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CONTENTS

EDITORIAL

The actualities of intellectual development – as revealed by the annual publications of international experts via WEF, INSEAD, and WIPO, amongst others (Global Risks Report, 2021; Global Innovation Index; Digital Economy and Society Index, DESI) – require more sophisticated evaluations of universal, political, and biological risk, environmental degradation, and societal fractures. New criteria and methods of their economic assessment are of special importance now. At the same time, some authors often speculatively include the keywords of pandemic, COVID-19, sustainability, smart economy, or human capital in the titles and/or abstracts of their manuscripts without presenting their own research results in these fields.

The current issue – IE-2021:2 – is dedicated to a variety of research topics, beginning with the digitalization of management (G. Parwita et al, L. Trachenko et al., M. Hamad, P. Polycronidou et al., Z. Chvátalová et al.), moving through the problems of financial engineering, fintech, and auditing (E. Pennings et al.), before considering educational potential (Dolgikh) and household demand (Kotykova et al), and finishing with problems of communication (Signore et al) and economic security (Zubko).

A broad international group (G. Parwita et al.) examined the nexus between human resources, knowledge management (KM), and creativity and their influence on organizational innovation capability in SMEs, suggesting some metacognitive strategies for KM practices. L. Trachenko et al. suggested a new optimization model for enterprise business management (engineering services), accounting for pandemic restrictions. Z. Chvátalová et al. evaluated the application of quantitative methods for the modification of business models on the basis of a sociological survey.

Utilizing DESI and new legislative frameworks, P. Polycronidou et al. considered the structural ICT labor deficit from a European perspective via the digitalization of employment. K. Ekimova and E. Dolgikh et al. assessed the educational potential of regional populations, presenting regressions between the factors that characterize educational activity and the technical, material, and informational basis of education.

The changes in the public funding of sustainable health care were reviewed by Karnitis et al. using benchmarking algorithms for higher performance levels and balancing cross-sectoral links during post-COVID-19 recovery. The efficiency of companies operating in the pharmaceutical industry (Visegrad) was evaluated by M. Hamad and T. Tarnoczi via the use of the VAIC model to determine the correlation between selected profitability ratios. The influence of financial expertise was reviewed by E. Pennings et al., who analyzed the findings from US markets by determining audit fees and audit quality.

O. Kotykova et al. presented interesting data from a wide survey of household food demand protection based on income level in Ukraine, in accordance with the UN Sustainable Development Goals. This issue of IE finishes with an article from F. Signore that considers the aspects of emotional exhaustion and their impact on communication in professional relationships – an especially important issue under pandemic conditions.

The approaching year will be the starting point for the vision of the new EU 2022–2050 environmental action programme. It will also mark the starting point for the preparation of subsequent national programmes, some of which have only recently appeared (as in Portugal). The IE Editing Board expects to receive more research and manuscripts dedicated to the methodological issues and national achievements in solving this complicated and sophisticated task.

Antanas Buračas

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LABOR DIGITALIZATION IN EUROPE

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Abstract. *The purpose of this research is the study of the effects of digital transformation on employment and their possible correlation with the labor deficit. The labor deficit in European countries, and especially those of the European Union, is studied. Secondary data regarding Information and Communications Technology (ICT) specialist skills, the employment rate, and the Digital Economy and Society Index (DESI) are collected and analyzed. Data analysis reveals that, on one hand, the labor deficit is undeniable; however, the greatest deficit relates to the lack of digital competences. On the other hand, with rapid technological advancements and the introduction of Artificial Intelligence to the production process, a new environment will be formulated both at the economic and social level. This study is based on the secondary data of specific indexes; in future research, an empirical study will be conducted in European countries to study labor digitalization in depth, especially in the post-COVID-19 era, as this pandemic has increased digitalization in all countries. The adoption of new legislative and prescriptive frameworks is necessary to address the labor deficit. It is necessary to take measures both at the European and national level, as well as to effectively utilize programs and initiatives that will protect the preexisting workforce and will establish the ground for new employees. This can be activated mainly through training, either in the form of new education (reskilling) or re-education*

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(upskilling). The originality of this research is based on the fact that it explores the impact of ICT Skills on employment and the dependence between ICT Skills and DESI. Its value is in revealing the structural problems of the labor market in Europe and the cross-country comparison of how digitalization can help to solve the labor deficit problem in European countries.

Keywords: *digital transformation, digital skills, labor deficit, DESI, European countries.*

JEL Codes: *J21; L86.*

1. Introduction

Digitalization is a phenomenon that affects virtually every process in the global economy today (Raj-Reichert et al., 2021). Labor markets are undergoing significant transformations associated with the adoption of new digital technologies (Martindale & Lehdonvirta, 2021). The consequences of digitalization on employment and work organization are very subtle (Cirillo & Zayas, 2019). The results of an empirical analysis suggest that digitalization may represent a major driver of labor productivity and both economic and employment growth, and that inclusive policies may effectively contribute to bridging the gap between the most favored and most disadvantaged parts of the population, thus helping to achieve the 2020 European targets (Evangelista et al., 2014).

Rapid technological advancements have aided businesses in every sector in seeking innovation that would give their businesses the boost necessary to increase their market share. Apart from industrial companies, Alberti and Pizzurno (2013) observed that family firms are significant players in the generation of innovation.

Due to the continuously reducing cost of computerization, technology is replacing human labor in routine tasks. The cost of technology has continued to fall, and manufacturers have thus been incentivized to substitute workers who perform routine tasks with machinery and other capital equipment, such as robots (Atkinson, 2019). This labor-capital substitution decreases the relative demand for workers performing routine occupations, while leading to an increase in the relative demand for workers performing non-routine tasks (Autor et al., 2003). The notion that middle-skill jobs have been disproportionately destroyed and that job distribution has hollowed out in the center has been identified as a key aspect of rising contemporaneous inequality in the labor market (Acemoglu & Autor 2011; Goos & Manning, 2007; Goos et al., 2014). Understanding how the employment structure evolves can advise policy makers in designing policies to best promote sustainable economic growth. This is especially salient given the widespread feeling of technological anxiety (Mokyr et al., 2015). People from more privileged backgrounds tend to be able to obtain greater benefits from new digital technologies (van Deursen & Helsper, 2015).

The debate concerning the structural evolution of the division of labor and its impact on job quality has been a central theme in social sciences for the last 200 years. In the late 1990s, the idea proliferated that technology is skill-biased, favoring high-skilled

workers and substituting low-skilled workers. While skill-biased technical change is a good explanation for the increase in the upper tail distribution of the composition of the labor force, it cannot explain a recent phenomenon: the decline in the share of middle occupations relative to high- and low-skilled occupations (Wright & Dwyer, 2003; Goos & Manning, 2007).

The impact of technology and digitalization on the labor market is a widely investigated topic in economic literature (Nicoletti et al., 2020; Grigoli et al., 2020). In the early 2000s, a set of studies created a stir in the social sciences by arguing that technological change leads to polarized employment structures (Autor et al., 2003; Goos & Manning, 2007; Wright & Dwyer, 2003). Instead of technology being skill-biased and leading to occupational upgrading, the routinization thesis views information communication technologies (ICT) as task-biased (Murphy & Oesch, 2018).

The Skill-Biased Technological Change hypothesis (SBTC) arose from the observation that demand is shifting in favor of more educated workers (Katz & Autor, 1999; Goldin & Katz, 2008; 2009; Acemoglu & Autor, 2011). In spite of its success in explaining many decades of data, however, SBTC cannot explain the phenomenon of job polarization. The key to understanding changes in labor demand is job polarization (Maselli, 2012).

This study investigates the digitalization processes, ICT skills, and employment rates in European countries in order to assess the problem of the labor deficit. In order to detect the possible solutions to the labor deficit, we use two specific indexes, ICT Specialist Skills and the Digital Economy and Society Index, and correlate their values with the corresponding values of employment rates in the EU27 for the last six years. The outcomes of this study support views on: (a) structural problems of the labor market in Europe; (b) the impact of digitalization on employment and the substitution of jobs; and (c) a cross-country comparison on how digitalization processes are used and help to solve the labor deficit problem in selected European countries.

2. Baseline

The polarization of labor is a phenomenon where the demand for labor does not rise linearly with skill level, but rather resembles a U-shaped function as depicted in Figure 1 (Maselli, 2012). Instead, there is a polarization in favor of both low-skilled and high-skilled jobs. As rich countries grow richer, growth in the consumption of services tends to outpace growth in the consumption of goods (David & Dorn, 2013). Employment in the goods-producing sector is disproportionately composed of middle-skill workers, while service sector workers are concentrated at the top and bottom of the skill distribution. Figure 1 illustrates the phenomenon of job polarization in the EU27 between 2000 and 2010. We would normally expect demand for workers to rise as the skill content of these occupations increases in a linear fashion. Instead, the figure is U-shaped, as predicted by job polarization. This is the result of an approximately 20% increase in the demand for low-skilled and high-profile occupations between 2000 and 2010, and a 4.5% decrease in the demand for middle-skilled occupations. Polarization occurred in 17 of the EU27 countries.

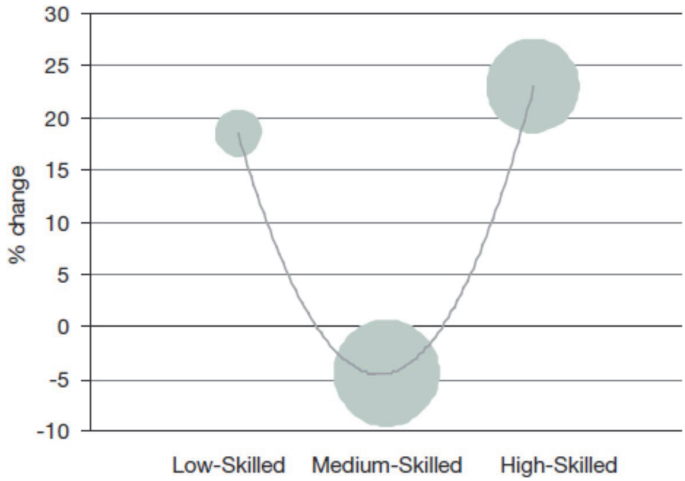

Figure 1. *Job polarization in the EU27, 2000–2010.*
Source: *Maselli, 2012*

The skills content of low-skilled jobs increased, leading to the phenomenon of up-skilling. Low-skillness should therefore be viewed as a fluid concept, the definition of which depends on the context. Job polarization may therefore be a misleading concept because low-skillness encompasses a wide range of jobs (Beblavý & Veselková, 2014).

The mere accessibility of ICT facilities is only a pre-condition for moving towards a digitalized society (Evangelista et al., 2014). ICT Specialist Skills is a very generic term which also includes other professions related to the ICT sector, such as: ICT Programmers, who develop programs and applications; ICT Users, who utilize the programs to produce data; Data Analysts, who effectively analyze the produced data to offer possible solutions; and ICT Service Managers, who should be able to gather information from all the above stages and take the most appropriate decision. This term also contains not just the knowledge that someone can attain from educational institutions, but also knowledge that can be gathered through experiences in the working environment, as well as any kind of training or education offered by companies to cultivate the skills of their personnel (OECD, 2016).

To be able to analyze the projected results in the best way, an index that expresses the percentage of employed persons with ICT Specialist Skills was used, which was calculated through the following formula:

$$\frac{Employed\ p.with\ ICT\ Sp.Skills}{Employed\ persons} \times 100 = \%Employed\ persons\ with\ ICT\ Sp.Skills$$

First, it should be noted that the term ICT Education in this paper refers to the knowledge that is provided only by the certified educational institutions of the countries in question.

However, the comparison and analysis of the average of the twenty-seven countries is not considered to be trustworthy due to the uneven fluctuation of the unemployment rate from 2010 onwards in countries such as Greece, which alters the average. Therefore, it is considered fair to analyze the way that these indexes evolve over time for each country or group of countries, and to compare them to assess the status of the educated persons of these economies.

Since these indexes concern employment and unemployment, it is natural for them to be negatively correlated as employment and unemployment are considered opposite phenomena. This means that the interpretation of the minimum and the maximum score for each index is different, as for employment the minimum is the least desirable score, while for unemployment the minimum is the most desirable score. Likewise, a maximum score for employment produces a strongly positive effect for a country, whereas a maximum score for unemployment is a worst-case scenario.

In recent years, a very popular tool among researchers of countries' digital efficiency has been the Digital Economy and Society Index (DESI), which is a complex summary of basic indicators depicting the digital performance of every EU member state and how highly they score in digital competitiveness when compared to another member state. The DESI measures the performance indicators of five main categories (Eurostat, 2021a):

- Connectivity – which measures broadband network coverage within the region of each member state (25% weight).
- Human capital – regarding the people equipped with proper digital skills (25% weight).
- Use of the internet – by citizens and to what extent (15% weight).
- Integration of Digital Technology – industries and business sectors (20% weight).
- Digital public services – measuring the number of public services that can be conducted online by each member state (15% weight).

These categories are further analyzed in various sub-categories. The DESI index concerning the EU27 countries was first published in 2014, and this is the reason for the limitation of the chronological span of data.

Figure 2 shows the ranking of Member States in the Digital Economy and Society Index in 2020 based on 2019 data. Finland, Sweden, Denmark, and the Netherlands had the most advanced digital economies in the EU, followed by Malta, Ireland, and Estonia. Bulgaria, Greece, Romania, and Italy had the lowest scores on the index.

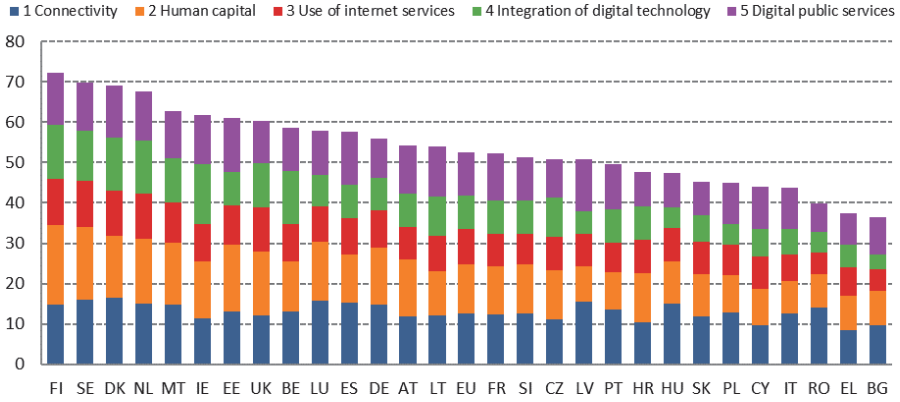

Figure 2. *The Digital Economy and Society Index 2020 ranking.*
Source: *European Commission (2020)*

Figure 3 depicts the progress of Member States as regards the overall level of digitization of the economy and society over the last 5 years. This is measured in terms of the progression of their DESI scores over that period.

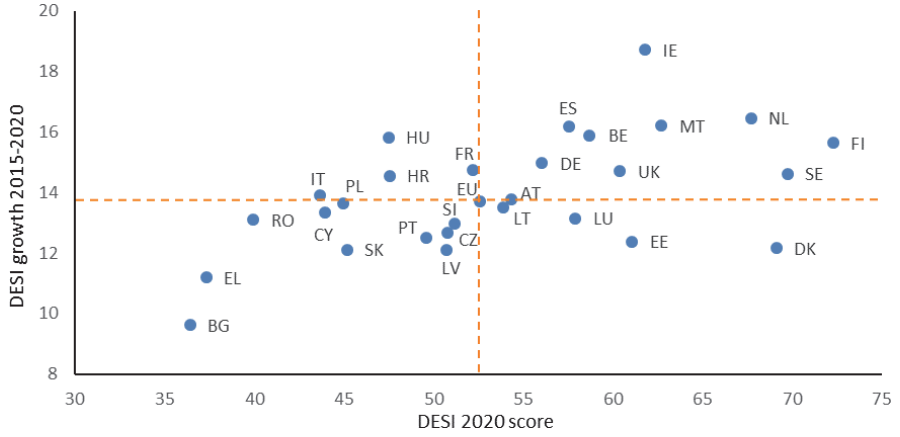

Figure 3. *Digital Economy and Society Index – progress of the Member States in 2015–2020*

The most significant progression was noted in Ireland, followed by the Netherlands, Malta, and Spain. These countries also performed well above the EU average, as measured by the DESI score. Common to these Member States are robust policies and targeted investment in all the areas measured by the DESI.

Finland and Sweden were amongst the leaders in overall performance in digitization, but in terms of progression over the last five years they were only slightly above average, together with Belgium and Germany.

3. Data and results

The data used in this study concern the following indexes: DESI, Employment, and ICT. DESI is a composite index that measures relevant digitalization and evolution indicators (Eurostat, 2021a); Employment is the employment rate for people aged 20 to 64 (Eurostat, 2021b); and ICT is the proportion of employed ICT specialists in total (Eurostat, 2021c). In Table 1, the averages of the above indexes in the 2015–2020 period are presented for all European Union countries in order of the highest to the lowest average DESI score. This period was used because the available data for the DESI index starts from the year 2014.

Table 1. *Average index values of the EU27 countries in the 2015–2020 period*

Index / Country	DESI	Employment	ICT
Finland	63.12	75.08	6.8
Denmark	62.4	76.93	5.08
Sweden	62.27	81.47	6.72
Netherlands	59.28	78.47	5.33
Estonia	54.73	78.38	5.58
Malta	52.82	73.8	4.3
Ireland	51.92	72.82	4.98
Luxembourg	51.02	71.68	5.6
Belgium	50	68.93	4.75
Spain	48.78	65.35	3.45
Germany	47.63	79.38	3.97
Austria	47.18	75.5	4.32
Lithuania	47.17	76.2	2.73
Latvia	45.4	75.28	2.97
France	44.77	70.73	3.9
Slovenia	44.77	73.33	3.87
Czechia	43.72	78.32	3.83
Portugal	43.58	73.22	3.28
Croatia	40.18	64.07	3.28
Slovakia	39.43	71.15	3.27
Hungary	38.68	73.07	3.62
Poland	38.23	71.13	2.93
Cyprus	37.78	71.98	2.88
Italy	36.27	62.25	3.43

Index / Country	DESI	Employment	ICT
Romania	33.33	68.78	2.15
Bulgaria	31.52	71.15	3.12
Greece	31.43	58.45	2.02

All indexes were studied in three distinct groups, which were compiled according to the DESI index: the group with the highest DESI values was labeled *H*; the group with intermediate DESI values was labeled *I*; and the group with the lowest DESI values was labeled *L*. Group H included Finland, Denmark, Sweden, the Netherlands, Estonia, Malta, Ireland, Luxembourg, and Belgium. Group I included Spain, Germany, Austria, Lithuania, Latvia, France, Slovenia, and Czechia. Group L included Croatia, Slovakia, Hungary, Poland, Cyprus, Italy, Romania, Bulgaria, and Greece. Statistical analysis was conducted with the Jamovi software.

Figure 4 presents the average values of the three indexes grouped as mentioned above. It is evident that all indexes follow similar behaviors throughout each group.

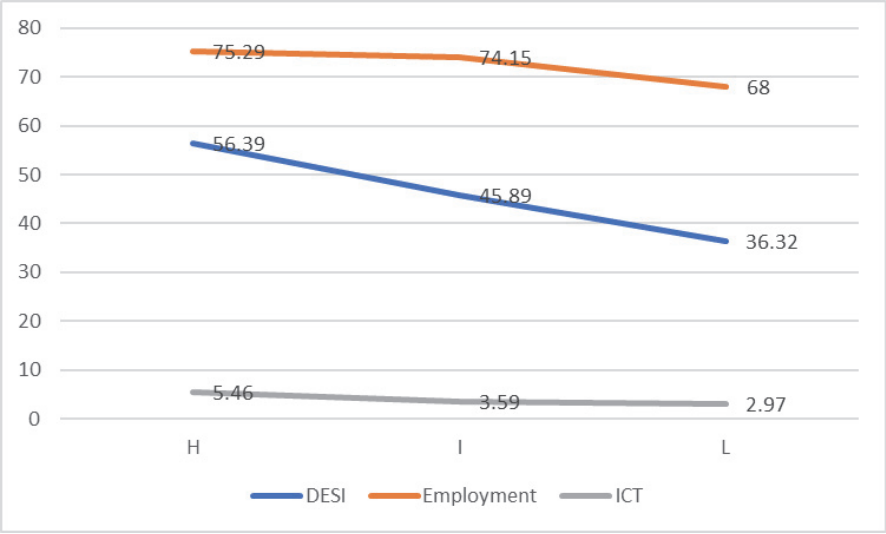

Figure 4. *The average index values of the groups*

Figure 5 presents the average values of the DESI index in all three groups throughout the period studied. All three groups' DESI indexes increased over time, and there is a clear distinction among groups.

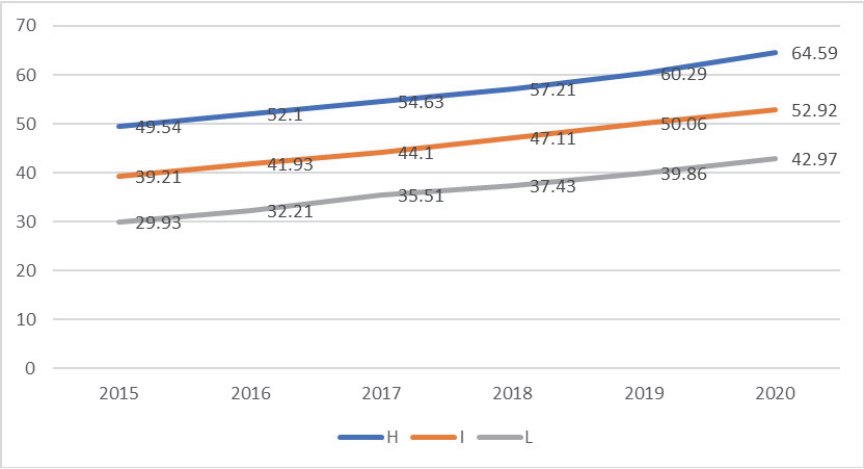

Figure 5. *The DESI indexes of the three groups over the 2015–2020 period*

However, if we calculate the change in the average DESI index for all three groups as the value of the current year minus that of the previous year (Figure 6), then the change experienced by Group H in 2020 was the largest of any throughout the entire period. Group L also experienced a large change in 2017, mainly because of Poland (a change of 9.70) and Slovakia (3.70); and Group I did so in 2018 mainly because of Lithuania (4.40) and Spain (4.10).

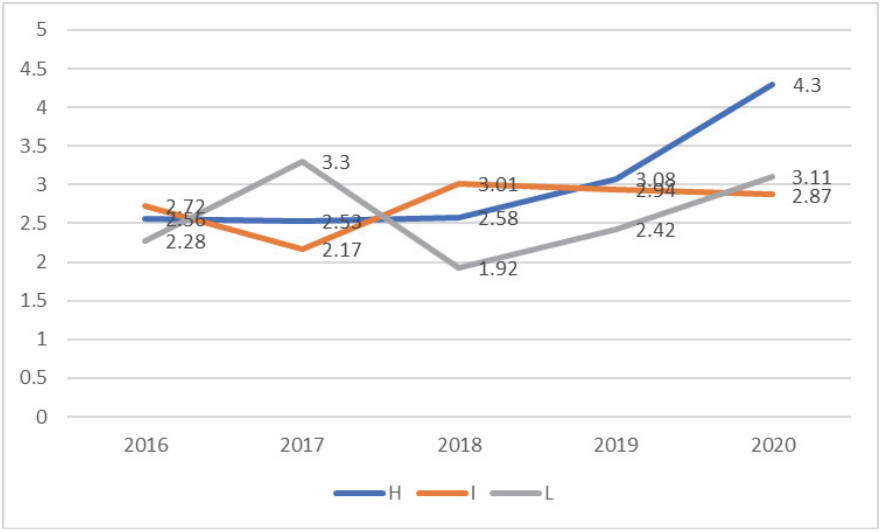

Figure 6. *Changes in the DESI rate of each group for the 2015–2020 period*

Figure 7 presents the average values of the employment index in each group. It is clear that all three groups increased over time – except in 2020, which was the year in which the COVID-19 pandemic affected the employment rate in all countries. The distinction among groups is again clearly indicated, with Group I being very close to Group H.

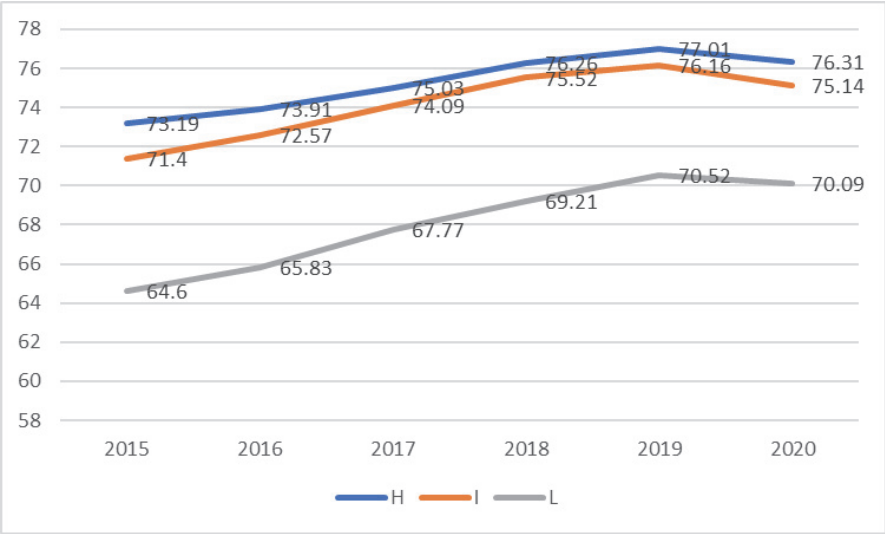

Figure 7. *The Employment index in the groups for the 2015–2020 period*

Moreover, if we calculate the average change in the Employment index for all three groups (Figure 8), then it is evident that in 2017 Group L had the largest change throughout the entire period due to Bulgaria (a change of 3.60), Romania (2.50), Croatia (2.20), and Cyprus (2.10).

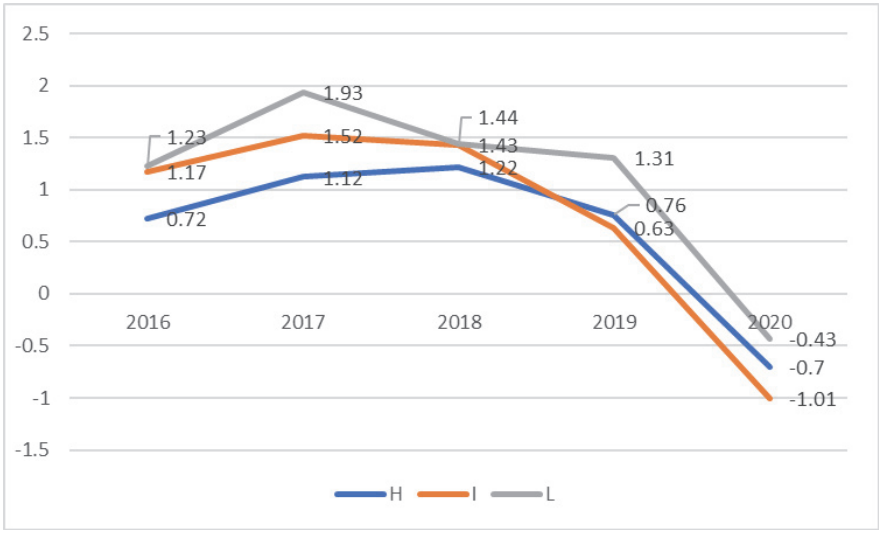

Figure 8. *Changes in the Employment rate of the groups for the 2015–2020 period*

Figure 9 presents the average values of the ICT index for the groups of countries. It is clear that all three groups increased over time, and the distinction among groups is again clearly indicated.

