample studied, should be interpreted cautiously and may not be representative of the entire SME sector in Poland. Nonetheless, the findings can serve as useful empirical material for diagnosing the situation in the SME sector, in particular for the purposes of regional innovation strategies and regional promotional programmes.

Conflict of Interest

The author declares no conflict of interest.

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Managing Compliance Risk in Organisations in the Transport-Forwarding-Logistics Sector

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ABSTRACT

Objective: To analyse and evaluate compliance risk management in organisations operating in the transport-forwarding-logistics (TFL) sector.
Research Design & Methods: A comparative analysis of the social reports of TFL companies submitted from 2019 to 2023, considering the issues of compliance risk, compliance management system and whistleblowing mechanisms.
Findings: Responding to rapid changes in the law and regulatory risk, the majority of the companies under study include compliance risk as a major risk category. These companies measure compliance risk through the number of whistleblowing reports and an assessment of its materiality on a quantifiable scale. The organisational arrangements of the compliance management system vary according to need, with three member groups in organisations performing the compliance function: top management and lower management, compliance officers, other members of the organisation.
Implications/Recommendations: The study findings may come useful for business owners, managers, compliance officers who are responsible for compliance management systems in their

organisations. The results obtained from the study indicate the inadequacy of the organisations in terms of compliance management. Therefore, the basic recommendations concern the need to form appropriate attitudes, build awareness of both the importance of compliance risk management and the consequences of the lack of such solutions and the benefits of their implementation. The introduction of regulatory solutions will be an additional stimulus for inducing implementing compliance risk management. Finally, there is a need for compliance education and improved whistleblowing mechanisms to ensure whistleblowers protection against retaliation.

Contribution: The article offers insights on the development of management and quality science in the field of compliance management systems and compliance risk management in organisations.

Article type: original article.

Keywords: compliance risk, risk management, organisation, TFL sector, logistics, transport, whistleblowing system, compliance management system.

JEL Classification: M19, M59.

1. Introduction

The importance of compliance management systems (CMS) has been growing in the management of contemporary organisations. This is mainly thanks to key legislative changes and the resulting numerous new obligations imposed on business (Barcik, 2019, p. 232). Compliance management in Polish organisations has likewise developed rapidly, with management playing the key role of building a compliance culture and awareness (Barcik, 2023). Compliance management is now becoming a widely accepted business standard (Makowicz & Jagura, 2020, p. 23).

Both the theory and practice of compliance risk management have been discussed (see Winnicka-Wejs, 2023a, pp. 9–10). A 2022 survey of HR professionals and managers on HR compliance in HR risk management revealed the need to deepen specific research fields and to narrow the inquiry to specific players in selected industries (Winnicka-Wejs, 2023a, p. 149). Given that, we focused the current study with the following scopes in mind:

– objective scope: compliance risk management (including whistleblowing systems),
– subjective scope: TFL businesses,
– geographical scope: Poland,
– timeframe: 2019–2023.

The following research questions were addressed:

1. What are major risk categories in TFL businesses?
2. How is the materiality of compliance risk assessed?
3. Is employee compliance training provided?

4. What are the organisational arrangements for the CMS in TFL businesses?
5. Are there whistleblowing systems in place and how are they organised?

The articles presents an analysis and evaluation of the management of compliance risk in organisations in the TFL (transport-forwarding-logistics) sector. This sector, identified in the section H of the Polish Classification of Activities (PKD) "Transport and warehouse management," is of key significance to the Polish economy. It generates around 6% of Polish GDP and provides employment for around 6% of the Polish workforce. In 2021, Polish businesses accounted for 19.8% of transport work within the European Union, ahead of Germany and Spain (Grzeszak, 2022, pp. 5, 8, 11). Ensuring compliance in the various areas of TFL organisations becomes crucial for their further development, given the primarily service-based nature of the operations carried out by these companies. The TFL sector is, of course, only one sector of the economy, and others could have been chosen. The present analysis and evaluation could serve as a reference point for studies on other sectors.

Over the past few years, compliance requirements in the logistics industry have grown substantially. Customers operating internationally normally have to follow rigorous compliance regulations and, for their own safety have a vested interest, and often an obligation, to enforce these regulations in dealings with their business partners, such as providers of logistic services (Steiner, Ölz & Scherlofsky, 2022). In this industry, compliance management is a universal challenge.

Transportation, shipping, and logistics often rank among the most risk--prone industries. There are a number of external factors which pose a risk to the freight-shipping and logistics sector, including growing market requirements, changing consumer expectations, and a volatile economic environment. These are the threats and hazards that force transport and forwarding companies and organisations to set up and maintain rigorous and innovative risk management strategies (Mercury Gate, 2022).

2. Literature Review

An earlier review of the Polish and foreign literature showed that compliance issues are more often present in legal studies than in the management and quality sciences, suggesting there is a lack of a management perspective in this area (see Winnicka-Wejs, 2023a, pp. 7–11). A review of the literature collected in the BazEkon database (2024, keyword: Compliance Management System) likewise reveals a research gap, as no publication on compliance risk issues in the TFL industry was found.

The subject of compliance risk has been studied in the banking sector (Chaikovska, 2018; Górna-Łunkiewicz, 2018), insurance companies (Paś, 2018), public

administration bodies (Wiatrak, 2021), sports clubs (Rutkowska, 2019), various crises (Pietrzak, 2020), in the context of Corporate Social Responsibility (CSR) (Barcik, 2020) and applied technologies (Ziarkowski, 2020).

Analysis of articles in the Scopus database (2024, with keywords: Compliance Management System, Logistics) showed that the subject of compliance is discussed mainly in the context of implementing specific legal requirements related to sustainability. Examples include reverse logistics for used electric appliances (Vargas, Campos & Luna, 2024), green logistics compliance (Mak *et al*., 2022), compliance with government transport emission law and practice (Kumar, 2021), and compliance with the goals of sustainable development (Dzwigol, Trushkina & Kwilinski, 2021). Compliance is also discussed with reference to the business continuity management (BCM) model (Chen & Xu, 2023), road safety compliance (Adu, Dorasamy & Keelson, 2023), and supply chain activity control ensuring compliance with customer requirements (Marzialia, Rossit & Toncovicha, 2022).

To study the characteristics of compliance risk management in TFL organisations, we extended our research to social reports (social responsibility, CSR, sustainability, ESG) produced by market players as part of non-financial reporting, which plays an increasingly important role in presenting the activities of contemporary organisations (Kwarcińska, 2023).

According to Global Reporting Initiative (GRI) guidelines (see Ignatowski, Sadowska & Wójcik-Jurkiewicz, 2020, p. 32), in the section covering ethical aspects of an organisation's performance the reporting takes into account indicators on: an organisation's values, principles, standards and corporate norms, its internal and external consultation mechanisms for ethical and lawful behaviour, and its internal and external whistleblowing mechanisms for reporting unethical or unlawful behaviour (GRI, 2016, pp. 60–61). Having access to that reporting enabled us to analyse the compliance management system solutions used by the TFL organisations.

3. Description of the Study Methodology

The study was based on a comparative study of selected social reports available at www.raportyzr.pl, where they are submitted as part of annual competitions.[1] The data in the reports were analysed with the use of content analysis. Reports

[1] The intention of the competitions is to disseminate the ideas of CSR, sustainable development, environmental protection and social involvement. The competition was organised for the first time in 2007 and continues to be organised by: Responsible Business Forum and Deloitte. Until 2014, the competition was co-organised by PwC and CSR Consulting, and in 2015 – by SGS company (Raporty Zrównoważonego Rozwoju, 2023).

from TFL organisations can be found, according to the competition's attribution, in the transport and logistics sector. In the timeframe adopted for this research (2019–2023), nine reports were recorded in total (2023 – 0, 2022 – 6, 2021 – 2, 2020 – 0, 2019 – 1). The period was defined in order to capture current trends. Preliminary analysis of the reports revealed that the majority of these reports were prepared in accordance with the GRI standard. Sections concerning the risk of non-compliance were extracted from selected documents. Table 1 presents a brief overview of the organisations whose reports were examined.

Table 1. Characteristics of the Reporting TFL Players Selected for Analysis

Name of the Company	Year of Submission of the Report for Competition	Profile of the Company Submitting the Report
VGL Solid Group	2022	Scope of activities: transport, freight forwarding, logistics and supply chain management services; headcount level: 750, number of customers: 8,500
Gdańsk Transport Company SA	2022	Scope of activities: the company built the AmberOne Motorway and operates it; headcount level: 8, number of users of the AmberGO system in 2021: 902,451
Prologis	2022	Scope of activities: logistics real estate; headcount level: 2,053, number of customers: 5,800 customers
7R SA	2022	Scope of activities: provision of modern logistics and production space for lease and sale; headcount level: 116
Kom-Eko Group	2022	Scope of activities: waste collection and management services, summer and winter maintenance of roadway and pedestrian routes and repair of their surfaces; headcount level: 572, number of customers: 3,797
Rohlig SUUS Logistics SA	2022	Scope of activities: comprehensive logistics service (road, sea, air, rail transport, warehousing services); headcount level: 1,785.
Metropolitan Transport Authority	2021	Scope of activities: organisation of local public transport services; headcount level: 287
Raben Group	2021	Scope of activities: transport and logistics services; headcount level in Poland, Czechia and Germany: 8,751
Raben Group	2019	

Source: the authors, based on: VGL Solid Group (2021, pp. 2, 4, 5), Gdańsk Transport Company SA (2021, pp. 3, 14), Prologis (2022, pp. 5, 46), 7R SA (2021, pp. 10, 31, 39), Kom-Eko (2021, pp. 7, 9, 77), Rohlig SUUS Logistics (2022, pp. 5, 10), Metropolitan Transport Authority (2020, pp. 10, 37), Raben (2020, pp. 4, 44).

4. Analysis of the Study Findings

4.1. Compliance Risk vs. Other Risk Categories in TFL Businesses

The first part of the analysis of the reports selected for the survey of TFL businesses concerned the identification of compliance risks against other risk categories. Information on the major risk categories provided in the reports is presented in Table 2.

Table 2. Major Risk Categories Presented in the Reports of the Businesses under Study

Name of the Company	Risk Categories
VGL Solid Group (2021)	– no information in the report
Gdańsk Transport Company SA (2021, pp. 10–11, 20–21)	– environmental, e.g. **changes in** environmental law, climate change, waste management – social, e.g. related to motorway safety or occupational health and safety – managerial, e.g. **rapid changes in law**, fraud, conflict of interest
Prologis (2022, p. 21)	– related to real estate – financial – corporate risk and new types of risk including **corporate governance, regulatory, legal, human capital-related risks**
7R SA (2021)	– no information in the report
Kom-Eko (2021, pp. 45, 46)	– climate risk – **regulatory compliance risk**
Rohlig SUUS Logistics (2022, p. 21)	– external – operational – environmental – HR – IT – **compliance**
Metropolitan Transport Authority (2020)	– no information in the report
Raben (2020, p. 18)	– operational, e.g. warehouse fire; related to mergers and acquisitions; shortage of employees and drivers in the market; environmental pollution – information security (cyber, leakage of sensitive and confidential data) – **law and ethics compliance risk (the risk of fraud, antitrust, bribery, harassment); compliance risk related to key suppliers** – external market (the risk of pandemics and lockdowns); regulatory risk related to changes in labour law; restrictions on vehicle emissions
Raben (2018, p. 90)	– risk related to human and financial factors – environmental and reputational risks

Source: the authors, based on reports published by the businesses under study.

Compliance risk appears in the reports where the main risk categories have been identified, most often in the context of rapid changes in the law and the regulatory compliance risk (cf. bolded names in Table 2).

4.2. Measurement of Compliance Risk in TFL Organisations

The next phase of the research focused on issues in measuring compliance risk in the TFL businesses. Table 3 presents data on compliance risk information and the number of such instances in the reports of businesses under study.

Table 3. Measurement of Compliance Risk in the Businesses under Study

Name of the Company	Report Contains Information about Instances of Compliance Risk Notifications	Number of Whistleblowing Cases in the Report
VGL Solid Group (2021)	.	.
Gdańsk Transport Company SA (2021, p. 14)	yes	0
Prologis (2022, p. 20)	yes	10
7R SA (2021, p. 46-47)	yes	0
Kom-Eko (2021, p. 26, 80)	yes	0
Rohlig SUUS Logistics (2022, p. 24)	yes	1
Metropolitan Transport Authority (2020)	.	.
Raben (2020, p. 17)	yes	9
Raben (2018, p. 89)	yes	16

Notes: A dot indicates that data is not available in the report.

Source: the authors, based on the reports of businesses under study.

The data in Table 3 shows that most companies surveyed in the TFL sector have enable whistleblowing. In three of them, non-conformities were reported and the reports provide their details. At Raben, 16 non-conformities were reported in 2018, 11 of which were related to driving behaviour, while in 2020 the number of non-conformities fell to 9 cases. Appropriate corrective actions were taken, with only 1 case deemed unfounded due to insufficient evidence. At Rohlig SUUS Logistics, a single case of bullying or discrimination was reported, but the investigation initiated did not confirm its occurrence. At Prologis, on the other hand, irregularities were reported 10 times, though the details remain unknown.

The analysis of the reports shows that compliance risks are identified in the surveyed companies. Meanwhile, the data in Table 3 can be useful for calculating a number of issues, including the percentage of irregularities and the percentage of resolved issues (see Morawiec-Bartosik, 2022, pp. 182–183). In these companies,

an estimation of compliance risk is made, which involves a formal assessment of its materiality expressed in the form of placing the level of risk on a specific, quantifiable scale. In the materiality matrix, "ethics and compliance" has a high stakeholder and company relevance (see Gdańsk Transport Company SA, 2021, p. 21; Kom-Eko, 2021, p. 23; Prologis, 2022, p. 48).

4.3. Employee Compliance Training as Preventive Action and a Response to Compliance Risk

In the next phase of the study, reports were examined to identify preventive measures companies can carry out as part of their compliance risk response (cf. Welenc, 2020). The compliance training was the focus. In only four of the analysed reports did information on employee compliance training appear:

– online training using a platform where information on corporate culture and values has been posted (VGL Solid Group, 2021, p. 23);

– employee training on policies and procedures by the global corporate compliance department. This is led by a global Chief Compliance Officer who works with representatives from human resources, information security, marketing and legal departments from around the world to provide effective, risk-based training (Prologis, 2022, p. 20);

– Code of Ethics training on an e-learning platform, *Compliance Break* podcast targeted at employees (15-minute episodes once a month) (Rohlig SUUS Logistics, 2022, pp. 24–25);

– training on anti-corruption procedures (Metropolitan Transport Authority, 2020, p. 39).

Some of the TFL businesses under study take specific measures to mitigate compliance risks. For instance, Gdańsk Transport Company, in two phases – the tender phase and the contract signing phase – clearly communicates its corporate values to future partners by presenting a set of requirements and commitments on sustainable development (Gdańsk Transport Company SA, 2021, p. 15). Raben Group, in order to prevent social risks, evaluates suppliers on the grounds of ethical criteria to ensure an appropriate working environment (Raben, 2020, p. 49).

A special role is also assigned to the codes of ethics, the provisions of which clarify and regulate ethics issues. The compliance documents are mainly dominated by codes of conduct (e.g. Code of Ethics, Business Conduct), bylaws (e.g. Work Regulations, Organisational Regulations, Telecommuting) and policies (e.g. Procurement Policy, Whistleblowing Policy), which detail shared values, core principles and standards of conduct (cf. Braun, 2017, pp. 308–315; Raben, 2018, pp. 74, 83; 2020, pp. 17, 43; Metropolitan Transport Authority, 2020, pp. 34, 38–39; 7R SA, 2021, pp. 41, 46; Kom-Eko, 2021, pp. 25–27, 76; VGL Solid Group, 2021; Prologis, 2022, pp. 20, 22; Rohlig SUUS Logistics, 2022, p. 23).

4.4. Organisational Solutions in CMS in TFL Businesses

The next phase examines the reports while presenting the organisational arrangements of CMS in TFL businesses (Table 4).

Table 4. Organisational Solutions in the Field of CMS in TFL Businesses

Name of the Company	Organisational Solutions of the CMS System
VGL Solid Group (2021, p. 16)	.
Gdańsk Transport Company SA (2021, p. 6)	.
Prologis (2022, p. 20)	The Ethics Committee establishes company policies and ensures that they are up to date, oversees ethics training for employees, provides advice and guidance to employees and investigates any reported cases of potential violations. Any significant concerns are reported to the Board Audit Committee in accordance with the Code and the Audit Committee By-laws. The Committee comprises the Chief Legal Officer and General Counsel of Prologis, the Director of Human Resources, the Director of Finance Director and Compliance Director
7R SA (2021, p. 46)	A compliance system is in place and overseen by the Compliance Officer, reporting to the Chief Financial Officer
Kom-Eko (2021, p. 26)	Corporate Compliance Attorney has been appointed to report all violations to him/her
Rohlig SUUS Logistics (2022, p. 24)	The immediate supervisor, HR Partner, Compliance Manager are competent to receive reports on violations. The Compliance Manager is responsible for handling irregularities; in their absence, the task falls to the HR Director
Metropolitan Transport Authority (2020, p. 39)	An ethics ombudsman is in place, trade union representatives and the CEO of Metropolitan Transport Authority are on regular duty
Raben (2020, p. 17)	Group Compliance Officer in place, the Audit Committee oversees the investigation of irregularities
Raben (2018, p. 90)	The corporate risk management system is based on standards developed by the AIRMIC association

Notes: the same as for Table 3.