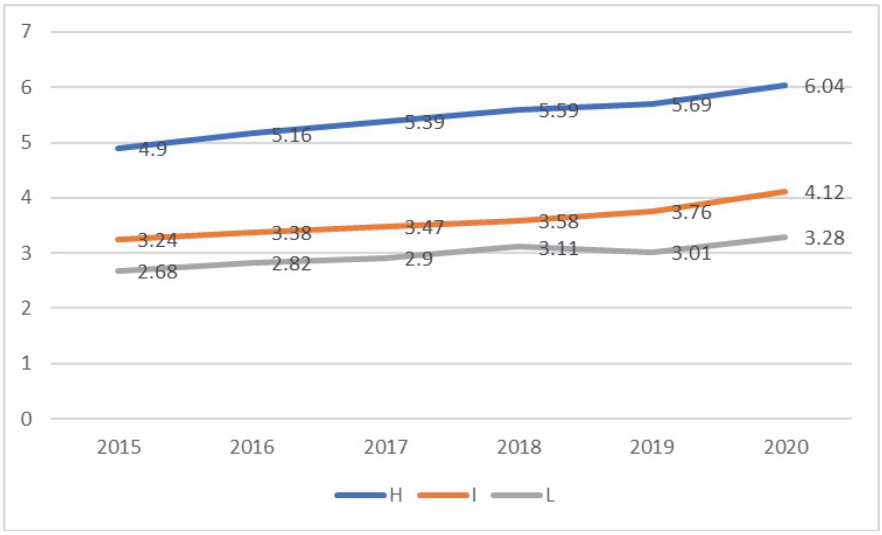

Figure 9. *The ICT index in the groups for the 2015–2020 period*

Additionally, if we calculate the average change of the ICT index for all three groups (Figure 10), then Group I followed the most consistently increasing course among all groups, and also experienced the largest overall change throughout the entire period – except in the year 2017, during which a slight reduction in the rate of growth occurred. The largest single-year change occurred 2020, and was mainly due to Germany (a change of 0.70), Latvia (0.60), Slovenia (0.50), and Portugal (0.40). The change experienced by Group H was very close to that of Group I due to Finland and Ireland (0.80), and Sweden and Estonia (0.50).

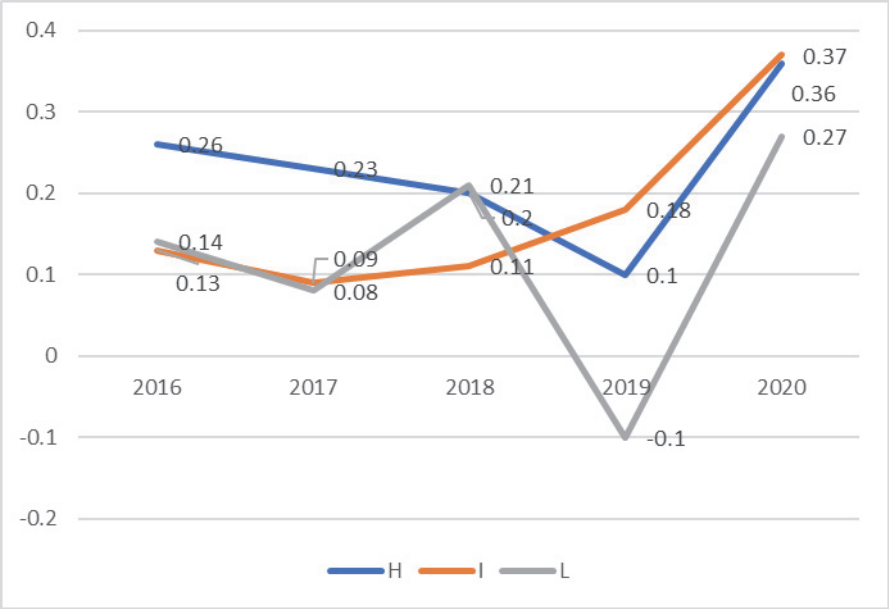

Figure 10. *Change in ICT rate for the period 2015–2020*

Furthermore, the correlation between the average values of all indexes was studied, and is presented in Table 2. All indexes were highly correlated in pairs, with the highest correlation observed between DESI and ICT.

Table 2. *Correlation matrix*

		DESI	Employment
Employment	Pearson's *r*	0.634	—
	p-value	<.001	—
ICT	Pearson's *r*	0.879	0.553
	p-value	<.001	0.003

Additionally, multivariate regression analysis was used to further analyze the correlation of these indexes (Field, 2018). Employment rate was used as the dependent variable and DESI and ICT as independent variables. The equation of the model was:

$$\text{Employment} = 55.079 + 0.3834^{*}\ \text{DESI} - 0.0787^{*}\text{ICT}$$

This model performed well ($F(2.24) = 49.4$, $p = 0.05$), and the adjusted R^2 of 0.552 indicated that the regression model accounted for 55.2% of the variability in the outcome measure. The statistical significance of each independent variable was measured with t-tests. Both variables were significant at a marginal level ($p = 0.05$). The variance inflation factor (VIF) of 2.44 indicated that there was no problem of collinearity between independent variables. The Durbin-Watson statistic of 1.89 indicated that there was no autocorrelation in the model, and a Cook's distance value of 0.0237 revealed that there was no problem with outliers.

5. Discussion and Conclusions

The main purpose of this paper was to investigate labor job digitalization processes, ICT skills, and employment rates in European countries in order to assess the problem of the labor deficit.

Regression analysis revealed the dependence of the employment rate on DESI and ICT skills. The accountability of the model was high, and can explain 55.2% of the variability in the outcome measure. All three indexes were highly correlated between each other, and the grouping of EU27 countries revealed that the employment rate of each country is affected by the performance of the DESI index and ICT skills.

These findings may be used as a starting point for the discussion on digitalization. Progress in digitalization, apart from the expected benefits for productivity and competitiveness (Fossen & Sorgner, 2019), may save jobs and preserve economic activities in a situation of high contagion (Carbonero & Scicchitano, 2021). Digitalization will increase the importance given to the digital channels of marketing and the sales of companies. It will also foster teleworking and the consumption of technological products as more people will interact using hybrid communication mechanisms accessible from anywhere, and not exclusively in the physical environments of companies and their homes (Almeida et al., 2020).

The repercussions and the pace of technological disruption in organizations are increasing and have been accelerated by the COVID-19 pandemic. Companies need to be prepared for this challenge, and to this end they need to foster a culture of innovation that involves the company's employees in this process. In fact, COVID-19 has accelerated the processes of digital transformation not only in companies but also in individuals and public entities. The enormous challenge for managers is to get involved in this change while trying to keep the business running in the face of a different and uncertain future.

Technological change has always had a decisive impact on the labor market. The COVID-19 pandemic is seen as an automation-forcing event, and its effects on technology and work are destined to last over time (Autor & Reynolds, 2020; Autor et al., 2020). Further research may test this hypothesis and investigate whether COVID-19 will have a persistent effect on technological change and further consequences on income inequality.

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ORGANIZATIONAL INNOVATION CAPABILITY: INTEGRATING HUMAN RESOURCE MANAGEMENT PRACTICE, KNOWLEDGE MANAGEMENT, AND INDIVIDUAL CREATIVITY

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Abstract: *Despite the work of several researchers in revealing organizational innovation capability, research that integrates human resource management practice (HRMP) and the knowledge management (KM) model in building creativity is still underdeveloped. Therefore, this study examines the nexus between HRMP, KM, and creativity, and its in-*

fluence on organizational innovation capability in small and medium enterprises (SMEs). This study analyzes data collected from 405 respondents from the managerial level of 135 woodcraft SMEs in Indonesia by employing the partial least square SmartPLS 3.2.7 method. The results show that HRMP, KM , and creativity significantly influence organizational innovation capability. Meanwhile, KM has no significant influence on organizational innovation capability. Another important finding is that creativity is a double mediator in the mediation mechanism tested in this research. Furthermore, this research helps managers to: optimize HRMP when seeking creative employees to boost innovation capability; develop analytical skills to improve KM practices; and realize that KM not only signifies knowledge acquisition, but also greatly establishes metacognitive strategies for adopting, disseminating, and creating new ideas. This research also discusses the associated limitations.

Keywords: *human resource management practice, knowledge management, organizational creativity, organizational innovation capability*

JEL Codes: *D23, D83, M12, O31, O34*

1. Introduction

Since time immemorial, innovation has been recognized as an important predictor of organizational success (Yi et al., 2021; Shafique et al., 2019; Loewenberger, 2013). Therefore, several preliminary studies have been carried out to determine the factors that facilitate or hinder organizations' innovation activities. In the Industry 4.0 and Society 5.0 eras, marked by technological changes, the dynamics of the business environment and brief, productive life cycles pressurize companies into creating innovations consistently (Arsawan, Koval, et al., 2020). Furthermore, several studies have also explored predictors of innovation such as creativity (Lam et al., 2021; J. Jiang et al., 2012), knowledge management (hereinafter – KM) (Ode & Ayavoo, 2020; Nowacki & Bachnik, 2016; Grimsdottir & Edvardsson, 2018), and human resource management practices (hereinafter – HRMP) (Rondi et al., in press; Haneda & Ito, 2018). In addition, these are implemented in several businesses, including in the service sectors (Ode & Ayavoo, 2020; Abbas & Sağsan, 2019), small-medium enterprises (hereinafter – SMEs) (Colclough et al., 2019; Arsawan, Rajiani, et al., 2020), manufacturing (Haneda & Ito, 2018), and the hospitality industry (Chang et al., 2011).

The issue regarding the role of innovation in business entities has been investigated globally using various variables; however, it needs to be comprehensively explained. Therefore, this research tries to bridge the existent gap as follows. First, although innovation has been investigated using various antecedent formations, it has never been tested with a comprehensive model involving the links between HRMP, KM, creativity, and innovation. This model is expected to provide a holistic description of HRMP and its contributions to creativity and organizational innovation capability. Conversely, KM is one of the important predictors of knowledge that potentially enhances creativity

(Saulais & Ermine, 2012) and innovation capability (Grimsdottir & Edvardsson, 2018; Mardani et al., 2018).

Second, the role played by the HRMP in building organizational innovation capability is still unexplored. Therefore, this research attempts to explain the relationship between these 2 variables (Barba-Aragón & Jiménez-Jiménez, 2020). Organizational innovation capability is examined because it is a fundamental part of development (Zhao et al., 2020; Chaubey et al., 2021), and great effort is needed to understand it due to its implications for employees. In addition, it is rarely analyzed, despite playing a critical role in boosting a company's success and competitiveness in the current dynamic business environment.

Third, analyses on HRMP in respect to organizational innovation capability are identified as a black box by several studies (Messersmith & Guthrie, 2010; Beugelsdijk, 2008). Accordingly, this research investigates the interrelations between HRMP and organizational innovation capability. These variables are also tested using mediation or moderation mechanisms to understand the relationship between them as well as to provide a structured, systematic, and comprehensive description (Easa & Orra, 2021).

Fourth, there is a dearth of research linking KM and organizational innovation capability, especially from the perspective of developing countries (Ode & Ayavoo, 2020) and SMEs with limited resources and reactive mentalities. Therefore, they are demanded to be more innovative in formulating strategies (Du, 2021) by adopting sustainable creativity (Saulais & Ermine, 2012; Areed et al., 2021; Yankovyi et al., 2021) and building an innovation culture (Arsawan, Koval, et al., 2020) in order to succeed in a competitive business environment and during high market turbulence (Grimsdottir & Edvardsson, 2018). According to the World Economic Forum (WEF, 2019), Indonesia was ranked 74th among developing countries. This simply means that it needs to further strengthen organizational innovation capability in various activities, especially in building SMEs and boosting its contributions to economic development and growth (Arsawan, Rajiani, et al., 2020).

Motivated by the various research gaps discussed above, this study aims to explore the role of HRMP and KM to enhance individual creativity and organizational innovation ability. The present study focuses on both direct and indirect relationships between HRMP, KM, creativity, and organizational innovation capability in the context of Indonesian SMEs for two reasons. Firstly, organizational innovation capability has not been considered crucial in the SME sector (Abdul-Halim et al., 2018), whereas the results of previous studies state that to build organizational performance in a sustainable manner it is necessary to increase innovation at all levels (Kwarteng et al., 2016) so as to increase competitiveness in the global market (Chang et al., 2017). Secondly, increasing innovation capability will strengthen the management process model in SMEs (Trachenko et al., 2021), thereby strengthening Indonesia's economic development (Arsawan, Koval, et al., 2020). Therefore, this will be the first study to examine the antecedents of individual creativity related to organizational innovation capability. Based on dynamic capabilities theory (Teece et al., 2009) and the perspective of the important role of innovation (Chaubey et al., 2021; Areed et al., 2021; Colclough et al., 2019), this study is important to garner insight in understanding dynamic scenarios, and provides an appropriate analysis

in explaining organizational innovation capabilities in Indonesian SMEs in order to increase growth, profits, and to contribute to gross domestic product (Anwar et al., 2018).

This study is organized as follows. First, it considers the research gaps and explores organizational innovation capability. In addition, it formulates hypotheses based on the impact of HRMP and KM on creativity and organizational innovation capability. Subsequently, it examines the role of individual creativity as a mediating variable between HRMP, KM, and organizational innovation capability. The results of these investigations are then further reported and analyzed. Finally, the research limitations and support are discussed.

2. Literature review and hypothesis development

2.1 Human resource management practice

HRMP is extremely important, especially in the fields of economics, human resources, and strategic management (Easa & Orra, 2021). HRMP describes the managerial processes that enable organizations to acquire valuable and extraordinary knowledge as well as influence innovative activities, thereby leading to high performance (Singh et al., 2021). HRMP influences employees' work-related attitudes, abilities, and behaviors with respect to achieving organizational goals (Minbaeva, 2013). It also plays an important role in supporting an organizational environment and promoting creativity and innovation in KM.

2.2 Knowledge management

Presently, organizations have to accept the challenges of the new knowledge-based economy, as well as integrate and protect knowledge (Teece, 2000). Subsequently, they need to maintain specific and dynamic capabilities to remain competitive (Mardani et al., 2018). KM plays a relevant role in compiling an organization's unique capital, both tangible and intangible (Saulais & Ermine, 2012). Ali et al. (2020) stated that knowledge works efficiently when members of an organization are aware of those that are proficient in a particular domain. KM consists of 3 interrelated processes, namely knowledge acquisition, conversion, and application (Mardani et al., 2018).

2.3 Creativity

It is clear from several previous studies that creativity plays an important role in developing sustainable excellence and adding value to an organization. In a challenging dynamic environment, there is a need for mechanisms that aid in the development of innovative solutions (Loewenberger, 2013), irrespective of the conflict between ability and commitment to organizational practices. Creativity is described as a divergent thinking approach that tends to combine previously unrelated knowledge, products, or processes to formulate something new (Fong et al., 2018) – both in the individual and teamwork

contexts (Somech & Drach-Zahavy, 2013). Creativity is related to work motivation in terms of building innovation (Lin & Liu, 2012), even though it is described as something new and useful (Amabile, 1986). This definition does not imply that there is a universal norm for judging novelty and usefulness (Kwan et al., 2018).

2.4 Organizational innovation capability

Innovation is a newly formulated business model that inspires diverse knowledge to be turned into creative results. According to Lam et al. (2021), it provides a mechanism for organizations to exploit the inflow and outflow of knowledge in order to become more creative. This extensive and diverse research focuses on organization-level innovation. This term contains conceptual ambiguity and varied interpretations; therefore, it has no generally accepted definition (Chaubey et al., 2021).

2.5 Hypothesis development

Studies linking and testing HRMP with creativity are sparse. Nevertheless, the research carried out by J. Jiang et al. (2012) reported that HRMP motivates employees to develop a sense of autonomy, thereby causing them to effectively solve problems – including creating new ideas to cope with job demands. Referring to the social exchange theory (Blau, 1964), the HRMP system, in accordance with high commitment, has a positive influence on employee creativity. In this circumstance, the role played by the manager provides a better understanding of organizational creativity patterns (Loewenberger, 2013). HRMP is crucial in order to facilitate the creativity of employees, and better HRMP of the organization will contribute to increased employee and team creativity and enhanced innovation capabilities. These innovations will be hard to imitate by other competitors (Binyamin & Carmeli, 2010; Bratnicki, 2005), thereby increasing the innovation orientation of the organization (Colclough et al., 2019), producing high productivity (Stojcic et al., 2018), and improving performance at the organizational level (Dabić et al., 2019; Byukusenge & Munene, 2017) as an important trigger in realizing sustainable competitive advantage (Chatzoglou & Chatzoudes, 2018; Sigalas & Papadakis, 2018). In the context of the type of organization, the findings of Liu et al. (2017) revealed that the role of HRMP in private organizations, family businesses, and entrepreneurial enterprises tends to be stronger in building creativity because characters of this type rely on their innovation strategies (Colclough et al., 2019). Based on the above, the following hypothesis was formulated:

H1: HRMP has a positive and significant influence on creativity.

Several studies, including the research carried out by Özbağ et al. (2013), have stated that HRMP fosters innovation. However, Barba-Aragón & Jiménez-Jiménez (2020) reported that it had an insignificant influence on innovation. This is because HRMP does not have a direct influence on organizational innovation capability, and requires the de-

velopment of certain behaviors that ultimately result in sustainability. This shows that it is present and plays an important role in promoting innovation at the organizational (Easa & Orra, 2021) and individual levels (I. Wayan Edi Arsawan, Rajiani, et al., 2020). Based on this, the following hypothesis was formulated:

H2: HRMP has a positive and significant influence on organizational innovation capability.

Various studies have reported the positive impact of KM on organizational existence and competitiveness. Considering that knowledge is needed to generate new innovations (Baldé et al., 2018), its practice influences creativity (Nonaka & Von Krogh, 2009). However, research on the way and manner in which knowledge influences creativity is limited (Schulze & Hoegl, 2008). Consequently, this research identifies the effect of KM on creativity (Joo et al., 2014). Based on this, the following hypothesis was formulated:

H3: KM has a positive and significant influence on creativity.

KM is an important predictor of organizational success (Areed et al., 2021); it effectively facilitates the knowledge exchange required for the improvement of organizational innovation capability, realized by developing new insight and abilities (Yi et al., 2021). Hock-Doepgen et al. (2021) stated that, via KM, organizations are enabled to identify and process knowledge into innovative business opportunities. This is carried out in order to manage, implement, develop, leverage (Mardani et al., 2018), and strengthen capability, knowledge creation, and innovative performance (Lai et al., 2014). Based on this, the following hypothesis was formulated:

H4: KM has a positive and significant influence on organizational innovation capability.

Furthermore, several empirical studies reported a similar notion regarding creativity and innovation, even though these two are entirely different (Gurteen, 1998). Creativity is described as a divergent thinking process that leads to the generation of new ideas (Saulais & Ermine, 2012; Gurteen, 1998). Conversely, innovation is the successful implementation of creative ideas in an organization (Chaubey & Sahoo, 2019). Creativity is related to innovation, which is the process of adopting and converting new ideas into market offerings (Scarborough, 2016; Luchaninova et al., 2020). This means that it is the main foundation or basis of innovative behavior (Chaubey & Sahoo, 2019) – both in the context of individual employees (Arsawan, Rajiani, et al., 2020) and the organization (Shafique et al., 2019). This led to the following hypothesis:

H5: Creativity has a significant and positive influence on organizational innovation capability.

HRMP plays a strategic role in developing organizational performance and competitive advantage through stimulating creativity and employee autonomy (Jiang et al., 2012; Loewenberger, 2013), which attract ideas (Shafique et al., 2019) that improve innovative work behavior (Arsawan, Rajiani, et al., 2020). Furthermore, creativity has a unidirectional relationship with innovation because it is considered the main foundation for its development (Chaubey & Sahoo, 2019). Based on this, the following hypothesis was formulated:

H6: Creativity mediates the relationship between HRMP and organizational innovation capability.

This research further states that the relationship between KM and organizational innovation capability is mediated by creativity. In other words, the KM dimension serves as the basis of creativity (Ode & Ayavoo, 2020; Bettiol et al., 2012), which further facilitates the development of innovative ideas (Kwan et al., 2018). This is because KM lays the foundation for building creativity, which, in turn, is a source of organizational innovation. This led to the following hypothesis:

H7: Creativity mediates the relationship between KM and organizational innovation capability.

Therefore, this research examines and explains the direct relationship between HRMP, KM, creativity, and innovation capability. Furthermore, creativity was tested as a variable in mediating the relationship between HRMP and innovation capability, as well as between KM and innovation capability. The research framework is shown in Figure 1.

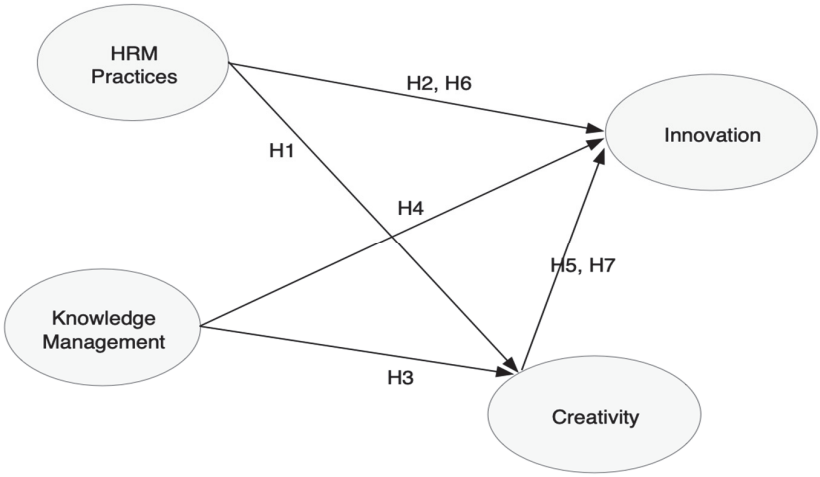

Figure 1. *Research framework*

3. Methodology

3.1 Sampling method

The research population was comprised of 204 woodworking SMEs spread across 7 regencies in Bali, Indonesia. Furthermore, the sample frames were selected using the simple random sampling method – namely the lottery methods without recovery. Moreover, every member of the population was sampled only once. The number of sample frames was determined using the formula created by Krejcie & Morgan (1970), and a total of 135 SMEs were involved. At each SME, 3 respondents were asked to fill out the research questionnaire – hence, the total number of respondents was 405, as shown in Table 1. Respondents were categorized based on 3 managerial levels: lesser, represented by supervisors; middle, represented by assistant managers; and top, represented by woodworking SME owners. They were considered to have knowledge of research variables and strategic policies related to organizational innovation capability.

Table 1: *Study population and sample*

No	Regencies (1)	Population (2)	Percentage of Population (3)	(x) Sample (4)	Sample (5)	Respondents (6)
1	Denpasar	5	0.024509804	3.30882353	3	9
2	Badung	18	0.088235294	11.9117647	12	36
3	Karangasem	1	0.004901961	0.66176471	1	3
4	Klungkung	53	0.259803922	35.0735294	35	105
5	Tabanan	14	0.068627451	9.26470588	9	27
6	Bangli	34	0.166666667	22.5	23	69
7	Gianyar	79	0.387254902	52.2794118	52	156
	Total	204	1.00	135	135	405

3.2 Measurements

All measurement tools were adopted from previous studies and modified for further analysis. All constructs were designed with a self-assessment report – namely a Likert scale approach of 1 to 5 (1 – *strongly disagree*, to 5 – *strongly agree*). The questionnaire was prepared in simple, easy-to-understand language, thereby achieving the research objectives. Furthermore, a total of 14 dimensions and 39 indicators were used to measure the research construct.

HRMP was measured with 3 dimensions, including training, job appraisal, and rewards, with 3, 5, and 4 indicators, respectively (Jiang et al., 2012). Variable KM was measured with 4 dimensions – namely KM transfer, storage, application, and creation, with 3 indicators each (Donate & Sánchez de Pablo, 2015)with structural equation modeling (SEM. The creativity variable was measured with 4 dimensions – namely people, process, pressure, and product, with 2 indicators each (Hansen et al., 2012). The innovation

capability variable was measured with 3 dimensions, namely market, product and process innovations with 2, 3, and 2 indicators respectively (Byukusenge & Munene, 2017).

4. Result and analysis

4.1 Profile of respondents

This research involved a total of 405 respondents employed in 135 woodworking SMEs that manufacture highly artistic, good quality, high-value products. The research objectives were realized by distributing questionnaires to supervisors, assistant managers, managers, and owners. This research also sought information on strategic policies related to these variables. Table 1 shows the demographic information of the respondents.

Table 2. *Profile of respondents*

	Classification	Frequency	Percentage
Business entity	PT (Limited liability company)	27	20
	CV (Limited partnership)	23	17.03
	Family business	85	62.97
Company age	1990–1999	27	0.2
	2000–2009	23	0.17037037
	2010–2016	85	0.62962963
Gender	Male	267	0.659259259
	Female	138	0.340740741
Age	21–30	27	0.066666667
	31–40	89	0.219753086
	41–50	194	0.479012346
	51–60	78	0.192592593
	>60	17	0.041975309
Marital status	Married	378	88.9
	Single	27	11.1
Education	Bachelor	354	0.874074074
	Master	43	0.10617284
	Doctor	8	0.019753086
Total workers	1–15	178	0.439506173
	16–30	166	0.409876543
	31–45	49	0.120987654
	46–60	12	0.02962963
Working status	Owner/manager	135	0.333333333
	Assistant manager	135	0.333333333
	Supervisor	135	0.333333333

4.2 Outer model measurement

Research data were analyzed using SmartPLS-3.2.7 software with a second-order approach. The measurement model was evaluated to determine the indicators' validity and reliability. It also included the dimensions used to test the inner model through the resampling bootstrapping process.

Based on the reliability measurement concept, this research used 3 instruments for each indicator – convergent validity, discriminant validity, and composite reliability (Hair, Hult et al., 2016). The first method used was convergent validity, which is a measure of the indicators' construct validity, as shown by the outer loading factor value. In the early stages of development of a measurement scale, also called exploratory research, a loading factor value between 0.50 and 0.60 is considered sufficient (Chin, 1998). In this study, the outer loading factor value of each indicator was between 0.539 and 0.993, thereby meeting the convergent validity requirements. The next step was to test discriminant validity, which was used to measure the indicators' reliability. This method compares the square root average variance extracted (√AVE) coefficient of each latent variable. In addition, the correlation coefficient between other latent variables in the model was considered. The recommended AVE value is greater than 0.50.

Table 3*: The values of AVE, AVE root, and coefficients between latent variables*

Variable	AVE	√AVE	Correlation coefficient			
			HRMP	KM	Cr	IC
HRMP	0.501	0.708	1.000			
KM	0.518	0.719	0.771	1.000		
Creativity	0.576	0.759	0.660	0.757	1.000	
Org. Innovation Capability	0.598	0.773	0.747	0.747	0.659	1.000

The AVE root value of HRMP was 0.719, which was greater than the correlation coefficient between other variables – namely 0.771, 0.660, and 0.747. The AVE root value of KM was 0.759, which was greater than the correlation coefficient between other variables – namely 0.757 and 0.747. The AVE root value of the innovation capability was 0.773, which was greater than the correlation coefficient between other variables – namely 0.659. This indicates that the indicators reflecting the dimensions of the variables in this research had good discriminant validity.

The third step was to use composite reliability to measure the reliability value between the variable indicators. The indicator test is reliable when composite reliability and Cronbach alpha have a value of >0.70 (Hair, Sarstedt et al., 2016its prevalence and challenges for social science researchers. Part II – in the next issue (European Business Review, Vol. 28 No. 2; Hair, Hult et al., 2016).

Table 4. *Construct reliability and validity*

	Cronbach's alpha	rho_A	Composite reliability	Average variance extracted (AVE)
X1	0.906	0.914	0.922	0.501
X1.1	0.798	0.817	0.881	0.711
X1.2	0.887	0.910	0.920	0.700
X1.3	0.810	0.823	0.876	0.639
X2	0.913	0.918	0.927	0.518
X2.1	0.744	0.752	0.762	0.517
X2.2	0.734	0.736	0.850	0.653
X2.3	0.795	0.806	0.879	0.709
X2.4	0.823	0.824	0.895	0.741
Y1	0.893	0.897	0.915	0.576
Y1.1	0.750	0.750	0.851	0.741
Y1.2	0.814	0.820	0.915	0.843
Y1.3	0.752	0.753	0.852	0.742
Y1.4	0.778	0.779	0.900	0.818
Y2	0.888	0.890	0.912	0.598
Y2.1	0.818	0.819	0.917	0.846
Y2.2	0.805	0.806	0.885	0.720
Y2.3	0.778	0.782	0.900	0.818

Model reliability is measured with Cronbach's alpha (Hair et al., 2013; Hair, Sarstedt et al., 2016)its prevalence and challenges for social science researchers. Part II – in the next issue (European Business Review, Vol. 28 No. 2. However, a Cronbach's alpha value of 0.7 is considered appropriate (Hair et al., 2014). As described in Table 4, all Cronbach's alpha values were >0.7. The convergent validity of the research model was assessed through the composite reliability (CR), average variance extract (AVE), and item reliability of each variable (factor loadings) (Hair, Sarstedt et al., 2016)its prevalence and challenges for social science researchers. Part II – in the next issue (European Business Review, Vol. 28 No. 2. According to the preliminary studies, the CR and AVE values need to be >0.7 and >0.5, respectively. Table 4 shows that all CR and AVE values maintained these criteria. The loading factors of all items at the individual level were also greater than 0.7.

4.3 Inner model measurement

After examining the outer model, the inner model was tested using 3 approaches – first, the initial evaluation of the model's feasibility through a review of the R^{2y} analysis. This shows the strengths and weaknesses of the relationships between the exogenous and endogenous variables. Therefore, R^2 shows the strengths and weaknesses of the research model. According to Chin, (1998) R^2 values of 0.67, 0.33, and 0.19 are classified as strong, moderate, and weak models, respectively.

Table 5: *Distribution of R^2 and adjusted R^2 values*

Variable	R^2	Adjusted R^2	Description
Creativity (Y_1)	0.469	0.458	Moderate
Innovation capability (Y_2)	0.690	0.681	Moderate
Average	0.579	0.569	

Table 5 shows that the R^2 values of creativity and innovation were 0.469 and 0.690, respectively. The R^2 values were used to obtain an average of 0.579. This means that the HRMP, KM, creativity, and innovation constructs explained only 57.9% of the relationships within the model, while the remaining 42.1% was explained by other external variables. The adjusted R^2 value was smaller than the distributed one. This means that there is a possibility of changing or expanding the research model to include other latent variables.

After an ideal value was realized from the R^2 analysis, it was tested using the *Q* Square Predictive Relevance (Q^2) method. This aims to measure the accuracy of the observed model. Q^2 ranges from 0 to 1 (Hair et al., 2013), and when the value is closer to 1, this means that the model has a better predictive ability. The Q^2 value is calculated using the formula:

$$Q^2 = 1 - [(1-R2y1)\ (1-R2y2) = 1 - [(1-0.469)\ (1-690)] = 1- [(0.531)\ (0.310)] = 0.836$$

A value of 0.836 was realized, which meant that the model was properly observed. This implies that the model was explained by 83.60% of the relationship between the variables. Conversely, the remaining 16.40% was illustrated by the factor error or other variables not included in the research model. The third step involved testing the goodness of fit (GoF) criteria, as this is a single measure which is realized by validating the overall structural model (Hair, Hult et al., 2016; Hair et al., 2013). This was conducted as follows:

$$GoF = \sqrt{com} \times R^2 = \sqrt{0.400} \times 0.579 = 0.481$$

A value of 0.4812, was realized from the GoF calculation. This implies that the predictive model is fit and accurate. However, this is based on the GoF value, including 0.10 (small), 0.25 (moderate), and 0.36 (large). Therefore, this research model is categorized as possessing a large GoF (Hair, Hult et al., 2016).

Furthermore, the effect size (f^2) was tested to provide detailed information about a group of independent and dependent variables realized through a system of structural equations (Hair, Hult et al., 2016). The criteria for effect size (f^2) range from 0.02 to 0.15 (weak influence), 0.15 to 0.35 (moderate influence), and >0.35 (strong influence) (Hair, Hult et al., 2016; Hair et al., 2014). Subsequently, supposing the f^2 value is within the 0.02 to 0.15 range, then the research model is assumed to be weak, whereas the 0.15 to 0.35 and >0.35 ranges are declared to have moderate and strong influences, respectively.

Table 6. *Cohen effect size analysis*

Construct*	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
HRMP -> OIC	0.213	0.211	0.054	3.948	0.000
KM -> OIC	0.088	0.090	0.049	1.809	0.071
Average	0.151				

*HRMP: human resource management practices, KM: knowledge management, OIC: organizational innovation capability

The results shown in Table 6 prove that the original sample for the HRMP and OIC constructs was 0.213. Conversely, the original sample for the KM and OIC constructs was 0.088. Therefore, the average original sample was calculated at 0.151, indicating that the relationship pattern was predictable (Hair, Hult et al., 2016).

4.4 Hypothesis test

Hypothesis testing was carried out through 2 stages, namely evaluating the direct and indirect influences of exogenous and endogenous variables. Table 7 shows that a direct relationship existed between the variables, which was determined by analyzing the path coefficient values through the original sample.

Table 7. *Path coefficients*

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	*p* values	Remarks
HRMP -> Cr	0.513	0.516	0.094	5.481	0.000	Accepted
HRMP -> OIC	0.444	0.444	0.100	4.444	0.000	Accepted
KM-> Cr	0.213	0.215	0.106	2.016	0.044	Accepted
KM-> OIC	0.062	0.060	0.089	0.694	0.488	Rejected
Cr -> IOC	0.415	0.415	0.078	5.321	0.000	Accepted

*HRMP: human resource management practice, KM: knowledge management, Cr: creativity, OIC: organizational innovation capability

The path coefficient used to determine the existence of a direct relationship between HRMP and creativity was 0.513, with T statistics of 5.481 > 1.96 (STDEV 0.094; O/STDEV 5.481 PV 0.000). This was significant; therefore, hypothesis 1 was accepted. These results are consistent with the research carried out by Jiang et al., (2012) which stated that HRMP is positively correlated to creativity. Increasing the implementation of HRMP dimensions such as training carried out in accordance with need analysis tends to trigger creativity through a divergent thinking process (Chaubey et al., 2021). This helps employees to proactively acquire knowledge (Jiang & Gu, 2015) in terms of creatively solving work-related problems (Jiang et al., 2012). Furthermore, the organization needs

to explore the appraisal system designed to meet the unique motivational requirements of creative employees (He et al., 2012; Mullin & Sherman, 1993). It is also relevant to create a proportionate reward system, although there is ongoing debate about this issue (Friedman, 2009).

Moreover, the path coefficient that determines the direct relationship between HRMP and IC was 0.444, with T Statistics of 4.444 > 1.96 (STDEV 0.100; O/STDEV 4.444; PV 0.000). This was significant; therefore, hypothesis 2 was accepted. These results are consistent with the research carried out by Easa & Orra (2021), which stated that innovation capability is influenced by the effectiveness of the implementation of HRMP in an organization. HRMP plays a strategic role in creating a conducive work environment, thereby stimulating the potential for organizational innovation to develop (Barba-Aragón & Jiménez-Jiménez, 2020). It is proven that HRMP is the starting point in building organizational innovation capability (Rondi et al., in press; Kianto et al., 2017producing higher innovation performance. We have empirically tested this idea in a survey dataset of 180 Spanish companies using structural equation modelling (SEM; Chang et al., 2011).

The path coefficient that determines the direct relationship between KM and creativity was 0.213, with T Statistics of 2.016 > 1.96 (STDEV 0.106; O/STDEV 2.016; PV 0.044). This was significant; therefore, hypothesis 3 was accepted. These results are consistent with the study carried out by Baldé et al. (2018), which stated that KM plays an important role in developing creativity (Joo et al., 2014; Nonaka & Von Krogh, 2009). This is also in line with the study carried out by Schulze & Hoegl (2008), which stated that research on the way and manner in which knowledge acquisition influences creativity is extremely limited.

The path coefficient that determines the direct relationship between KM and OIC was 0.062, with T Statistics of 0.694 > 1.96 (STDEV 0.089; O/STDEV 0.694; PV 0.488). This was insignificant; therefore, hypothesis 4 was rejected. In woodworking SMEs, KM had an insignificant influence on organizational innovation capability because the knowledge possessed was not fully shared. In addition, KM was not optimally implemented due to differences in the characteristics of SMEs (Mota Veiga et al., 2021). Therefore, these results contradict the research carried out by Ode & Ayavoo (2020) and Mardani et al. (2018) , which stated that organizational innovation capability is closely related to creating and exploring available knowledge resources in organizations (Lam et al., 2021).

The direct correlation coefficient of creativity with OIC was 0.415, with T Statistics of 5.321 > 1.96 (STDEV 0.078; O/STDEV 5.321; PV 0.000). This was significant; therefore, hypothesis 5 was accepted. These results are in line with the research carried out by Lin & Liu (2012), which stated that creativity and the ability to produce new work is considered the starting point and root of innovation; it also increases the chances of successful innovation (Botega & da Silva, 2020).

After this, the position of the mediating variable in an indirect relationship was determined. This model was comprised of 2 mediation pathways, which were tested according to the research framework. Based on the studies carried out by Hair, Hult et al. (2016) and Hair et al. (2014), the VAF method was adopted with respect to the following criteria: VAF < 0.20 represents no mediation, 0.20 to 0.80 represents partial mediation, and > 0.80 represents full mediation.

Table 8. *Mediation effect test*

Link*	Mediator*	Independent variable-mediator	Dependent Variable-mediator	Direct	Indirect	Total effect	VAF (%)	Decision
HRMP-IC	Cr	0.513	0.415	0.444	0.213	0.659	0.323	Partial mediation
KM-IC	Cr	0.213	0.415	0.062	0.088	0.150	0.587	Partial mediation

**HRMP: human resource management practice, KM: knowledge management, Cr: creativity, IC: innovation capability, VAF: Variance Accounted For*

Table 8 provides and justifies the information concerning the mediation role. From this perspective, the mediating influence on the research model was determined by using a non-parametric bootstrapping approach (Hair, Sarstedt, et al., 2016)its prevalence and challenges for social science researchers. Part II – in the next issue (European Business Review, Vol. 28 No. 2. The mediating factor was assessed by absorbing some of the direct influences on the independent and dependent variables, respectively. Finally, calculations using variance accounted for (VAF) were performed to evaluate the size of the indirect and total link (Hair et al., 2014). In this context, a VAF greater than 80% is categorized as full mediation; a VAF between 20 and 80% is categorized as partial mediation; and a VAF less than 20% is categorized as exerting no mediating influence (Hair et al., 2014).

However, because 2 mediation pathways were tested in this research, it was concluded that creativity partially mediates the relationship between HRMP and IC. The VAF value was equal to 24.4%; therefore, hypothesis 6 was accepted. These results are consistent with the studies carried out by J. Jiang et al. (2012), which stated that creativity serves as a mediating variable between HRM and innovation. Overall, these results suggest that HRMP enhances creativity by hiring employees with creative potential and further using the reward systems and job design to boost motivation (Jiang et al., 2012). In Indonesia, the HRM function of woodworking SMEs plays an important role in facilitating organizational innovation capability by hiring and rewarding creative employees, (Arsawan, Rajiani, et al., 2020) thereby enabling them to design jobs that increase intrinsic motivation and social facilitation.

Creativity also partially mediated the relationship between KM and IC, with a VAF value of 37.50%. Therefore, this means that hypothesis 7 was accepted. In the second mediation pattern, creativity acted as a mediator between KM and organizational innovation capability. According to Ode & Ayavoo (2020) and Bettiol et al. (2012), KM facilitates the development of creative ideas towards increasing innovation capability (Kwan et al., 2018). Thereafter, optimally absorbed knowledge increases capability (Arsawan et al., 2018). This is because KM lays the foundation for building creativity, which is perceived as a source of organizational innovation, as shown in Figure 2.

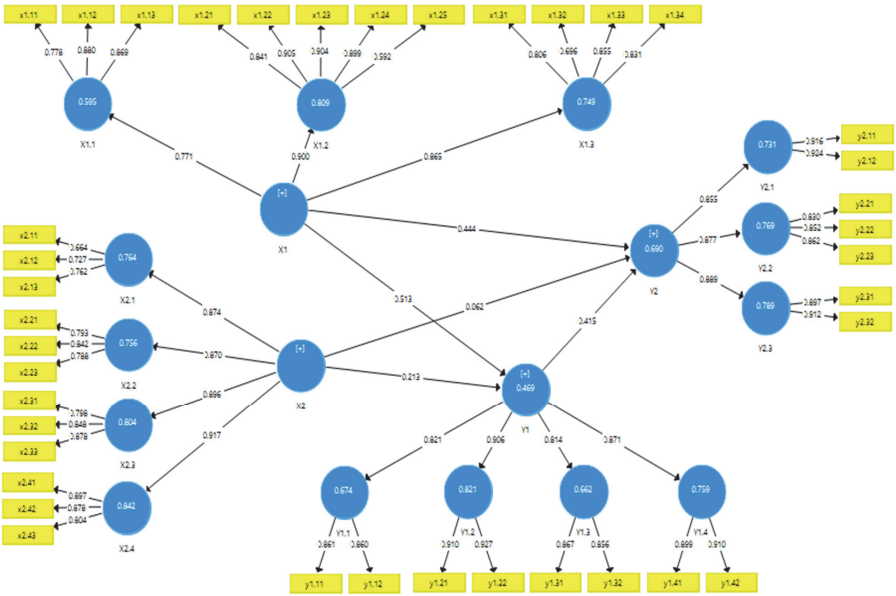

Figure 2. *Output analysis*

5. Conclusion

5.1 Theoretical implications

Several preliminary studies have reported that KM is an important antecedent of a company's innovation capacity (Ode & Ayavoo, 2020). As explained in the introduction to this paper, this research has succeeded in closing the following 4 gaps by offering knowledge and the conceptualization of newly comprehensive models, and providing a clear and systematic understanding of the interrelationships between variables.

1. Research on innovation capability has been investigated in various antecedent formations. However, before now it had not been tested with a comprehensive model involving the links between HRMP, KM, creativity, and innovation. Therefore, this model provides a holistic understanding that HRMP largely contributes to creativity and organizational innovation capability. Meanwhile, KM is one of the more important predictors in terms of knowledge that potentially aids in developing creativity (Saulais & Ermine, 2012) to increase organizational innovation capability (Grimsdottir & Edvardsson, 2018; Mardani et al., 2018)innovation, and performance. We aim to shed some light on the consequences of Knowledge Management (KM.
2. This research explains the relationship between HRMP and innovation. This has not previously been extensively examined (Barba-Aragón & Jiménez-Jiménez,

2020), even though innovation is an important aspect of organizational development (Chaubey et al., 2021; Zhao et al., 2020).

3. This research explains the way and manner in which HRMP influences innovation through a mediation model to provide a structured description (Easa & Orra, 2021), as well comprehensively illustrating views concerning the relationship between these two variables – an area which was previously regarded as a black box (Messersmith & Guthrie, 2010; Beugelsdijk, 2008). In this research, creativity acts as a double mediator connecting HRMP and innovation, as well as within the KM and innovation pathways.
4. SMEs in developing countries, especially Indonesia, provide important insights into building innovation as a culture (Arsawan, Koval, et al., 2020) by adopting creativity in a sustainable manner (Areed et al., 2021; Saulais & Ermine, 2012). They also view innovation as an important strategy (Du, 2021) in order to compete in a competitive business environment and withstand high market turbulence (Grimsdottir & Edvardsson, 2018).

5.2 Managerial implications

From a managerial perspective, this research provides a grid for practitioners to gain a better understanding of their tasks in terms of optimizing the role of creativity and innovation capability in SMEs. First, this research shows that managers need to optimize HRMP when seeking creative employees to boost innovation capability. There is a need to develop analytical skills to improve KM practices at all managerial levels, because these practices support creativity (Stojanović-Aleksić et al., 2019). Therefore, innovation is developed while capability is sustainable. Managers need to realize that KM not only signifies knowledge acquisition, but also greatly establishes metacognitive strategies for adopting, disseminating, and creating new ideas.

Managers are also expected to optimally manage intellectual capital (Grimsdottir & Edvardsson, 2018), enabling employees to develop in respect to their potential. Furthermore, the appreciation of their contribution fosters collective intelligence and the professional development of innovation (Ayanbode, 2020). Conversely, managers need to strategically focus on designing innovative policies from a multidimensional approach (Exposito & Sanchis-llopis, 2018). Consequently, developing relevant HRMP patterns also aids in building innovative work behavior (Arsawan, Rajiani, et al., 2020), business performance, and sustainability (Arsawan, Koval, et al., 2020) – especially in terms of HRM (Popescu et al., 2020).

5.3 Limitations and future research

This research has some limitations. First, it used a self-reported instrument in determining the way respondents felt about the variables. Self-reporting is suitable for measuring psychological ownership, and, in terms of research variables, it is the best

evaluation method. However, only respondents themselves are able to understand this effect – although this is inseparable from the effects of bias.

Second, the subjects of this study were limited to woodworking SMEs in Bali, a context which indeed demands creativity and innovation. Therefore, these results need not be generalized. In future, behavioral research needs to be carried out to investigate the relationship between creativity and innovation capability by involving more variables and adopting a longitudinal design. Therefore, it is necessary to conduct comparative research in order to compare SMEs with other fields, such as the educational, banking, and information technology sectors. Moreover, research opportunities regarding innovation are more interesting when other control variables such as company size, age, and ownership type are used.

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THE ASSESSMENT OF THE EDUCATIONAL POTENTIAL OF THE REGIONAL POPULATION OF THE RUSSIAN FEDERATION

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Abstract. *Aim: This article covers an important subject – the assessment of the educational potential of the regional population of the Russian Federation. This is one of the most fundamental issues in modern society to be considered for the future development of Russia. The authors look at the concept of educational potential, systematize its key indicators, and perform an index analysis of factors that characterize educational activity and the technical, material, and informational basis of education in the Russian regions.*

Methodology: This article introduces a number of integrated components that characterize educational activities as well as the technical, material, and informational basis of education. A structured list of recommendations is provided for the implementation

of multidimensional regional classification, in line with both individual as well as broad indicators covered in the analysis.

Results: The regression model is based on an integral indicator that characterizes educational activity and defines the index of educational performance: the share of employed, higher-educated members of the population aged 25–64 years in the total number of economically active people of the same age group. Integral indicators characterizing educational activity and the technical, material, and informational basis of education were used in the benchmark analysis which defined leading and lagging regions in the Russian Federation. Based on these indicators, a multidimensional breakdown structure was developed to distinguish the weaknesses of other regions in relation to the leader.

Conclusion: These results may be useful for statisticians and economists for research on the level of informatization of the population and the economy.

Keywords*: education, expected and average period of training, cross-country comparisons, multidimensional grouping, population educational potential*

JEL Codes: *I25*

Introduction

Education is the most important driving force for progress in the socio-economic, scientific, and technological development of society. The "World Declaration on Higher Education for the 21st Century: Approaches and Practical Measures" (1998, Preamble) highlights that "on the verge of the 21st century we are witnessing an unprecedented demand for higher education and its wide diversification along with an ever-increasing awareness of its crucial importance for socio-cultural and economic development and creation of a future in which younger generations will have to master new skills, knowledge and ideas."

Education is a vital characteristic in examining human potential as it affects the quality of employment and, therefore, the development of the economy of any given country (Han, 2016).

According to a study by Blundell, Dearden, and Sianesi (2001), over the period of their work lives, employees with higher education on average receive bonus payments equal to 24% of their wages – equivalent to around 160,000 GBP (about 15.5 million RUB). The subject of the direct relationship between level of education and income of the population has also been raised in research by S. McKeen, J. Conlon, and S. Harkness.

In B. Knall's "Circle of Backwardness" concept, the author highlights that one of the reasons for economic backwardness lies in the poor level of the public education system and professional training development. Therefore, a country's development depends on focusing attention on these areas.

At the international level, special attention is paid to the research of education for many reasons, including the assumption that education level is part of the integrated assessment of a person's development level. The Human Development Index is published

annually as part of the UN development program, and its calculation is based on the following indicators: longevity, education, and standard of living using Gross National Income estimates. The above indicators are included in the Human Development Report. The list of characteristics of the education system for the 2010–2019 period has undergone significant changes (Wolff et al., 2014).

The following data was published for the reported period: average and expected time of training; number of the population with at least secondary education; and the non-profit education index.

In 2019, the list of indicators included into the report was affected by digitalization processes, and a few more were added to the publication of the corresponding year: "Percentage of primary and secondary schools with Internet access"; "Percentage of primary school teachers with profession-specific education"; "Student to teacher ratio"; and "International Student Assessment Program Grades in mathematics, reading and science" (Gromov et al., 2016).

One of the components of the Human Development Index covered by UN studies and presented in the Human Development Report is a consolidated educational quotient. The measuring range of this quotient is from 0 to 1, and the closer a value is to 1, the higher the level of education is in the country. The highest levels of expected study period were observed in the European countries and in Central Asia (14.6 years); however, the average number of years in this group of countries was 10.2. This group was also characterized by a high non-profit education index (0.682), while the student to teacher ratio was one of the lowest – 18 people (Woessmann & Hanushek, 2007).

The countries of Latin America and the Caribbean showed high levels of average and expected study periods (8.6 and 14.5 years, respectively). There was also a high level of non-profit education index (0.553), and 21 students per teacher in this group. Despite rather high levels of expected and average study periods, the gap between them was 5.9 years – hence we can say that the expectations of many students were not met (Hasaev & Bolgova, 2015).

The lowest rates for the average and expected study period were common for sub-Saharan African countries (5.7 and 10 years, respectively). The non-profit education index in this group of countries was 0.308, and the student to teacher ratio was 39 to 1 – which indicated a significant problem with staff in this region (Bakumenko & Kostromina, 2018).

The Russian Federation is not among the leading countries in terms of the educational quotient. In 2018, the average study period in our country was in 32nd place (12 years), compared to 77th place (8.8 years) in 2010. Analysis of the expected study period index amongst different countries for the 2010–2018 period showed that Russia was in 39th place (15.5 years) compared to 48th place in 2010 (14.1 years).

The Russian Federation did not participate in the 2010 UN research on the student to teacher ratio; however, in 2018 it was in 69th place with a ratio of 21 to 1.

The relatively weak position of Russia amongst other countries in terms of the consolidated educational quotient, as well as the extensive usage of the integral criterion in global practice, proves the importance of this research (Makarov et al., 2014).

1. Theoretical Aspects

The rating of the innovative development of the Russian Federation's constituent territories prepared by the Institute of Statistical Studies and the Economy of Knowledge of the National Research University "Higher School of Economics" was used as a basis for this study.

Since 2008, experts have calculated the rating of innovative development based on a number of components including "socio-economic conditions of innovative activity." In addition to macroeconomic indicators and the digital potential of the population, the indicated unit also includes characteristics of the educational potential of the population (Grezina et al., 2012).

Below is the list of indicators characterizing the educational potential of the regional population in the Russian Federation:

- the share of people aged 25–64 years with higher education in the total number of the population in this age group (%);
- the total number of university students – bachelor's degrees, specialist programs, or master's degrees – per 10,000 people (number);
- the share of students enrolled in programs specializing in mathematical and natural sciences, engineering, technology and technical sciences, or fundamental medicine in the total number of university students studying for bachelor's degrees, specialist programs, or master's degrees (%);
- the share of the economically active population aged 25–64 years who continuously upgrade their qualifications;
- the share of students enrolled in tertiary education mid-level training programs per 10,000 people (number);
- the share of students enrolled in tertiary education mid-level training programs specializing in mathematical and natural sciences, engineering, or technology and technical sciences (%).

It should be noted that the indicators used to characterize the population's educational potential emphasize the assessment of the development of innovation, and therefore only include indicators typical for particular areas such as engineering, fundamental medicine, etc. (Soloviev & Pestrikov, 2008).

The ranking published by the Institute for Statistical Studies and Economics of Knowledge subordinated to the National Research University "Higher School of Economics" determined the Tomsk region as a leader, showing the highest educational potential in terms of the number of university students per 10,000 people as well as the share of students enrolled in programs specializing in mathematical and natural sciences, engineering, or technology and technical sciences. Meanwhile, the Tomsk region occupies lower positions with regard to the number of people continuously upgrading their qualifications as well as the number of people with a university degree (11th and 32nd places, respectively) (Blundell et al., 2001).

It is worth noting that Moscow and Saint Petersburg have an unusually wide discrepancy regarding two indicators – the number of people continuously upgrading their

qualifications (1st and 3rd places, respectively) and the number of people with a university degree (72nd and 59th positions, respectively).

Given the significance of this study and the disproportionate levels of regional development, it seems necessary to configure an integrated evaluation of the educational potential of the population (Ferguson & Fernández, 2015).

2. Database and Methods

For the purpose of a comprehensive assessment of educational potential in the constituent entities of the Russian Federation, the authors introduce a multidimensional analysis with the application of two integral components: the "Index of educational activity" and the "Index of the material, technical, and informational basis of education", which in turn include the following indicators (Table. 1) (Wolska et al., 2019).

Table 1. *Index components.*

Title	Term
Index of educational activity	
Number of higher-education program students per 10,000 people (number)	$x_{1.1}$
Number of higher-education teaching personnel per 10,000 students (number)	$x_{1.2}$
Average grade in the SNE – State National Exam (state funded university places)	$x_{1.3}$
Average tuition cost, RUB	$x_{1.4}$
Index of the material, technical, and informational basis of education	
Educational organization floor area per 1 building, sq. m.	$x_{2.1}$
Share of students in dormitory accommodation in the total number of applicants, %	$x_{2.2}$
Share of computers used for educational purposes in the total number of PCs in higher-educational organizations, %	$x_{2.3}$
Share of educational organizations with distance learning programs in the total number of programs nationwide, %	$x_{2.4}$
Higher-education organizations' expenses on scholarships per student, thousand RUB	$x_{2.5}$

Source: *analytical database of Ministry of Science and Higher Education of the Russian Federation and the National Research University "Higher School of Economics" (www.minobrnauki.gov.ru, www.ege.hse.ru, accessed 9 March 2020).*

The indicator calculations provided in Table 1 are based on data from the following reporting forms, submitted by the Ministry of Science and Higher Education of the Russian Federation:

- • Form No. VPO-1 "Information about the higher education organizations offering bachelor's programs, specialty programs, and master's programs."
- • Form No. VPO-2 "Information on the material, technical, and information basis and the financial and economic activities of higher education organizations."

In addition to the forms listed above, we also used the data on the monitoring of the admission quality of Universities of the Russian Federation provided by the National Research University "Higher School of Economics".

In total for 2018, data on 84 constituent entities of the Russian Federation was used to complete this research. The Nenets Autonomous region was excluded from the analysis due to the lack of data on most indicators (Korshunov & Gaponova, 2017).

3. Research Findings: a Model of the Assessment of the Educational Potential of the Regional Population af the Russian Federation

3.1. Descriptive statistics

The methodology assigns a rating and is designed so that, in the initial stage, the database to be processed is generated. The main characteristics of the analyzed indicators are presented in Table 2.

Table 2. *The indicator values included in the integral evaluation of the educational potential of the regional population of the Russian Federation.*

Title	Lowest value	Highest value	Range of Dispersion	Median	CV, %
Number of students of higher-education programs per 10,000 people (number)	14	605	591	240	16
Number of higher-education teaching personnel per 10,000 students (number)	1	41	40	13	48
Average grade in the SNE – State National Exam (state funded university places)	49.7	78.0	28.3	64.5	8
Average tuition cost, RUB	66,985	269,055	202,070	114,199	29
Educational organization floor area per 1 building, sq. m.	1,472	9,035	7,563	4,766	28
Share of students in dormitory accommodation in the total number of applicants, %	5.4	100,0	94,6	91.8	19
Share of computers used for educational purposes in the total number of PCs in higher-educational organizations, %	26.5	91.1	64.6	67.2	16
Share of educational organizations with distance learning programs in the total number of programs nationwide, %	0.00	16.58	16.58	0.76	64
Higher-education organizations' expenses on scholarships per student, thousands RUB	16,779	94,803	78,024	46,107	25

This calculation was based on data from the analytical database of the Ministry of Science and Higher Education of the Russian Federation and the National Research University "Higher School of Economics" (www.minobrnauki.gov.ru, www.ege.hse.ru, accessed 9 March 2020).

Based on the variation coefficient values given in Table 2, most of the regions of the Russian Federation are similar in the majority of indicators. The only exceptions are the number of higher-education teaching personnel per 10,000 students and the share of educational organizations with distance learning programs in the total number of programs nationwide (with variation coefficients of 48% and 64%, respectively) (Kapelushnikov, 2016).

At the same time, it can be observed from the majority of indicators included in the integral assessment of the educational potential of the regional population of the Russian Federation that the median divides constituent entities into two separate groups. This means that when we look at the number of higher-education program students per 10,000 people, the indicators vary by 226 people in the first group (from 14 to 240 people per 10,000 people) to 365 people in the second (from 240 to 605 people per 10,000 people).

The first group consolidates regions with indicator values lower than the median; the second with indicator values greater than the median (Klucharev, 2008).

There is a significant lag between the leading Krasnoyarsk region (with 605 people) and the rest of the regions in the second group – i.e., Moscow and Saint Petersburg (with more than 550 people) and the Tomsk region (with more than 540 people). The lowest number of students per 10,000 people was in the Yamalo–Nenets region (14 people)

The number of higher-education teaching personnel per 10,000 students in the first half of the regions varied from 1 to 13 per 10 students, while in the second half it equaled 28 people. The highest number of teaching personnel was in Saint Petersburg (with 41 people), Moscow (38), and the Tomsk (37), Volgograd (36), and Rostov (30) regions. In 26 regions, this value did not exceed 10 teaching staff per 10,000 students. It is not by coincidence that this particular indicator demonstrated such a wide variation across the regions.