Source: the authors, based on corporate reports.

Table 4 shows that the businesses under study differ in their organisational structure arrangements, roles and responsibilities. For instance, not every company uses the term Compliance Officer; some opt for Ethics Officer or Compliance Director. In practice, the companies themselves decide whether to follow a holistic or partial model, and the CMS does not have to cover the entire organisation but is tailored to the needs of the specific organisation (see Makowicz, 2020, p. 30).

Table 5. Characteristics of Whistleblowing Systems in TFL Businesses

Whistleblowing Mechanisms	Company / Solution Applied							
	VGL Solid Group	Gdańsk Transport Company SA	Prologis	7R SA	Kom-Eko	Rohlig SUUS Logistics	Metropolitan Transport Authority	Raben
Whistleblowers	.	Personnel, third party companies	Personnel	Personnel, suppliers	Personnel	Everybody	Personnel, customers	Personnel, workmates
Availability of whistleblowing system	.	.	24/7	.	24/7	24/7	24/7	24/7
Information on whistleblowing mechanisms	.	GTC Code of Ethics	.	Good Practice Code	.	Code of Ethics, training	Code of Ethics, Intranet	Code of Ethics
How whistleblowers communicate	.	Confidential	Openly or anonymously	Anonymously	Anony-mously	Openly or anonymously	Openly	Openly or anonymously
Policy to protect whistleblowers from retaliation	.	.	Yes	.	Yes	.	.	Yes
Whistleblower communication channels	.	Whistleblowing to independent party	Hotline, online or telephone, direct supervi-sor, supervisor's superior, any member of the Ethics Com-mittee	Whistleblower channel, suppliers – any company representative	By mail, in writing	By e-mail or verbally to one's line manager, HR Partner or Compliance Manager	By mail or in person to the Ethics Officer	Platform for report-ing irregularities on the website or to a supervisor or HR department; hot-line and notification form available in 11 languages

Notes: the same as for Table 3.

Source: the authors, based on the following reports: VGL Solid Group (2021), Gdańsk Transport Company SA (2021, p. 14), Prologis (2022, p. 20), 7R SA (2021, p. 47), Kom-Eko (2021, pp. 26, 85), Rohlig SUUS Logistics (2022, p. 24), Metropolitan Transport Authority (2020, p. 39), Raben (2018, p. 90; 2020, p. 17).

Certainly, in the businesses under study, three groups of organisational members performing the compliance function can be distinguished: top management and lower management (e.g. personnel director, direct supervisor), compliance officer (compliance manager), other organisational members (trade union representatives) (cf. Makowicz, 2020, pp. 55–56).

4.5. Characteristics of Whistleblowing Systems in TFL Businesses

The final part of the report focused on the whistleblowing systems in the TFL businesses. A summary of the reporting arrangements is presented in Table 5.

It shows that whistleblowing can be performed by both employees and other stakeholders (third-party companies). The whistleblowing systems are available 24/7 and whistleblowing mechanisms are most often included in the codes of ethics. Reports can be public (the whistleblower agrees to fully disclose his or her identity), confidential (with an option of identifying the whistleblower but without sharing his or her personal data with unauthorised persons), or entirely anonymous (the whistleblower may not be identified). There are specific communication channels: ethics hotlines, online forms, e-mails, and direct reports to dedicated services (cf. Table 5).

5. Conclusions

The analysis of the TFL companies' reports (2019–2023) yielded interesting findings on compliance risk management and answers to the research questions:

1. 62.5% of the TFL businesses under study identify compliance risks and include them among major risk categories, most often in the context of rapid regulatory changes and regulatory compliance risk.

2. 75% of the businesses under study measure compliance risk through the number of whistleblowing reports filed. Some of them assess compliance risk in terms of its significance on a quantifiable scale.

3. Less than half of the businesses under study provide compliance training to their personnel as a preventive measure. Such training is a risk response.

4. The organisational arrangements for the CMS in TFL businesses vary according to need. Generally speaking, compliance is overseen by three groups: top management and lower management, compliance officers, other members of the organisation.

5. Whistleblowing systems are in place, though as many as five reports lack information about policies on whistleblower protection against retaliation. This may indicate an initial phase of implementation of EU-compliant whistleblowing systems. This may not be the fault only of the companies, but also of the delayed implementation of EU law into national law, as confirmed in earlier studies of the largest listed companies (see Skoczylas-Tworek, 2023).

Based on a thin-slice analysis of businesses that participate in CSR competitions, the present study does have constraints. The fact that the business participate at all suggests that they are more aware of CSR than their counterparts in the TFL market, which are not required to report and manage compliance. However, in the businesses studied here, the need for compliance education and improved whistle-blowing mechanisms has also been recognised (cf. Winnicka-Wejs, 2023a, p. 148; 2023b, p. 590).

This study refers to previous findings stating that CMS are crucial for ensuring that logistics organisations operate within the boundaries of legal and regulatory requirements, mitigating risks, and enhancing overall operational efficiency, and are ready to face the dynamic challenges of the logistics world with confidence and integrity (Catania, 2024).

An equally important prerequisite of effective risk management and compliance in the logistics sector is the best practice of setting up a sound compliance programme, which, along with the entire regulatory system overseeing the logistics sector, makes it paramount for all operations to meet legal requirements. Doing so limits the threat of penalties, protects corporate reputations and allows for more streamlined operations. Prospective risks need to be identified, compliance with the law ensured and company operations kept running smoothly. Given that supply chains are in constant flux, planning proactively is a prerequisite for all the above (My Logistics Magazine, 2024).

Understanding and incorporating compliance laws and standards is essential, and a key challenge in logistics management (Inbound Logistics, 2023). Future research should include a larger and more diverse number of TFL organisations, as the present study was exploratory in nature. Further research should focus more on the quantitative evaluation of risks. This could be achieved by comparing the frequency of occurrence of some risk features or other indicators, or by comparing them to countries similar to Poland in terms of business specifics. The information that would be needed for such an endeavour is available on the GRI website. Conducting a cross-country analysis might also make the choice of CSR reports more interesting.

Authors' Contribution

The authors' individual contribution is as follows: Each contributed 50%.

Conflict of Interest

The authors declare no conflict of interest.

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Job Satisfaction and Employee Loyalty: A Causal Relationship Examined with the Use of Structural Equation Modelling

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ABSTRACT

Objective: Identification of the impact of job satisfaction on employee loyalty.
Research Design & Methods: A quantitative approach was applied. Critical analysis of literature and an expert panel was used to identify variables. A questionnaire study was carried out online

on the sample of 419 administrative and office employees. Structural equation modelling was used to examine the existence of the assumed relationship.

Findings: It has been proved that job satisfaction is a multidimensional construct. It is composed of three elements: 1) career development including the possibilities of training, development, realisation of passions and non-pay benefits, 2) physical job conditions including ventilation, bathrooms, social back office, noise and temperature level, as well as ergonomic standards of equipment, aesthetics of the workplace and 3) interpersonal relations covering relations with co-workers and supervisors, as well as social communication in the workplace. Each of these dimensions turned out to impact employee loyalty and this impact is statistically significant on a level $\alpha = 0.001$. The strongest impact occurs in case of the two intangible factors: career development (1.024), then interpersonal relations (0.902). For physical working conditions the impact is noticeably weaker (0.211).

Implications/Recommendations: It turned out that employee loyalty is strongly impacted by the intangible factors of the work environment. This observation may constitute an important human resources management tool for managers and in particular in the process of motivating the employees.

Contribution: Confirming the assumed relationship between the revealed dimensions of job satisfaction and employee loyalty with the use of a sophisticated multidimensional statistical analysis.

Article type: original article.

Keywords: employee satisfaction, job conditions, motivation, employee loyalty, work quality assurance.

JEL Classification: M5, M12.

1. Introduction

Having a job is a basic dimension of the human condition (Weber, 2011). In contemporary perspectives, job satisfaction ranks as one of the most commonly discussed and researched topics in the field of social sciences. The widely accepted belief that prioritising employee satisfaction is advantageous for organisations, with happy and fulfilled employees being especially valuable, has become universally recognised (Andrew, 2017; Chanda & Goyal, 2020). Therefore, over the years many authors have proposed tools for measuring job satisfaction (Smith, Kendall & Hulin, 1969; Spector, 1985; Bettencourt, Gwinner & Meuter, 2001), these are considered in detail in a study by van Saane *et al*. (2003).

However, some authors argue that few employees are really loyal and highlight the importance of recognising and maintaining loyalty (Knippen & Green, 1996). Thus, in every industry, employee loyalty should be considered a key element for the growth and sustainability of a business. Consequently, exploring the factors that could influence employee loyalty has become a significant area of research

(Farrukh, Kalimuthuan & Farrukh, 2019). The main objective of building employee loyalty is to achieve a situation in which employees will knowingly become committed, accept responsibilities and pursue them with their own best efforts. In order to achieve employee loyalty, the organisation must take good care of them (Antoncic & Antoncic, 2011). Loyal employees should be treated as very valuable assets, as they help organisations to make large profits. This is because they will take care of the customers in a better way and they understand customers' expectations and tend to meet them (Meyer & Allen, 1997; Michlitsch, 2000). Additionally, keeping loyal employees reduces the turnover rate, as they plan to stay with the organisation for longer. This avoids the additional costs of recruiting new employees, training them, losses in productivity caused by the new, unskilled employees, but, most importantly, to retain valuable experience and knowledge acquired by long--term employees (Hinkin & Tracey, 2000; Omar, Jusoff & Hussin, 2010).

Plenty of authors suggest the existence of a clear, strong and positive relationship between job satisfaction and employee loyalty, where satisfaction is claimed to be an important prerequisite of loyalty (Matzler & Renzl, 2006; Turkyilmaz *et al*., 2011; Farrukh, Kalimuthuan & Farrukh, 2019; Murtiningsih, 2020; Nguyen *et al*., 2020; Yuliyanti, 2020). Hence, in this paper we endeavoured to assess whether the forementioned causal relationship exists for administrative and office workers.

2. Relationship between Job Satisfaction and Employee Loyalty: Literature Review and Developing Hypotheses

Identifying the relationship between job satisfaction and employee loyalty is a difficult area of research. It encompasses hidden, not directly observable, and multidimensional aspects of measured phenomena and complex relationships between them. In this study it was assumed that job satisfaction is a construct formed by the three dimensions: 1) career development, 2) physical working conditions, and 3) interpersonal relations.

The first factor is career development. According to Razak *et al*. (2016), employee training and development must guarantee that a company possesses personnel with the requisite quality to attain its objectives. This can only be accomplished if employees possess the knowledge and skills necessary for efficient job performance, coupled with continuous improvement, thereby maximising their potential for growth (Urbancová & Vnoučková, 2018). Costen and Salazar (2011) also demonstrated that training and development possibilities strongly influence employee loyalty in the lodging industry. Later, Yuliyanti *et al*. (2020) showed that career development has a significant positive effect on job satisfaction and employee loyalty. It has also emerged as an important determinant of employee loyalty in an exploratory study by Pandey and Khare (2012). Urbancová and Vnoučková (2018)

revealed that recognising the significance of employee development is crucial for aligning the needs of both the employer and the employee within the employment relationship. This practice fosters commitment, loyalty, and enhanced performance in agricultural companies. Tarasco and Damato (2006) identified training in the form of ongoing professional development as an important contributory factor to employee satisfaction and loyalty. Ineson, Benke and László (2013) showed that career development impacts employee loyalty in the hotel industry. Taking this into consideration, the following hypotheses have been posed:

H1: Career development positively influences employee loyalty.

The second factor encompasses physical working conditions or technical aspects of the work environment. This is one of the drivers of employee loyalty in small and medium enterprises, as suggested by Nguyen *et al*. (2020). Turkyilmaz *et al*. (2011) revealed that working conditions were the second most important requirement for employee loyalty in the public sector. Abdullah *et al*. (2009), on the basis of their exploratory study, claim that working conditions seem to have a significant relationship to employee loyalty in the hotel industry. The results of another study (Yuliyanti *et al*., 2020) show that the work environment has a significant positive effect on job satisfaction and employee loyalty. Lee and Jablin (1992) discovered that, among other factors, unsatisfactory job conditions lead to weak employee loyalty. Klopotan, Buntak and Drožđek (2016) suggest that favourable working conditions lead to increases in both worker satisfaction and loyalty. Finally, in the well-known study presented by Heskett, Sasser and Schlesinger (1997), working conditions, among other factors, lead to job satisfaction and, ultimately, to higher levels of loyalty. Hence, the following hypotheses have been posed:

H2: Physical job conditions positively influence employee loyalty.

The third dimension encompassed interpersonal relations. Many authors believe that interpersonal relationships help in improving the level of satisfaction among employees which makes them stay in one organisation for a longer period of time (Prabhakar, 2016). Other researchers (Klopotan, Buntak & Drožđek, 2016) suggest that if employees work with colleagues with whom they have a good relationship, and if there is a pleasant social atmosphere, they tend to be more satisfied and loyal. Also a correct, open relationship with a supervisor contributes to satisfaction and loyalty. According to Al-Hussami's (2008) research, those employees with whom a supervisor bonds and establishes an amicable relationship have higher employee loyalty than others. In another study, conducted by Yang *et al*. (2008), employees experiencing cooperation from colleagues and a collegial work environment turned out to be more satisfied with their job and more loyal to the organisation. Ineson, Benke and László (2013) showed that employee loyalty depends on social relationships at work in the hotel industry. Furthermore, Matzler and Renzl (2006) demonstrated that good interpersonal relationships, especially trust, positively influence

employee loyalty. Finally, interpersonal relationships are also said to be one of the creators of employee loyalty in small and medium enterprises, as discovered by Nguyen *et al*. (2020).

Considering these statements, the following hypothesis has been posed:

H3: Interpersonal relations positively influence employee loyalty.

The three hypotheses combined form a research model.

3. Research Method

For data collection, we employed a survey methodology utilising printed questionnaires distributed among respondents to gather a sufficient number of responses for testing the proposed model. The questionnaire comprised three sections: 1) observable variables measuring the quality of the services (15 variables), 2) variables characterising loyalty (4 variables), and 3) control variables (6 variables).

The initial stage of the project involved conceptualising the term "job satisfaction," considering it as a multidimensional construct. The authors initiated this process by conducting a thorough analysis of the literature, identifying observable variables that were subsequently utilised in the empirical study. These observable variables are presented in Table 1.

Table 1. Job Satisfaction – Dimensions, Items and Their Sources

Dimension	Item	References
Career development (CAR)	CAR1: I am satisfied with the possibility of taking part in professional training in my company	Smith, Kendall & Hulin (1969), Churchill, Ford & Walker (1974), Pandey & Khare (2012), Munir & Rahman (2016), Urbancová & Vnoučková (2018), Yuliyanti *et al*. (2020), Dicke *et al*. (2020)
	CAR2: I am satisfied with the opportunities for professional development in my company	
	CAR3: I am satisfied with the possibility to realise my passion in my company	
	CAR4: I am satisfied with non-wage benefits	
Physical job conditions (PHY)	PHY1: I am satisfied with the ventilation at work	Smith, Kendall & Hulin (1969), Munir & Rahman (2016), Klopotan, Buntak & Drožđek (2016), Amin *et al*. (2021), Kuzey (2021), Karaferis, Aletras & Niakas (2022)
	PHY2: I am satisfied with the sanitary facilities at work	
	PHY3: I am satisfied with the social facilities at work	
	PHY4: I am satisfied with the ergonomics at work	
	PHY5: I am satisfied with the noise level at work	
	PHY6: I am satisfied with the temperature at work	
	PHY7: I am satisfied with the standard of the equipment in my workplace	
	PHY8: I am satisfied with the aesthetics of my workplace	

Table 1 cnt'd

Dimension	Item	References
Interpersonal relations (IRE)	IRE1: I am satisfied with my relationships with co-workers	Smith, Kendall & Hulin (1969), Matzler & Renzl (2006), Munir & Rahman (2016), Prabhakar (2016), Kuzey (2021), Karaferis, Aletras & Niakas (2022)
	IRE2: I am satisfied with my relationships with my supervisors	
	IRE3: I am satisfied with communication at work	

Source: the authors.

In the second phase, conceptualisation of the term "employee loyalty" was considered. The authors carried out a critical literature analysis, the results of which are shown in Table 2 as observable variables and their sources.

Table 2. Employee Loyalty – Items and Their Sources

Construct	Item	References
Employee loyalty (LOY)	LOY1: I think my company is a very good employer	Dick & Basu (1994), Oliver (1999), Manzuma-Ndaaba *et al*. (2016), Banahene, Ahudey & Asamoah (2017)
	LOY2: I really like my company	
	LOY3: I am planning to continue to work for this employer	
	LOY4: I disseminate positive opinions about my employer	

Source: the authors.

The answers were recorded on 7-point Likert scales. We used an online survey questionnaire to get a high response rate. The sample had a purposive character. The research encompassed 419 persons working as administrative and office employees in various branches, e.g. the construction industry, the industrial production sector, education and other services. The empirical study was carried out with the use of the Google Forms platform.