The highest average State National Exam results were in Moscow (78 points), Saint Petersburg (76.9), the Tomsk region (74.6), the Republic of Tatarstan (73.2), the Novosibirsk region (71.2), and the Sverdlovsk region (70.7). The lowest was recorded in the Magadan region (49.7).

It should be noted that all of the above indicators demonstrate great variation across all of the regions of the Russian Federation. As an example, we can take the share of students in dormitory accommodation in the total number of applicants, which ranged from 5.4% to 100% in 2018. The lower number was recorded in the Chechen Republic, and 100% was recorded in 15 other regions.

It is important to note that tuition costs varied significantly across the regions. For instance, the lowest fee in 2018 was 66,985 RUB (the Republic of Kalmykia) and the maximum fee was 269,055 RUB (the Republic of Sakha, Yakutia). Notwithstanding high variation in the range of dispersion, the coefficient of variation that characterizes the homogeneity of the regions was within the norm (Heckman & Kautz, 2013).

In half of the regions, average tuition costs did not exceed 114,200 RUB. The lowest cost of education was in Belgorod (85.3), Kostroma (96.6), Pskov (96.6), the Altay region (97.4), the regions of the North Caucuses Federal District (79.8 – 99.4), and the Republic of Mari El (95.1).

The highest tuition costs were in the Republic of Sakha (Yakutia) (more than 200,000 RUB), the Khanty–Mansiysk Autonomous District, Moscow, and the Sakhalin Region.

Significant lags between the indicators included in the index of the technical, material, and informational basis of education can be observed in two groups: the share of students in dormitory accommodation in the total number of applicants ($x_{2.2}$), and the share of educational organizations with distance learning programs in the total number of programs nationwide ($x_{2.4}$). The first half of the regions indicator ($x_{2.2}$) showed significant variation from 5.4% to 91.8%, although it should be noted that 5.4% is a rather exceptional case which came from the Chechen Republic – the rest of the regions from the first group illustrated variations between 37.4% and 91.8%.

The share of students in dormitory accommodation in the total number of applicants in the second group of regions varied from 91.8% to 100%.

The share of educational organizations with distance learning programs in the total number of programs nationwide had an overall low indicator level across the country, and in half of the regions did not exceed 0.76%. In the entire 73 regions of the Russian Federation, its level was lower than 2% (Bondarenko, 2017).

In the present conditions of higher education organizations managing to continue the educational process by using distance learning technologies, it has become obvious that such programs are a necessity and a modern reality (Kuzjmonov, 2018).

3.2. The standardization of the data.

After all of the statistics of the regions were collected, data was normalized to secure its homogeneity and compatibility:

$$x'_{ij} = \frac{x_{ij} - x_{ij\,\min}}{x_{ij\,\max} - x_{ij\,\min}}, \quad (1)$$

where x'_{ij} – normalized value of the indicator i for the region j;
x_{ij} – value of the indicator i for the region j;
$x_{i\min}$ and $x_{i\max}$ – are the minimum and maximum values of the indicator i across regions (Rubin & Wright, 2017).

3.3. The calculation of indexes of educational activity and the material, technical, and informational basis of education.

The next step was the calculation of the (larger) components of the educational potential index. The following formula determines the mathematical average of the normalized values of a number of indicators:

$$I_{kj} = \frac{\sum x'_{ij}}{n_k}, \quad (2)$$

where I_{kj} – value of index component k for the region j;
n_k – number of indicators included into the index component k.

The calculated results of the aggregate indicators allowed for leading and lagging regions to be disclosed according to the educational activity index and the index of the material, technical, and informational basis of education. If several regions had similar index values, they were assigned equal seniority.

Table 3 provides a list of the leading regions pursuant to the larger component values of the integral evaluation of the educational potential of the regional population.

Table 3. *The regions of the Russian Federation with the highest levels of components which generated the country's educational potential in 2018.*

Ranking	Educational activity index	Index of technical, material, and informational basis of education
1	Moscow	Moscow
2	Saint Petersburg	Saint Petersburg
3	Tomsk region	Novosibirsk region
4	Krasnodar region	Krasnoyarsk region
5	Volgograd region	Kemerovo region
6	Moscow region	Khanty–Mansi Autonomous Area
7	Rostov region	Transbaikal region
8	Republic of Tatarstan	Mari El Republic
9	The Republic of Sakha (Yakutia)	Primorsky District
10	Sevastopol	Republic of Karelia

Source: *the same as under Table 1.*

The regions of the Southern Federal District (Sevastopol and the Krasnodar Krai, Volgograd, and Rostov regions) are among the main leaders in the value of the index of educational activity. As for the composition of the group of leaders in terms of the index of the material, technical, and informational basis of education, it mainly includes the subjects of the Siberian and Far Eastern Federal Districts.

Moscow and Saint Petersburg were the leaders in both the educational activity index and the index of the material, technical, and informational basis of education (1st and 2nd place in both indicators, respectively). What is most interesting is that the structure of the leader regions taking places 3rd to 10th diverges completely. As an example, we can look at Sevastopol, which ranks 10th in the educational activity index value and 83rd in the index of the material, technical, and informational basis of education (Table 4) (Bobkov & Gulyugina, 2012).

Table 4. *The regions of the Russian Federation with the lowest values of components which determined the educational potential of the population in 2018.*

Ranking	Educational activity index	Index of the material, technical, and informational basis of education
75	Altai Republic	Republic of Crimea
76	Kabardino–Balkarian Republic	Kamchatka region
77	Novgorod region	Yamal–Nenets Autonomous Region
78	Vologodskaya region	Leningrad region
79	Magadan region	Jewish Autonomous Region
80	Kostroma region	Sakhalin region
81	Kurgan region	Pskov region
82	Chechen Republic	Republic of Adygea
83	Astrakhan region	Sevastopol
84	Jewish Autonomous Region	Chechen Republic

Source: *the same as under Table 1.*

The structure of the regions that lagged the most in the value range of larger components also varied significantly. The subjects of all federal districts were represented (with the exception of the Volga region) among the 10 regions with the minimum values of the educational activity index. As for the lagging subjects in terms of the index of the material, technical, and informational basis of education, the subjects of the Southern and Far Eastern Federal Districts predominated in this group.

The fact that in the Far Eastern Federal District there are subjects who fell into the group of both the maximum and minimum values of the index of the material, technical and, informational basis of education allows us to conclude the heterogeneity of subjects in this district.

Entities like the Chechen Republic and the Jewish Autonomous Region were amongst the 10 regions with the lowest values of the examined indicators. Thus, the Chechen Republic is 82nd by the index of educational activity, and 84th by the index of the material, technical, and informational basis of education. The Jewish Autonomous Region is 84th and 79th, respectively.

Therefore, vastly disproportionate results were revealed, indicating that components which configure regional educational potential vary significantly by levels of development, which in turn affects the general assessment of general educational potential.

To evaluate the results of educational activities, we examined the correlation between the educational activity index and the share of the employed population aged 25–64 years with higher education in the total number of the employed population in the corresponding age group (Leongardt, 2012).

The indicator of the level of education of the population assessed by the proportion of people aged 25 to 64 years with higher education in the total number of this age group

demonstrates a fairly high level of variation across the regions of the Russian Federation. The lowest percentage of people with higher education was 23.6% in the Jewish Autonomous Region, and the maximum value of 50.2% was recorded in Moscow. However, in half of the regions the proportion of the population with higher education was less than 32.6%

The largest proportions of the population with higher education (more than 40%) were encountered in only 8 regions: Moscow (50.2%), St. Petersburg (44.3%), Sevastopol (43.9%), the Moscow region (42.4%), the Yamalo–Nenets Autonomous Region (47.4%), and the Republics of North Ossetia–Alania (44.8%), Karachay–Cherkess (43.7%), and Kalmykia (42.1%). A greater number of regions (51 in total) demonstrated variation between 30% and 40%.

Therefore, it would be valid to raise the question of how much influence the components flagged in this research have on the regional level of education.

Correlation analysis between the index of educational activity and the share of the employed population aged 25–64 years with higher education in the total employed population of the corresponding age group showed a direct and moderate correlation ($R = 0.349$). The results were significant at $p < 0.05$ (Evirgen, 2016).

The general linear regression model that includes all of the regions of the Russian Federation allowed us to track and predict the share of employment of those aged 25–64 years with higher education, using the components included in the indicator of educational activity.

The statistical adequacy of the regression model ($\hat{Y} = 27{,}98 + 13{,}69x$) is supported by the following factors: the significance check shows that the null hypothesis was not rejected with a probability of 0.95 ($F = 11.37$, $Se = 5.06$). The determination coefficient was 0.121. This means that 12.1% of the variation in the share of the employed population aged 25–64 years with higher education in the total employed population of the corresponding age group (Y) is explained by the factors included in the educational activity indicator (X). The calculated coefficient of elasticity allows us to conclude that with a 1% increase in the level of educational activity, the share of the employed population aged 25–64 with higher education in the total number of the employed population will increase by 15.8% (Yahontova, 2014).

The creation of universities with special status and with special funding from the federal budget was one of the elements of the strategy of the educational policy of the Government of the Russian Federation. As a result, a network of federal universities was created. Of course, this has had a positive impact on the level of education in the regions. This is due to the fact that federal universities have formed methodological materials for the development of innovative educational programs, as well as modernized the educational process. In addition, these universities actively organize networking with other educational organizations, as well as with scientific institutions and business partners, in order to form joint programs and to solve important problems of the socio-economic development of the regions (Dill & Soo, 2005).

There were 10 federal universities and 29 national research universities in Russia in 2019 which were allocated in the regions as follows: the largest number of universities in

this category was concentrated in the Central, Volga, and Siberian federal districts; Moscow is a leader, as it has the largest number of educational organizations (11); the rest of the country has one national or federal university per region.

The results of the calculation of the index of educational activity and the index of the material, technical, and informational basis of education allowed leading and lagging regions to be identified (Smirnov, 2013).

3.4. Classification of the regions of the Russian Federation

Regions were categorized into groups in line with the difference between the leader and the rest of constituent entities in terms of the educational activity index value (Table 5).

Table 5. *Classification of the regions of the Russian Federation according to the lag between the leader (Moscow) and other regions in the index value in 2018.*

Index value lag between the leader and other regions, %	Number of regions	Regions
Up to 40	4	Saint Petersburg Regions: Tomsk, Volgograd Krasnodar region
40–50	8	Regions: Moscow, Rostov, Novosibirsk, Tyumen, Oryol Republics: Tatarstan, Sakha (Yakutia) Sevastopol
50–60	24	Khabarovsk District Regions: Voronezh, Samara, Kursk, Sverdlovsk, Nizhny Novgorod, Saratov, Chelyabinsk, Yaroslavl, Omsk, Kaliningrad, Ryazan, Irkutsk, Smolensk, Leningrad Primorsky, Stavropol, Kamchatka, Krasnoyarsk Republics: Mordovia, North Ossetia–Alania, Adygea, Kalmykia Khanty–Mansi Autonomous Area
60 and more	47	Republics: Bashkortostan, Karelia, Karachay–Cherkess, Buryatia, Tuva, Chuvash, Dagestan, Ingushetia, Mari El, Udmurtia, Komi, Khakassia, Crimea, Altai, Kabardino–Balkaria, Chechen Regions: Belgorod, Ulyanovsk, Arkhangelsk, Kaluga, Orenburg, Ivanovo, Tula, Penza, Amur, Sakhalin, Tambov, Kirov, Tverskaya, Murmansk, Lipetsk, Vladimir, Pskov, Kemerovo, Bryansk, Novgorod, Vologda, Kostroma, Astrakhan, Jewish Autonomous Perm, Altai, Transbaikal Districts: Yamal–Nenets Autonomous, Chukotka Autonomous

Source: *the same as under Table 1.*

The first group, with a minimal difference between their educational potential index value and that of the leader region (Moscow), included only four regions, together with St. Petersburg.

The second group – with a lag of 40–50% – consisted of 8 entities, not including the North–West and North Caucasian federal districts (Kolomak, 2008).

The group with a lag of 50 to 60% consisted of regions that represent different federal districts. A large proportion (37%) of the 24 regions were part of the Central and Volga Federal Districts.

The third group, with a severe difference between their educational potential index values and that of the leader region, included 47 entities, 10 of which are part of the Central Federal District and 9 of which are part of the Far Eastern Federal District.

Table 6. *The classification of the regions of the Russian Federation in 2018.*

Federal district	Classification per difference in index value with the leader region, %				Total
	Up to 40	40–50	50–60	60+	
Central	-	2	5	10	17
North–West	1	-	2	5	10
Southern	2	2	2	2	8
North Caucasian	-	-	2	5	7
Volga	-	1	4	9	14
Ural	-	1	3	2	6
Siberia	1	1	3	5	10
Far East	-	1	3	7	11
Total	4	8	**24**	**47**	83

Source: *the same as under Table 1.*

Most regions that fell behind the leader region (Moscow) by 60% or more were part of the North Caucasian, Volga, and Far East Federal Districts.

Let us examine the regional breakdown according to the difference in the value of the index of the material, technical, and informational basis of education with the leader region.

As for this index, Moscow also demonstrated the highest scores and was again used as a basis for comparison. Similarly to the results for the index of educational activity, analogous intervals were selected to compare the outcomes of the two indexes (Tsomartova, 2010).

Table 7. *The classification of the regions of the Russian Federation by level of difference in the value of the index of the material, technical, and informational basis of education with the leader region (Moscow) in 2018.*

Index value lag between the leader and other regions, %	Number of regions	Regions
Up to 40	62	Saint Petersburg Regions: Novosibirsk, Kemerovo, Murmansk, Samara, Moscow, Tomsk, Ivanovo, Arkhangelsk, Voronezh, Belgorod, Sverdlovsk, Lipetsk, Kurgan, Tyumen, Oryol, Omsk, Smolensk, Ryazan, Bryansk, Tver, Amur, Tambov, Rostov, Volgograd Kaluga, Kostroma, Penza, Novgorod, Chelyabinsk, Tula, Irkutsk, Kirov, Kursk, Orenburg, Nizhny Novgorod, Yaroslavl, Kaliningrad, Saratov, Vladimir Krasnoyarsk, Transbaikal, Primorsky, Altai, Perm, Krasnodar, Stavropol, Khabarovsk Districts: Khanty–Mansi Autonomous, Chukotka Autonomous Republics: Mari El, Karelia, Bashkortostan, Tatarstan, Chuvash, Mordovia, Sakha (Yakutia), Udmurt Republic, Tuva, Komi, Khakassia
40–50	16	Republics: Ingushetia, Kalmykia, Altai, Buryatia, Kabardino–Balkaria, North Ossetia–Alania, Dagestan, Karachay–Cherkess, Crimea Regions: Astrakhan, Magadan, Ulyanovsk, Leningrad, Jewish Autonomous Kamchatka Krai Yamal–Nenets Autonomous Region
50–60	5	Regions: Sakhalin, Pskov Republics: Adygea, Chechen Sevastopol

Source: *the same as under Table 1.*

Only 3 intervals are present in Table 7. The first group (with a lag of up to 40%) included 62 regions, the largest number of which (48%) are part of the Central (17) and Volga (13) federal districts.

The second group – with a lag of 40–50% – included 16 regions, 5 of which are part of the North Caucuses federal district.

The most disadvantaged group, with the maximum difference between its index value and that of the leader region, included only 5 regions.

Table 8. *The classification of the Russian Federation regions in 2018*

Federal district	Classification per index value difference with the leader region, %			Total
	Up to 40	40–50	50–60	
Central	17	-	-	17
North–West	8	1	1	10
Southern	3	3	2	8
North Caucasian	1	5	1	7
Volga	13	1	-	14
Ural	5	1	-	6
Siberia	9	1	-	10
Far East	6	4	1	11
Total	**62**	**16**	**5**	83

Source: *the same as under Table 1.*

This analysis made it possible to identify regions with an equally high level of both educational activity and the development of the material, technical, and informational basis of education. These are the St. Petersburg, Tomsk, and Volgograd regions and Krasnodar Krai. It is recommended to use the successful experience of these regions in the formation of education policy (Frolich et al., 2010).

It should be noted that even though the above indexes are related to the same field of study, they nevertheless characterize different components, making it impossible to combine them into one integral indicator at this stage.

Conclusion

The research outcomes of the study of regional ratings can become a basis for the development of differentiated measures aimed at stimulating the progress of educational potential, as well as monitoring the implementation of regional programs for the advancement of education.

The constructed regression model will make it possible to predict in each individual region the change in the share of the employed population aged 25–64 with higher education in the total number of the employed population by using a predictor – the level of educational activity, which includes various components. It is necessary to take into account the situation of the subjects of the Russian Federation in terms of the level of development of the factor trait, and to change its value in each individual region. This can be achieved by carrying out comprehensive social and economic measures to improve the indicators included in the index, thereby adjusting the overall level of educational activity in the country (Bolli & Somogyi, 2011).

The individual review of each index will help to identify problem regions using individual characteristics of the education system. Each index, individually or in a group of

indicators, can affect individual components of the education system, which will allow the Ministry of Education and Science to respond more quickly to problems in this area in each region (Anikina et al., 2014).

In the context of an extremely innovative economy and a knowledge-based society which draws on the increasing use of information and communication technologies, the role of higher education organizations becomes particularly significant in ensuring all sectors of the economy have a supply of highly qualified personnel. Universities play an important role in the process of the formation of the political and scientific elite and the moral climate in society, and therefore the enhancement of educational potential should be subject to the close attention of state and regional governments.

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THE APPLICATION OF QUANTITATIVE METHODS FOR THE MODIFICATION OF A BUSINESS MODEL IN THE DIGITAL ERA, WITH THE SUPPORT OF THE MAPLE SYSTEM

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Abstract. *Businesses can gain strength and thus purposefully optimize their commercial models by means of implementing open innovations. The innovation process is increasingly conditioned by the innovative activities of customers. It is necessary to perform quick, low-cost, and rational research so that outputs can be updated and implemented into business models in-time. Digital transformation supports these processes because it represents a good opportunity for free spatial-temporal communication, and for the timely interaction of the participating parties.*

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This contribution stems from research (under the supervision of the paper's co-author, von Böhlen, 2021) performed in the German automotive industry, and follows up on the work of Simberova and von Böhlen (2021). The aim is to perform further and more detailed analyses and to interpret facts that ensue from selected research outputs.

These analyses are oriented solely towards the issue of open innovations as seen from the customer's perspective: innovations used for scaling business models in the automotive industry. Focus is especially placed on factors and relationships which affect customers' willingness to enter the open innovations process. The customer's social status has been taken into account. The rate and willingness of customers to engage in innovation activities has been measured – in connection with a whole range of factors, especially financial, those based on benefits, and others. Another form of analysis was a statistical evaluation that identified the degree of interest in some selected types of benefits. The independence of selected agents that stem from the survey evaluation was also considered, and quantitative methods, mainly statistical calculations, and transparent statistical visualizations were employed for this purpose. The methods of descriptive statistics and categorical analysis were used for processing data sets in the environment of the advanced Maple System.

These findings confirm that the customer is becoming a non-stationary and important source of information and possibly also a source of inferences regarding open innovations. Society is thus increasing its potential to work not only for the customer, but also with them. It is necessary to be ready to react to current pitfalls and to communicate with the customer continuously. Pertaining to implementing open innovations, these analyses have given interesting concrete output and findings regarding decision-making in the process of amplifying the business model in the automotive industry, as seen from the customer's viewpoint, and in the era of digitization. Further, they have opened a whole range of challenges related to further analyses of the matter at hand.

Keywords: *automotive industry; business model; Maple; statistical methods; open innovation; questionnaire evaluation; visualization*

JEL Codes: *C02; C10; M19; O36*

1. Introduction

The term innovation, especially open innovation, has been playing an important role in the sphere of commercial enterprises. Currently, in this process, the customer represents the key factor. The innovation process begins with an impulse – an idea, a proposal, a thought – and ends with the implementation on the market; more precisely, it ends with feedback. Producers and employees ought, naturally, to be willing to hear the customer domain, and should likewise offer enough space for communication with customers and for utilizing their innovative capabilities. Customers, on the other hand, ought to want to be motivated by producers and employees, and to have a convenient pathway to share their ideas and thoughts on a product or service, its innovation, and its implementation.

Business companies may amplify and thus optimize, in a meaningful way, their business models. This can be a part of the innovation process which is conditioned by customers' innovation activities. Innovations are, at present, seen as a moving force of a firm's performance – especially for the support of its competitiveness, prosperity, economic development, sustainability, efficiency, ability regarding digitization and automation, and so on. At the same time, the assessment of innovation projects, the management of innovative strategies, and the costs linked to these processes all pertain to important implementation factors.

Not only acceleration and turbulence in all spheres of human life, but also the stormy protests of planet Earth as it reacts to the heavy, unfavorable, and ill-advised interventions of man are necessarily leading to concrete changes along with new forms of human activities. The deployment of information and communication technologies (ICT) and the digital transformation of society represent basic instruments for the implementation of changes, in order to bring about rational and sustainable life on planet Earth.

For the formation or amplification of business models, it is necessary to perform inexpensive, rational, and telling research. A suitable digital transformation can provide free communication space-time for the timely interaction of the producer, seller, employee, and customer. Recently, blogs, online panels, and open customer communities have emerged as popular communication platforms. For instance, Eugene Ivanov's views are discussed on the *Innovazione* blog, which considers from this vantage point the issue of using crowdsourcing, and probes for opening innovations in connection with forming three basic commercial models based on: market-created innovation, sustainable innovation, and efficient innovation (La Vopa, 2017).

Many experts occupy themselves with the open innovations issue. In the Czech Republic, this phenomenon is supported by the Ministry of Industry and Commerce (MPO). In May, 2021, the MPO published the "Výzva programu podpory Inovace-Inovační projekt v rámci implementace Operačního programu Podnikání a inovace pro konkurenceschopnost 2014–2020" (in English – "Call of the Innovations Support Program – Innovations Project as Part of the Implementation of the Enterprise and Innovation for Competitiveness Operational Program 2014–2020).

Let us mention Veber et al.'s (2016) publication, in which the authors dealt with innovations both from a macroeconomic and a microeconomic point of view – namely: designing corporate innovation strategies, considering the implementation cycle of innovations as a tool to support prosperity and competitiveness, and perceiving innovations' coverage of all areas (tangible and intangible). The authors concern is also with the transformation of the German economy into a clean energy one.

The *Hospodářské noviny* newspaper (in English – *Economic Newspaper*) presented, as early as 2007, in the words of Laura Moris, the process of innovation implementation in several points. Briefly, this began with the tracing of a suitable community for collaboration, launching, and directing the innovation process; then involved communications forums; then testing by means of feedback; before finally performing the innovation process (*Zákaznické inovace*, 2008).

At present, a project supported by the Czech Technology Foundation (in Czech – *Technologická agentura České republiky*) listed as TL02000215 is being implemented at the Faculty of Business and Management of the Brno University of Technology, under the supervision of the co-author of this article, I. Simberova. The faculty website observes: "The project aims at strengthening the innovative capacity, competitiveness, sustainability and level of digitization of SMEs. It enables SMEs: a) to evaluate a level of digital maturity b) to increase innovation activity c) to generate sustainable value creation for customers d) to apply the implementation of digital transformation to business models e) to increase company performance f) to accelerate the learning process and the development of competencies in the business models and digital transformation g) to internationalize."

American professor Henry William Chesbrough (2003) introduced the term *open innovation* thus: "Open innovation is a paradigm that assumes that firms can and should us external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. Open innovation combines internal and external Ideas into architectures and systems whose requirements are defined by a business model."

Chesbrough's recently published important and ambitious work is called *Open Innovation Results: Going Beyond the Hype and Getting Down to Business* and "offers a clear-eyed view of the challenges that limit organizations' ability to create and profit from innovation and practical tools for overcoming those challenges". Moreover, "it is not enough to do pilots or proofs-of-concept in your innovation unit. Your innovation results must be broadly shared throughout the organization, across the siloes, and the businesses themselves must invest in time, money, and people to absorb the new innovation and take it to market" (Counts, 2019).

In Faber (2009), the author is concerned with the definitional and theoretical-conceptual basics of open innovations, and presents the approaches of other experts to the question at hand. For instance, Faber analyses Chesbrough's open innovation approach.

Eamurai, Khantanapha, and Piriyakul (2019) described research results for the purposes of an awareness of the open innovations of car-part producers in Thailand. It is pointed out that information stemming from the customer needs to be shared because it is an important source for the development and improvement of organizations' innovations.

Open innovations do not necessarily expand the company's innovative performance, as analyzed by Yapa, Senathiraja, Poesche, and Kauranen (2019). They point out that open innovations are based on knowledge flow: "We argue that boundary conditions matter in innovation performance and sequential coherence can explain why some succeed while others fail in open innovation... ability to scan the entire chain of knowledge flow across boundaries and taking corrective measures for any bottlenecks or hindrances observed can bring better results from open innovation initiatives."

The concept of innovation can be seen from different perspectives. The authors of this article, Volkova and Jākobsone (2016), have previously observed the importance and application of design and design thinking as significant sources of potential for innovative methods, which lead to strengthening competitiveness in difficult business conditions. Through their research, they confirmed design as an effective innovative method for improving business processes and business models.

Wang and Peng (2020) dealt with open-source patent strategy (Tesla's open-source patent strategy, in particular), which encourages technology sharing and innovation and solves the logic of intellectual property protection. The authors also referred to the possibility of the application of their ideas in China's new energy vehicle industry.

In connection with the study of human-resource outsourcing models in both the manufacturing and service sectors, Žitkienė and Blusytė (2015) noted that innovations in information and communication have created opportunities to produce and consume services in different places; however, people who would process those technologies are needed.

Geels (2004) made four contributions by addressing some open issues for the "Sectoral systems of innovation," which have emerged as a new approach in innovation studies.

According to Franco and Haase (2020), smaller companies implement open innovations with a higher probability. The reason for this involves the acquisition of a competitive advantage and solidification of their market confidence.

According to Jočienė (2015): "Revolutionary work was carried out by Osterwalder and Pigneur (2010), leaders in the field of business model innovation. They introduced the concept of a business model through the generalised view of 470 practitioners from a number of different countries. They used business models in an attempt to better explain how firms do business. The summarised business models were presented in nine building blocks and called the 'Business Model Canvas', which was considered to be the best schematic model representing a simplified version of a business organisation from a high-level perspective."

Ili, Albers, and Miller (2010) dealt with external sources to increase innovativeness: "Open Innovation proves to be more adequate in the attempt to achieve a better R&D productivity for companies in the automotive industry than a closed innovation model."

Kortum, Rebstadt, Gravemeier, and Thomas (2021) dealt with the optimization of customer communication based on customers' daily behavior. The basis of their analysis focused on the creation of a platform concept as an open innovation model.

Due to the ramifications of the fundamental resulting facts in the area of open innovations and business models, and due to the scope of this paper, let us further discuss only selected authors who deal with the mentioned area, i.e., open innovations, innovation strategies, innovation management, organizational and technological changes, the effects of the external environment, the market, and similar. These authors include: Enkel and Gassmanni (2009), Goffin and Mitchell (2016), Krstevski and Mancheski (2016), Skarzynski and Gibson (2008), and many others.

Although there are a number of publications related to this field of study, the bibliographical review of scientific databases and the verification of other resources performed within the framework of this research have shown that there is no suitable study relating to the mapping of how customers evaluate the space for open innovation in the area of the automotive industry.

This detailed survey was conducted in May–June 2021 in the German automotive industry in the form of an online questionnaire (an appropriate approach in the pandemic context) with the aim of performing analyses and interpretations on two planes: from the

customer's, and from the employee's viewpoint. This research was very extensive, and offers a wide range of scientific analyses. Our article is based on an analysis of research outputs at the customer level – how customers assess the topic of open innovations and their implementation. It is necessary to uncover the potential of whether and how open innovations provide "material" for scaling the business model in the automotive industry sphere. The relevant aspect under study is to consider how this knowledge can be used to strengthen competitiveness, but it is equally necessary to map the customer's perception of open innovations' implementation with regard to the development of the price elasticity of supply and demand.

2. Methodology

From the point of view of methodology, this article is based on an analysis of selected research outputs, i.e., on an analysis of the statistical data file generated by customer responses in the tracking of particular statistic characteristics. Let us briefly lay out the characteristics of the questionnaire survey: the questionnaire was structured – the first set of questions was only indicative for the researcher; a key set of questions followed, which were aimed at generating customers' and employees' responses and signaling their attitudes; and the last group of questions served to identify the respondents. There is no need to address a set of non-customer queries for the purposes of this article. The questions were of a mostly closed and often dichotomous character. The final form of the questionnaire was comprised of 23 questions, although the respondents answered more questions (in more detail). The evaluation of some of the 23 questions involved the merging of several sub-replies into a single reply.

Quantitative methods – mainly statistical calculations and transparent statistical visualizations – were used to evaluate the questionnaire itself. These methods involved: descriptive statistics; categorical analysis for processing data sets – statistical characteristics, contingent tables, statistical graphs; pie charts; histograms; column graphs; bar graphs; mosaic plots (explanatory facts from a 2D and 3D point of view); and the four-part tables as a special case of contingency tables, with an χ^2 test of the independence at the appropriate level of significance (according to the *p*-value, here at the 95% confidence level). The received quantitative outputs were interpreted with the aim of verifying the possibilities or properties of the innovation process in forming business models in the automotive industry area.

Quantitative output processing was conducted in the Maple system – a product of the Canadian company Maplesoft, Inc. This product has been developed for almost 40 years; a new release version is published annually, responding to the present impulses. The system is connected with a whole range of contemporary technological paraphernalia, and employs the intuitive character of work. Calculations are performed not only in numerical, but also in a precise symbolic mode, and it is also possible to employ a complete variety of interactive elements as well as sophisticated and modifiable 2D and 3D visualizations and simulations. This system offers a range of calculations, table processing, and

visualizations, employing the manipulation of practical sliders; a further advantage is found in the several procedures of the readily accessible Help feature.

When assessing this research, the Statistics package was used. This package "is a collection of tools for mathematical statistics and data analysis. The package supports a wide range of common statistical tasks such as quantitative and graphical data analysis, simulation, and curve fitting. In addition to standard data analysis tools the Statistics package provides a wide range of symbolic and numeric tools for computing with random variables. The package supports over 35 major probability distributions and provides facilities for defining new distributions. Much of the functionality in the Statistics package is accessible through the Context Panel. Context-sensitive functionality is available when selecting any data container (such as a Vector, list, or Array), known probability distributions (such as Normal(1,2)), or random variables" according to the Maple system's 2021 Help section. Maplesoft, Inc. considers its product a complex system: it creates platforms (sub-systems) designated for communication of users with specific aims, for concrete issues; and it also offers an application center, learning webinars, and a whole range of further possibilities for solving the challenges we are faced with today.

3. Results, comments, and discussions

It should be noted at the beginning that debate is led alongside commentary next to the partial outputs, especially regarding the possibilities of contrast with the obtained visualizations.

3.1. Gradual concrete steps

Firstly, for orientation, a sample of respondents is presented descriptively according to the selected statuses (gender, age, average monthly income in euros, current employment status, highest educational qualification).

Then, focus shifts to confronting the willingness of customers to engage in the process of implementing open innovations "with" and "without" benefits offered to customers (i.e., with all the possible combinations of answers to two questions simultaneously) based on their average income (at levels of €0, €500, €1,500, €2,500, €3,500, €4,500, €6,000, €8,500, €10,000+). From the point of view of mathematics, we observe the dependence of the explained variable on two explanatory variables (the 3D model – see below). We consider the impact of the financial indicator to be a useful finding. At present, in the context of a global environmental, climate, epidemiological, economic, and social crises, the financial aspect plays a key role in the preferences of customer utility; all the more so within decision-making in the area of the automotive industry. Thus, we have focused on the link between the two basic survey questions, considering the respondent's social status.

Other characteristics include: the respondent's gender, age, education, and profession, which we have also marginally considered in the interpretations of the outputs.

Another analysis is a statistical evaluation that identifies the degree of interest in some selected types of benefits.

Finally, we have dealt with the independence of the selected pairs of questions of the questionnaire.

3.2. Identification of the set of participating respondents

First, let us briefly introduce and identify the sample of the *research* respondents (of the questionnaire survey) who, as customers, are willing to be interested in issues related to the issue of open innovations and their implementation or participation in optimizing the business model. Visualization using pie charts offers a quick orientation to the issue.

(A) Gender: *What is your gender?*

This question was close-ended and dichotomous (male/female). The gender representation (%) can be seen in Fig. 1:

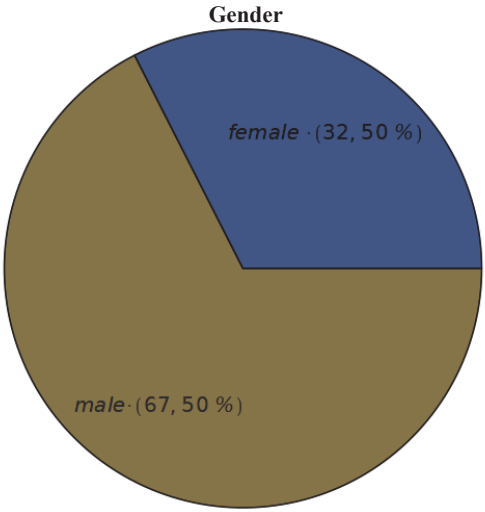

Figure 1. *The proportion of female and male respondents, %*
Source: *authors' elaboration*

Comment and discussion: The survey respondents – i.e., those who have an interest in open innovation in the automotive industry – were approximately two thirds male and one third female. There were twice as many men as there were women. This majority could be assumed to represent the notion that men are more interested in cars and that they often also care for women's cars. However, the percentage of women is not negligible, which also signals their emancipation when making decisions in the area of the automotive industry. The business model should respond to this.

(B) Age distribution: *How old are you?*

This question was close-ended, with five options (see Table 1). The age scales were divided into 10-year intervals, the left boundary not being included in the interval, the right boundary being included; i.e., we understand the intervals as left-open, right-closed. The age distribution can be seen in Fig. 2:

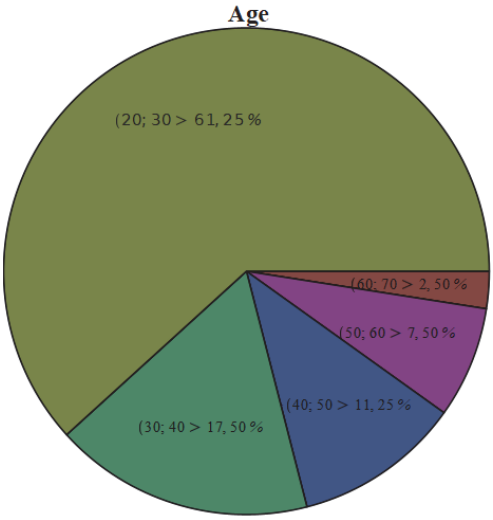

Figure 2. *The age distribution, %*
Source: *Authors' elaboration*

Table 1. *The age distribution, %*

Age (years)	(20; 30>	(30; 40>	(40; 50>	(50; 60>	(60;70>
Frequency	61.25 %	17.50 %	11.25 %	7.50 %	2.50 %

Source: *Authors' elaboration*

Comment and discussion: The youngest respondent was 21, and the oldest was 67 years old. If we divide the age groups into 10-year intervals, we can see that more than 60% of respondents were within the youngest group. This is logical, as members of this group likely have a great interest in forming their future at the onset of their productive age and they consider the car an important means for life. On the other hand, they feel experienced enough for their opinion to be taken into account. In fact, however, this may pose a contradiction, and can be misleading. The other age groups did not dominate as much, and over 60 years old was the least occupied group. Nevertheless, these people, although possibly very experienced, also have an interest in contributing to further development in

the automotive industry despite their proximity to retirement – an encouraging and pleasing observation. This is another important piece in the formation of the business model.

(C) Average income: *What is your average income? (rounded)*

The question was close-ended, with nine answer options: €0, €500, €1,500, €2,500, €3,500, €4,500, €6,000, €8,500, €10,000+), monthly.

For a better understanding of the matter, the following options were selected. A rounding of the average monthly income of the respondents (in euros) was taken into account – these values were taken as mid-points of the corresponding classes of the real income sets.

For our purposes, considering quite an irregular frequency in partial eventualities, some neighboring eventualities were, logically, merged as follows:

- An important reality is zero income;
- Averages incomes around €500 and €1,500 were merged, because both values represent a low-income level;
- Average incomes around €2,500 and €3,500 dominated, therefore they were left separate (they possibly represent a frequent level of average income and interest in open innovation, considering also the age distribution of the sample of participating respondents);
- Average incomes around €4,500 and €6,000 were merged;
- Average incomes around €8,500 and €10,000 or more (i.e., €10,000+) were merged;
- This means that after this modification, we have obtained a total of six categories (see Fig. 3 and Table 2).

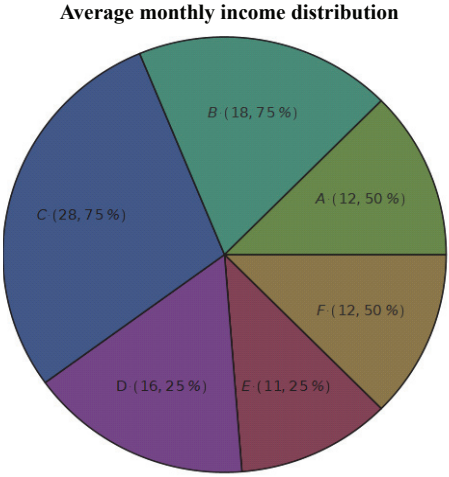

Figure 3. *The average income distribution, %*

Source: *Authors' elaboration*

Table 2. *The average income distribution, %*

	Average monthly income	Frequency
A	€0	12.50 %
B	€500, €1,500	18.75 %
C	€2,500	28.75 %
D	€3,500	16.25 %
E	€4,500, €6,000	11.25 %
F	€8,500, €10,000+	12.50 %

Source: *Authors' elaboration*

Comment and discussion: We can see that the average incomes of €500, €1,500, €2,500, and €3,500 represent more than half of the total respondents who were interested in the relevant issue. It is not insignificant that a fairly large part of the respondents who contributed their opinions had zero income. Thus, a business model also needs to take into account the opinions of customers such as students, homemakers, and other people who are financially dependent on others. High-income groups are obviously interested in innovation.

(D) Current employment status: *What is your current employment status?*

This question, once again, was close-ended. Eleven answer options were selected from: apprentice; dual student; employee; full-time student; independent; official; other; part-time student; retiree; unemployed; and worker. Current employment status is presented in Fig. 4 and in Table 3:

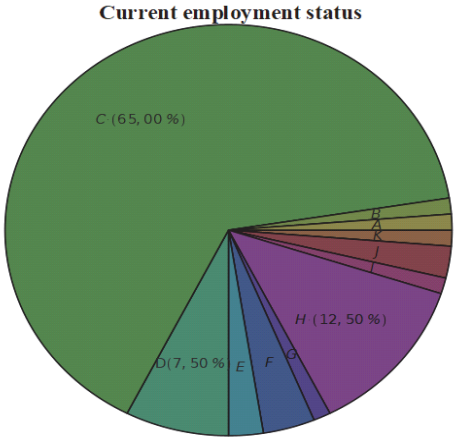

Figure 4. *The current employment status distribution, %*
Source: *Authors' elaboration*

Table 3. *The current employment status distribution, %*

	Current employment status	Frequency
A	Apprentice	1.25 %
B	Dual student	1.25 %
C	Employee	65.00 %
D	Full-time student	7.50 %
E	Independent	2.50 %
F	Official	3.75 %
G	Other	1.25 %
H	Part-time student	12.50 %
I	Retiree	1.25 %
J	Unemployed	2.50 %
K	Worker	1.25 %

Source: *Authors' elaboration*

Comment and discussion: Employees clearly dominated the sample of the participants (65%). It seems that employees are greatly interested in implementing open innovations, and thus also in the option of intervention of the end-user when the business model is being formed in the area of the automotive industry. Students came next. Due to the very scarce frequency of all of the other options of employment status, we have not written the percentage values on the pie chart – Table 3 provides a detailed overview. Employees and students (who are enhancing their qualifications via education) felt the need to express themselves regarding business model formation. Unemployed and retired people, however, were also interested in exercising their opinions. We consider this to be an important factor, and we suppose that these respondents were people who commonly actively involve themselves in similar challenges.

(E) The highest educational qualification: *What is your highest educational qualification?*

This question was, once again, close-ended. Nine answer options were selected from: advanced technical college; bachelor's; diploma; general university entrance qualification; master's; other; promotion; secondary school diploma; and vocational training. The highest educational qualifications of the respondents are presented in Fig. 5 and in Table 4:

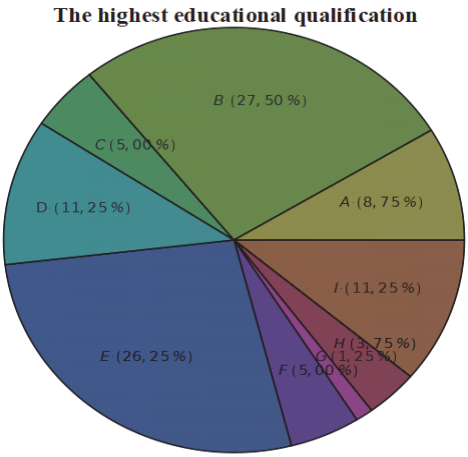

Figure 5. *The highest educational qualification, %*
Source: *Authors' elaboration*

Table 4. *The highest educational qualification (%) – respondent frequency*

	The highest educational qualification	Frequency
A	Advanced technical college	8.75 %
B	Bachelor's	27.50 %
C	Diploma	5.00 %
D	General university entrance qualification	11.25 %
E	Master's	26.25 %
F	Other	5.00 %
G	Promotion	1.25 %
H	Secondary school diploma	3.75 %
I	Vocational training	11.25 %

Source: *Authors' elaboration*

Comment and discussion: Respondents with a bachelor's or master's degree show the greatest interest in open innovations and their implementation, representing more than half of the proportion of all participating respondents. Nearly one quarter is then formed by the general university entrance qualification and vocational training group. Overall, when forming innovation strategies, it is worthwhile to focus on customers with an education and with expertise. We may say that this reality provides the assumption of a wide variability of opinions, and it is probably a good indicator for scaling the business model.

3.3 Confronting the findings from questions A and B based on social status defined by average level of income

Question A. *Would you actively send improvements to a product to an automotive manufacturer or dealer?*

Answer options
Yes
No

Question B. *Would you actively provide an automobile manufacturer or dealer with improvements to a product if you received benefit for them?*

Answer options
Yes
No
I would also provide information free of charge

The financial viewpoint very often plays an important part in a person's – or, more importantly, a customer's – decision-making process. We deem it appropriate to know whether a given respondent wishes to contribute to the open innovations process (the strength of their willingness to engage in certain steps beyond their purchasing obligations) with or without any benefit or support, and information about how this relates to the respondent's financial status.

Therefore, in this part of the paper, we mutually confront questions A and B, based on the respondents' social status, as defined by average income levels. This can further be imagined as a combination of two inputs on a segmented basis formed by the levels of the respondents' average income. Other social statuses will also be marginally included in the final quantitative evaluation and interpretation.

We have already mentioned that the viewpoint of the average incomes is slightly modified – in congruence with the descriptive results coming from the research – by means of creating only six categories of answers from the original nine by merging some neighboring responses. The resulting numerical values will be, for reasons of more synoptic comparison, listed in percentages, while the number of respondents of the current category in each of the six categories will be taken as the base.

This is why we also list purely the graphic visualization using histograms for every eventuality. In order to avoid rounding errors, we have processed the calculations in Maple as symbolic calculations, precisely.

All of the combinations of answers to questions A and B may be easily expressed. Question A contains two answers: *yes* and *no*; question B contains three answers: *yes*, *no*, and *I would also provide information free of charge* (for simplicity's sake, we will abbreviate the third option to *also free of charge*) – so a total of six combinations.

Let us map the situation in Table 5 from the point of view of a mathematical concept, i.e., in an analogy expressing the arranged pairs in a Cartesian product of the given answer sets.

Table 5. *The arranged pairs of answers to questions A and B*

also free of charge	[*yes*; *also free of charge*]	[*no*; *also free of charge*]
no	[*yes*; *no*]	[*no*; *no*]
yes	[*yes*; *yes*]	[*no*; *yes*]
B. / A.	***yes***	***no***

Source: *Authors' elaboration*

It is clear that the resulting graphs can be presented in the form of a 3D visualization. In this simple case, we will convert the 3D visualization into a 2D one, arranging both triplet columns alongside each other in the figures, in order to achieve a more synoptic display. This is done for each average income level – see the histograms in Figures 6–12.

All combinations of *yes* answers to question A are, in the graphic expression, colored red, and the *no* answers carry the blue color.

The column mid-points on the horizontal axis are marked by numbers – 1, 2, 3, 6, 7, 8. The column's mid-points 1 and 6 mean *yes*, 2 and 7 mean *no*, and 3 and 8 *also free of charge* in reply to question B. On the vertical axis, we are monitoring the frequency of the answer-pairs' individual eventualities, in percent.

The percentage always corresponds to the number of respondents in the given category.

(A) Category: average monthly income €0 *(Fig. 6)*

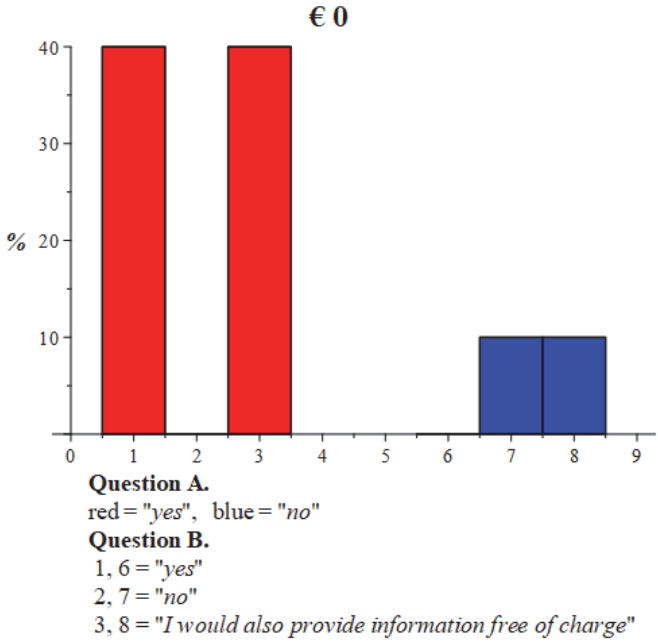

Figure 6. *An average income of €0*
Source: *Authors' elaboration*

Comment and discussion: Most participating respondents in this category clearly want to join the open innovations process actively, and many even without remuneration despite their zero income. Let us note that a further output (analysis) of the research (which we do not list here for reasons of brevity) says that these are men and women aged, on average, 37 years, with various types of education. Their age, enthusiasm, and possible expectations seem to positively inspire them.

(B) Category: average income €500 and €1,500 (*Fig. 7*)

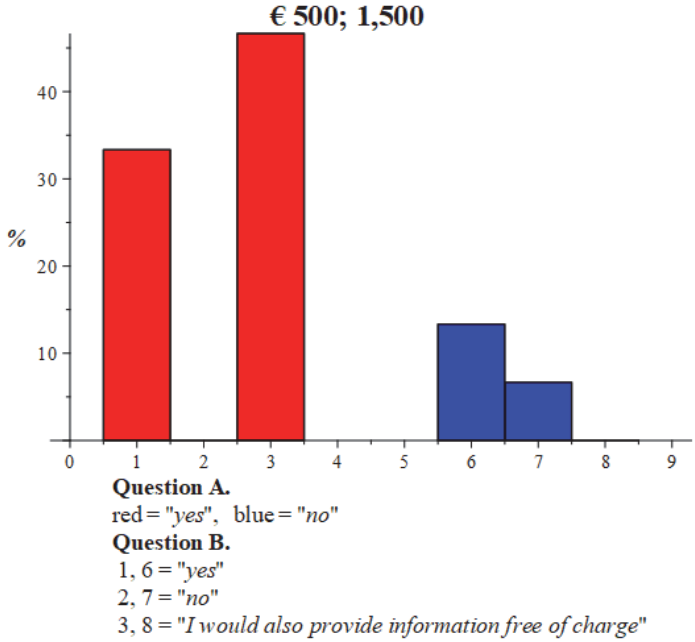

Figure 7. *An average income of €500, €1,500*
Source: *Authors' elaboration*

Comment and discussion: This figure shows that a majority of the respondents is interested in participation in the process of open innovations. This interest, however, decreases in the case of a €500 income. These people may be quite busy and their very low-level income causes them to be less concerned with the innovations process. Alternatively, they may be so financially comfortable that they do not need to earn themselves money and are not interested in customer activities. The age average of respondents in this category is around 30 years; in the €1,500 income category, however, older people are represented as well. This category is made up of mostly employees and people with a certain degree of expertise. Men as well as women are present here.

(C) Category: average income €2,500 *(Fig. 8)*

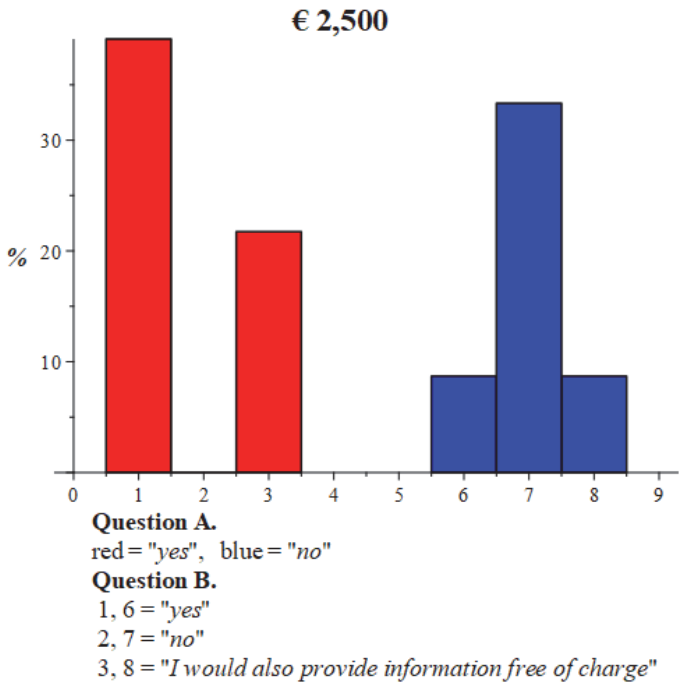

Figure 8. *An average income of €2,500*
Source: *Authors' elaboration*

Comment and discussion: This category is represented the most. The interest in the innovations process is most pronounced as well. Interestingly, a relatively large percentage of respondents in this category retains no enthusiasm despite the offer of benefits. Further consultation with the research outputs implies that women represent one third of this category, whilst men represent two thirds, with the age values drifting towards higher levels. Nevertheless, the predominant group here is around 30 years of age. Employees form an expected majority, although there is considerable variability in employee/educational social status.

(D) Category: average income €3,500 *(Fig. 9)*

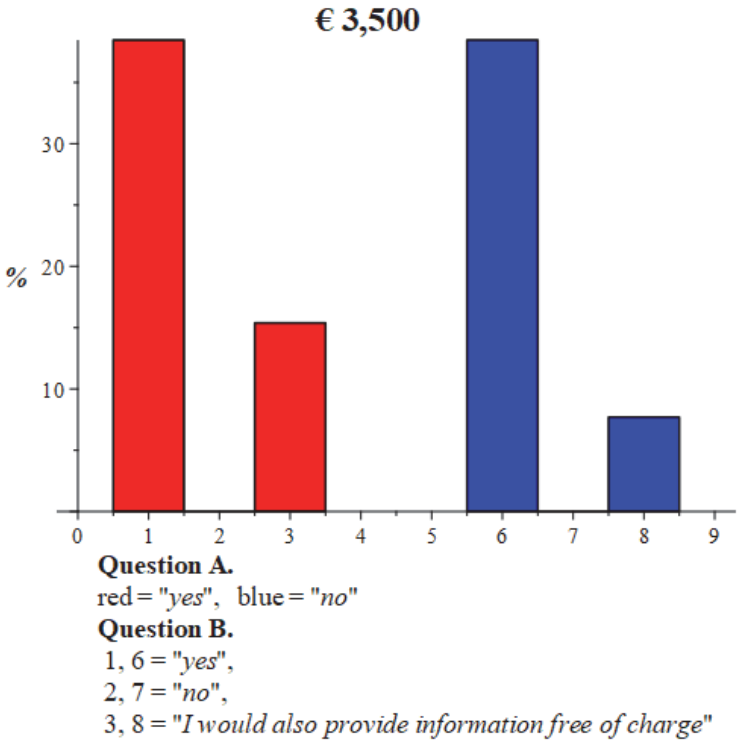

Figure 9. *An average income of €3,500*
Source: *Authors' elaboration*

Comment and discussion: This group of respondents is also quite numerous, is formed mainly by employees, and resembles category (C) in its social characteristics, although with a higher number of men. Figure 9 interestingly shows that the majority bears a positive attitude towards participating in the innovations process; and that those who expressed their disinterest in these issues in question A are motivated to change their opinion owing to benefits.

(E) Category: average income €4,500 or €6,000 *(Fig. 10)*

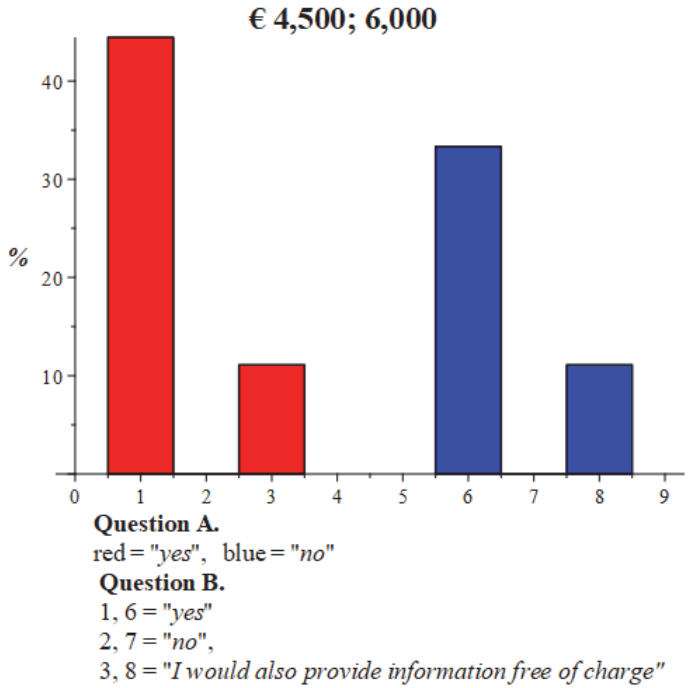

Figure 10. *An average income of €4,500, €6,000*
Source: *Authors' elaboration*

Comment and discussion: We can see that quite a large number of respondents are interested in taking part in the open innovations process (moreover, that benefits are a good motivator). The age average of this group sits around 34 years. It seems these could be successful and maybe also experienced people who want to put forward their opinions on the future. Both men and women are represented.

(F) Category: average income €8,000 or €10,000+ *(Fig. 11)*

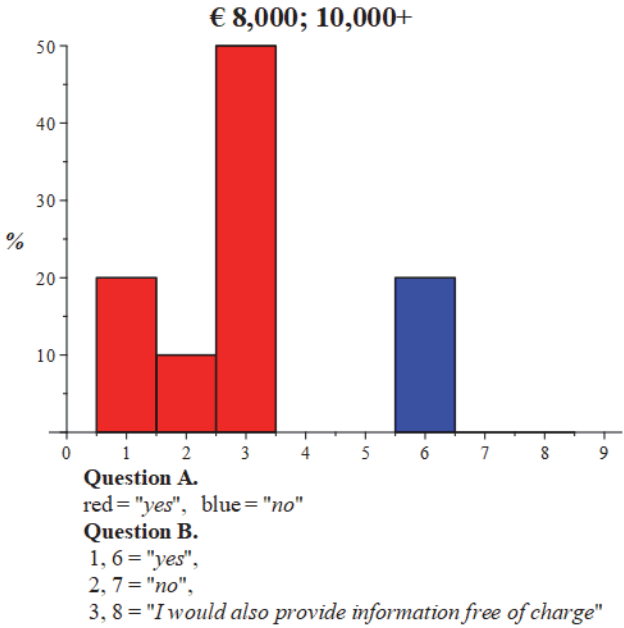

Figure 11. *An average income of €8,000, €10,000*
Source: *Authors' elaboration*

Comment and discussion: Figure 11 shows that these richer people are accustomed to taking part in making decisions themselves and are interested in achieving their goals. Their education status points to especially accomplished people with varied job types. All of the respondents in this group are men around 30 years of age. Their willingness to participate without benefits is significant.