The responses were analysed with the use of a method of structural equation modelling (SEM). This is a set of statistical techniques used in order to examine causal relationships between observable and latent variables (Pearl, 2000; Hair *et al*., 2014). We used both models of SEM: the measurement model and the structural model. The measurement model deals with testing the constructs' items in order to assure that each set of items measures their corresponding construct, while the structural model proceeds by testing the influence of constructs on each other. Both proposed models were tested using Statistica 13.0 software.

4. Results

4.1. Measurement Model

As in the earlier study (Lotko, 2022), to assess the proposed model an initial step involved conducting a confirmatory factor analysis (CFA) to verify the reliability and validity of the constructs proposed within the measurement model. Values of factor loadings indicate a statistically significant relationship of the observable variables with:

1. Factor 1 is loaded by four variables measuring: the degree of contentment derived from training opportunities, personal development, pursuing passions, and non-monetary benefits with a dimension representing career development (CAR).

2. Factor 2 is loaded by eight variables describing: the satisfaction level regarding ventilation, restroom facilities, social back office, noise level, temperature, ergonomic standards of equipment, and the aesthetic aspects of the workplace. This dimension describes physical job conditions (PHY).

3. Factor 3 is loaded by three variables: the satisfaction level concerning interactions with colleagues and supervisors, as well as communication in the workplace with a factor describing interpersonal relations (IRE).

4. Factor 4 is loaded by four variables, encompassing cognitive, emotional, conative, and active dimensions of employee loyalty (LOY).

The assessment of the CFA model occurs in two stages: 1) evaluating the goodness-of-fit of the structural model and 2) assessing the convergent and discriminant validity of the measurement model. To appraise the goodness-of-fit of the CFA model, the study employed threshold values recommended by Hair *et al*. (2014) and utilised, for instance, by Alolayyan *et al*. (2020). These thresholds include χ^2/df, goodness-of-fit (GFI), root mean square error of approximation (RMSEA), Comparative Fit Index (CFI), and Tucker Lewis Index (TLI or Non-normed Fit Index, NNFI). Table 3 presents the fit indices obtained for the measurement model.

Table 3. Assessment of the Measurement Model

Obtained Fit Indices					
χ^2/df	p	GFI	RMSEA	CFI	TLI
8.23	0.00	0.80	0.14	0.91	0.91
Suggested Fit Indices					
≤ 5	≤ 0.05	≥ 0.80	≤ 0.08	≥ 0.90	≥ 0.90

Source: the authors.

To evaluate the factor structure, reliability, and discriminant validity, a collective CFA encompassing all variables was performed. The outcomes of the CFA model, as presented in Table 4, demonstrate that the measurement model results

for reflective measures exhibit a satisfactory fit, as the majority of the fit values meet the recommended cut-off scores: $p = 0.00$, GFI = 0.80, CFI = 0.91, TLI = 0.91. Nevertheless, $\chi^2/df = 8.23$ and RMSEA = 0.14 are out of the suggested range.

Table 4 displays the factor loadings (FL) and composite reliability (CR) for each construct, along with Cronbach's alpha (α) and average variance extracted (AVE), ensuring the model's reliability.

Table 4. Reliability Measures for the Measurement Model

Constructs	FL	CR	α	AVE
CAR	0.75–0.82	0.63	0.88	0.60
PHY	0.72–0.81	0.91	0.91	0.56
IRE	0.66–0.80	0.41	0.84	0.50
LOY	0.60–0.80	0.81	0.93	0.51

Source: the authors.

Moreover, for evaluating discriminant validity, both the variable correlation matrix and the square root of the AVE were utilised. The square root of AVE for each construct should adhere to the Fornell-Larcker (1981) criterion, meaning it should surpass the correlations between any two dimensions in the model. As depicted in Table 5, this criterion was successfully satisfied.

Table 5. Validity Assessment for the Measurement Model

Constructs	CAR	PHY	IRE	LOY
CAR	**0.77**	–	–	–
PHY	0.45*	**0.75**	–	–
IRE	0.62*	0.49*	**0.71**	–
LOY	0.71*	0.47*	0.70*	**0.71**

* $p < 0.001$.

Notes: The diagonal values represent the square root of the AVE, while the off-diagonal values indicate the correlations between constructs.

Source: the authors.

Additionally, convergent validity has been validated based on three criteria proposed by Fornell and Larcker (1981). Firstly, the factor loadings should equal or exceed 0.5. Secondly, for each factor AVE should exceed the value of 0.5. Finally, CR should be higher than 0.7. As shown in Tables 4 and 5, the three conditions which approve convergent validity were met, only for interpersonal relations is the value of CR below the threshold (0.41).

4.2. Structural Model

Structural and especially standardised path coefficient estimates are shown in Figure 1.

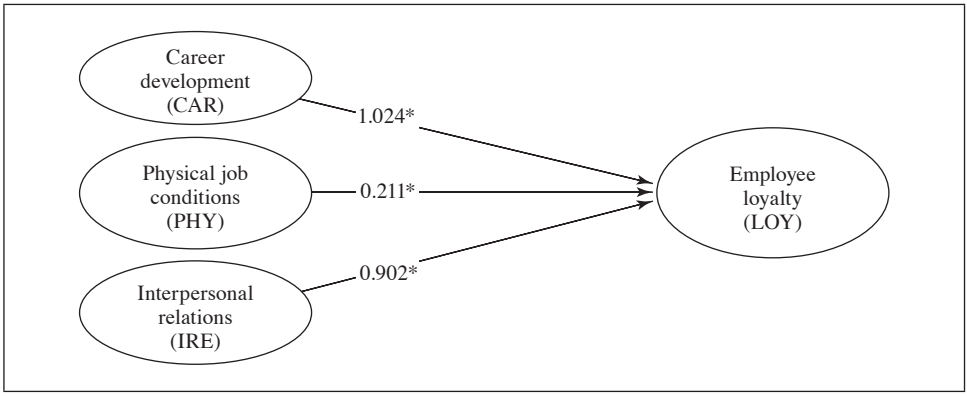

Fig. 1. Structural Model

* $p < 0.001$

Source: the authors.

Table 6 presents a summary of testing hypotheses with the use of SEM.

Table 6. Summary of SEM Results for the Proposed Model

Predictor Variables	Criterion Variable	Hypothesised Relationship	Standardised Coefficient
Career development	employee loyalty	H1 → supported	1.024*
Physical job conditions		H2 → supported	0.211*
Interpersonal relations		H3 → supported	0.902*

* $p < 0.001$.

Source: the authors.

As can be seen in Table 6, the impact of career development on employee loyalty is $\beta_1 = 1.024$ with $p < 0.001$. Hence hypothesis H1 has been verified. Furthermore, the influence of physical job conditions on employee loyalty is only $\beta_2 = 0.211$ and it is also statistically relevant. Therefore hypothesis H2 can also be confirmed. Finally interpersonal relations influence employee loyalty with $\beta_3 = 0.902$ with $p < 0.001$. In this way hypothesis H3 has been confirmed. As can be seen from Table 7, two factors have the greatest impact on employee loyalty: career development and interpersonal relations. In the case of the third factor, physical job conditions, the impact

is relatively smaller, but still significant. This leads to the statement that intangible factors are most significant for employees' employee loyalty, while physical, tangible factors have a smaller influence on loyal attitudes and behaviour.

Finally, Table 7 summarises the obtained values of indices estimating the model.

Table 7. Assessment of Overall Model Fit

Obtained Fit Indices					
χ^2/df	p	GFI	RMSEA	CFI	TLI
5.51	0.00	0.85	0.10	0.90	0.91
Suggested Fit Indices					
≤ 5	≤ 0.05	≥ 0.80	≤ 0.08	≥ 0.90	≥ 0.90

Source: the authors.

As can be seen in Table 7, in general the structural model shows an average fit. This can be seen in the values of the following indices: GFI = 0.85, p = 0.00, CFI = = 0.90, TLI = 0.91. Again, in case of χ^2/df = 1.55 and RMSEA = 0.10 the values are slightly beyond the suggested range (MacCallum, Browne & Sugawara, 1996).

5. Discussion

The meaning of job satisfaction and its impact on employee loyalty has been covered by many studies applying SEM in this area. The discussed results come from the most recent years.

The first authors (Dhir, Dutta & Ghosh, 2020) conducted a survey among Indian managerial executives. Responses have been tested using the SEM approach. They tested a model that illustrates how person-job fit, person-organisation fit and perceived supervisor support affect job satisfaction and employee loyalty. Job satisfaction turned out to be a mediator, leading to employee loyalty.

The research conducted by Phuong and Vinh (2020) enhances our comprehension of the connections between job satisfaction, employee loyalty, and job performance. Employing SEM to test hypotheses, the study data obtained from employees in Vietnamese lodging enterprises. The empirical findings revealed, among other outcomes, a positive direct influence of job satisfaction on employee loyalty.

Chen, Xu and Yao (2022) examined the assumed relationship in a high risk industry – mining. These authors investigated the relationship between employee satisfaction and employee loyalty through a survey that targeted employee loyalty, work quality, job satisfaction, and the relationship between enterprise image and switching costs. The hypotheses were tested using SEM. Employee loyalty turned out to be significantly associated with enterprise image and employee satisfaction, work quality indirectly affected loyalty through satisfaction.

Another study (Vuong *et al*., 2021) analyses factors affecting doctors' satisfaction and loyalty from a survey of doctors working in public hospitals in Vietnam. Again, SEM was employed to test the relationship among the factors in the research model. The results indicated that employees satisfied with their job tend to be loyal to the organisation.

The other paper (Nurlaila & Nurdin, 2020) deals with examining the effect of quality of work life and job satisfaction on loyalty and its impact on employee performance. The collected data was analysed by SEM. The results show that quality of work life affects employee performance, job satisfaction affects employee performance, the quality of work life affects employee loyalty and job satisfaction affects employee loyalty. All of these causality results strengthen the previous theories.

The purpose of another study (Murtiningsih, 2020) was to analyse the effect of compensation, training and development, and organisational culture on job satisfaction and employee retention. The study used the SEM analysis to test the hypotheses. The results show that compensation, and training and development have a positive effect on job satisfaction. Furthermore, job satisfaction has a positive impact on employee retention.

In a subsequent paper, Farrukh, Kalimuthuan and Farrukh (2019) examined how job satisfaction, trust, and leadership support affect employee loyalty within the hotel industry in Saudi Arabia. The researchers gathered data through a structured questionnaire and employed SEM to test their hypotheses. The findings of this study also suggest that factors related to job satisfaction have an impact on employee loyalty.

In an interesting study (Wahyuningrat & Rusmawan, 2022), the authors attempted to determine the influence of different factors on employee loyalty. To achieve this, senior public health centre employees were analysed. Data analysis used SEM method. The results of hypothesis testing show that all of the considered constructs: 1) leadership, 2) work culture, 3) work environment, 4) interpersonal communication, and 5) workload have a positive effect on loyalty.

The results obtained by Waqas *et al*. (2014) reveal that there is a positive and strong relationship between job satisfaction and loyalty. These authors explained that the factors that influence job satisfaction in the strongest manner are appreciation and recognition, workplace environment and empowerment.

In summary, it can be claimed that all of the analysed studies confirm the existence of a positive and statistically significant impact of different dimensions of job satisfaction on employee loyalty, so they are in concordance with the findings of our study.

6. Conclusions

Today human resources management (HRM) seems especially difficult because employees are highly qualified and aware of their rights while working in an organisation. Therefore, it is imperative that organisations identify the needs of their employees and satisfy them to ensure effective accomplishment of its goals and objectives (Raziq & Maulabakhsh, 2015). The presented study provides an approach for designing HRM policy, as it explains the impact of various factors on employee loyalty. These results could help understand various underlying factors contributing to job satisfaction and employee loyalty. They are as follows:

1. Using SEM it was shown that the impact on loyalty to the employer of each of the identified three dimensions of job satisfaction is positive and statistically significant.

2. In detail, employee loyalty is impacted in highest degree by career development (1.024), and then interpersonal relations (0.902), while physical job conditions (0.211) had the smallest impact.

3. The obtained model fit can be recognised as average.

4. The obtained results find strong confirmation in literature.

The results of the study deliver knowledge on the important role of job satisfaction, first of all derived from intangible aspects, in building employee loyalty. Developing these aspects can be a good tool for designing HRM policy, as it can influence employees' attitudes and behaviour towards the organisation.

7. Managerial Implications

Employees are a determining factor for every effective organisation. This is because efforts to fulfil the organisation's mission are determined by the quality of human resources (Darmawan *et al*., 2020). Therefore, organisations must carry out the management and development of human resources in a professional and planned manner. They need to pay attention to ensuring that the employees are satisfied (Earl *et al*., 2011; Turkyilmaz *et al*., 2011) and how employees build loyalty towards organisations (Ibrahim & Al Falasi, 2014; Darmawan *et al*., 2020). As suggested in many studies, employee loyalty can enhance efficiency, improve business outcomes, foster business growth, and reduce employee turnover (Meyer & Allen, 1997; Antoncic & Hisrich, 2004). Additionally, loyal employees play a role in shaping the company's image within its environment and among external stakeholders, including customers (Antoncic & Antoncic, 2011).

In our study it turned out that in the case of all three dimensions of job satisfaction, the influence on employee loyalty was found to be statistically significant. Considering the standardised path coefficients obtained, it is noteworthy that intangible factors (career development and interpersonal relations) impact employee

loyalty to a far more substantial degree than work environment. The fact that organisations should be aware of the importance of intangible factors is also confirmed by other researchers (Ineson, Benke & László, 2013). This observation leads to the following implications concerning the impact of the three dimensions of job satisfaction on employee loyalty:

1. Career development. Constant development of skills is a must for contemporary workers. Career development is the main imperative to retain employees and is perceived as one of the key attractors to organisation (Kreisman, 2002). Then Abdullah *et al*. (2009) confirmed that opportunity for career development has increased the tendency of employees to become loyal to the organisation. It implies that the employees feel they have a future with the organisation. Because of this, good, sound career development advice should be offered to valued employees. Additionally, a clearly defined career structure should be introduced. Staff development programmes should be offered especially to promising workers with longer experience with the organisation (Ineson, Benke & László, 2013). Popular managerial tools used in career development are SWOT analysis, career testing, self-assessment, personality tests, competency guides, career planning resources, and mentoring.

2. Personal relations. They refer to a strong association among individuals working together. Employees working together should share a special bond for them to deliver their level best (Obakpolo, 2015). Valued interpersonal relationships can influence organisational outcomes by increasing institutional participation, establishing supportive and innovative climates, increasing organisational productivity and reducing staff turnover (Berman, West & Richter, 2002; Song & Olshfski, 2008). Petterson and Arnetz (1998) suggest that attaining the goals of an organisation depends much on the understanding between employees and supervisors, whereas effective communication plays a vital role in running the organisation. The basic management concepts concerning interpersonal relations in organisations encompass components such as communication, trust, care, participative leadership, shared goals and values, mutual trust, mutual respect, understanding motivation, and conflict management (Obakpolo, 2015; Brhane & Zewdie, 2018). To improve in this area, the following should be considered: cultivating a positive outlook, acknowledging the expertise of others, showing real interest in others, practicing empathy (Petterson & Arnetz, 1998).

3. Physical working conditions. This is the third factor, having a smaller, but still significant, influence on loyalty. The positive effects of a good work environment for both individual health and corporate success has been discussed in many reviews (Shain & Kramer, 2004; Dul & Ceylan, 2011). Examples of reported effects are both health and business related, like better employee health and welfare, less sick leave and accidents, increased productivity, creativity, and lower staff turnover.

The researchers believe physical conditions, including lighting, noise, and microclimate, impact well-being and potential health issues even in administrative and office settings (Aleksandrova, 2005; Katz, 2017). Enhancing these factors aims to adjust their parameters in a way that ensures ergonomic working conditions, preventing dysfunction in the human organism and, consequently, maintaining or improving the quality and efficiency of work (Niciejewska & Kač, 2019). Managing specific elements of the work environment is essential for achieving better working conditions overall (Costa-Font & Ljunge, 2018).

We believe that managerial implications of this study can be useful for a better understanding of HRM in the area of employee satisfaction and allows it to be linked with employee loyalty, with positive effects for both individual and organisational success.

8. Limitations and Further Research

Although the research was conducted in different industries, one should remember that only administration and office workers were surveyed. This is a limitation, as it affects the differentiation of the sample. Also the geographical range of the research was restricted to the Mazowieckie voivodeship. The authors' questionnaire used in the research contained a limited number of observable variables – 15 items for job satisfaction and 4 for employee loyalty. It should be borne in mind that in some other research tools the number of variables is significantly larger, e.g. the Job Descriptive Index – 72 items (Smith, Kendall & Hulin, 1969), the Job Satisfaction Survey – 36 items (Spector, 1985). These limitations suggest ways to further improve the research.

The following can be listed as directions for further research: 1) increasing the number of observable variables in the questionnaire, as well as increasing the number of assumed dimensions constituting the job satisfaction construct, 2) introducing the variables intervening between job satisfaction and employee loyalty, e.g. commitment (Andrew, 2017), 3) widening the geographical scope of the research, and also including employees in different jobs, and 4) examining and discovering the impact of employee loyalty on modern organisational performance, aimed at reaching their goals under conditions of constant change (Chanda & Goyal, 2020).