(G) In summary – all categories – average monthly income *(Fig. 12)*

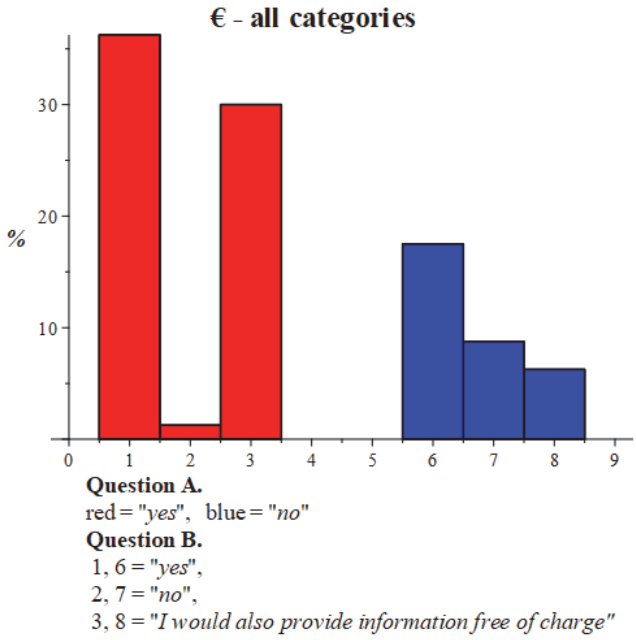

Figure 12. *Average income – all categories*
Source: *Authors' elaboration*

Comment and discussion: Figure 12 shows the sum of all average income level categories (i.e., the percentage corresponds to the total number of the respondents in the research). This means that we are monitoring the opinions of all respondents. We may say that this respondent sample is mostly interested in actively forming the business model in the automotive industry, and to contribute thus to the implementation of open innovations with the support of their own suggestions and ideas. Adequate, appropriately targeted benefits can also be a motivator here.

3.4. Identifying the degree of respondents' interest in some selected types of benefits

We further analyzed in great detail the set of benefits which generated respondents' interest (they could have chosen more than one simultaneously). For our analyses, we selected the following: payment method, first access to new products, discounted product prices, free test drive for a period of 1–3 months, and extended warranty. The relationships of disinterest and interest of respondents in the selected benefits is visualized using column graphs (the bar graph) in the Maple system in Fig. 13a and 13b.

The benefits were labelled as follows: A = *payment method*, B = *first access to new products*, C = *discounted product prices*, D = *free test drive for a period of 1–3 months*, and E = *extended warranty*.

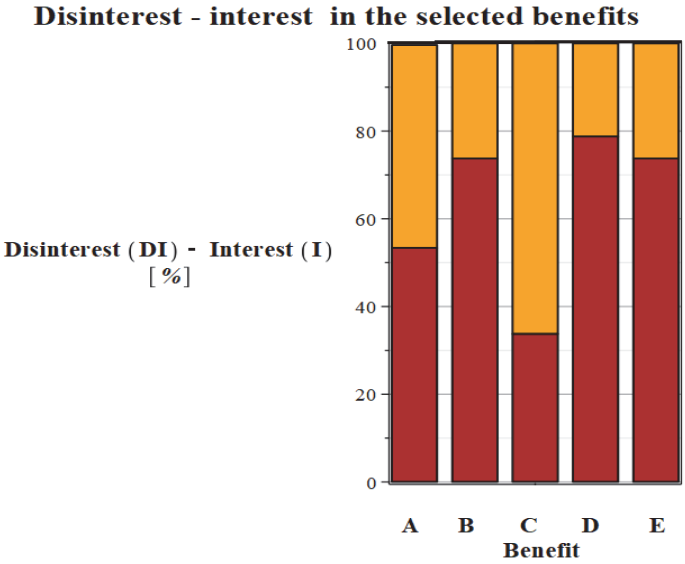

Figure 13a. *The proportion of respondents' disinterest to interest in selected benefits (DI – red, I – yellow), separately, %*
Source: *Authors' elaboration*

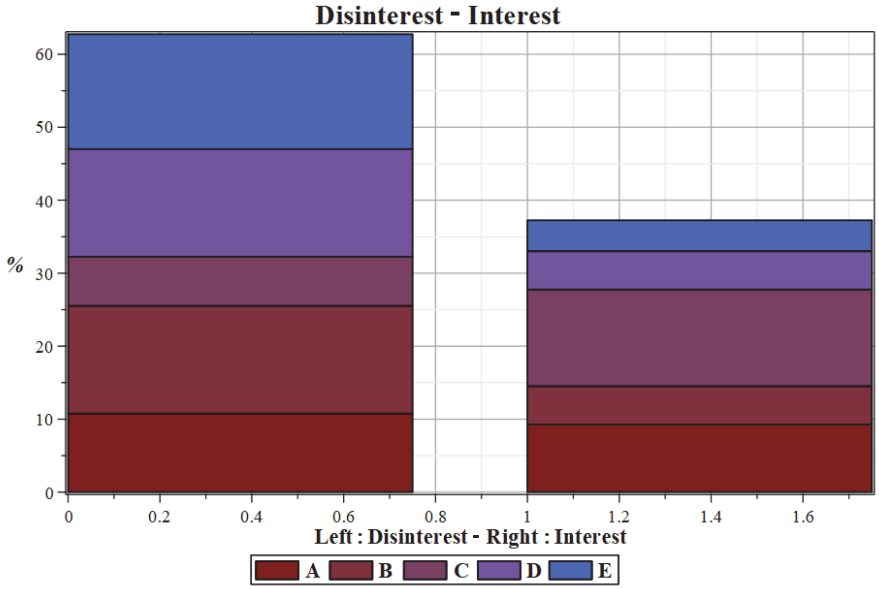

Figure 13b. *The proportion of respondents' disinterest (left) to interest (right) in selected benefits, total, %*
Source: *Authors' elaboration*

Comment and discussion: The assessment of the visualizations (Fig. 13a and 13b) shows that an interest in the benefits offered does not play a dominant role, with the exception of a lowered price (see the top lighter part of the columns; the bottom darker part of the columns indicates disinterest, 13a; by analogy, 13b presents this fact), which also corresponds to our other analyses and findings, and which supports the correctness of our choice of social status (above) as focused on the respondents' financial status (which most probably plays a key part in customers' activities and decision-making).

Respondents are least interested in the trial period, as 78.75% of respondents were disinterested, as opposed to those who are keen on this benefit, i.e., 21.25%.

A similar situation in similar proportions occurs with the interest in the two benefits of access to new products and an extended warranty; i.e., 73.75% of respondents were disinterested, and 26.25% interested.

Payment method generated similar proportion of disinterest to interest, with 53.75% saying *no* and 46.25% saying *yes* to this.

Product price discount doubtless holds the most prominent position among all benefits, with only 33.75% of respondents disinterested and 66.25% interested.

3.5. Analysis of the independence of the respondents' answers to selected questions of the questionnaire using a four-part contingency table

Finally, we will consider the evaluation of the independence of respondents' answers to selected questions of the questionnaire (to some extent in connection with the previous analyses).

Four-part tables (a special case of contingency tables) have been used for the analysis of selected questions when the measured tokens take on only one of two categories. For the analysis of independence, we have applied the characteristic of the χ^2 test.

The results of the hypothesis test (according to the *p*-value – here at the 95.0% confidence level) determine whether it is possible and meaningful to accept or reject the idea of the mutual independence of two statistical features (here, this relates to customer decisions or reactions).

We therefore took an interest in the potential mutual influence or non-influence of the testimony forces of some dichotomic question-pairs from the questionnaire survey. We established an H_0 zero hypothesis on the independence of alternative statistical indicators, and used a four-part table.

We do not reject the hypothesis at the = 0.05 significance level, where t, where is the tabulated (1--quantile of the Person's chi-squared test, with the degree of freedom, and is the so-called "hypothesis non-rejection scope".

The chosen set of questions from the questionnaire survey for the independence tests were as follows:

Question 1: Have you ever been asked by a manufacturer or retailer what could be improved about the product?

Question 2: Would you actively provide a car manufacturer or dealer with improvements to a product?

Question 3: Why would you not tell companies about your ideas/wishes – would companies not implement such wishes anyway?

Question 4: Are you prepared to pay more for a future car that better suits your needs/expectations?

Question 5: Do you think an automotive company would generate more revenue/sell more cars if it implemented its customers'/users' ideas better?

The set of mosaic plots (TreeMaps) in Figure 14 visualizes the distribution of paired answers to the questions whose independence we examined – i.e., questions: 1 versus 4; 1 versus 2; 2 versus 3; 4 versus 5; 1 versus 5; and 2 versus 5).

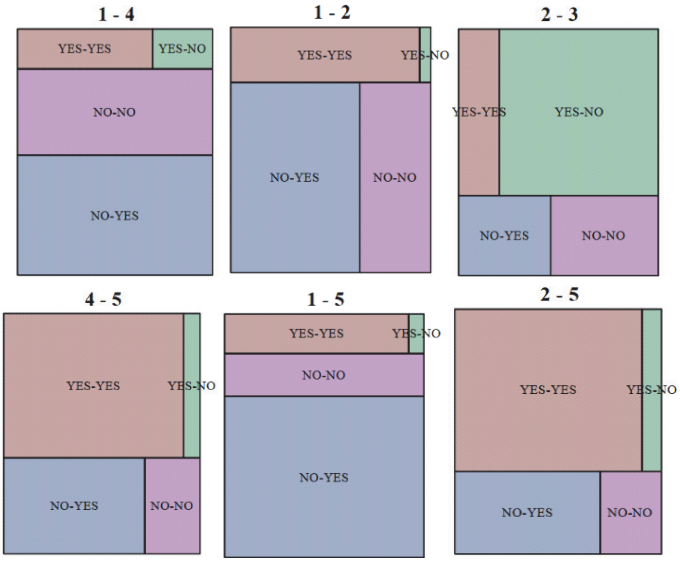

Figure 14. *The distribution of paired answers to questions*
Source: *Authors' elaboration*

For each question pair, we calculated the Chi-Squared statistic at the 0.05 significance level (confidence level 0.95), and we verified whether or not they pertain to the rejection scope. From this, we derived the non-rejection or rejection of the hypothesis concerning the independence of statistical characters determined by the question form. These results are presented in Table 6.

Table 6. *The Chi-Squared test of independence*

Pairs of questions	Test	Statistic	Degree of freedom	Significance level	Confidence level	Hypothesis H_0
1–4	Chi-Squared	0.55109	1	0.05	0.95	Cannot reject
1–2	Chi-Squared	6.09981	1	0.05	0.95	Can reject
2–3	Chi-Squared	5.69557	1	0.05	0.95	Can reject
4–5	Chi-Squared	5.52622	1	0.05	0.95	Can reject
1–5	Chi-Squared	1.24584	1	0.05	0.95	Cannot reject
2–5	Chi-Squared	5.36078	1	0.05	0.95	Can reject

Source: *Authors' elaboration*

Comment and discussion: Out of the six estimated options, we cannot reject independence only in two cases; in the others, we do reject independence.

The manufacturer's/seller's request for the customer's suggestion for improvement of the automobile does not affect the customer's willingness to pay an elevated price for acquiring an improved automobile. This means that the manufacturer/seller should inform the customer of the car-producing company's possibilities so as to generate interest in product improvement in connection with the formation of the level of automobile prices.

The manufacturer's/customer's request for the customer's suggestion for improvement of the automobile does not affect the company's turnover increase. This is an interesting conclusion which probably shows, in the automotive industry, a certain form of "worlds apart" of the these two parties.

In all the other cases we have rejected independence, and this is relevant because these links are logical ones.

The customer's request for the customer's suggestion for improvement does affect (is connected with) the customer's willingness to actively engage and offer their thoughts to manufacturers/sellers. Thus, the customer is clearly being motivated by the manufacturer/seller on the one hand; on the other, the customer is being actively helpful here.

The customer's willingness to offer their suggestions to manufacturers/sellers is affected by the direct knowledge of whether or not the manufacturers/sellers are going to implement the customer's efforts.

The customer's preparedness to pay a higher price for an automobile purchase probably affects their presupposition of a link to the automobile company's increased sales and profits; it would be interesting to determine these reasons.

The customer's willingness to provide suggestions and thoughts on improvements is influenced by their awareness that assumes a connection to generating higher revenue or increasing automobile sales; the question is whether this connection is backed by only shallow knowledge, or rather based on automatic judgement.

The abovementioned outputs show that a bilateral, active approach between the customer and the manufacturer/seller (through motivation, willingness, and open access to information) is a moving force for the implementation of open innovations, and thus also for the scaling and optimization of business models in the automotive industry.

4. Conclusion and final discussion

Our paper is based on research (under the supervision of the paper's co-author, von Böhlen) performed in the German automotive industry, and follows the paper of Simberova and von Böhlen (2021) with the aim of performing further analyses and interpretations of the facts stemming from the research. The mentioned research also follows up on some facts in connection with the solution of the project at the Faculty of Business and Management, Brno University of Technology (under the supervision of the paper's co-author, Simberova).

The summary of these analyses gradually builds the basis for a future holistic achievement of the project goal. In particular, we want to support these points: to increase innovation activity, to apply the implementation of digital transformation to business models, and to increase company performance.

The study of Simberova and von Böhlen (2021) is concerned with the possibilities of forming a business model of the automotive industry through open innovations. It analyses facts on two levels – from the customer's stance and from the producer's viewpoint. It finds deficiencies on both of these levels: in the spheres of open innovations and their applications. Namely, these are "…employees also see changing customer behavior and the considerable adjustments resulting from digitization as the greatest challenges for their industry, …, it makes sense, particularly for the automotive industry, to intensify contact between the customer and the company even more and to organize open innovation properly…" (Simberova & von Böhlen, 2021). Research has shown that in a high percentage "… the automotive industry has never really involved its customers in the development process…," (Simberova and von Böhlen, 2021), although approximately "… 70% of those surveyed are willing to provide information to the industry and participate in development as part of open innovation…" (Simberova & von Böhlen, 2021), while nearly one half of customers would be interested in buying a vehicle should new concepts and greater flexibility be introduced.

This research gives us ample ground to deduce further and deeper opinions, be they reasoned or consequential ones, regarding identifying information leading to the application of open innovations and possibly forming new concepts for the amplification and optimization of commercial models. This study presents a summary of factual information. The customer platform is shown to include an entire range of diversified attitudes. In our contribution on using quantitative approaches, we aim at identifying a more detailed awareness of the experience and attitudes of the employee towards open innovations in the automotive sphere.

The term innovation, especially open innovation, has been playing an important role in the sphere of commercial enterprises. As we have mentioned, in this process, the customer currently represents the key factor. The innovation process begins with an impulse, an idea, a proposal, a thought, and ends with the implementation on the market – more precisely, it ends with feedback. Producers and employees ought, naturally, to be willing to hear the customer domain; they should likewise offer enough space for communication with customers and for their innovative capabilities. Customers, on the other hand, ought to want to be motivated by producers and employees, and to have a convenient pathway to share their ideas and thoughts on a product's or service's innovation and its implementation.

At the beginning of this work, we laid out our research issues with the following focus-points: to identify key phenomena/processes within human resources with an emphasis on the implementation of the open innovations for creating, scaling, and optimizing the business model in the automotive industry; to target the customer exclusively as well as their interest and motivation for creating open innovations in the business model; and to implement selected quantitative (especially statistical) methods with the support of the Maple System for a final assessment and interpretation of the survey's outputs.

A bibliographical review of scientific databases and the verification of other resources has shown that there is no suitable study relating to the mapping of how customers evaluate the space for open innovations in the automotive industry; therefore, a detailed

survey was conducted in the German automotive industry in May–June 2021 in the form of an online questionnaire performed by the paper's co-author. Our article is based on an analysis of selected outputs of this research.

Open innovations and the optimization of business companies are undergoing a great boom, but at the same time, it is appropriate to identify the partial opportunities and risks of this new transformation.

Opportunities – our findings suggest appropriate activities of automotive companies that might aim at customers for the support of the process of open innovations. These are as follows:

- involve customers by increasing awareness, motivation, remuneration, and benefits (offers of which needs to be considered, analyzed, and selected in detail), etc.;
- show interest in the customer's views and ideas;
- reflect, in particular, the financial level from both an individual and a general point of view, against and the background of global events;
- organize regular product (improvement/development) workshops;
- publish problems and seek solutions coming from the customer community;
- adjust the contact platform and communication comfort for customers – for example, by using digitization or automation;
- honor and diversify customers' social status, gender, age, and avoid underestimating isolated ideas; here, exceptions ought to be taken into consideration (either age-wise or income-wise), and experience can play an important part, as can differentiated interests in benefits;
- acquire, sensitively and purposefully, new customers with a willingness to participate in the process of open innovations and, in conjunction with this, in feedback.

The commentaries in the previous paragraph include an entire range of more detailed findings.

Possible pitfalls – in the course of our analyses, we have identified a number of risks, both predictable and unpredictable. These include:

- the duration of the current pandemic; the ecological, economic, and environmental crisis; and a possible future outbreak;
- the risks arising from government regulations;
- generating additional costs;
- changing customer behavior in connection with the change of customers' social status;
- digitization that cannot be kept up with;
- non-connectable systems, the need for manual processing or personal participation;
- incorrectly set metrics.

Fig. 15 shows the summary of some key topics for the implementation of open innovation.

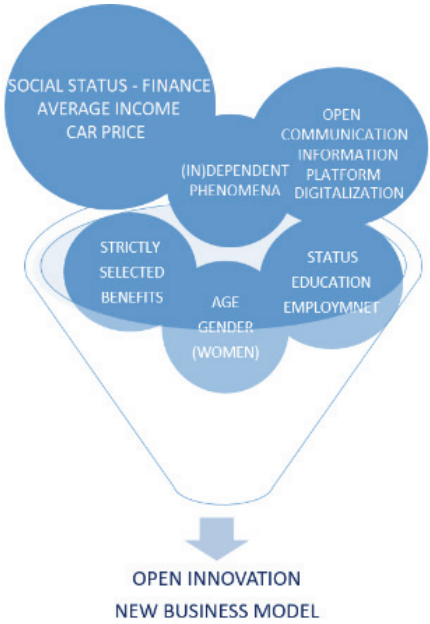

Figure 15. *The filter for the implementation of open innovation for business model optimization*
Source: *Authors' elaboration*

Our analyses have shown significant specific outputs and data in decision-making for the expansion of the business model in the automotive industry in the era of digital transformation in connection with the introduction of open innovation from the customer's point of view.

An appropriate grasp of the creation of the business model based on the implementation of open innovations allows one to streamline the processes within companies of the automotive industry and thus gain a competitive advantage, including adequate feedback.

We believe that it is not appropriate to underestimate the area of customer contacts as well as the principles of sustainable development.

This research opens a whole range of challenges for solving problems related to the implementation of innovation processes in the automotive industry sphere. In the future, we presuppose more diversification of the assessment and analyses of research in several possible manners: a) the modification of the questionnaire as a reaction to the present evaluation of its contents; b) a repeated enquiry of the already participating respondents and an expansion of their numbers; and c) further bibliographical research, or collaborations, respectively. We also mean to touch on problems that have not been dealt with fully yet.

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APPLYING OPTIMIZATION MODELS FOR THE FORMATION OF THE MANAGEMENT SYSTEM OF BUSINESS PROCESSES

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Abstract: *The purpose of this paper is to build a model for the optimization of the management system of business processes of enterprises, taking into account the time factor. Additional limitations in the model allow the influence of the quarantine restrictions on enterprises' economic activity in the context of the COVID-19 pandemic to be identified.*

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The methods used in this paper are: analysis; synthesis; systematization; theoretical generalization; the method of Charnes and Cooper; the synergistic approach; and modelling. The negative impact of the COVID-19 pandemic on the economic activity of enterprises in Ukraine, in particular in the engineering services sector, is discussed. The economic-mathematical model of the rational formation of the management system of the business processes of enterprises in the engineering services sector, taking into account the time factor, is developed. This allows business processes to be optimized and economic activity to be improved in terms of the global pandemic. The results of using the optimization model for the management system of the business processes of project design, electrical maintenance, manufacture of electrical equipment, starting-up and adjustment works, and consulting are presented. The economic-mathematical model is an effective tool for the improvement of quality management systems and the activity of enterprises as a whole. The scientific novelty of this research may be considered from the prospects of two aspects of the optimization of business process systems: 1) the value of the financial resources in time; and 2) the impact of quarantine measures related to restrictions on carrying out economic activities in time. The application of the economic-mathematical model of the optimal organization of business process systems to enterprises in the engineering services sector will allow top-level managers to receive important information for managerial decision-making, which is aimed at improving the quality of the management system, achieving the key business objectives, and maximizing profit.

Keywords*: optimization, system of business processes management, economic-mathematical model, engineering services, ISO 9001:2015.*

JEL Codes: *C61, M11, M21*

1. Introduction

The contemporary circumstances of the competitive environment in internal and international markets require any enterprise to orient towards business processes, which directly affect its activity and need to be adjusted constantly under the influence of an ever-changing external environment. Meanwhile, an efficient business process management system is a crucial component of an enterprise's quality management system in the context of the requirements of international standards – particularly ISO 9001:2015 (Trachenko & Weis, 2019). In the context of the global COVID-19 pandemic, the introduction of quarantine restrictions caused a significant negative impact on the economic activity of businesses and companies in Ukraine. The majority of enterprises which carry out their activities on contracts concluded in advance have been forced to abandon these contracts and their counterparties, and have suffered losses as a result. This also concerns enterprises in the engineering services sector. Suspension and postponement of the implementation of business processes leads to losses that, above all, are related to the loss of monetary value based on the economic law of the decreasing value of money. However, even in crisis situations any enterprise tries to maximize its financial performance. This

is why, for enterprises in the engineering sector, the necessity of the application of the modern toolkit of planning, modelling, and optimizing business processes is obvious. The construction and application of economic-mathematical models which take into account the time factor will allow enterprises not only to improve the efficiency of the management of business processes, but also to minimize the consequences of negative economic situations at these enterprises. In addition, it is possible to consider the optimization of business processes in accordance with the requirements of environmentally safe activities to ensure sustainable development (Kovshun et al., 2021; Latysheva, 2020; Filipishyna, 2020).

2. Literature review

A significant number of scientists have studied the problems of optimizing the business processes system by means of different methods (Glover et al., 2003; Barnett, 2003; April et al., 2004). Korzachenko (2013) argued that it is advisable to optimize business processes. This optimization contributes to the improvement of the efficiency of the enterprise's activity, increasing profits, productivity, and growth, reducing costs, and improving the quality of goods and services. Meško and Meško (1994) investigated the problem of choosing the best combination of investment projects which maximize return on investment. The authors associated investment in certain business processes with an increase in incomes and costs, and applied the proposed fractional-linear optimization model to the example of metallurgy. Munsamy and Telukdarie (2021) modelled the business processes system by estimating energy demand within it, with the aim of identifying the possibility to predict the influence of changes in the energy sector on business. Waszkowski and Nowicki (2020) proposed a model of business processes in the area of contract management for enterprises in the service sector. Models designed in the ARIS software environment with the usage of dynamic analysis allowed for the identification and optimization of a number of processes for the studied enterprise. In the research of Trachenko et al. (2021) and Yankovyi and Trachenko (2019), the optimization of the business processes system in the engineering services sector was conducted, which was focused on the maximization of enterprises' profit. The main limitations were the costs of the implementation of the business process and the number of personnel. Vergidisa et al. (2007) focused their attention on studying multi-objective optimization in building business processes, which allowed alternative options to be obtained for the optimized systems. Yankovyi et al. (2019) considered the production business process and carried out the optimization of the capital-labor ratio within the framework of two-factor production functions. Chukurna et al. (2019) studied the influence of the time factor on the price of engineering enterprises' products. The problems of the optimization of business processes at enterprises in terms of crises were studied in the publication of Gurova and Sadekova (2016), where the stages of this optimization in order to maintain and increase an enterprise's position in the market were highlighted.

Despite the fact that there are a significant number of scientific studies on issues concerning the optimization of business processes at enterprises of different industries

and sectors, the application of optimization modeling methods in order to take into account the time factor has not been given sufficient attention. Moreover, while building optimization models, the current challenges related to the COVID-19 pandemic should be taken into account.

The purpose of this article is to build an optimization model for the management system of business processes at an enterprise, taking into account the time factor. The introduction of additional limitations into the model will allow for changes in the system which relate to the influence of quarantine restrictions in the processes of enterprises' economic activity in the context of the COVID-19 pandemic to be identified.

3. Methodology

The methods of analysis and synthesis, systematization, and theoretical generalization were used for studying approaches to the optimization of enterprises' business processes. The method of Charnes and Cooper was used for aligning towards a linear programming problem by means of introducing new variables. The synergistic approach was used for the formation of the synergistic economic effect of the management system of business processes of an enterprise in the engineering services sector. Modelling was employed for the creation of an economic-mathematical model of the optimal organization of business processes, taking into account the time factor and reducing cost and profit to the present value by means of the depreciation coefficient. The approbation of the developed model at an enterprise in the engineering services sector was also conducted.

In the authors' opinion, it is advisable to build a mathematical model for the rational formation of the management system of business processes at an enterprise in the engineering services sector, taking into account the time factor. This approach may be substantiated in the following way: an enterprise's success, particularly in the engineering services sector, depends significantly on the ability of the company's top-level management to react to changes in the internal and external business environment. In order to reduce the risks caused by possible environmental changes, an enterprise should form and adapt a management system of business processes for them.

To achieve this goal, it is advisable to develop a mathematical model for the rational formation of the management system of business processes at an enterprise in the engineering services sector taking into account the time factor. The application of a modern methodological toolkit is due to the current stage of existence of the information economy (Kholiavko et al., 2020; Vdovenko et al., 2019). Let us formulate the following basic assumptions to compose an economic-mathematical problem statement (Bolshakov, 2002; Berezhnaya & Berezhnoy, 2002; Fomin, 2001):

- we will consider that, while formulating this system, it is possible to identify n main business processes (i – type of activity) which correspond to respective activities;
- the realization of each type of activity is carried out during the discrete period $[1,T]$, where t represents the number of intervals;

- the size of the economic effect from the implementation of business process i in the management system is directly proportional to the investment in this direction during the whole period [1,T], that is:
$$E_i = a_i \sum_{t=1}^{T} x_{it}, i = \overline{1,n}, \quad (1),$$
where x_{it} represents funding for the direction i during the interval of time t in the analyzed period, and a_i represents proportionality ratio, that is, volume of the economic effect from the investment of the unit of financial resources in the direction (business process);
- for each interval of time t, for investment in the formation of the enterprise quality management system, the financial resources of the total volume F_t are allocated.

Therefore, the problem statement for the formation of the management system of business processes at enterprises in the engineering services sector may have the following meaning: it is necessary to distribute the available financial resources between identified directions in each interval of time in order to maximize the total economic effect from their implementation.

Then, the target function of the relative economic-mathematical statement of this problem will be presented as follows:
$$E_0 = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} (a_i \sum_{t=1}^{T} x_{it}) \to max. \quad (2)$$

The necessary limitations, which define the requirements for the searched variables x_{it}, may be written in the following way:
$$\sum_{i=1}^{n} x_{it} \le F_t, \quad t = \overline{1,T}, \quad (3)$$
$$E_i = a_i \sum_{t=1}^{T} x_{it} \ge \underline{E_i}, \quad i = \overline{1,n}, \quad (4)$$
$$e_i = \frac{a_i \sum_{t=1}^{T} x_{it}}{\sum_{t=1}^{T} x_{it}} \ge \underline{e_i}, \quad i = \overline{1,n}, \quad (5)$$
$$R = \frac{\sum_{i=1}^{n} (a_i \sum_{t=1}^{T} x_{it})}{\sum_{i=1}^{n} \sum_{t=1}^{T} x_{it}} \ge \underline{R}. \quad (6)$$
$$x_{it} \ge 0, \quad i = \overline{1,n}, \quad t = \overline{1,T}, \quad (7),$$

where e_i and R represent the indicators of the efficiency of the implementation of the separate direction and the entire management system of business processes at the enterprise, respectively; and represent their minimal allowable values; and represents the lower limit of the economic effect value from the implementation of direction i in the formation of the management system of business processes at an enterprise in the engineering services sector.

Limitation (3) of the optimization problem (2)–(7) describes the financial capabilities of the formation of the management system of business processes at an enterprise in the engineering services sector during all intervals of time in the researched period [1, T]. Inequations (4)–(6) set the requirements for the main economic parameters of the management system of business processes which are being formed (the relevant indicators of economic effects and efficiency). Inequation (7) is a natural condition of the non-negativity of variables x_{it}.

Ultimately, the linear programming model (2)–(7) allows for the identification of the structure of the management system of business processes at the engineering enterprise

that maximizes the total economic effect (2) from its implementation. Traditionally, effect E is presented as a simple sum of effects from separate directions E_i. Such an approach is possible in the case of a relatively simple economic system (in this case, for the management system of business processes at an engineering enterprise). However, while becoming more complex, this system may demonstrate synergistic characteristics (Myhaylovska, 2011). It is important to form a register of synergies in order to achieve certain strategic results (Hutsaliuk et al., 2020).

For this management system of business processes at an enterprise in the engineering services sector, this means that a certain synergistic effect, E_c, may be formed in this system from the interrelation of separate directions of this system's creation. In the simplest case, this may be given by means of a monotonically increasing function of separate (disaggregate) economic effects, E_i:

$$E_c = \Psi(E_1, E_2, \dots, E_n). \tag{8}$$

The identification of the specific type of this function requires separate and specific studies [25].

In the problem (2)–(7), the target function is a total economic effect. One limitation is the requirement of the efficiency of the management system of business processes at the engineering enterprise which is being formed (6). However, in some sense the inverse problem is of interest, in which it is necessary to maximize its efficiency, in some requirements, to the volume of obtained economic effect in the process of the formation of the management system of business processes. In this case, the target function of the relevant optimization model should be presented as follows:

$$R = \frac{\sum_{i=1}^{n}(a_i \sum_{t=1}^{T} x_{it})}{\sum_{i=1}^{n}\sum_{t=1}^{T} x_{it}} \to max. \tag{9}$$

Moreover, it is necessary to replace limitation (6) with the inequation:

$$\sum_{i=1}^{n} E_i = \sum_{i=1}^{n}(a_i \sum_{t=1}^{T} x_{it}) \geq E_0. \tag{10}$$

The obtained model with the target function (9) and limitations (3)–(5), (7), and (10) is a problem not of linear but of fractional-linear programming. However, it is well-known that problems of this type may be kept to the problem of linear programming by using the method of Charnes and Cooper by means of the introduction of new variables, which for the target function (9) will be presented as:

$$y_0 = \frac{1}{\sum_{i=1}^{n}\sum_{t=1}^{T} x_{it}}, \quad y_{it} = y_0 x_{it}. \tag{11}$$

Next, let us take into account the time factor in the built models, namely the influence of inflation processes, which lead to a loss of the purchasing power of financial resources with time. In order to do this, we will calculate the depreciation of money in the interval of time t according to the following formula:

$$k_{it} = \frac{1}{1+r_{it}}, \quad i = \overline{1,n}, \quad t = \overline{1,T}, \tag{12}$$

where r_{it} represents inflation rate in the interval of time t for the direction i of the management system of business processes at an enterprise in the engineering services sector (in general, all r_{it} may have different values).

Using, we will write coefficient K_{it} of investment depreciation x_{it} in the time period [1, T]. In doing so, we will assume that the financing (investment) is provided in the beginning of each interval of time in this period. Then, the influence of the inflation processes should be taken into account in the interval of time (t–1) inclusively, and, relatively, the above-mentioned coefficient is calculated with the formula:

$$K_{it} = \frac{1}{\prod_{l=1}^{t-1} k_{it}} = \frac{1}{\prod_{l=1}^{t-1}(1+r_{it})}, \quad i = \overline{1,n}, \quad t = \overline{1,T}. \tag{13}$$

If the inflation rate level for the direction i remains constant during the whole period [1, T] and has value r_i, then (13) may be written in a simpler way:

$$K_{it} = \frac{1}{(1+r_{it})^{t-1}}, \quad i = \overline{1,n}, \quad t = \overline{1,T}. \tag{14}$$

Hence, if we consider the influence of inflation, the real value of investment x_{it} will be defined with value $K_{it}x_{it}$, which is necessary to use while calculating economic effects E_i.

Then, the elements of the formulated economic-mathematical models (1)–(11), taking into account the factor of the depreciation of financial resources over time, acquire the following view:

$$E_i = a_i \sum_{t=1}^{T} K_{it} x_{it}, \quad i = \overline{1,n}, \tag{15}$$

$$E_0 = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n}(a_i \sum_{t=1}^{T} K_{it} x_{it}) \to max. \tag{16}$$

$$E_i = a_i \sum_{t=1}^{T} K_{it} x_{it} \geq E_i, \quad i = \overline{1,n}, \tag{17}$$

$$e_i = \frac{a_i \sum_{t=1}^{T} K_{it} x_{it}}{\sum_{t=1}^{T} x_{it}} \geq \underline{e_i}, \quad i = \overline{1,n}, \tag{18}$$

$$R = \frac{\sum_{i=1}^{n}(a_i \sum_{t=1}^{T} x_{it})}{\sum_{i=1}^{n} \sum_{t=1}^{T} x_{it}} \geq \underline{R}. \tag{19}$$

$$R = \frac{\sum_{i=1}^{n}(a_i \sum_{t=1}^{T} K_{it} x_{it})}{\sum_{i=1}^{n} \sum_{t=1}^{T} x_{it}} \to max. \tag{20}$$

$$E_0 = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n}(a_i \sum_{t=1}^{T} K_{it}\, x_{it}) \geq E_0. \tag{21}$$

The optimization models (1)–(11) of the formation of the management system of business processes at enterprises in the engineering services sector, which are built based on ratios (15)–(21), are also problems of linear and fractional-linear programming – the methods of solution for which are well known.

4. Results

Let us apply the presented models to the example of an enterprise which operates in the engineering services sector.

In the models, five processes are considered: x_1 – project design of electricity supply objects; x_2 – electrical maintenance; x_3 – manufacture of electrical equipment; x_4 – starting-up and adjustment works; and x_5 – consulting.

The volume of profit from the implementation of these business processes, the costs of each business process, and the total volume of financial resources which the enterprise may direct to project implementation during the year are presented in Table 1.

The total volume of financial resources of the enterprise is distributed evenly during the project period.

The enterprise's projects on the implementation of business processes are carried out over three years on contracts concluded in advance. In this regard, the purpose of building the proposed models is the identification of the optimal (most profitable for the enterprise) combination of business processes which will be implemented during the given period, and the volume of financial resources, which will be directed in a separate business process.

Table 1. *Annual input data for building an optimization model*

Indicators	x_1	x_2	x_3	x_4	x_5	***Total***
Volume of the economic effect (profit) from the implementation of business process, a_i, EUR	163,900	5,235,900	393,500	370,400	146,800	6,310,500
Costs of the implementation of business processes, EUR	127,200	3 820,500	309,900	289,800	110,900	4,658,300
Total volume of financial resources, F_i, EUR.	1,652,200					

Source: *developed by the authors based on the enterprise's financial report (Chesm LLC, 2021)*

By combining the implemented business processes in a certain way over time, the enterprise will be able to achieve maximum profit at the given target level of efficiency of the separate business processes, as well as across the project as a whole. This will enable the diversification of enterprise activity to reduce risks (Kalinin et al., 2019), and will be related to the production and technical development strategies of the company (Danyliuk et al., 2020).

Since this research is aimed at taking into account the time factor for the optimization of the business processes management system, it is necessary during calculations to take into consideration money, which is reduced to its present value by means of the investment depreciation coefficient. In this case, for the calculation of this coefficient it is possible, in addition to the inflation rate, to consider the average return on deposits in Ukraine (8.52%) (Minfin, 2019).

Table 2. *Reduced financial resources while r_{it} = 0.0852 (2019–2024)*

	t_0 (2019)	**t_1 (2020)**	**t_2 (2021)**	**t_3 (2022)**	**t_4 (2023)**	**t_5 (2024)**
Depreciation coefficient of money (k_{it})	1.0000	0.9215	0.8491	0.7825	0.7210	0.6644
Total volume of reduced financial resources in a year, F't, EUR	1,652,200	1,522,400	1,402,900	1,292,800	1,191,300	1,097,700

Source: *calculated by authors*

As can be seen from Table 2, the volume of financial resources depreciated to the present moment in time t_0 reduces gradually under the influence of inflation processes. Moreover, it is necessary to take into account that the volume of predicted profits from the implementation of business processes will also reduce gradually in line with its depreciation to the present value (Table 3).

The next step is to perform calculations in accordance with the built models using the MS Excel Solver software package. The first model (2), with limitations (3)–(7), does not provide for the consideration of the time factor during calculations. Instead, it maximizes profits at the given level of finance resources and is based on limitations regarding the minimal level of efficiency for the separate business processes and the implemented project as a whole.

Table 3. *Profit volume of business processes reduced to the present value (2019), EUR*

	t_0 (2019)	t_1 (2020)	t_2 (2021)	t_3 (2022)	t_4 (2023)	t_5 (2024)
x_1	163,900	151,000	139,200	128,300	118,200	108,900
x_2	5,235,900	4,824,800	4,446,000	4,096,900	3,775,300	3,478,900
x_3	393,500	362,600	334,100	307,900	283,700	261,400
x_4	370,400	341,300	314,500	289,800	267,100	246,100
x_5	146,800	135,300	124,700	114,900	105,900	97,600

Source: *calculated by authors*

The results of the optimization of the business processes system of the enterprise due to the target function (2) and limitations (3–7) are presented in Table 4.

Table 4. *The results of optimization of the business processes system of the enterprise in the engineering services sector ignoring the time factor (the period of project implementation is three years), 2019–2021*

Years	Business processes	Costs of business process implementation, EUR	Profit from business process implementation, EUR	Total costs of project implementation, EUR	Total profit from project implementation, EUR
2019	x_{10}	-	-	4,952,000	6,686,900
	x_{20}	3,820,500	5,235,900		
	x_{30}	309,900	393,500		
	x_{40}	-	-		
	x_{50}	110,900	146,800		
2020	x_{11}	-	-		
	x_{21}	-	-		
	x_{31}	-	-		
	x_{41}	289,800	370,400		
	x_{51}	110,900	146,800		

Years	Business processes	Costs of business process implementation, EUR	Profit from business process implementation, EUR	Total costs of project implementation, EUR	Total profit from project implementation, EUR
2021	x_{12}	-	-		
	x_{22}	-	-		
	x_{32}	309,900	393,500		
	x_{42}	-	-		
	x_{52}	-	-		

Source: *calculated by authors*

The results of optimization, which are presented in Table 4, demonstrate that in the first year of project implementation (2019) it is advisable to implement the business processes of electrical maintenance, manufacture of electrical equipment, and consulting. In 2020, starting-up and adjustment works should be implemented alongside consulting, and in 2021 work should focus on the manufacture of electrical equipment. This will allow the enterprise to obtain a total profit of EUR 6,686,900, with total costs of project implementation in three years of EUR 4,952,000.

The building of the second model (16), with limitations (17–19), provides for taking into account the time factor and reducing costs and profits to the present value by means of the depreciation coefficient. As a result of the application of the optimization algorithm, the combination of business processes which is presented in Table 5 was created.

Hence, taking into account the time factor allows for different results of optimization to be received. In accordance with the built model, in 2019 it is advisable to implement the business processes of: project design of electricity supply objects, electrical maintenance, and manufacture of electrical equipment. In 2020, it is necessary to implement the project design of electricity supply objects, and in 2021 both the project design of electricity supply objects and consulting. Under this option, the total costs of project implementation will be EUR 4,576,900, while the expected profit will be EUR 6,208,200.

Table 5. *The results of the optimization of the business processes system of an enterprise in the engineering services sector taking into account the time factor (the period of project implementation is three years), 2019–2021*

Years	**Business processes**	**Costs of business process implementation, EUR**	**Profit from business process implementation, EUR**	**Total costs of project implementation, EUR**	**Total profit from project implementation, EUR**
2019	x_{10}	127,200	163,900	4,576,900	6,208,200
	x_{20}	3,820,500	5,235,900		
	x_{30}	309,900	393,500		
	x_{40}	-	-		
	x_{50}	-	-		
2020	x_{11}	117,200	151,000		
	x_{21}	-	-		
	x_{31}	-	-		
	x_{41}	-	-		
	x_{51}	-	-		
2021	x_{12}	108,000	139,200		
	x_{22}	-	-		
	x_{32}	-	-		
	x_{42}	-	-		
	x_{52}	94,200	124,700		

Source: *calculated by authors*

The COVID-19 pandemic caused serious social and economic changes on a global scale. These changes did not bypass the Ukrainian economy. Quarantine restrictions, the ban on public gatherings, and the introduction of other strict measures in Ukraine made it necessary to reschedule, postpone, and cancel many activities and the implementation of numerous projects.

The COVID-19 pandemic is a source of global economic crises, since businesses face a great number of new prospects and challenges within their systems. Approaches to work and business activities are changing due to the risks of discontinuity of business, strict time limits for decision-making, threats to safety, and decreases in productivity. The current situation has had a significant impact on business processes, which enterprises must develop and manage.

For the studied enterprise in the engineering services sector, the introduction of the quarantine restrictions in 2020 affected them negatively, as they related to the delay of the execution of projects. In accordance with this, 2020 may be considered as a year during which no projects were implemented. This requires modifications in building the optimization model, which means that while calculating the depreciation coefficient of money (k_{it}), the intervals of time $t = 0, 2, 3$ should be used (2019, 2021, and 2022, respectively).

It is possible to use economic models for prediction (Ahmand et al., 2021). If the enterprise had predicted in advance that in 2020 it would be fully unable to conduct its activity, the optimal combination of business processes would have looked as presented in Table 6.

Therefore, taking into account the impact of the quarantine restrictions (the impossibility of implementing planned business processes during 2020) produces the following combination of business processes: in 2019, it is advisable to conduct the project design of electricity supply objects, electrical maintenance, and consulting; in 2020, works are not provided due to the quarantine restrictions; in 2021, the project design of electricity supply objects and consulting are conducted; and in 2022, only consulting (Arsawan et al., 2020; Yankovyi et al., 2021). This will allow a profit of EUR 5,925,400 to be obtained, while the costs of project implementation will be estimated at EUR 4,347,500 during 2019–2022.

Table 6. *The results of the optimization of the business processes system of an enterprise in the engineering services sector taking into account the time factor (the period of project implementation is three years – 2019, 2021, and 2022) and the effect of quarantine restrictions.*

Years	Business processes	Costs of business process implementation, EUR	Profit from business process implementation, EUR	Total costs of project implementation, EUR	Total profit from project implementation, EUR
2019	x_{10}	127,200	163,900	4,347,500	5,925,400
	x_{20}	3,820,500	5,235,900		
	x_{30}	-	-		
	x_{40}	-	-		
	x_{50}	110,900	146,800		
2020	x_{12}	108,000	139,200		
	x_{22}	-	-		
	x_{32}	-	-		
	x_{42}	-	-		
	x_{52}	94,200	124,700		
2021	x_{13}	-	-		
	x_{23}	-	-		
	x_{33}	-	-		
	x_{43}	-	-		
	x_{53}	86,800	114,900		

Source: *calculated by authors*

However, since the enterprise enters into contracts for the implementation of business processes in advance, in 2019 it begins its activity in accordance with the optimized model, the results of which are presented in Table 5 (carry out the processes x_1, x_2, x_3)

(Yankovyi et al., 2021). After the introduction of quarantine restrictions, it should conduct optimization again, the results of which are presented in Table 7.

Therefore, in building the optimization model in 2019, the implementation of the three business processes of project design of electricity supply objects, electrical maintenance, and manufacture of electrical equipment was set out (Yankovyi et al., 2021). For 2021–2022, optimization was carried out, the results of which showed that, due to the quarantine restrictions, in order to maximize profit the enterprise will need to conduct the business process of consulting only in 2022. The application of this approach will create a large number of practical measures in order to form an optimal set of business activities at the enterprise to increase its profit (Laurinavičius, 2018).

As a result, the cost of project implementation (reduced to the present value) will be estimated at EUR 4,344,400, and the profit (reduced to the present value) will be EUR 5,908,200. Thus, the enterprise will obtain profit lower than expected by EUR 300,000 (−4.83%).

Table 7. *The results of the optimization of the business processes system of an enterprise in the engineering services sector taking into account the time factor (the period of project implementation is three years – 2019, 2021, and 2022) and effect of quarantine restrictions.*

Years	**Business processes**	**Costs of business process implementation, EUR**	**Profit from business process implementation, EUR**	**Total costs of project implementation, EUR**	**Total profit from project implementation, EUR**
*2019**	x_{10}	127,200	163,900	4,344,400	5,908,200
	x_{20}	3,820,500	5,235,900		
	x_{30}	309,900	393,500		
	x_{40}	-	-		
	x_{50}	-	-		
2021	x_{12}	-	-		
	x_{22}	-	-		
	x_{32}	-	-		
	x_{42}	-	-		
	x_{52}	-	-		
2022	x_{13}	-	-		
	x_{23}	-	-		
	x_{33}	-	-		
	x_{43}	-	-		
	x_{53}	86,800	114,900		

Source: *calculated by authors*

7. Conclusions

The ways of applying mathematical models, which are common to most economic systems, their existing limitations, and their main functions were considered. The necessity of the optimization of business processes system for enterprises in the engineering services sector was substantiated, and the feasibility of using optimization models by managers as one of the most important instruments of operational management for the minimization of the negative impact of external environment factors was proved. The consideration of the time factor when optimizing the management system of business processes enables enterprises to predict costs and financial results, reducing them to the present value. This will also enable enterprises to optimize and improve their activity in terms of the COVID-19 pandemic.

The economic-mathematical model of the rational formation of the management system of business processes was developed, and the optimization calculations for the management system of business processes at an enterprise in the engineering sector (the period of project implementation was three years), in which the time factor and effect of quarantine restrictions were taken into account, was conducted. The results allowed for the prediction of costs and financial results, which were reduced to the present value by means of the depreciation coefficient. In accordance with the developed optimization model, as a result of quarantine restrictions, in 2022 the enterprise will have to implement the business process of consulting only. The costs of project implementation (reduced to the present value) will be EUR 4,344,400, and the profits (reduced to the present value) will be EUR 5,908,200. This demonstrates that the enterprise will obtain profit EUR 300,000 lower than expected (−4.83 %).

This is substantial information for the enterprise's top-level management for the development of corrective measures and appropriate managerial decisions. Moreover, the application of optimization models may become an important instrument of the operational management for the top-level managers of enterprises, as they aim at the minimization of the negative impact of the external environment. The proposed models will allow enterprises in the engineering services sector to ensure the improvement of the efficiency of the decision-making process.

Further research may relate to the minimization of risks while optimizing the business processes systems of enterprises. The introduction of additional limitations to the model will provide the opportunity to develop a comprehensive approach to analyze enterprises' business processes. The application of this approach will create a large number of practical measures in order to form an optimal set of business activities at an enterprise to increase its profit. This is the subject of considerable research interest in terms of the presently unstable economic environment.

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DETERMINATION OF THE AMOUNT OF HEALTHCARE PUBLIC FUNDING: THE LATVIAN CASE

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Abstract. *Decisions on public funding allocation are significant challenges for any healthcare system. The Latvian health financing policy faces challenges that threaten its long-term sustainability and the values of solidarity. According to the World Health Organization, health, as a state of complete physical, mental and social well-being, is one of the fundamental rights every human, and is dependent upon the fullest cooperation of individuals and states. This also includes the task to "substantially increase health financing." Such concepts require the regular measurement of progress in order to explicate the achieved level in statics and dynamics and to make strategic decisions for the coming period, including those on public healthcare expenditure. The purpose of this article is to evaluate the necessary allocations of general government budget expenditures, ensure justification for the strategic decisions for the next planning period on healthcare expenditure, evaluate the achieved level in statics and dynamics, and provide policy recommendations for future health financing system reforms.*

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Research methodology – To achieve the goal of the research, comparative analysis and methods of theoretical research were used. Intelligent data mining methods were employed for the discovery of and the creation of knowledge on existing regularities in health system expenditure based on mutually comparable factual cases – the declared statistical indicators of the EU27 countries.

Findings – Using data mining analytical tools, the minimum of the general government health expenditure in EU countries was computed in this study: around €1,500 per capita in 2018. The optimal segmentation of general government health expenditure according to the COFOG classification was also computed.

Research limitations – The minimum expenditure calculated is especially relevant for low-expenditure Central and Eastern European countries, while the total public health expenditure segmentation is applicable for any EU country. The benchmarking algorithms are well-suited for comparing aspects of the health sector, identifying leaders with the best performance and best practices, and analyzing how higher performance levels are achieved. However, it should be borne in mind that some dispersion could be caused by heterogeneous environmental conditions.

Practical implications – Governments can consider making sustainable policy decisions and performing the programming process of allocating public resources. This would also help to balance cross-sectoral links between public healthcare and the economy during post-COVID-19 recovery.

Originality/Value – The use of the data mining analytical tools in this study answered a question that is very important for society: What is the minimum amount an EU country should spend on health? The processing of financial data shows that the widespread assumption of the necessary general government health expenditure of 5% of the GDP is not substantiated.

Keywords: *healthcare sector, treatable mortality, health expenditure, benchmarking algorithms.*

JEL Codes: *C21, I18, H51.*

1. Introduction

Decisions on the allocation of public funding are some of the most significant challenges for any healthcare system. The Latvian health financing policy faces challenges that threaten its long-term sustainability and the values of solidarity. According to the World Health Organization (WHO), health, as a state of complete physical, mental, and social well-being, is one of the fundamental rights every human, and is dependent upon the fullest cooperation of individuals and states. This also includes the task to "substantially increase health financing." Such concepts require the regular measurement of progress to explicate the achieved level in statics and dynamics and to make strategic decisions for the coming period, including those on public healthcare expenditure. The purpose of this article is to evaluate necessary allocations of general government budget expenditures,

ensure justification for the strategic decisions for the next planning period on healthcare expenditure, evaluate the achieved level in statics and dynamics, and provide policy recommendations for future health financing system reforms.

In the scientific literature, the policy debate on health systems has been dominated in recent decades by concerns about sustainability and the system's ability to fund itself in the face of growing cost pressures. The accumulation and management of prepaid financial resources to ensure universal health coverage, for example, means that all people can access health services of good quality without experiencing financial hardship (Abiiro & De Allegri, 2015; Hao et al., 2020; Kluge et al., 2017; Kutzin, 2013; Mathauer et al., 2020). The 2009–2015 period saw a general drop in health spending in many countries, but since then, expenditure on health systems has been rising again across the region (Karanikolos et al., 2013; Reeves et al., 2014). Some recent research has been devoted to the impact of the COVID-19 pandemic on public health system funding (see, e.g., Blondel & Vranceanu, 2020).

Another research direction relates to the funding sources of the health system. There is a policy trend in initiating and expanding social health insurance through labor taxes in low- and low-middle-income countries that goes against available empirical evidence. However, very little evidence exists to justify the pursuit of labor-tax financing for healthcare in these countries, and persistent evidence suggests that such policies could lead to increased inequality and fragmentation of the health system. Other authors (Barroy et al., 2018; Belsky et al., 2015) suggest that the successful expansion of resources to health comes mainly from the other three sources in the domestic fiscal space (macroeconomic, reprioritization, and efficiency enhancement), and not from earmarked taxes such as payroll taxes.

Within the scientific literature, investigations into the link between health expenditures and health outcomes can also be found. Berger and Messer (2002) showed that health expenditures, among other factors, had a significant impact on mortality rate. Crémieux et al. (2005) considered a particular type of expenditures – pharmaceutical spending, with more pharmaceutical spending correlating with higher life expectancies. Elola et al. (1995) showed that the impact of health expenditures changed depending on the type of healthcare system in place: national health services seemed to be more efficient than social security systems. Jaba et al. (2014) used life expectancy and health expenditures from the World Development Indicators (WDI) that covered 175 countries from 1995 to 2010, and found a strong correlation between the input and output of the healthcare system across countries with different income levels and geographical locations. The correlation between public financing and health system outcomes was also discussed by Balabanova et al. (2012), Ortiz-Ospina and Roser (2017), and Petersone et al. (2019).

Countries with higher expenditures on healthcare per person tend to have populations with higher life expectancies. It can also be observed by looking at changes over time that as countries spend more money on health, the life expectancy of the population increases. Recently, Luonga (2020) discussed the role of health expenditures in health outcomes, showing that health expenditures significantly affected the fatality rate resulting from a COVID-19 outbreak. For example, in the case of the Latvian

health financing system, the focus was on applying different systemic approaches to the financing scheme and acute resource and hospital infrastructure issues. The Latvian healthcare financing system and its reforms were analyzed by Araja and Kruzs (2016), Bankauskaite and O'Connor (2008), Mitenbergs et al. (2014), and Vane (2018). The recent development of the Latvian health system is represented by Behmane et al. (2019) and the OECD (2019). The topicality of research into Latvia is also related to its relatively recent adoption, in December 2017, of the Healthcare Financing Law. This law was devoted to changing the principles of the national healthcare financing system, with the aim of converting the current system from a general tax revenue funded National Health Service system into a Compulsory Health Insurance system by linking entitlement to health services to the payment of income-related mandatory social insurance contributions. This also raises the problem of the minimum amount an EU country should spend on health. Based on research presented earlier in this paper (Petersone et al., 2018), the authors believe that the revenue pooling of health expenditures should be financed from general budget revenues rather than earmarked social contributions to simultaneously improve market labor outcomes and equity while simplifying the tax system. However, there is a lack of research determining the adequate and necessary amount of funding required to ensure financing of universal health coverage in specific European Union countries, e.g., Latvia. There are some country-specific forecasts of the necessary health expenditures considering ageing-related expenditure components, and non-demographic factors are estimated to be the main drivers of health spending (European Commission, 2015; Przywara, 2010). Demand for healthcare is likely to increase with higher economic prosperity, as a better standard of living changes people's attitudes to their health. Since advances and improvements in medical technology, techniques, and pharmacology are critical factors in delivering quality care, they are also increasingly expensive. With a focus on high-cost products, medicine and technology are major factors driving health system expenditure.

2. Methodology

According to the WHO, health, as a state of complete physical, mental, and social well-being, is one of the fundamental rights of every human, and is dependent upon the fullest cooperation of individuals and states (WHO, 2006). In turn, target 3c of United Nations (UN) Sustainable Development Goal 3 includes the task to "substantially increase health financing" (UN, 2015).

Such concepts require the regular measurement of progress to explicate the achieved level in statics and dynamics and to make strategic decisions for the coming period, including those on public healthcare expenditure. At the same time, it is practically impossible to directly calculate the adequate level of funding required for the efficient and sustainable functioning of the national health system.

This study used intelligent data mining methods for discovery and knowledge creation on existing regularities in health system expenditure based on mutually comparable factual cases – the declared statistical indicators of the EU27 countries.

Although the EU healthcare system is not tightly regulated, the activities of the European Commission aim to harmonize various aspects of national legislation to increase the performance of national health systems: "Union action, which shall complement national policies, shall be directed towards improving public health, preventing physical and mental illness and diseases, and obviating sources of danger to physical and mental health" (European Union, 2008, Article 168). In general, it can be assessed that the EU countries operate in a relatively single regulatory environment with a uniformly defined scope of statistical data.

Therefore, benchmarking algorithms can be used for computation as they are well-suited to: comparing aspects of the health sector; identifying the leaders with the best performance and best practices; analyzing how higher performance levels are being achieved; and assessing how the less successful and those that are lagging behind could progress faster. Nevertheless, it should be borne in mind that some dispersion could be caused by heterogeneous environmental conditions, particularly climatic conditions, which in some countries are certainly more favorable to an individual's health than in other countries.

3. Indicators of the performance of the health system

Determination of the dependent (output) variable, which best describes the performance and efficiency of the national health system and reflects the progress achieved, is the first task for benchmarking. The reliable possibility of using one specific quantified indicator for this purpose is significant for analytics. Several indicators are used in practice to describe the performance of the health system.

Life expectancy at birth is a widely used indicator, and adequate access to healthcare is associated with longevity, especially among older adults (Hao et al., 2020). At the same time, it is acknowledged that alongside health services, the individual's lifestyle, early prevention, social services, and the surrounding socio-economic environment have an impact on longevity (see, e.g., OECD, 2021).

The healthy life years of an individual is also a frequently used indicator. Nevertheless, various individual lifestyle factors, financial and social stress, and harmful habits strongly influence the intensity of biological processes in the body. Accelerated biological ageing has been identified in 30+ and 40+ year-olds (see, e.g., Belsky et al., 2015); they have not been diagnosed with age-related diseases, and they do not visit doctors, but there are significant disturbances in respiratory, digestive, circulatory, renal, hepatic, and immune functions.

The self-perception of one's health is a statistical indicator in which the subjective factor plays a huge role. Some unfavorable processes in the body can develop and have a hidden effect, but the individual still feels good or even very good. In these cases, health examinations are often performed irregularly, and the diagnosis of diseases is incidental. Self-perception is a component of an individuals' quality of life; its objectivity in assessing the efficiency of the health system is questionable.

The complex Euro Health Consumer Index (EHCI) is Europe's leading comparative indicator measuring the efficiency of national healthcare systems (Health Consumer Powerhouse, 2019). This two-level index integrates 46 indicators grouped into 6 clusters according to expertly-defined weighting factors, which makes the index quite complicated for practical calculations. The EHCI includes many important indicators but is less related to healthcare – e.g., patients' rights, individual lifestyles, etc.