Authors' Contribution

The authors' individual contribution is as follows: Aleksander Lotko 40%, Małgorzata Lotko 30%, Stanisław Popek 10%, Grzegorz Szałas 10%, Adam Popek 10%.

Conflict of Interest

The authors declare no conflict of interest.

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The Impact of Organisational Climate on Staff Creativity: An Empirical Study of the Interplay

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ABSTRACT

Objective: The article aims to empirically review the impact of organisational climate on staff creativity, with job satisfaction as a mediating variable.

Research Design & Methods: Following a literature search, a conceptual model of the interplay between organisational climate, job satisfaction, and staff creativity was formulated. The proposed model was empirically verified by means of a confirmatory analysis via structural equation modelling (SEM CFA) on a sample of 1,000 employees, with the use of data collected in December 2023 and with a focus on exploring the impact of organisational climate on staff creativity through their job satisfaction.

Findings: The quantitative research enabled us to test the relation model between organisational climate and staff creativity. The results of the study confirm the indirect effect, through job satisfaction, of organisational climate on the creativity of employees.

Implications/Recommendations: The study suggests that job satisfaction plays a key role as a mediator in the interplay between organisational climate and staff creativity.
Contribution: The study fills a gap with regard to the interplay between organisational climate and staff creativity, taking into account the job satisfaction mediation. Further research could look more closely at the impact of individual organisational climate components on staff creativity. Future research could add other mediators and moderators between the variables.

Article type: original article.

Keywords: organisational climate, staff creativity, job satisfaction, human capital.

JEL Classification: M12, M54, J24.

1. Introduction

Organisational climate is linked to a range of employee attitudes (Karatepe, Aboramadan & Dahleez, 2020; Mutonyi, Slåtten & Lien, 2020; Góralczyk, 2022). Meta-analyses of independent studies likewise bear this out: there are strong correlations between organisational climate and organisational commitment, job satisfaction, intention to leave the organisation, as well as their outcomes, i.e., effectiveness and job performance. Other studies have also found a link between organisational climate and counterproductive employee actions along with workplace violence (Turek, 2018). Research has largely focused on the connection between how people perceive and feel about what is happening in the organisation encompassing employee attitudes and their economic impact. Meanwhile, revolutionary technological developments and labour market circumstances shine a light on the quality of employees' competences, which determine the way individuals and organisations evolve today. One of these traits is creativity, and it plays a key role. These notions led us to conduct the research presented in this paper on the relation between organisational climate and the creativity of Polish employees in 2023. The aim was to empirically verify the impact of the former on the latter, with job satisfaction as a mediating variable.

The article consists of five parts: 1) a theoretical background on the nature of organisational climate and its links with job satisfaction and staff creativity, which are the basis for the research hypotheses, 2) a section on methods of empirical research, including a brief account of the objective, assumptions, the research sample, 3) a section describing the outcomes of statistical analyses, 4) a discussion section, with conclusions, and 5) a section presenting the limitations and direction for future research. Following the literature search, a conceptual model of the interplay between organisational climate, job satisfaction, and staff creativity was formulated. The proposed model was empirically verified by means of a confirmatory analysis via structural equation modelling (SEM CFA) with a focus on exploring

the indirect impact, through job satisfaction, of organisational climate on staff creativity. The analytical data were provided by the authors' empirical survey, conducted using the CAWI method in December 2023, on a sample of 1,000 respondents.

2. Theoretical Background

2.1. Organisational Climate in Relation to Staff Creativity

A review of theoretical approaches indicates a diversity of concepts and interpretative latitude, resulting in dozens of definitions for the notion of organisational climate (Wziątek-Staśko & Krawczyk-Antoniuk, 2022b). Wziątek-Staśko and Krawczyk-Antoniuk (2022a) believe that organisational climate continues to be a subject of scholarly interest, yet it is frequently addressed in an overly intuitive manner, or it is marginalised. In a similar vein, Wojciechowska and Dziwulski (2021) observe that the body of research produced by Polish scholars in this area remains limited and would benefit from further expansion, systematisation, and development, as well as greater consistency and conceptual clarity.

We have adopted a definition that recognises organisational climate as a set of generalised opinions and perceptions, shared by employees, about objective and important factors as well as behaviours, concerning the internal environment of an organisation (von Rosenstiel & Bögel, 1992). Organisational climate refers to the common understanding, feelings and attitudes of the members of an organisation towards its basic components. It reflects the norms, values and attitudes that distinguish one organisation from another (Emmanuel, Nwakoby & Augustina, 2020). It also influences the behaviour of all members of the organisation along with their motivation and satisfaction (Amiri *et al*., 2023).

An unfavourable organisational climate creates an environment full of suspicion and hostility, causing cooperation to break down. The right climate, by contrast, effectively improves staff morale and participation in decision-making, enhances staff creativity and innovation, and thus increases productivity (Moslehpour *et al*., 2019). It has a significant impact on staff behaviour and performance, as well as on the efficiency of the organisation as a whole (Yesuf, Getahun & Debas, 2024). The variety of organisational climate components identified in the relevant literature is confirmed by the development of dozens of organisational climate survey tools (Juchnowicz, Mazurek-Kucharska & Turek, 2018).

The organisational climate is influenced by both external and internal determinants. The former include the business environment, technological advances, and labour market situation, while the latter include strategy, organisational culture, structure, management style and practices. Hence, staff competences that respond to today's challenges play an important role in its formation. Among these, creativity holds a special position, especially given the role it plays in creating an organisa-

tion's innovative potential – namely, in generating ideas and initiating action across various areas of the organisation's activity. At the same time, the organisational climate creates conditions for the development of staff creativity, i.e. the type of working environment that can potentially foster creative work.

Creative people are often curious, open to change, and have intrinsic motivation. These traits shape the individual's relatively durable ability to come up with new ideas and solutions, as well as to engage in entrepreneurial creative thinking and action (Wojtczuk-Turek, 2014). Creativity is also featured in the competency profiles utilised in human resource management practices (Pocztowski, 2018). It is unique because it cannot be effectively developed by traditional means such as issuing orders, instructions or offering financial incentives. It can be inspired and nurtured, but not directly controlled (Zawadzki, 2010).

That it is among the paramount attributes of human capital is evidenced in the conclusion from Steve Jobs' biography: the key to gaining market advantage in the 21st century is to have creativity combined with technology and a passion for developing breakthrough products and services (Lipka & Waszczak, 2012). Creative ideas transformed into innovative discoveries and implementations have been a key source of competitive advantage since the 1990s (Sołoducho-Pelc, 2018). Following an analysis of the literature on organisational climate and staff creativity, the first hypothesis was formulated:

H1: Organisational climate has a positive impact on staff creativity.

2.2. The Impact of Job Satisfaction on How Organisational Climate Affects Staff Creativity

Job satisfaction goes a long way to determining the quality of human capital (Schultz & Schultz, 2002). We assume that satisfaction (or lack thereof) is the positive or negative feelings and behaviours that relate to the job duties performed by employees. Defining satisfaction solely as feelings or sensations (e.g. Locke, 1969), and thus confining it within the emotional sphere, limits its consequences (Juchnowicz, 2014). The vital role of satisfaction is evident in its capacity to anticipate and also influence various attitudes towards one's work, profession, and organisation. These are essential components of a staff's competence potential for creativity, flexibility, and a willingness to develop (Ćulibrk *et al*., 2018; Wang *et al*., 2022).

In addition to the direct impact job satisfaction has on competence potential, research findings also point to links with other components of organisational human capital, including an individual's affective well-being, organisational climate, and organisational culture (Carr *et al*., 2003). Satisfied employees are often more motivated and committed to their duties. This results in a greater willingness to undertake challenges, do experiments and consider new solutions, all of which are crucial for creativity (Shalley & Gilson, 2004). Research has shown that job

satisfaction is enhanced by a positive organisational climate, particularly one that is open, has a collaborative spirit, and is accepting of diversity, all of which are conducive to unleashing creative potential (Schneider & Snyder, 1975; Amabile, 1988). Indeed, job satisfaction can act as a catalyst to creativity, stimulating employees into more exploratory thinking, generating ideas, and experimenting with new solutions (Woisetschläger, Hanning & Backhaus, 2016). This is particularly relevant when considering knowledge workers and the Y and Z generations, which view creativity and job satisfaction as important values (Ng, Schweitzer & Lyons, 2010; Twenge, 2023).

Creativity falls under the discretionary behaviour of employees, which involves the conscious and deliberate use of creative abilities to generate solutions or ideas that benefit the organisation, even though this is often not formally required. As such, it is a sort of unofficial contribution by an employee, which may be viewed as a way to compensate for any perks that they receive (Yesuf, Getahun & Debas, 2024). While this was initially explained by social exchange theory (Blau, 1986), more recent research confirms the positive correlation between staff satisfaction and discretionary behaviour (Bettencourt, Brown & MacKenzie, 2005).

Creativity manifests an employee's autonomy – his or her ability to take autonomous decisions and initiative on the job (Ryan & Deci, 2000). By being creative, employees manifest their active role in the organisation and express their loyalty through creative actions for the benefit of the organisation. A mutual exchange between an employee and the organisation, one in which the latter particularly values creativity, can additionally stimulate the employee's desire to engage more in creative processes. When employees evaluate the exchange with the organisation positively, the result is job satisfaction (Podsakoff *et al*., 2000).

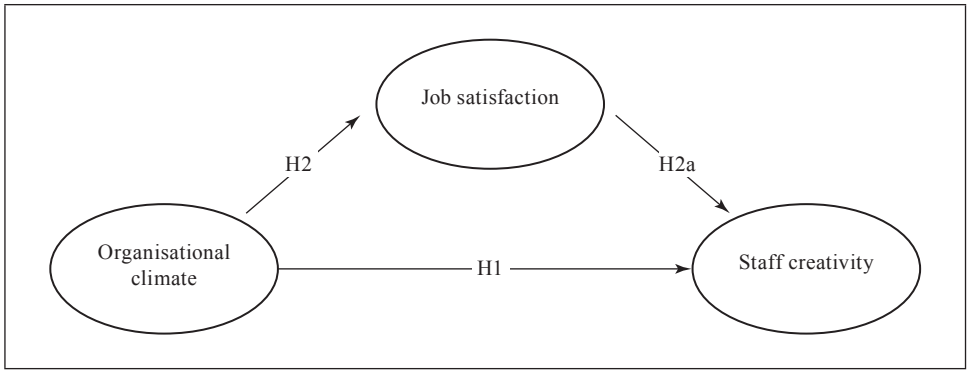

Fig. 1. The Impact of Organisational Climate on Staff Creativity, Allowing for the Mediating Effect of Job Satisfaction – Research Model

Source: the authors.

Following a literature review on the interplay between organisational climate, job satisfaction and staff creativity, the second hypothesis and its sub-hypothesis were formulated:

H2: Organisational climate has a positive impact on job satisfaction.

H2a: Organisational climate, by enhancing job satisfaction, has a positive impact on staff creativity.

The dependencies between the study constructs are displayed in Figure 1.

3. Research Method

3.1. Research Sample Characteristics

To test the model of the interplay between organisational climate and job satisfaction and staff creativity, a quantitative survey was conducted in December 2023 on a sample of active Polish employees (N = 1,000). It used the CAWI method, based on a nationwide, accredited survey panel. The survey process was executed by Biostat. A predetermined target sample size was identified, and the data collection phase was concluded upon reaching this established sample size. A representative sample was achieved by means of random scheme selection. The survey was dominated by respondents with tertiary education (57%), employed under a contract of employment (83%) in non-managerial positions (74%), in the private sector (75%). The majority of the sample was female (68%). The sample was balanced in terms of age (30% each from Generations X, Y and Z and 10% baby boomers) and in terms of the size of the organisation (15% of respondents from micro, 23% from small, 25% from medium, 14% from large, and 23% from very large companies).

3.2. Variables

To measure organisational climate, the study used an 18-statement questionnaire originally developed by von Rosenstiel and Bögel (1992) and adapted for Poland (Durniat, 2018). It was further supplemented with our own questions to assess job satisfaction (3 statements) and staff creativity (4 statements). The respondents rated the statements on a 5-point Likert scale, with 1 standing for "strongly disagree" and 5 for "strongly agree."

To confirm that the tested constructs were valid and the variables appropriate, confirmatory factor analyses (CFA) were performed. The confirmation of the theoretical model was an attempt to match the data collected with the theoretical concept underlying the construction of the questionnaire. Those statements within the construct that did not meet the requirements – one statement for creativity and two for organisational climate – were removed from the CFA so we could proceed with structural equation modelling (SEM) in the next stage.

The dependent variable in the model was staff creativity. It was measured using three statements that explored declarations of setting a variety of career goals, of being eager to learn, and of being ready to engage in new assignments. For the dependent variable, the Cronbach's alpha reliability coefficient was 0.767.

The explanatory variables were measured as follows:

1) organisational climate – the variable was measured with 16 items to determine: overall assessment of organisational climate, fellow employees, supervisors, work arrangements, information and communication, performance reviews and promotion opportunities. The Cronbach's alpha reliability coefficient here was 0.955;

2) job satisfaction – the variable was measured using three items to determine: the degree of enjoyment from one's work, the degrees to which one is proud and aware of the sense of one's work. The Cronbach's alpha reliability coefficient was 0.878.

All the variables were constructed in a reflective manner. The standardised estimates for path loadings between the statements and each of the constructs were significant and exceeded the loading value of 0.5 (Table 1).

Table 1. The Model Variables

Variable	Item	Path Loading Value
Staff creativity	I set myself a variety of professional and personal goals	0.808
	I try to keep learning all the time	0.795
	I often pick up new tasks at work not out of duty, but to make something better or more efficient	0.591
Organisational climate	It is a pleasure to work in our company	0.802
	In our company, care is taken to make the working conditions decent	0.790
	Our company is committed to employee well-being	0.844
	If people face trouble at work, they can count on their co-workers for help	0.691
	Our sense of community is lacking; everyone just takes care of themselves	0.538
	Everyone is free to express their own views and sentiments here	0.690
	Good work is duly rewarded by our superiors	0.806
	Our supervisors make sure that cooperation between employees is smooth and conflict-free	0.774
	The goals and tasks set for us are engaging challenges	0.713

Table 1 cnt'd

Variable	Item	Path Loading Value
	Engaging and somewhat extraordinary tasks are distributed fairly	0.752
	We are updated well enough on key business matters and events	0.750
	Our management considers the staff's ideas and suggestions	0.781
	The briefings as well as the rollout of new hardware and software are so well-reported that we always know what is to come	0.721
	Our pay system is fair	0.769
	Job achievements are fairly recognised in our company	0.822
	Our company appreciates receiving new ideas and suggestions	0.816
Job satisfaction	I enjoy my job, and go to work with pleasure	0.819
	I believe that my work serves a purpose	0.846
	I take pride in my work	0.858

Source: the authors.

4. Research Findings

4.1. General Remarks

The objective of the study was to assess the quality of a conceptual model which assumed some relations between organisational climate, job satisfaction, and staff creativity. The model employed latent variables, i.e. variables that cannot be directly observed, but can be detected through other observable variables (Juchnowicz, Kinowska & Gąsiński, 2024). Using CFA and path analysis, the structure of the variables was verified and the relations between the latent variables were examined.

Analyses were conducted with IBM SPSS AMOS software (version 29).

4.2. Validation of the Measurements

At the preliminary stage of the analyses, validity and reliability of the scales were checked. The CR values for the latent variables were above 0.7, thus providing evidence of structural and convergent construct validity. The AVE values for all latent constructs were higher than 0.5, so the convergent validity was considered sufficient. Meanwhile, discriminant validity was verified using the Fornell-Larcker criterion (Fornell & Larcker, 1981), which holds that the square root of the AVE should be greater than the correlation between the constructs. The requirement is met, save one correlation. The scales in question reveal both convergent and discriminant validity, which confirms their theoretical validity (Table 2).

Table 2. Evaluation of the Psychometric Properties of the Scales

Construct Scale	CR	MSV	AVE	Correlations / Square Root of AVE[a]		
				Organisational climate	Job satisfaction	Staff creativity
Organisational climate	0.955	0.651	0.573	**0.757**	–	–
Job satisfaction	0.879	0.651	0.708	0.807	**0.841**	–
Staff creativity	0.779	0.370	0.545	0.479	0.608	**0.738**

[a] On the diagonal, the square root of AVE is in bold type.

Notes: CR – composite reliability, MSV – maximum shared variance, AVE – average variance extracted.

Source: the authors.

4.3. Estimation of the Structural Model

A model of the construct relations was estimated using the SEM CFA approach. The measurement model can be considered a good fit with the chi-square value standing at 1,618.465 (206 *df*), $p < 0.001$. Absolute fit indices, like GFI = 0.856 and AGFI = 0.823, are at a satisfactory level (close to 0.9). Relative fit indices (called the incremental fit) are also close to 0.9. The RMSEA of 0.083 is not too far away from 0.08, which is regarded as an acceptable value, and the confidence interval for the RMSEA includes no value of 0.1, which would disqualify the model.

To probe the relations between organisational climate, job satisfaction and staff creativity, path coefficients were estimated (Table 3).

Table 3. Path Coefficients for the Studied Interplay of Variables

Structural Paths	Path Coefficients
Organisational climate → staff creativity	–0.035
Organisational climate → job satisfaction	0.807*
Job satisfaction → staff creativity	0.636*
Organisational climate → job satisfaction → staff creativity	0.479*
RMSEA	0.083
CFI	0.910
AGFI	0.823

* $p < 0.001$.

Source: the authors.

The variables in our model explained around 37% of the staff creativity variances (R2 = 0.370) and around 65% of the job satisfaction variances (R2 = 0.651).

The findings support the hypothesis that organisational climate has an indirect effect on staff creativity through job satisfaction (H2a) ($\beta = 0.479$, $p < 0.001$). They also confirm the hypothesis that organisational climate has an effect on job satisfaction ($\beta = 0.807$, $p < 0.001$).

Due to a lack of statistical significance, the hypothesis that organisational climate boosts staff creativity (H1) was rejected ($\beta = -0.035$, $p > 0.1$).

5. Conclusions

Our findings confirm that organisational climate influences staff creativity significantly, albeit indirectly, via job satisfaction. Confirming the positive impact of organisational climate on job satisfaction is a step towards understanding the mechanisms behind employee job satisfaction, including the levels of that satisfaction. The results suggest that job satisfaction plays a key role as a mediator in the interplay between organisational climate and staff creativity, which is consistent with findings reported in the literature (Amabile, 1988; Schneider, Ehrhart & Macey, 2013).

The direct impact of organisational climate on staff creativity requires additional exploration. In the studies conducted, there was no empirical support for the hypothesis that organisational climate directly affects staff creativity. This implies that all of the influence was mediated by job satisfaction. Other studies have found that organisational climate can influence creativity through factors other than satisfaction, such as autonomy and encouragement from superiors (Zhou & George, 2001).

The findings show that the interplay between organisational climate, job satisfaction, and staff creativity is complex. This can be relevant to both researchers and human resource management (HRM) departments alike. The findings also suggest the need to consider job satisfaction as a mediator in the relation between organisational climate and staff creativity. This approach can contribute to the development of more sophisticated theories of creativity in the organisational context.

The results might also encourage HRM practitioners to foster a positive organisational climate, thereby enhancing job satisfaction and boosting staff creativity. The study implies that job satisfaction should be taken into account while designing HR policies and HRM practices. Initiatives addressing motivation, career development or employee/supervisor rapport-building can contribute to higher job satisfaction and, ultimately, higher staff creativity.

The study confirmed that organisational climate has an indirect effect on staff creativity through job satisfaction. At the same time, a direct effect was no found. Nonetheless, the study suggests that job satisfaction indeed plays a key role in medi-

ating between organisational climate and staff creativity. The results indicate the interplay between the variables is complex. They also clearly show that theories of creativity in organisations call for further development, with job satisfaction as a mediating factor.

6. Limitations and Directions for Future Research

Ultimately accomplished with a static approach, the study captures the interplay between organisational climate, job satisfaction, and staff creativity. Accordingly, the relations were time-dependent and variable in nature. Further study of the relations would benefit from a long-term perspective.

This study focused specifically on Polish employees. To generalise the results, it would be necessary to undertake research covering staff in other countries and regions.

A research study on organisational climate and staff creativity should integrate dual perspectives: those of employees and employers. The present study analysed the interplay between the constructs on a sample of employees. To achieve a more complete picture, it would be advisable to conduct the study from the perspective of employers. In addition, this study measured the constructs through a specially designed employee self-assessment questionnaire. Conducting validating research on the results by means of other evaluation sources would be revealing.

In future research, the components of the constructs under study and the relations between them should be studied in greater detail. Moreover, future research can be extended to include other mediators and moderators of the interplay between organisational climate and staff creativity. Comparative studies between different sectors and types of organisations could be conducted to gain insight into how these factors alter the impact of organisational climate on staff creativity.

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Authors' Contribution

The authors' individual contribution is as follows: Marta Juchnowicz 40%, Hanna Kinowska 40%, Hubert Gąsiński 20%.

Conflict of Interest

The authors declare no conflict of interest.

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Evaluation of Protective Mask Notifications to the Safety Gate/RAPEX System during the COVID-19 Pandemic

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ABSTRACT

Objective: This study aims to assess the protective mask notifications used in the Safety Gate/RAPEX system (an early warning system for managing safety used by the European Commission) between 2020 and 2022 in the context of the COVID-19 pandemic. This study continues research into the impact of the COVID-19 pandemic on the notification of protective masks for this system.

Research Design & Methods: Legacy data analysis combines literature evaluation and critique with document research method.

Findings: Notifications on protective masks offered between 2020 and 2022 were analysed taking into account four factors: the types of legal provisions that were not met, the non-compliances uncovered, and the categories of voluntary and required measures applied. In 2020, 41% of notifications failed to refer to a specific standard pertaining to the regulation on personal protective equipment. In contrast, during the two subsequent years, we can observe a systematic decrease in the lack of standard indication. Between 2020 and 2022, the reasons for notifications

against protective masks that occurred most frequently included ineffective filtration and the lack of adequate testing of the product by a competent body. Voluntary and required measures taken by economic entities against non-compliant protective masks that may pose risks to consumers have been characterised.

Implications/Recommendations: The COVID-19 pandemic affected the completeness of notifications for protective masks in the Safety Gate/RAPEX system and the availability of protective masks that were not tested and had ineffective filtration, to consumers. Voluntary and required measures mostly included product withdrawals from the market and from end users. It is recommended that Member State regulatory authorities improve the quality of the notifications provided.

Contribution: Notifications on protective masks are characterised in the Safety Gate/Rapex system in the context of the COVID-19 pandemic. The need for continuous improvement of the effectiveness of European market surveillance and the dangerous products early warning system was identified.

Article type: original article.

Keywords: protective masks, Safety Gate/RAPEX system, COVID-19 pandemic, dangerous products.

JEL Classification: D18, F15, K32.

1. Introduction

The European Commission (EC) has an early warning system for managing safety, called Safety Gate/RAPEX. The database used by this system provides information on dangerous non-food products sold on the EU markets (Neza & Centini, 2016). These include personal protective equipment (PPE) that do not comply with EU requirements, including protective masks (filtering half masks). The availability and protection effectiveness of masks took on unprecedented importance during the COVID-19 pandemic. The dictum to cover one's mouth and nose in public spaces was introduced as a main preventive measure to limit the spread of the SARS-CoV-2 virus (Krzyżak *et al*., 2020). In order to address the shortage of PPE, an essential task during the pandemic, the European Commission issued recommendations which allowed for the introduction of PPE on the EU market without CE marking, for a limited period of time, provided that they were recognised by the relevant market surveillance authorities as compliant with essential health and safety requirements (Commission Recommendation (EU) 2020/403).

The Safety Gate/RAPEX system is key to protecting consumers from hazardous products. Protective masks, as products directly related to public health, require special compliance with standards and regulations. Analysis of the protective masks notifications in the Safety Gate/RAPEX system could provide important

information on changes in the quality and compliance of products launched during the COVID-19 pandemic. During that period there was a surge in demand for protective masks, leading to an increased number of Safety Gate/RAPEX notifications (European Commission, 2021). This is supported by the results of a study by Wierzowiecka and Dąbrowska (2023), which identified a lack of notifications in the first five years examined and a high level of notifications observed in 2020 (158 notifications), followed by a similar number in 2021 (139 notifications) and a decrease in 2022 (55 notifications).

This shows that the COVID-19 pandemic increased the number of protective mask notifications to the Safety Gate/RAPEX system. 98% of all notified protective masks were ones intended for consumer use. From 2020 to 2022, the countries with the highest number of protective mask notifications (45%) included Germany and Belgium, suggesting that these countries had the most operationally efficient market surveillance authorities. Data in the Safety Gate/RAPEX system concerns the number of protective mask notifications in terms of their origin. It was found that, during the study period, 85% of notifications of non-compliant protective masks originated from China (Wierzowiecka & Dąbrowska, 2023). The preponderance of products originating in China in the early warning system has been confirmed by other studies (Pigłowski, 2018a; Purves & Echikson, 2021).

The COVID-19 pandemic had a huge impact on both society and the economy (Mohajan, 2020; Clemente-Suárez *et al*., 2021; Naseer *et al*., 2023). The pandemic led to rapid and frequent changes in the PPE regulations (Goniewicz *et al*., 2020). The rapid introduction of new products to the market may have affected the quality of the testing and certification processes that are indispensable to the CE marking being affixed to protective masks as required. Understanding how the law and standards were applied in practice *vis-à-vis* the Safety Gate/RAPEX notifications concerning protective masks can provide valuable information for future emergencies. In addition, knowledge of the most common actions taken by operators in response to notifications can improve our understanding of how effectively the Safety Gate/RAPEX system protects consumers from unsafe products. It can also help companies better prepare for potential risks as well as avoid recurring problems.

The COVID-19 pandemic may have led to errors or inaccuracies in the Safety Gate/RAPEX notifications, with serious implications for public safety. Research findings on the quality of notifications of various products to the Safety Gate/RAPEX system confirm that the system has gaps and incomplete information (Purves & Echikson, 2021). At the same time, other studies based on the Safety Gate/RAPEX system database fail to provide complete data on the protective mask notifications in this system, especially between 2020 and 2022. Findings from those studies extended to the relationships between the category of notified prod-

ucts and other data including country of origin, level of risk and measures adopted (Muss & Lesiów, 2018; Pigłowski 2018a, 2023). Still other studies have focused on identifying the main risks for consumers, including injury, poisoning, allergic reactions, and choking and suffocation, with the risks varying significantly with the product groups (Hernik, 2022). Studies have also been done on particular product categories reported in the Safety Gate/RAPEX system, such as personal care products (Klaschka, 2017), microbiologically contaminated cosmetics and cosmetic products with too many preservatives (Neza & Centini, 2016), and passenger cars (Pigłowski, 2018b).

For its part, research on protective masks primarily evaluates them for their mechanical, physicochemical and performance properties, including wettability, absorbency and stretch (Mędrowska & Łagan, 2021), filtration efficiency (Mueller *et al*., 2018; Konda *et al*., 2020; Wang *et al*., 2023), total internal leakage (Steinle *et al*., 2018), or analysis of individual respiratory protection by protection classes and contaminant type (Harmata & Kamionek, 2021). Research findings, including a review of standards and test methods for protective masks, have been identified (Forouzandeh, O'Dowd & Pillai, 2021). Pecchia *et al*. (2020) conducted research on regulatory frameworks for the personal protective equipment during crises. Work has also been done on commercially available anti-smog filtering half masks with and without CE marking and their compliance with the requirements of the harmonised standard EN 149:2001 + A1:2009 (Brochocka, Pośniak & Skowroń, 2018). Others have addressed the differences between CE-certified and non-CE--certified masks (Damiani *et al*., 2021).

In addition, in the context of the COVID-19 pandemic, research has been conducted on the requirements and orders to wear protective masks (Badora-Musiał, 2020), the ethical aspects of state-level decisions on the wearing of protective masks (McDonald *et al*., 2020), and public attitudes towards the dictum to cover one's nose and mouth (Krzyżak *et al*., 2020).

Few detailed scientific studies have been done that directly analyse the impact of the COVID-19 pandemic on the Safety Gate/RAPEX protective mask notifications in the context of proper identification of unfulfilled legal provisions, reasons for notifications (such as lack of tests, lack of CE marking), or specific voluntary and required measures taken by economic operators in response to notifications. There remains a need for detailed analyses and consideration of the specific circumstances of the COVID-19 pandemic period. Such studies are crucial for public health and the quality of protective products during a health crisis. Accordingly, this paper seeks an answer to the following questions:

1. Did the COVID-19 pandemic affect the proper identification of legislation and standards in the protective mask notifications to the Safety Gate/RAPEX system between 2020 and 2022?

2. Was the lack of CE marking the most common reason that the Safety Gate/RAPEX system received notifications on protective masks between 2020 and 2022?

3. Did the COVID-19 pandemic affect the performance of required testing of the protective masks the Safety Gate/RAPEX system was notified about between 2020 and 2022?

4. What were the most common voluntary and required measures taken by economic entities as a result of the Safety Gate/RAPEX notifications between 2020 and 2022?

Again, this research assesses the protective mask notifications to the Safety Gate/RAPEX system between 2020 and 2022 in the context of the COVID-19 pandemic. Research methods included the secondary data research (literature evaluation, critique, and document research). The legacy data in the Safety Gate/RAPEX system was the main subject of research.

2. The European Rapid Alert System for Dangerous Products – Safety Gate/RAPEX

The Safety Gate/RAPEX system (Rapid Alert System for dangerous non-food products) is a notification system intended for the rapid exchange of information between the national authorities of countries within the European Economic Area (the 27 Member States of the European Union and Iceland, Liechtenstein and Norway) and the European Commission on measures taken with regard to dangerous products on the market in the European Economic Area. The exchange of information refers to measures and actions taken on dangerous consumer and professional products (excluding food, feed, pharmaceuticals and medical devices) to prevent and reduce the risks for consumers. The Safety Gate/RAPEX system comprises two types of notifications: notifications and notifications for information. This notification system aims to prevent dangerous products from being delivered to consumers and to take corrective measures, such as the withdrawal or recall of such products from the market (Commission Implementing Decision (EU) 2019/417).

The RAPEX system was established under Article 12 of Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety (GPSD). The guidelines for managing the EU Rapid Information System RAPEX and the related notification system were governed by Commission Implementing Decision (EU) 2019/417 of 8 November 2018. These guidelines establish notification mechanisms and related processes, the types of data to be entered, the deadlines for different actions, and define and categorise voluntary and required measures taken by economic entities who introduced dangerous products to the market (Commission Implementing Decision (EU) 2019/417). Voluntary measures are implemented voluntarily by the product-responsible entity, while required

measures are taken as a result of an order from Member State authorities (Vincze, Al Dahouk & Dieckmann, 2019).

In order to enable more effective corrective measures to be taken for products that present a risk on the European market, the RAPEX system was upgraded under EU Regulation 2023/988 on General Product Safety (GPSR). It entered into force on 12 June 2023 and became applicable on 13 December 2024, replacing the General Product Safety Directive (GPSD) 2001/95/EC. In order to provide better clarity and reach consumers more effectively, the abbreviated name has been changed from RAPEX to Safety Gate. Under this regulation, Safety Gate comprises three elements:

– Safety Gate rapid alert system – an early warning system for non-food dangerous products allowing national authorities and the European Commission to exchange information on such products,

– Safety Gate portal – an Internet portal for informing the public and enabling members of the public to lodge complaints,

– Safety Business Gateway portal – an Internet portal enabling businesses to fulfil their obligation to inform authorities and consumers about dangerous products and accidents (EU Regulation 2023/988).

3. Characteristics of the EU Legal Requirements for Protective Masks

Protective masks (filtering half masks) are face masks designed to protect against particles such as solid and liquid aerosols. They are subject to various legal standards around the world. These standards specify certain necessary physical properties and performance characteristics for half masks to comply with a given standard (3M, 2021).

In the European market, filtering half-masks belong to the category "personal protective equipment," which are products manufactured to protect the health and safety of their users. Such products must comply with the Community harmonisation legislation, which provides for their CE marking in accordance with Regulation (EC) No 765/2008 of the European Parliament and of the Council setting out the requirements for accreditation and market surveillance relating to the marketing of products.

The essential requirements for all PPE, as concerns their being made available on the EU market, are set out in Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment (PPER). These requirements apply to design principles, harmlessness, comfort and effectiveness, lightness and durability, while taking into account the category of PPE and the risks identified (Regulation (EU) 2016/425). Personal protective equipment intended to protect the respiratory system should allow one to breathe air in a contaminated

atmosphere. This air must be obtained under a suitable method, here the filtration. The filtration capacity, as well as the tightness of the facepiece, must ensure an adequate level of safety for the user. The materials used for a particular equipment must guarantee proper breathing and adequate hygiene. If the equipment includes filters, the instructions must include information on the maximum storage time for a new filter in its original packaging (Regulation (EU) 2016/425; Brochocka, Pośniak & Skowroń, 2018).

The standard applicable to filtering half masks and harmonised with Regulation 2016/425 is: EN 149:2001 + A1:2009 Respiratory protective devices – Filtering half masks to protect against particles – Requirements, testing, marking.

Filtering half masks are classified according to their filtration efficiency and total internal leakage, i.e. (Majchrzycka, Pośniak & Górny, 2020):

– FFP1 (P1 – aerosol particle penetration of 20%),
– FFP2 (P2 – aerosol particle penetration of 6%),
– FFP3 (P3 – aerosol particle penetration of 1%).

This means that the subsequent numerical values indicate the increasing filtering efficiency of potentially harmful particles in the air. Depending on the type, FFP1, FFP2 and FFP3 masks are impermeable to respectively: 80%, 94% or 99% of harmful aerosol particles 300 nm and above (Badora-Musiał, 2020).

The Safety Gate/RAPEX system does not include medical masks within the scope of Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices (MDR). By covering the mouth and nose, medical masks provide a barrier to minimise the direct transmission of infectious agents between staff and patients and do not constitute personal protective equipment (CIOP, 2021). While their primary purpose is to protect the patient, in certain circumstances they may also protect the user from the splashing of potentially contaminated fluids. Medical masks should comply with the requirements of harmonised standard EN 14683 + AC:2019 Medical face masks – Requirements and test methods (Rubio-Romero *et al*., 2020).

4. Materials and Research Methods

This study analysed the protective mask notifications to the EU Early Warning and Information Exchange System for non-food dangerous products (Safety Gate/RAPEX) during the COVID-19 pandemic (2020–2022). Given the results of the previous research (Wierzowiecka & Dąbrowska, 2023), which indicated a high number of Safety Gate/RAPEX notifications for protective masks during these years and the fact that the majority of non-compliant consumer protective masks originated from China, questions were raised regarding the legal provisions that went unsatisfied, the reasons for the notifications and the preventive measures applied to economic entities. Data from the Safety Gate/RAPEX system were

used to analyse the protective mask notifications between 2020 and 2022. They considered:

– the reason for notifications by type of legislation,
– the types of non-compliance identified,
– the categories of voluntary measures taken by economic entities,
– the categories of required measures applied to economic entities.

The numerical material indicating notifications related to the above factors underwent statistical analysis, using Statistica 13.3, with a chi-square independence test (Stanisz, 2006). The test was applied to verify the hypotheses on the dependence of the frequency of factors differentiating the notifications on the year of the survey. Calculations were not performed for those causes for which – according to the test conditions – there were at least two empirical counts lower than 5. The verification was performed at the significance level $\alpha = 0.05$, based on the test probability value *p*. The test results are presented in Tables 3–6.

Secondary data research methods (literature evaluation, critique, document research) were used alongside the legacy data analysis.

The article is based on the analysis of the EU legislation on product safety and the Safety Gate/RAPEX system, as well as the requirements for personal protective equipment, including protective masks. Other research results on the Safety Gate/RAPEX system and protective masks were analysed.

As the Safety Gate/RAPEX system which produced the data only allows notifications to be filtered according to basic parameters, such as product categories or notifying country, in order to obtain the data indispensable for the analysis, every mask notification during the period under consideration was reviewed.

5. Results

A study done by Wierzowiecka and Dąbrowska (2023) analysed the number of Safety Gate/RAPEX notifications on protective masks launched on the EU market between 2015 and 2022 (Table 1).

Table 1. Number of Safety Gate/RAPEX Notifications of Protective Masks between 2015 and 2022

Years	2015–2019	2020	2021	2022
Number of notifications	0	158	139	55

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

As a follow-up to the study, by using the data from the Safety Gate/RAPEX system, notifications of protective masks between 2020 and 2022 were analysed through the lens of the legal provisions they transgressed (Table 2).

Table 2. Percentage of Safety Gate/RAPEX Notifications on Protective Masks by the Legal Provisions That Constituted Grounds for Notifications between 2020 and 2022

Legal Provision as Grounds for Notification	Percentage		
	2020	2021	2022
Non-compliance with PPER (Personal Protective Equipment Regulation)	97	98	93
Non-compliance with MDR (Medical Devices Regulation)	2	0	0
Non-compliance with GPSD (General Product Safety Directive)	0	1	2
Non-compliance with GPSD (General Product Safety Directive) and BPR (Biocidal Products Regulation)	0	1	0
No indication	1	0	5

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

In 2020, 97% of notifications were for non-compliance with the requirements of Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment (PPER). Non-compliance with the requirements of Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices (MDR) was indicated as the reason for 2% of notifications, while no legal provision was indicated in 1% of notifications. In contrast, in 2021, failure to comply with the requirements of Regulation (EU) 2016/425 of the European Parliament and of the Council (PPER) was cited as the reason for the majority of notifications (98%). Only 1% of the remaining notifications included non-compliance with the requirements of Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety (GPSD). One notification also covered non-compliance with the requirements of Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products (BPR). This notification related to the presence of polyhexanide in the mask fabric. The reasons for the 2022 notifications followed a similar pattern, with 93% related to the PPER regulation, 2% including non-compliance with the GPSD and 5% failing to indicate a legal provision for the notification.

The reason for non-compliance with the requirements of the PPER most frequently involved the non-compliance of protective masks with the requirements of EN 149:2001 + A1:2009 Respiratory protective devices – Filtering half masks to protect against particles – Requirements, testing, marking. A breakdown of the percentage of non-compliance with EN 149 as a reason for non-compliance with the requirements of PPER between 2020 and 2022 and the results of analysis with the use of chi^2 test are presented in Table 3.

Table 3. Percentage of the Safety Gate/RAPEX Notifications of Protective Masks in Relation to the Reasons for Non-compliance with the Requirements of the Personal Protective Equipment Regulation between 2020 and 2022

Reason for Notification	Percentage			Chi^2	*p*
	2020	2021	2022		
Non-compliance with EN 149 standard	59	88	91	29.57	< 0.001
No indication of PPER particular standard	41	12	9	33.41	< 0.001

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

The *p* values allow us to reject both hypotheses – that the frequency of reporting non-compliance with EN 149 standard and the frequency of no indication of the correct standard – is independent of the particular years of the pandemic. In 2020, as much as 41% of the notifications failed to indicate a specific standard referring to the PPER regulation. In the two subsequent years, a steady decrease in the lack of indications of EN 149 standard can be observed (12% in 2021 and 9% in 2022). This indicates that notifications were incomplete in the first year of the pandemic.

This was followed by an examination of the number of the Safety Gate/RAPEX notifications between 2020 and 2022 related to protective masks with regard to the reasons for non-compliance. Table 4 presents the results on the reasons for non--compliance indicated in the notifications, in percentage terms, and the results of analysis with the use of chi^2 test.

Table 4. Percentage of the Safety Gate/RAPEX Notifications of Protective Masks and the Reasons for Non-compliance between 2020 and 2022

Reasons for Non-compliance	Percentage			Chi^2	*p*
	2020	2021	2022		
The product has not been adequately tested	39	27	8	25.48	< 0.001
Ineffective filtration	37	58	85	46.02	< 0.001
Inadequate facial fit	18	10	3	22.42	< 0.001
Inadequate mask design	6	4	2	–	–
Incomplete documentation and/or wrong directions for use	0	1	2	–	–

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

The *p* values allow us to reject all hypotheses of the frequency of reasons for non-compliance (inadequate testing, ineffective filtration and inadequate facial fit) being independent of the year of testing. The frequency of the lack of testing clearly decreased in the subsequent years of the pandemic, which may be indicative of a hasty introduction of protective masks into the market, without adequate research

into the high demand for these products on the market. On the other hand, with the subsequent years of the pandemic, the number of notifications indicating ineffective filtration as the reason for non-compliance clearly rose. This may be because the supervision of testing became better organised as the pandemic progressed, revealing that protective masks were ineffective in terms of filtration.

In 2020, the most frequently occurring reason for non-compliance (39%) was the lack of adequate testing of the product by a competent authority. A slightly smaller number of notifications (37%) identified that the product featured ineffective filtration. 18% of notifications were for improper facial fit, which could lead to an ineffective use of the mask. A year later, in 2021, the most frequently occurring reason for non-compliance (58%) was ineffective filtration. 27% of notifications were for improperly tested product, 10% for improper facial fit and 4% for improper mask manufacture. In 2022, as many as 85% of notifications were for ineffective filtration, while only 3% of notifications were for product not being properly tested. Other reasons were reported occasionally. Note that more than one reason for non-compliance could be given in a notification, and in many cases the product failed to meet the technical requirements for multiple reasons. When non-compliance is identified, economic entities are obliged to take preventive and restrictive measures. Table 5 presents voluntary measures (those taken without the intervention of the Member State authorities) implemented for the protective masks that were reported. It includes the results of analysis under chi^2 test.

Table 5. Percentage of Notifications Including the Application of a Particular Voluntary Measure by Economic Entities between 2020 and 2022

Category of Voluntary Measure		Percentage						Chi^2	*p*
		2020		2021		2022			
Withdrawal of product from the market (including the online market)		48		43		22		18.26	0.003
Withdrawal of product from end users		24		34		36		15.96	0.012
No marketing authorisation granted	suspension of sale	7	24	11	16	18	20	3.21	0.126
	import rejected at border	10		1		0			
	marketing ban	7		3		2			
Destruction of product		4		4		10		–	–
Marking of product with appropriate warnings		0		2		8		–	–
Attachment of required documents		0		1		2		–	–
Taking actions to remove the product defect		0		1		2		–	–

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

In 2020 and 2021, the economic entities opted most often for product recall (48% in 2020 and 43% in 2021). In 2022, this voluntary measure was also taken in numerous, though fewer, cases (22%). Recalling product from end users was another common voluntary measure – 24%, 34% and 36% in the three years, respectively.

The *p* values allow us to reject the two hypotheses on the frequency of the distinguished categories (recall and end-user recall) being independent of the different years of the pandemic. The values in Table 5 indicate that a decrease in the percentage value was observed for the first case, especially in 2022, while there was an increase in the percentage value in the second case, especially after 2020.

For the purpose of testing, a common category of voluntary measures was formed. It concerned actions intended to prevent non-compliant protective masks from entering the market (withholding of sales, rejection of imports at the border, prohibition of marketing). The value $p = 0.126$ does not allow us to reject the hypothesis that the frequency of no marketing authorisations granted is independent of the year of testing. The percentage of this measure remained at a similar level.

In contrast, required measures (those forcing the economic entity to implement preventive, corrective or restrictive actions for products posing risks) are imposed by Member State authorities. Table 6 presents the percentage of notifications including the application of a particular required measure by economic entities between 2020 and 2022 and the results of analysis under chi^2 test.

Table 6. Percentage of Notifications That Included the Application of a Given Required Measure by Economic Entities between 2020 and 2022

Category of Required Measure		Percentage						Chi^2	*p*
		2020		2021		2022			
Withdrawal of product from the market (including the online market)		15		43		44		18.24	0.001
Withdrawal of product from end users		7		34		17		10.96	0.002
No marketing authorisation granted	suspension of sale	0	46	11	16	7	33	12.25	0.002
	import rejected at border	20		1		3			
	marketing ban	26		3		23			
Destruction of product		1		4		0		–	–
Marking of product with appropriate warnings		30		2		3		–	–
Attachment of required documents		0		1		0		–	–
Taking actions to remove the product defect		0		1		0		–	–
Actions taken to remove the product defect		1		0		3		–	–

Source: the authors, based on the Safety Gate/RAPEX database (European Commission, 2023).

It was found that in 2020, for 30% of notifications, Member State authorities ordered that the product be marked with appropriate warnings. In contrast, 26% of notifications referred to a ban on launching the protective masks on the market and 20% to a rejection of imports at the border. The product recall referred only to 15% of notifications. In contrast, in 2021 and 2022, such a required measure was applied most frequently (43%). In addition, in 2021, entities were frequently ordered to withdraw the protective masks from end users (34%) and to halt sales (12%). Required measures that were also frequently applied in 2022 included marketing bans (23%) and product recall from end users (17%).

As in the case of voluntary measures, for the purpose of testing, a common category of required measures was created for efforts aimed at preventing non-compliant protective masks from entering the market. The *p* values allowed for the rejection of all hypotheses on the frequency of the distinguished categories being independent of the particular years of the pandemic. The values in Table 6 show that there was a threefold increase in recall frequency after 2020, while an increase in end user recall frequency was observed after 2020 and a decrease in 2022. There was a nearly threefold decrease after 2020 in actions aimed at granting no marketing authorisation and a twofold increase after 2021.

6. Discussion

Upon undertaking the analysis of the data from the Safety Gate/RAPEX system database, questions were raised regarding the notifications of protective masks relative to the reasons for notifications by type of legislation, non-compliance identified, and measures taken against notified economic entities.

In terms of the correct indication of legal provisions and standards in the notifications of protective masks in the Safety Gate/RAPEX system between 2020 and 2022, it was found that an overwhelming majority (more than 90% each year during the period examined) of non-compliance with the requirements of Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment (PPER) was correctly indicated. In 2020, on the other hand, only 2% of notifications concerned non-compliance with the requirements governing Medical Devices Regulation (MDR) and were specified in detail as non-compliance with the requirements of EN 14683 Medical face masks – Requirements and test methods. The Safety Gate/RAPEX system fails to cover medical devices falling within the scope of Regulation (EU) 2017/745, but in this case the products notified were *de facto* not certified as medical devices by an authorised notified body. The information on the packaging was misleading to the consumer by suggesting that the product met the requirements of the aforementioned MDR. Furthermore, these notifications were made as information notifications.

In 2020, when the COVID-19 pandemic began, many notifications (41%) failed to indicate a specific standard referring to the PPER regulation. In the two subsequent years, the lack of indications of a standard had decreased (12% and 9%), demonstrating that the situation eventually stabilised and that the notifying entities became more knowledgeable. The results indicate that the COVID-19 pandemic had an impact on the completeness of protective mask notifications, particularly with regard to indications of non-compliance with the relevant harmonised standard. This is confirmed by the results of a study conducted in the first half of 2020 and published by European Centre for International Political Economy on the quality of the Safety Gate/RAPEX notifications, which found that many notifications contained basic product information at best. This became apparent at the start of the COVID-19 pandemic with regard to pandemic-related products including masks and disinfectants (Purves & Echikson, 2021). Admittedly, the European Commission requests additional details from national authorities before approving the alerts if insufficient data is provided. However, the European Commission is legally obliged to publish the available information in the Safety Gate/RAPEX system as early as possible, with the assumption that it can be updated later, which is not always the case (Purves & Echikson, 2021). The results of research (Pecchia *et al*., 2020) indicate that the European Union's regulatory framework regarding the PPE certification for a crisis situation such as the COVID-19 pandemic is inadequate.

The lack of CE marking was not the most common reason that the Safety Gate/RAPEX system received notifications on protective masks between 2020 and 2022. Between 2020 and 2022, the most frequently reported reasons for notification were in fact ineffective filtration and a lack of adequate product testing by a competent authority. Products notified had CE marking, but it was not supported by relevant tests confirming compliance with the requirements and at the same time constituting grounds for CE marking. By issuing a declaration of conformity and marking their product with the CE marking, manufacturers were certifying that their product complied with requirements, which was in fact not true. Research has confirmed that protective masks without CE marking failed to meet the protective and performance requirements of EN 149 (Brochocka, Pośniak & Skowroń, 2018) and caused side effects in patients who used them (Damiani *et al*., 2021).

In answer to the question on the impact of the COVID-19 pandemic on the lack of testing of protective masks notified to the Safety Gate/RAPEX system between 2020 and 2022, it was found that in 2020, the reason for notifying authorities about non-compliant protective masks, which occurred most frequently (39%), was that adequate testing was not performed by a competent authority. In 2021, inadequate testing was the second most common reason for notifications (27%), while in 2022 the figure fell precipitously, to 3%, i.e. after decreasing the risk resulting from the COVID-19 pandemic. It can therefore be concluded that the COVID-19 pandemic

led to the required testing of protective masks about which the Safety Gate/RAPEX system was notified between 2020 and 2022. The relevance and types of testing required for protective masks to be effective in the context of the COVID-19 pandemic is highlighted by Forouzandeh, O'Dowd and Pillai (2021). In contrast, Pecchia *et al*. (2020) found that standards for protective masks that can be maintained under normal conditions become untenable in EU Member States during crises.

We can observe that, during the period under study, filtration coming in below the manufacturer's guaranteed values was the main reason for notifications. Insufficient particle retention in the material and/or total filtration capacity were the main causes of the sub-par performance. These two reasons were cited in more than half of the notifications (35% in 2020, 58% in 2021, 85% in 2022). Inspections showed that protective masks failed to provide manufacturers' guaranteed filtration performance. Were additional protective measures not applied, an excessive volume of particles or micro-organisms could pass through the masks, increasing the risk of infection. Indeed, Wang *et al*. (2023) highlighted the urgent need for improved standards of filtration efficiency as well as the fit of protective masks to improve their overall protective efficiency against COVID-19.

The fourth question – What were the most common voluntary and required measures taken by economic entities as a result of the Safety Gate/RAPEX notifications between 2020 and 2022? – proved possible to answer. In 2020, numerous required measures were taken. These included orders to mark product with appropriate warnings (30%), bans on placing the product on the market (26%) and the halting and rejection of imports at the border (20%). These figures are supported by the results of the Safety Gate/RAPEX notification survey from January to August 2020, which found that not all dangerous products listed in the Safety Gate/RAPEX system were recalled. Some were simply banned from import, while others had a risk warning printed on them (Purves & Echikson, 2021). This may be indicative of Member States' non-standard approach during the COVID-19 pandemic towards protective masks the Safety Gate/Rapex system received notice on. In the two subsequent years, the most frequently cited required measure was product recall (including in online markets). Considering the entire period under study, measures involving protective mask recalls and recalls from end users accounted for more than half of the required actions taken.

Voluntary measures taken on the initiative of the economic entity which launched the product or distributed it on the market with regard to protective masks presenting some risk mostly involved product recalls and/or recalls from end users (in total 72% in 2020, 77% in 2021, 58% in 2022). This may indicate that economic entities were responsible, at least those acting in the absence of intervention from a Member State authority or under agreements concluded with these authorities.

The survey involved some limitations mainly related to the heterogeneity and incompleteness of notifications, as specified above. Notifications should contain as complete information as possible. Where required information is not available at the time of notification, the notifying Member State shall clearly indicate it in the form, together with an explanation to that effect (Commission Implementing Decision (EU) 2019/417).

7. Conclusions

The results obtained allow for the following conclusions:

1. The COVID-19 pandemic had an impact on the completeness of protective mask notifications to the Safety Gate/RAPEX system, particularly with regard to the lack of indication of a harmonised standard that was not satisfied.

2. The COVID-19 pandemic had an impact on the availability, to consumers, of protective masks that had not been tested.

3. Ineffective filtration was the most common reason that Safety Gate/RAPEX notifications of protective masks were made between 2020 and 2022.

4. Voluntary measures taken by economic entities and required measures taken against economic entities which launched non-compliant protective masks mostly included protective mask recalls and recalls from end users.

A statistically significant relationship was found between the differentiating factors and the years of the COVID-19 pandemic. Only in the case of the frequency of voluntary measures existing in the notifications, which involves no marketing authorisation granted, was no statistically significant relationship found.

In the case of protective masks, especially in the context of pandemic COVID-19, the Safety Gate/RAPEX system played an important role in monitoring and recalling unsafe products from the market. It is nevertheless recommended that Member State regulators take measures to improve the quality of notifications submitted. Well-documented notifications expedite public outreach and effective recalls of dangerous products. The COVID-19 pandemic highlighted weaknesses in the market surveillance system and increased the need for reform. Recommendations related to enhancing the notification system are confirmed by the European Commission's actions and the modernisation of the Safety Gate early warning system, as foreseen by EU Regulation 2023/988 on general product safety (GPSR).

Authors' Contribution

The authors' individual contribution is as follows: Joanna Wierzowiecka 95%, Victoria Dąbrowska 5%.

Conflict of Interest

The authors declare no conflict of interest.

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Geopolitical Risk and Military Spending in Poland

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ABSTRACT

Objective: To examine the impact of geopolitical risk on military spending in Poland in the years 1993–2022.
Research Design & Methods: Autoregressive distributed lags, error correction, and Granger causality test were used.
Findings: Polish budgetary spending on defence is influenced by geopolitical risk in both the short and long term.
Implications/Recommendations: An increase in geopolitical risk motivates the Polish government to increase its military spending.
Contribution: The research verifies the theoretical nexus between external security risk and defence burden in Poland, a study which had never been done.

Article type: original article.

Keywords: external security risk, defence burden, demand, expenditure, cointegration.

JEL Classification: C52, F51, H56.

1. Introduction

Geopolitical issues are garnering increasing attention due to the ongoing Russian-Ukrainian conflict, which places society and security at the heart of academic and public debate. As Smith (1980) observes, national security is both an objective measure and a subjective peace of mind that is based on the social sense of freedom from being attacked. According to the theory, war and terrorism have the greatest impact on the perception of national security in the international dimension. When external threats increase, individuals turn to the government and express their support for military spending (Eichenberg & Stoll, 2003). Rising defence spending is a clear sign to citizens that their government seeks to improve the country's military capability,[1] and to restore a sense of security.

While numerous studies have been done on the nexus between external security risk and economic security (Khan, Khurshid & Cifuentes-Faura, 2023), fewer have examined the relationship between geopolitical risk and military expenditures, and none have looked at geopolitical risk and military spending in the countries of Eastern Europe, though their strategic and geopolitical importance has risen substantially. Certainly, part of the problem resides in the lack of a well-published proxy for geopolitical risk (Sweidan, 2023).

To fill this void in the literature, we examined the effect of geopolitical risk on Polish military expenditure. The text is structured as follows. The first section presents the connections between the state demand for defence and geopolitical risk index, followed by an analysis of the values of geopolitical risk for Poland. The second part reports on the autoregressive distributed lags model that was used to examine whether the shifts in the geopolitical risk index had an impact on Polish fiscal spending on the army. The model was enhanced by an error correction mechanism and the Granger causality test. The final section discusses the results and conclusions.

The research proves that the geopolitical risk has a positive impact on military spending, both in the short- and long-term perspective. It also confirms that the Polish government reacted to changes in the external security risk by adjusting defence expenditure during the period under consideration.

2. Geopolitical Risk and Demand for Defence

The Geopolitical Risk Index (heather GPR) is a relatively new formula for measuring risks associated with wars, terrorist acts, and tensions between nations or political agents that affect the normal course of international relations. GPR meas-

[1] More trained soldiers, reliable equipment, proven procedures, etc. demonstrate the country's defensive strength in the event of war or conflict.

ures the possibility of an adverse event realisation and escalation by calculating the likelihood of both violent and non-violent acts occurring (Caldara & Iacoviello, 2022). The GPR index is constructed based on the automated text-search done within the electronic archives of six American, three British, and one Canadian newspapers.[2] These newspapers have high circulation, consistent coverage of international political events, and digital archives that span a long period (Caldara & Iacoviello, 2022). This approach to measurement reflects the intention to capture events that have global dimension and repercussions.

GPR is computed monthly, by examining the number of articles pertaining to adverse geopolitical events in each newspaper as a proportion of the total number of news articles. Eight distinct categories of text-related issues are tracked: war threats, peace threats, military build-ups, nuclear threats, terror threats, beginning of war, escalation of war, and acts of terror (Caldara & Iacoviello, 2022). The index takes values from 0 to 1. The greater the value of GPR, the higher the external risk to national security. The GPR measures the frequency with which articles discuss the geopolitical issues outlined above, using this formula:

$$\text{GPR} = \frac{\text{Articles mentioning adverse geopolitical events}}{\text{Total number of articles}}.$$

The GPR database provides access to the historical GPR (index since 1900), and the recent GPR (index since 1985). GPR is formulated as both a global and a national indicator (currently for 44 countries). The global GPR quantifies negative activities and security threats occurring around the world, but it affects the sense of security in different ways in different countries. The GPR for a nation counts country-specific factors such as geographic location, history, and social characteristics. Therefore, an index handled by country more accurately represents the national security situation because it captures the difference stemming from the strictly domestic factors that make one country more vulnerable to the same external risk than another due to the distance to the hostile country and the length of common borders.

Unfavourable events (acts and threats) that are calculated as GPR, such as terrorism or war, represent, at the same time, an external risk to national security. The security environment, in turn, is widely recognised as a fundamental factor influencing the demand for defence (Smith, 1980). Although national security encompasses both external and internal threats, as stated by Clements, Gupta and Khamidova (2021), advanced economies are more concerned with external secu-

[2] *Chicago Tribune*, *The Daily Telegraph*, *Financial Times*, *The Globe and Mail*, *The Guardian*, *The Los Angeles Times*, *The New York Times*, *USA Today*, *The Wall Street Journal*, and *The Washington Post* (Caldara & Iacoviello, 2018).

rity threats (Okamura, 1991). External security risk can be qualified as a strategic factor for more military spending owing to the objective perception of risk as well as public perception of insecurity (subjective one). Subjectivity plays a part here since individuals have a good deal of access to information about the global security environment that affects their perception of threats. In conclusion, increasing insecurity in society leads governments to spend more on the military (hereafter military spending, or MS) to build up defence capabilities and restore the perception of security (Waszkiewicz & Taksás, 2023).

3. Quantifying External Security Risk – Empirical Literature Review

Since the Cold War, external threats have been associated with arms race theory, which focuses on the negative cooperation between nations in conflict. In effect, both opponents invest more and more in armament and manpower. Authors who have employed this methodology sought to assess external security risk by analysing the quantity of soldiers in the nations in conflict, their equipment, the quantity of long-range missiles and bombers (Murdoch & Sandler, 1982). The arms race model shows that both adversaries experience a spiral increase in budgetary outlays on the army, but neither feels safe, resulting in a security dilemma (Herz, 1950). Terrorist attacks in the USA and Europe at the start of the 21st century led researchers to link external threats to transnational terrorist incidents (Mickolus *et al*., 2011). The number of causalities (deaths) as an index gains interest not only because of terrorism, but also because of the wars (in Afghanistan and Iraq) in the first decade of the 21st century (Goldberg, 2018). Both George and Sandler (2018) and Flores (2011) consider a given country's location relative to its allies and potential enemies to determine the scale of the peripheral security threat.

Some authors have proposed their own indicators to calculate external security risk. Collier and Hoeffler (2002) estimated an arms race multiplier to demonstrate how rising expenditure on the army impacts the strategic policy of neighbouring states. Aizenman and Glick (2003) developed an indicator for the external threat a nation faces based on the number of wars it has been involved in, the number of adversaries it encounters in each war, and the duration of each war. Nordhaus, Oneal, and Russet (2012) have developed a means of predicting probability that a nation will be involved in a fatal militarised interstate dispute. Hou and Chi (2022) employ indicators of tensions based on data gleaned from the Global Database of Events, Language, and Tone (GDELT).

The GPR constructed by Caldara and Iacoviello (2022) presents a new method of assessing external security threats both to the world, and specific nations. Presented gauge records a duality of national security (Ficoń, 2020) quantifying the continuing process and the changing states of external security risk to the nation. In a similar

vein, Khan, Su and Rizvi (2022), employing the panel bootstrap Granger causality method, examined a causal link between GPR and MS in 1991–2018 in China, India, and Saudi Arabia. Demirci and Ayyıldız (2023) likewise conducted a causality analysis on a panel based on GPR to MS. It confirmed the existence of a dependency for Mexico, Indonesia, South Korea, and Turkey during the period 1990–2021. Using the autoregressive distributed lags model, Sweidan (2023) examined the impact of GPR on MS for the United States (1950–2021). He does not provide any evidence of causality between GPR and MS.

In summary, prior to 2020 researchers used a variety of indicators to measure the scale of external security risk, and they were beneficial in particular circumstances – but not for comparative analysis. Furthermore, security risk was an additional explanation variable, not the leading one in the research. Lastly, while numerous studies examining external security risk based on the GPR index have been published, the number of papers looking at military expenditure remains insufficient.

4. Geopolitical Risk Index for Poland

For the nations of Eastern Europe, external security threats are intrinsically linked to Russia. The Russian-Ukrainian war has only further driven home this reality. Poland was chosen for analysis for two reasons. First, it has played a leading role in providing support to Ukraine since the start of the conflict (Francis, 2023). Second, the GPR index is calculated only for two post-soviet countries, Poland and Hungary. Although both states share a border with Ukraine, the Polish frontier is five times longer. The geopolitical situation of Poland is also different, as it plays a strategic role for Ukrainian defence. With this in mind, we used the recent GPR, which recorded the average annual trend presented in Figure 1.

Figure 1 shows GPR values for Poland (POL), which reveal that the first security shock happened in 2014, leading values to move higher, where they remain today. Having said that, GPR index was not stable in the years 1993–2013. In any case, the scale of the changes in GPR cannot be compared to the events of 2014, 2021, or 2022, all of which, and particularly the latter two, sent the index precipitously higher.

In 2021, the second shock in GPR occurred. It was linked to the issue of migration at the Polish-Belarusian border that had started in July of that year. From a strategic perspective, the refugee crisis presents non-confrontational operations running on non-military ground within the framework of a hybrid war (Hall, Flemming & Shotter, 2021). Certainly, such actions had a detrimental impact on Poland's national security. The third shock in GPR was recorded when the Russian--Ukrainian conflict began, causing the GPR index to peak for Poland in 2022.

When examining Poland, the key question is how MS reacted to the trajectory of the GPR. Whether the state respond to the increasing external security threat or whether the jumps in GPR happened after the rise in budgetary spending on the army? Figure 2 presents a preliminary answer.

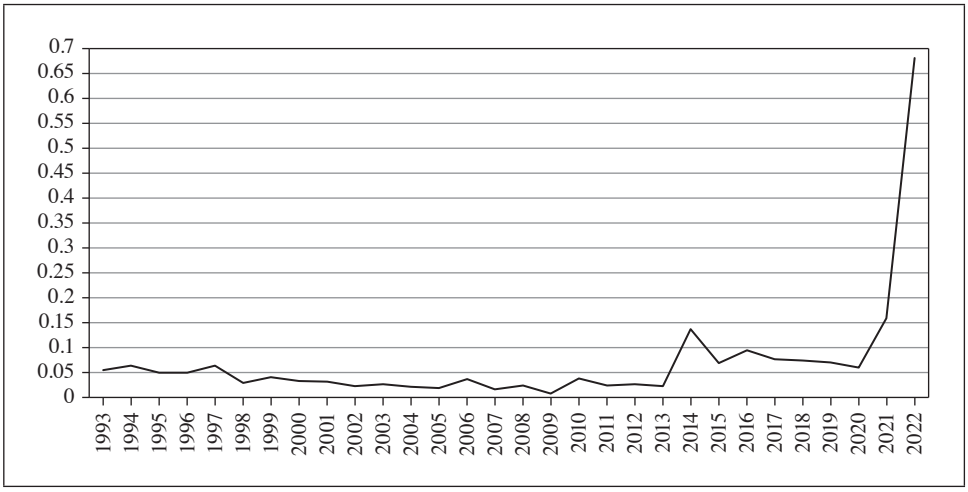

Fig. 1. GPR for Poland (Annual Average), 1993–2022
Source: the author, on the basis of GPR Statistics.

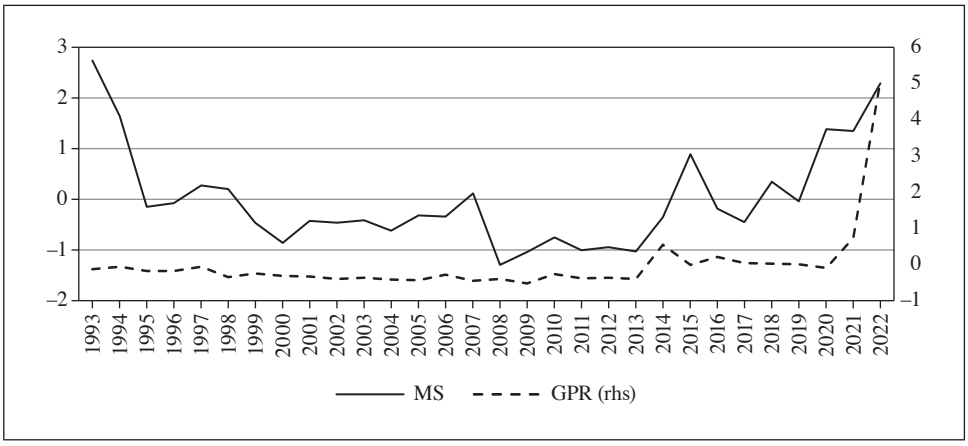

Fig. 2. MS and GPR in Poland (Annual Average, Normalised Values), 1993–2022
Source: the author, on the basis of GPR Statistics and SIPRI Statistics.

As Figure 2 shows, a relatively small increase (decrease) in GRP induced greater adjustment within budgetary spending on defence. That is clearly visible after 1997, 2006, 2014, and more clearly after 2020. The changes in the trends of GPR and MS justify an in-depth econometric analysis to look for a causal relationship.

5. Empirical Analysis

5.1. Arrangements and Data

According to Smith (1980), the demand for defence (MS) is a function of civilian output in the national economy (GDP) and security environment that is associated with external security risk (GPR). On that basis, the following model was constructed:

$$MS = \text{function}(GDP, GPR).$$

Benoit (1973) examined the relationship between economic growth and military spending, while numerous empirical studies have provided mixed results (Topcu & Aras, 2017; Topal, Unver & Türedi, 2022). Both Eichenberg and Stoll (2003) and Hartley and Russett (1992) showed that society anticipates the government will allocate more funds to the military sector when external threats increase. Table 1 presents the characteristics of time series from the literature.

Table 1. Characteristics of Applied Time Series

Data	Source	Time Range	Units
Military spending (MS)	SIPRI Statistics	1993–2022	percent of GDP
Geopolitical Risk Index (GPR)	GPR Statistics	1993–2022	points
Gros domestic product (GDP)	World Bank Statistics	1993–2022	growth rate (year/year)

Source: the author.

Concerning Table 2, original data present annual frequency with 30 observations each. GPR is characterised by the highest instability, while MS exhibits the lowest.

Table 2. Descriptive Statistics (Original Data)

Statistics	Variable		
	MS	GDP	GPR
Mean	0.019	4.161	0.070
Maximum	0.024	7.102	0.681
Minimum	0.017	–2.020	0.007
Standard deviation	0.001	2.035	0.120
Observations	30	30	30

Source: the author.

Furthermore, two difficulties occurred during the data preparation. First, the GPR statistics needed to be recalculated from monthly to annual data (the average of 12 months). Second, all input values were converted into logarithms to improve the data features. As the GDP growth rate was negative for the years of the COVID-19 pandemic, we changed the logarithm base according to the formula: $\min(Y + a) = 1$, where a remains constant (3.020). This converted all observations to positive ones before log transformation.

5.2. Method Applied

The autoregressive distributed lags (ARDL) model was proposed by Pesaran and Pesaran (1997) and Pesaran, Shin and Smith (2001). In that procedure, bound test cointegration is used to verify long-run relations between integrated variables. Traditional cointegration methods may suffer from the difficulties with endogeneity, while the ARDL method can distinguish dependent and independent variables. Thus, estimates obtained from the ARDL method are unbiased and efficient, since they avoid the problems that may arise in the presence of serial correlation and endogeneity (Dimitraki & Win, 2021). If the cointegration relation exists, the model can be changed into an error correction model (ECM) that combines short-run dynamics with long-run equilibrium (Nkoro & Uko, 2016). As the only joint causality is established by the ECM, we also applied the Granger causality test to find the long-term relationship between individual regressors and the dependent variable.

The ARDL technique was selected for its efficiency with small samples. Furthermore, The ARDL model also makes it possible to use variables with varying order of integration, including initially non-stationary data. The ADF unit roots test was therefore first applied to evaluate the stationarity of the data. Then, using the test for optimal lag specification (Akaike, Schwarza, and Hanna-Quinna), the appropriate lag interval and leading information criterion were selected for our model.

As each system is susceptible to external shocks (shifts in economic policy or unexpected geopolitical events), it is advisable to verify whether there are any structural breaks in the model. A DF unit root with break test for individual series, and Bai-Perron test to seek for time of structural break were therefore performed. The breaking points were then verified using the Chow test.

The final ARDL model was then formulated as a linear equation (equation 1).

$$\begin{aligned}\Delta \ln \mathrm{MS}_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln \mathrm{MS}_{t-i} + \sum_{i=1}^{p} \beta_{2i} \ln \mathrm{GDP}_{t-i} + \sum_{i=1}^{p} \beta_{3i} \ln \mathrm{GPR}_{t-i} + \\ + \beta_4 \Delta \ln \mathrm{MS}_{t-i} + \beta_5 \Delta \ln \mathrm{GDP}_{t-i} + \beta_6 \Delta \ln \mathrm{GPR}_{t-i} + \varepsilon_t,\end{aligned} \tag{1}$$

where ln represents a natural logarithm, $t = 1, 2$ determines the time (lag) and ε_t identifies the standard error terms.

Based on the ARDL model, a bound cointegration test that assumes a maximum of one cointegration relationship was conducted. The verification procedure is connected to asymptotic critical values between two extremes, namely between the lower bound critical value I(0) and the upper bound critical value I(1). The only test statistics above I(1) confirm the existence of the cointegration vector. ECM is derived from the ARDL model through a simple linear transformation that integrates short-run adjustments with long-run equilibrium without losing long-run information (equation 2). Error correction term (ECT) informs how quickly long--term balance is restored in the model.

$$\Delta \ln MS_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln MS_{t-i} + \sum_{i=1}^{p} \beta_{2i} \ln GDP_{t-i} + \\ + \sum_{i=1}^{p} \beta_{3i} \ln GPR_{t-i} + \alpha_1 ECT_{t-1} + \varepsilon_t. \tag{2}$$

With a view to completing the model's correctness, it was evaluated for serial correlation, normal distribution, heteroscedasticity, model stability, and functional form. To do this, four tests were used: the Breusch-Godfrey, the Breusch-Pagan, the Jarque-Bera, cumulative sum of squares (CUSUM), and the Ramsey reset.

The Granger causality test yields crucial information about the dependency between individual regressors and the dependent variable. If the past observations of X help to predict the current state of Y, there is a causal relationship between time series (Granger, 1969). Our examination focuses on the two equations in the GPR-MS relation (3a and 3b). A similar pair of equations needs to be investigated for GDP-MS (3c and 3d).

$$LMS_t = \sum \alpha_1 LMS_{t-i} + \sum \alpha_2 LGPR_{t-i} + \varepsilon_{i,t} \tag{3a}$$

$$LGPR_t = \sum \beta_1 LGPR_{t-i} + \sum \beta_2 LMS_{t-i} + \varepsilon_{i,t} \tag{3b}$$

$$LMS_t = \sum \beta_1 LMS_{t-i} + \sum \beta_2 LGDP_{t-i} + \varepsilon_{i,t} \tag{3c}$$

$$LGDP_t = \sum \beta_1 LGDP_{t-i} + \sum \beta_2 LMS_{t-i} + \varepsilon_{i,t} \tag{3d}$$

5.3. Calculations and Outcomes

We began by examining the order of integration for MS, GDP, and GPR based on augmented Dickey-Fuller test (Table 3) and Phillips-Perron test (Table A.1 in Appendix 1). In all tests, a significance level of 5% or 1% was accepted.

Both methodologies confirm that our time series exhibits a mixed order of integration.[3] The dependent variable is I(1), whereas the independent variables present

[3] The KPSS test confirms the identical order of integration for individual variables.

I(0) and I(1) order of integration. The ARDL model can thus be said to be well--adjusted to the characteristics of the data employed.

Table 3. Test for Unit Roots (ADF)

ADF Unit Roots	I(0)		I(1)	
	T-stat.	*p*-value	T-stat.	*p*-value
LMS				
Intercept	–2.61	0.10	–5.51	0.00***
Trend and intercept	–2.55	0.29	–6.39	0.00***
None	–0.05	0.69	–5.64	0.00***
LGDP				
Intercept	–5.62	0.00***	–	–
Trend and intercept	–6.00	0.00***	–	–
None	–0.89	0.31	–6.46	0.00***
LGPR				
Intercept	0.13	0.96	–7.62	0.00***
Trend and intercept	–1.71	0.71	–8.45	0.00***
None	–0.80	0.36	–7.63	0.00***

Notes: Significance level: *** 1%.

Source: the author.

Next, a possible lag interval was verified (Table A.2 in Appendix 1), with lag-length selection based on the minimum information criteria values. The results obtained show that the AIC criteria plays a leading role. There should be no more than 2 lags in the final model to guarantee a stable economic system. ARDL model (1.0.1) was selected and is presented in Table 4.

We also examined whether there was a structural break in the particular time series and in the whole model was examined, and models were built with a structural break according to Table A.3 in Appendix 1. Unfortunately, none of them proved that the dummy variable is significant. The main model was therefore reparametrised, ultimately yielding an ECM model (Table 5).

The results proved ECT can restore over 60% of long-term equilibrium to the system. That indicates that all regressors (MS, GDP, and GPR) jointly impact MS. From the long-term perspective, GDP presents a negative sign whereas GPR is a positive one. The pairwise Granger causality test was then applied to establish long-term causality between individual independent variables and the dependent one. The results are presented in Table 6.

Table 4. ARDL Model and Bound Cointegration Test

Variable	Coefficient	Standard Error	T-stat.	*p*-value
ARDL (1.0.1)				
LMS(–1)	0.35	0.13	2.56	0.02**
LGDP	–0.32	0.02	–1.64	0.11
LGPR	0.03	0.01	2.41	0.02**
LGPR(–1)	0.03	0.02	1.95	0.06***
C	–2.27	0.52	–4.34	0.00
R-sq.	0.70	Mean dependent var		–3.93
Adj. R-sq.	0.66	S.D. dependent var		0.07
F-stat.	14.44***	AIC		2.23
Bound Cointegration Test				
F-stat. = 8.10	5%		1%	
Sample size	I(0)	I(1)	I(0)	I(1)
30	3.53	4.42	5.15	6.26
Asymptotic	3.10	3.87	4.13	5.00

Notes: Significance level: *** 1%, ** 5%.

Source: the author.

Table 5. Error Correction Model (ARDL 1.0.1)

Variable	Coefficient	Standard Error	T-stat.	*p*-value
LMS(–1)	–0.64	0.14	–4.69	0.00***
LGDP	–0.03	0.01	–1.64	0.11
LGPR	0.06	0.01	4.04	0.00***
Cointegration Coefficients				
LGDP	–0.05	0.03	–1.44	0.16
LGPR(–1)	0.10	0.02	4.75	0.00***
C	–3.51	0.11	–28.08	0.00***

Notes: Significance level: *** 1%.

Source: the author.

In the long-term perspective, MS is strongly impacted by GPR. The cumulative effect of a GPR shock on MS unfolds over four years (Fig. A.1 in Appendix 2). A rapid increase in MS reflects a government's reaction to external security risk. Such a scenario can happen as the result of a trade-off within the budget (Waszkiewicz, Kutasi & Marton, 2025). We can also conclude that MS (after shock) remains higher than it was before due to the continuation of armament programmes and the

Table 6. Pairwise Granger Causality Tests

Null Hypothesis	F-stat.	*p*-value
LGDP does not Granger cause LMS	3.29	0.055*
LMS does not Granger cause LGDP	0.70	0.505
LGPR does not Granger cause LMS	5.71	0.00***
LMS does not Granger cause LGPR	1.38	0.27

Notes: Significance level: *** 1%, * 10%.

Source: the author.

Table 7. Diagnostic Tests for ARDL Model (1.0.1)

Verification	Test	Stat	*p*-value
Normal distribution	Jarque-Bera	1.42	0.49
Serial correlation	Breusch-Godfrey	0.17	0.84
Heteroscedasticity	Breusch-Pagan	0.81	0.59
Functional form	Ramsey RESET	1.14	0.33
Model stability	CUSUM sq.	Stable	

Source: the author.

increased number of soldiers. Furthermore, MS might be impacted by GDP in the long run because the significance level is only slightly above 5%. In consequence, the question still requires further empirical analysis. Nonetheless, there is no impact from MS to GDP or to GPR. Lastly, the system's correctness was examined based on residuals. All diagnostic tests show that the ARDL model was specified correctly (Table 7). CUSUM square test confirms the model's stability (Fig. A.2 in Appendix 2).

6. Results Discussion

Due to the recent increase in GPR, we have attempted to examine its effects on national defence. Theory has shown that a perception of insecurity can pose a determinant of the scale of military spending. Yet, there is a lack of literature examining this issue in the context of countries from NATO's eastern flank. Both the country's geographical location and the accessibility of the GPR for the individual states of Eastern Europe impacted the decision to select Poland for analysis. The objective was to examine whether Polish military spending reacted to changes in GPR between 1993 and 2022. To achieve this goal, the ARDL model was used with an error correction mechanism, followed by the Granger causality test.

The ARDL model has confirmed a one-directional causality between GPR and MS, both in a short- and long-term perspective. A positive relation indicates that a growing external security risk impacts the rise in public spending on defence. Timely government responses can turn insecurity into a temporary driver, but this requires avoiding time lags in budgetary decisions regarding higher defence expenditure.

Our empirical outcomes are in line with theory presented by Smith (1980), Okamura (1991), and Eichenberg and Stoll (2003): external security threats, when rising, urge national government to finance deterrence capability. The results are also convergent with our preliminary analysis of statistical figures for Poland, indicating an interrelation between the trends in original data. Furthermore, our findings are in accordance with empirical studies conducted by Khan, Su and Rizvi (2022) and Demirci and Ayyıldız (2023). Further, the outcomes confirm that it is highly possible that there is one-directional causality from GDP to MS. This could suggest that rising military spending is not an effect of economic growth, but of temporal shocks in the geopolitical environment.

This contribution advances the literature in three ways. First, it confirms that GPR has a robust impact on MS. This means that people might want the government to spend more money on the army when there are more strategic dangers outside. Second, policymakers must bear in mind that timely budgetary reaction mitigates a sense of insecurity within society. Lastly, GPR is a reliable measure of external security risk, being capable of expressing the state's insecurity as a current state and a continuous process.

The strategic approach to military spending (its level) is an interesting academic issue today. Furthermore, there are other opportunities for research on GPR and MS, including nonlinear methods. At the same time, numerous theoretical and empirical inquiries remain unanswered, such as whether the increase in military expenditure in one country can adversely impact external security risk in neighbouring states.

7. Concluding Remarks

The Russian incursion on the Crimean Peninsula and the conflict between Russia and Ukraine that started in 2022 led to escalation and materialisation of military and paramilitary threats in the region. The changing geopolitical environment, including Poland's growing strategic role, should encourage us to examine if external security risks have affected Polish defence expenditure. On theoretical grounds, the relationship between security risk and budgetary outlays on the army is undisputed, though empirical research returns mixed results.

Taking this all into consideration, we examined the nexus between GPR and MS in Poland for the last three decades. We have found that GPR has had a positive

impact on the level of MS in Poland, both in a short- and long-term perspective. It was noted that GPR can induce only a temporary security shock, provided that the government's budgetary response is adequate and not delayed. Furthermore, GPR might be a reliable indicator for measuring the duality of national security.

Conflict of Interest

The author declares no conflict of interest.

Appendix 1

Table A.1. Unit Roots Test (Phillips-Perron)

Phillips-Perron	I(0)		I(1)	
	T-stat.	*p*-value	T-stat.	*p*-value
LMS				
Intercept	–2.67	0.09*	–5.64	0.00***
Trend and intercept	–2.46	0.34	–14.16	0.00***
None	–0.06	0.69	–5.77	0.00***
LGDP				
Intercept	–5.69	0.00***	–	–
Trend and intercept	–8.57	0.00***	–	–
None	–1.50	0.12	–27.14	0.00***
LGPR				
Intercept	–0.84	0.79	–7.61	0.00***
Trend and intercept	–1.38	0.84	–13.46	0.00***
None	–0.87	0.32	–7.63	0.00***

Notes: Significance level: *** 1%, ** 5%, * 10%.

Source: the author.

Table A.2. Lags Selection

Variable	AIC	SC	HQ	Final Selection
LMS	1	1	1	1
LGPR	2	2	2	2
LGDP	0	0	0	0
Model	2	1	2	2

Source: the author.

Table A.3. Structural Break Points

Individual Time Series			
DF unit root with break	T-stat.	*p*-value	Year
LMS	4.49	0.044**	2019
LGPR	3.24	0.539	2014
LGDP	5.63	0.000***	1999
System Break Point			
Multiple breakpoint test (Bai-Perron test)	F-stat.	Crit. value	Year
	9.28	8.58	1999
Chow Test			
Year	F-stat.	*p*-value	
1999	0.27	0.76	
2014	7.82	0.00***	
2019	7.34	0.00***	

Notes: Significance level: *** 1%, ** 5%.

Source: the author.

Appendix 2

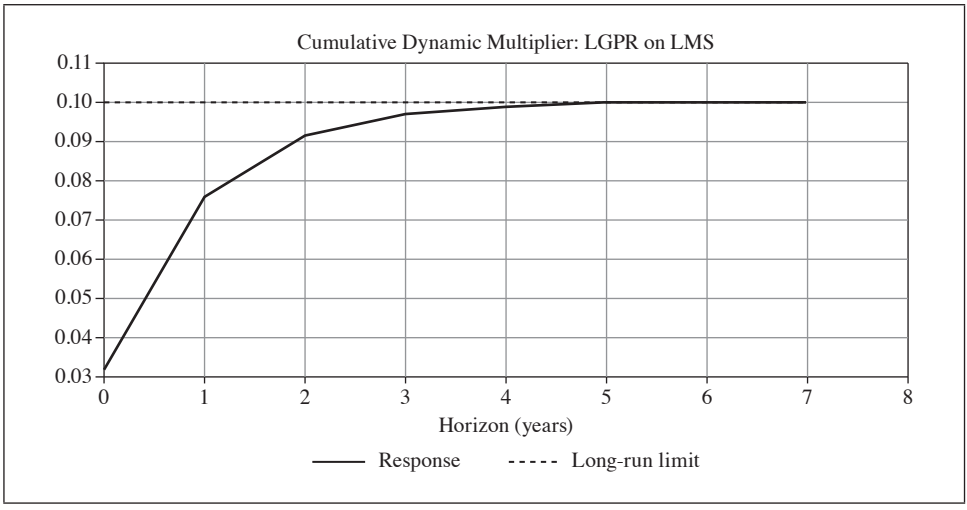

Fig. A.1. GPR Shock and MS

Source: the author.

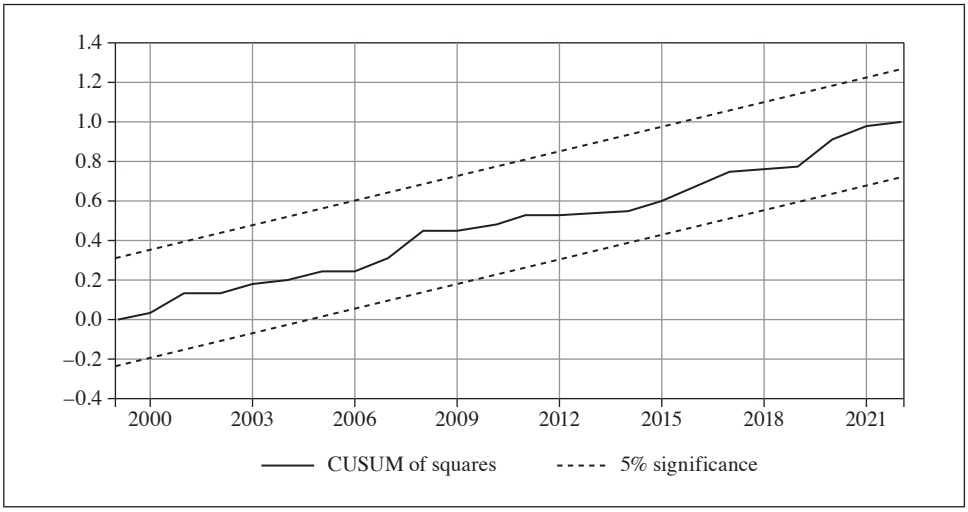

Fig. A.2. CUSUM Square Test

Source: the author.

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