Indicators of avoidable mortality have become popular in recent years as "a general 'starting point' to assess the effectiveness of public health and healthcare systems in reducing deaths before 75 years of age from various diseases and injuries" (OECD & European Union, 2020). Treatable mortality (TM) indicates the number of individuals (Fig. 1a – 2018 is currently the latest available year) who could be cured if the health sector functioned perfectly (Eurostat & OECD, 2021). Preventable mortality (PM) rates are also significantly influenced by the efficiency of healthcare services, but various factors of an individual's lifestyle and prevention are also important (Eurostat & OECD, 2021). Lists of preventable and treatable causes of death are strongly defined; therefore, statistical indicators are highly reliable. The inter-correlation between the avoidable mortality indicators is very strong (Fig. 1b), which means that healthcare plays a crucial role in PM.

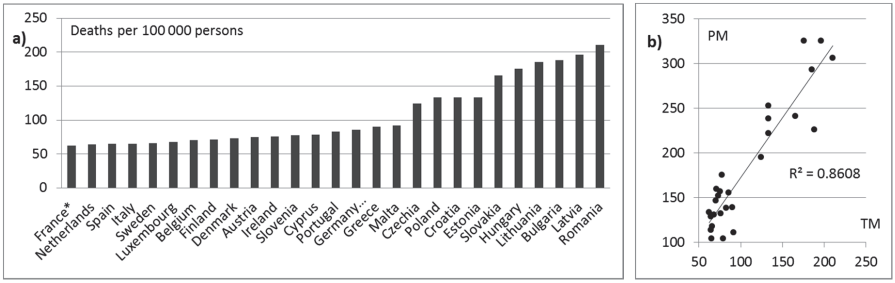

Figure 1. *a) Treatable mortality rates; b) relationship between treatable and preventable mortality.*
EU27 countries, 2018.

*estimated. Source: *Eurostat & OECD (2021).*

The above shows that TM is the indicator that best illustrates the performance and efficiency of the health system in its purest form (Allin & Grigon, 2014). TM is a *hard* statistical indicator; it does not include predictions and/or subjectivity, so it is definitely more reliable compared to others. All other indicators also more or less depend on some aspects (public and/or private) that are only indirectly related to healthcare; the impact of these aspects can be well illustrated by the relationships between TM and other indicators (see, e.g., Schober et al., 2018).

The correlation between TM and life expectancy is very strong. The impact of healthcare performance on longevity plays a dominant role; the importance of other factors is incomparably minor. This means that if TM readings are not available, the use of life

expectancy at birth is justified. Correlations between TM and other indicators are only weak or moderate. This is understandable due to the significant impact of all other factors shown above.

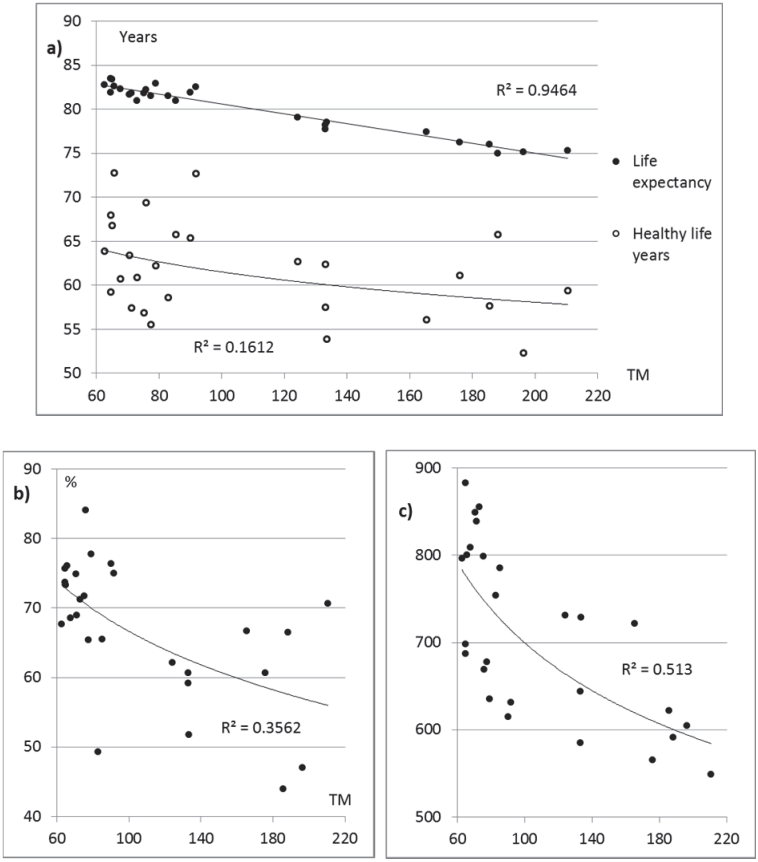

Figure 2. *Relationships between treatable mortality and: a) life expectancy at birth and in healthy life years; b) the share of people with good or very good perceived health; and c) the EHCI. EU27 countries, 2018.*

Sources: *Eurostat & OECD (2021); Health Consumer Powerhouse (2019).*

This study used TM as an output indicator for computing procedures; TM directly reflects the efficiency and performance of the national health systems in EU countries.

4. Public health expenditure

It is widely assumed that when general government health expenditure reaches a certain percentage of GDP, the health system can function adequately. The most commonly cited proportion is 5%, with a reservation in the WHO's recommendations but without reference to a specific source. In reality, however, the WHO provides comprehensive advice on how to finance the health system, saying nothing about the adequate amount of funding required (WHO, 2017, 2021). Moreover, the WHO itself points out that "it is also apparent from frequent references to an alleged WHO 'recommendation' that countries should spend 5 per cent of GDP on health, a recommendation which was never formally approved and which has little basis" (WHO, 2003).

Analysis of the financial data shows that this widespread assumption of the necessary public expenditure for the health system is not substantiated. The trendline in Figure 3 strongly indicates a reduction in TM accompanying an increasing proportion of general government health expenditure as a percentage of GDP, but the correlation is so weak ($R^2 = 0.1933$) that the 5% level cannot be considered as a statistically significant one.

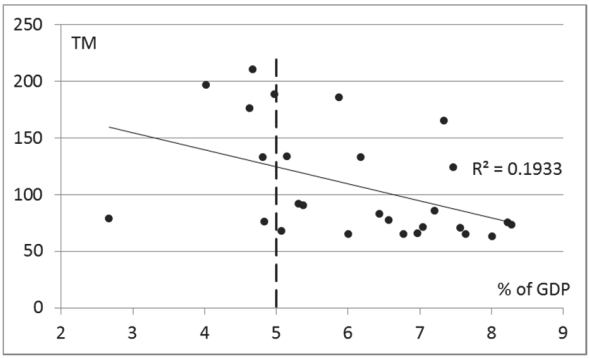

Figure 3. *The relationship between general government health expenditure as a % of GDP and treatable mortality. EU27 countries, 2018.*

Source: *Eurostat & OECD (2021); OECD (2019).*

The EU27 countries have a relatively different approach to national budgeting:

- total general government expenditure as a share of GDP is different in various EU countries (from 25.7% in Ireland to 55.6% in France – the EU27 average was 46.6% in 2018), depending on the national tax policy;
- health expenditure as a share of total general government expenditure is, in turn, different (from 6.2% in Cyprus to 18.8% in Ireland – the EU27 average was 15% in 2018), mainly reflecting the rank of public health in the list of government priorities.

Healthcare services are mainly focused on the individual, taking into account each person's specifics; "health must always be seen in reference to individuals" (Danzer et

al., 2002). Over 90% of general government health expenditure is used for outpatient and hospital services, as well as for medical products and equipment.

However, the above setting of 5% of GDP is directly aimed at so-called population health "as the health outcomes of a group of individuals, including the distribution of such outcomes within the group" (Silberger et al., 2019). Both substantial input variables of the health system – the amount of GDP from which the financing is calculated, and the size of the group of individuals relative to the country's population – are completely ignored. It is clear that even with the same proportion of health expenditure as a share of GDP, the set, quality, availability, and accessibility of health services will depend directly on both GDP and the number of patients.

These shortcomings can be remedied by using general government health expenditure per capita as an indicator of the actual amount of public health funding (Fig. 4). The correlation between general government health expenditure per capita and TM is strong ($R^2 = 0.6853$).

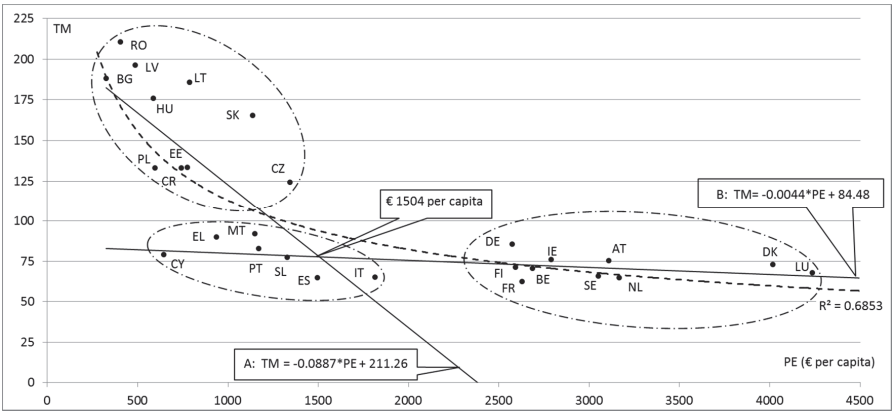

Figure 4. *The relationship between general government health expenditure per capita and treatable mortality.*

EU27 countries, 2018. Authors' calculation based on Eurostat data.

Three national clusters are clearly identifiable:

1. Western and Northern European countries with a general government health expenditure of more than €2,500 per capita and a TM of less than 90 per 100,000 persons aged under 75 years. In these countries, further increases in public health expenditure lead only to an insignificant reduction in TM. Active R&D, increasing the efficiency of medicines and medical technologies, and digital transformation of the health processes and system are the keys to further progress.
2. Central and Eastern European countries, where general government health expenditure is less than €1,500 per capita and TM exceeds 120 per 100,000 persons. In these countries, the healthcare sector is underfunded, the salaries of medical

staff are too low, and in many regions, infrastructure and technologies are outdated. The increase in general government health expenditure effectively reduces TM even without the serious advancement of the health system.

3. Southern European (Mediterranean) countries form the connecting cluster, which is positioned below the trendline. TM in these countries is comparable to Western and Northern European countries, while only Italy provides slightly higher public health funding than Central and Eastern European countries. At least two reasons can be given for this seeming contradiction: (1) it has been known for centuries that the healthy climate, the specific menu, the lifestyle (long lunches, active communication, and the balance between work and leisure reducing stress in general), and the environment (both natural and in terms of ancient heritage) in this region positively affect health; and (2) traditionally high out-of-pocket (private) health expenditure in this region significantly complements low public expenditure.

These features of the clusters of countries confirm the previously-expressed conclusion that the health status in a particular country is also influenced by national specifics (see, also, Jaba et al., 2014).

The location of the data points and the significantly different slopes of the trendline at low and high public health expenditure show that for further analysis it is expedient to create, in the common data area, two partially overlapping data sub-areas, and to develop trendlines for the data points in each sub-area:

- all data points of countries where the TM is less than 100 persons per 100,000 population (the first and third clusters of countries) are included in one sub-area;
- the data points of countries where general government health expenditure is less than €2,000 per capita (the second and third clusters) are included in another sub-area.

The intersection of the two trendlines shows the minimum health expenditure of the general government sector per capita which is necessary to reduce TM in the country to the value at which the low-TM trend begins to occur: around €1,500 per capita in 2018.

The year-on-year TM dynamics at changing levels of general government sector health expenditure are influenced by contradictory factors. A comparison of 2011 and 2018 data shows that politicians in the EU27 countries have mostly decided that the positive impacts of innovation and digitalization outweigh the negative impacts of the shortcomings of the health system and increased costs. In 19 EU countries, general government sector health expenditure grew more slowly than GDP; in five, public expenditure even decreased (Fig. 5).

Nevertheless, TM reduction was achieved in all countries; naturally, in the low-expenditure segment the changes were higher. The achievement of progress shows that there have been structural and/or functional improvements in the health systems of all EU countries.

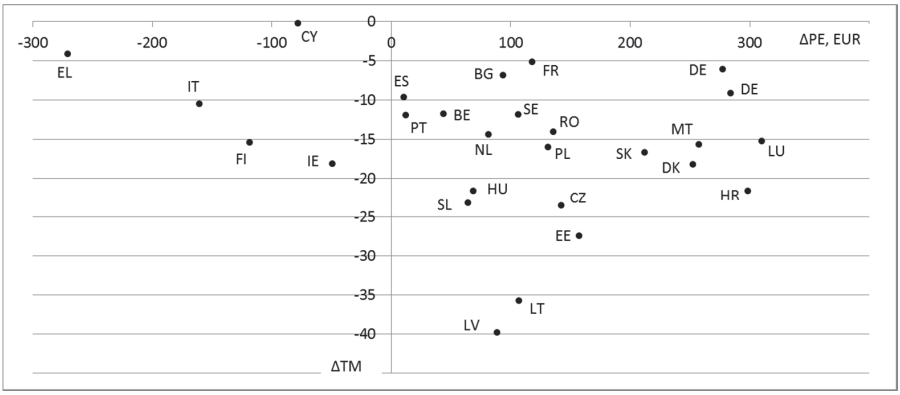

Figure 5. *TM decrease (ΔTM) to the changes of general government health expenditure per capita (ΔPE), 2011–2018. EU27 countries.*
Authors' calculation.

5. The segmentation of public health expenditure

In addition to the assessment of the required general public health expenditure, the distribution of general government health expenditure between segments (functions) is also important. A more detailed analysis of general government expenditure, using the generally accepted COFOG classification, indicates the optimal distribution of public expenditure between functions. Reviewing the segmentation of public health expenditure in each EU country reveals functions that are relatively underfunded.

The authors applied the above-described methodology for determining health expenditure to the relatively large segments of expenditure (medical products, appliances and equipment – Fig. 6a; outpatient services – Fig. 6b; and hospital services – Fig. 6c.), which together account for over 90% of total public health expenditure. If there are good regularities among the data points of the high-expenditure countries, then there are large dispersions among the low-expenditure countries. Therefore, for each expenditure segment, a trendline was developed that, better than others, corresponds to the distribution of data points of this specific segment.

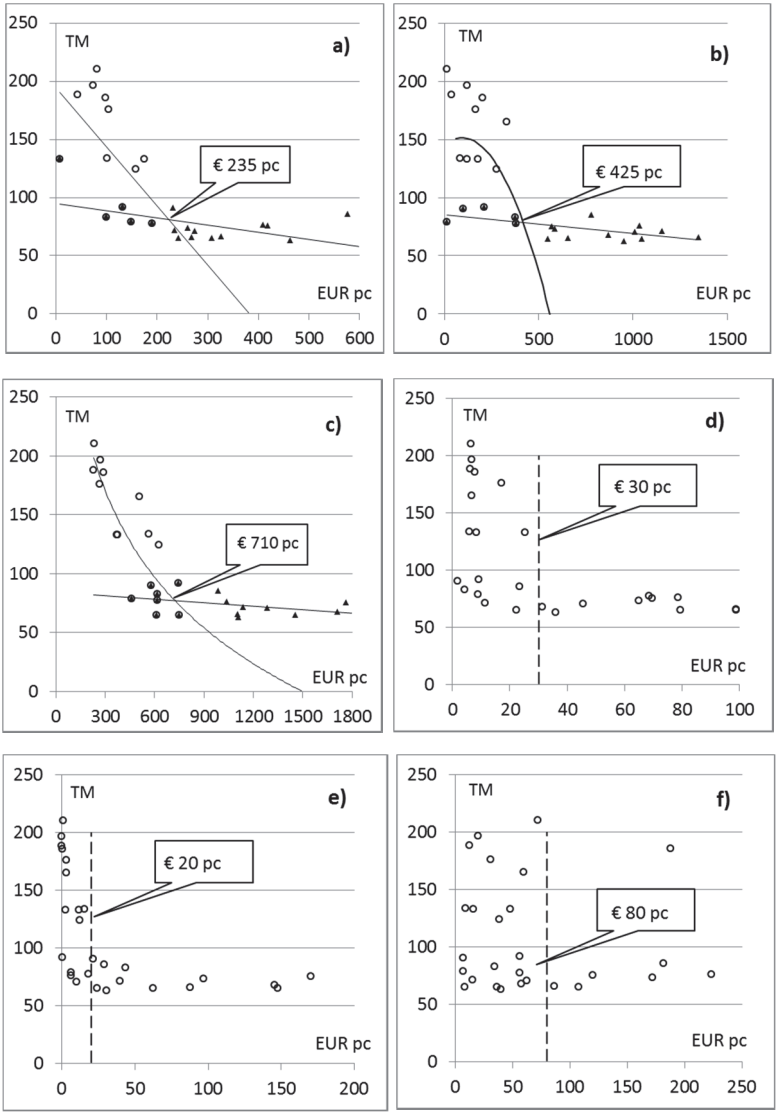

Figure 6. *Relationships between treatable mortality and general government health expenditure per capita for: a) medical products, appliances, and equipment; b) outpatient services; c) hospital services; d) public health services; e) R&D health; and f) health n. e. c. EU27 countries, 2018.*

Source: *Eurostat.*

For the small expenditure segments (public health services – Fig. 6d; R&D health – Fig. 6e; and health n. e. c. – Fig. 6f), uncertainties among the low-expenditure countries were too high. Therefore, for these segments a 10–15% increase in the maximum value of expenditure by low-expenditure cost countries was taken as the required minimum.

The health sector is not currently heavily regulated at the EU level, and the priorities of national strategies naturally differ. In addition, the allocation of expenditure by COFOG sections is treated differently. As a result, the large dispersion of data points (even outliers) shows the segmentation of general government health expenditure at the national level. However, the number of EU countries is large enough to compare the computed segmentation with the statistically reported distribution of EU27 average general government health expenditure (Fig. 7).

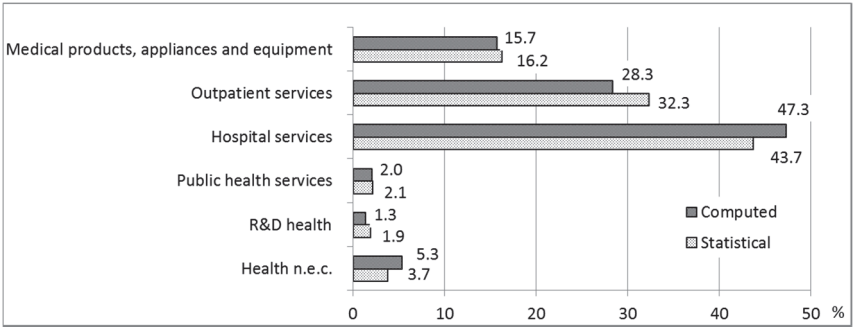

Figure 7. *The distribution of general government health expenditure by function, EU27, 2018.*
Source: *Eurostat*

It can be seen that, in general, there are no serious differences between statistical and computed segmentations. The experience of the COVID-19 pandemic has shown weaknesses in the health system at the EU and the Member State level (in fact, also globally). Hospital capacity proved to be insufficient in a critical situation, as "… money does help to provide the best treatment, and also to allow hospital admissions on lighter indications, which might not be cost-effective but does provide better outcomes" (Health Consumer Powerhouse, 2019).

At the same time, it must also be borne in mind that improving the quality and availability of outpatient services will reduce the workload of hospitals, which is in fact similar to an increase in funding. Potential regular mass vaccination will require increased investment in public services, and the absence of this investment may hamper the further advancement of the health sector, health R&D (i.e., innovation), and digital transformation.

6. Discussion and conclusions

The use of analytical data mining tools in this study answered a very important question for society: What is the minimum amount an EU country should spend on health? Financial data processing shows that the widespread assumption of the necessary general government health expenditure of 5% of GDP is not substantiated.

This computation should be based instead on expenditure per capita, corresponding to a sector in which over 90% of total expenditure is focused on services for an individual. Treatable mortality was used as the indicator of the outcome of the health system as it best shows the performance and efficiency of the health system in its purest form.

Comparing the regularities of countries with low health expenditures and countries with low treatable mortality, the minimum general government health expenditure per capita which is necessary to reduce treatable mortality in a country towards a currently achievable value was computed: around €1,500 in 2018. The mathematical computation used ensured the most objective possible definition of minimum public health expenditure in EU countries. Out-of-pocket expenditure on healthcare was not analyzed as it is determined by the free market and shortages of public healthcare services.

The optimal segmentation of general government health expenditure according to the COFOG was computed using a similar algorithm. It should be noted that the COFOG's apparently different treatment varies from country to country.

The computed minimum expenditure is especially relevant for low-expenditure Central and Eastern European countries. Public health expenditure in 2018 varied considerably between these countries, but in only three (Czechia, Slovakia, Slovenia) did it exceed €1,000 per capita. It will not be possible to bridge such a gap by leaps and bounds; increasing health expenditure by reducing funding to other general government functions is not compatible with the principles of structuring general government expenditure. Our recommendation is to gradually increase health expenditure. As total general government expenditure increases overall year-on-year, most of this increase should be channeled towards health expenditure, setting the EU27 average proportion of 15% of total expenditure as the first target; only four Central and Eastern European countries had reached this level in 2018 – Czechia, Lithuania, Slovakia, Slovenia.

Pre-COVID regularities show that even this increase would ensure significant progress in the proper functioning of the health system; thus, in Latvia, this measure would reduce total mortality by 10–14%. A reduction in preventable mortality and an increase in the general level of health in society could result in an increase in life expectancy of 3–4.5 years.

After reaching the EU27 average, the next goal should be set: to reach the figure that was €1,500 per capita in 2018, adjusted for the impact new treatments and technologies and inflation. The last is by no means insignificant (e.g., an increase of around €100 in 2017 compared to 2011).

The calculated segmentation of total general government health expenditure can be recommended as a guideline for any EU27 country. Although the statistical average distribution in the EU27 is quite close to the calculated one (Fig. 7), the current segmentation in countries is quite different. It is not possible to make a general recommendation as to

which segment funding should increase as a matter of priority; in any case, the step-by-step approach mentioned above should also be applied. Thus, in Latvia the largest comparable expenditure deficit is for outpatient services, while hospitals are in a relatively better position. It should also be borne in mind that improving the quality and availability of outpatient services will reduce the workload of hospitals, which is in fact similar in effect to an increase in funding.

It has to be strongly emphasized that the COVID-19 crisis is currently having a huge impact on regularities: despite rising public health expenditure, mortality rates have also risen sharply. Expenditure in the public health services segment has comparatively increased the most due to expenditure on anti-COVID measures. National governments need to realize that increased levels of general health expenditure must be maintained after the COVID-19 outbreak, as the impact of a pandemic on mortality can be long-lasting.

Despite the current, hopefully short-term, derogations from the general regularities, we urge governments to take these regularities into account, making sustainable policy decisions and performing the programming process of allocating public resources. It would also help to balance cross-sectoral links between the economy and public healthcare during post-COVID recovery.

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AN EFFICIENCY ANALYSIS OF COMPANIES OPERATING IN THE PHARMACEUTICAL INDUSTRY IN THE VISEGRAD COUNTRIES

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Abstract: *The primary aim of this research was to analyse the corporate performance of selected companies in the pharmaceutical industry in the Visegrad countries using the value added intellectual coefficient (VAIC) model. The secondary aim was to find relations between VAIC components and company profitability ratios by country. Data for analysis were downloaded from the EMIS database for the years 2016–2019. Several statistical methods (MANOVA, ANOVA, t-test, correlation analysis, panel model) were used to analyse and compare companies by country. Based on the analysis of variance and the pair-wise t-test, it can be concluded that there is no statistically significant difference between the countries selected concerning the VAIC ratio and its components. Furthermore, it can be concluded that there is a medium correlation between selected profitability ratios (OROS, ROA, OROA) and VAIC and its components, except for the capital employed efficiency ratio. It was determined that the components of the VAIC indicator impact the operating ROA using the panel model, except for in the Czech Republic. Based on a study of the literature on the application of VAIC and the evaluation of the results of the analyses,*

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it can be argued that the VAIC ratio is suitable for measuring corporate performance from a specific perspective.

Keywords*: corporate performance, intangibles, intellectual capital, value added intellectual coefficient, Visegrad countries, pharmaceutical industry.*

JEL Codes: *O34, M41, L25, L65*

1. Introduction

With the development and expansion of the knowledge economy and the information society, the hard-to-measure resources that can play an increasing role in corporate value-creating will grow. At present, so-called "invisible capital" plays an increasingly important role in company value creation. This capital is referred to as intellectual capital or intangible assets in the economic literature. Regardless of their name, these "assets" are not material goods but intangibles that companies try to measure and state in their respective accounting, and in their financial statements in a less successful way. Lev and Daum (2004) presented the increasing presence of intangibles in businesses. Companies' market value has increased significantly since the 1980s, and the difference between book and market value has also increased. The difference between these two values is the companies' intellectual capital, which is revealed in financial statements. The average value of the intellectual capital to intangible assets ratio calculated for companies in the S&P 500 Index increased from 38% to 62% over almost ten years, while their book values fell from 62% to 38%.

According to Damodaran (2012), the firm value is the sum of the present values of future free cash flows. This assumption is an implicit approach that utilises tangibles and intangibles to generate corporate cash flows. However, the question can arise as to whether any other value-creating sources are invisible and do not appear on the balance sheet. A large number of researchers have named these invisible goods as intellectual capital (Edvinsson, 1997; Lev, 2001; Sanchez-Canizares et al., 2007). Intellectual capital can include information, knowledge, intellectual property, experience, and relationships, making a company more successful. Now, intellectual capital has become more relevant than ever before. Many studies have tried to explain the difference between book value and market value, and the assumption prevails that it mainly stems from the invisible intellectual capital that companies cannot state in their accounting. Accounting tries to account for as much intellectual capital as possible, with more or less success depending on state regulation. Therefore, several studies and models have been developed that approach the value of intellectual capital from different perspectives (Stewart, 1991; Kaplan & Norton, 1996; Edvinsson, 1997; Sveiby, 1997; Pulic, 2004).

Intellectual capital has had various definitions, and each of them have had differing views. However, all of these studies agree that the recognition and continuous measurement of intellectual capital is difficult regarding these unique goods. Intellectual capital can be divided into three groups: human capital, structural capital, and relational capital.

In each group's case, the accounting system's goal is to account for most of these goods using various methods of measuring intellectual capital. In this way, some parts of invisible assets will become visible in accounting.

Although intellectual capital is difficult to measure, several researchers have developed a model to do so. One tool developed is the value added intellectual coefficient (VAIC) model used in many studies to measure intellectual capital. At the same time, this tool has some critics. One such critic was Bakhsha et al. (2017), who suggested that the model is not suitable for measuring intellectual capital. They believe that the model classifies total employee costs as human capital, not representing total human capital.

Furthermore, the opposite effect of human and structural capital can lead to a distortion of earnings. Andriessen (2004) stated that there is a problem with the principles of the model, which can lead to difficult-to-interpret results. Stahle et al. (2011) noted that VAIC can measure the efficiency of a company's labour and capital investments, and cannot measure intellectual capital well. The main reason for the lack of consistency in VAIC results lies in the confusion of capitalised and cash flow entities in the structural capital calculation.

At the same time, several studies have shown that the VAIC ratio and its components are one of the most favourable methods to measure corporate performance (corporate efficiency). Therefore, many researchers have considered this model to be suitable for measuring and determining the impact of intellectual capital on corporate performance, such as Chen et al. (2005), Kamath (2008), Zeghal and Maaloul (2010), and Ermawati et al. (2017).

The VAIC calculation is based on value added, and it is a measurement tool to reveal employees' and management's contribution to value creation. Using value added can determine how employees contribute to increasing wealth. Higher added value can ensure higher dividends for owners and higher investments for further developments. As a measurement tool, value added unifies all economic activity of participants considering one goal: to create the highest possible corporate value. The calculation of VAIC and its components is based on corporate value added. This method is easy to use because it uses publicly available data (financial statements).

The primary goal of this research is to measure the corporate performance of companies using VAIC in the pharmaceutical industry in countries in the Visegrad Group (Czech Republic, Hungary, Poland, and Slovakia), taking into account the opinion of Stahle et al. (2011). In the case of pharmaceutical companies, intangible assets and intellectual capital play a major role. Some intellectual capital can be capitalised under accounting regulations and recognised as an intangible asset (Sveiby, 1997), such as R&D that can be recognised as intangibles (IASB, 2020), yet other parts of the business are embedded as hidden capital. This research looks seeks to answer whether there are statistically significant differences among Visegrad countries considering intellectual capital efficiency (ICE) and corporate performance. The analysis applies several statistical methods for these examinations, using the packages of the R statistical system.

Several researchers have examined the effectiveness of intellectual capital and its impact on financial performance regarding companies in the pharmaceutical industry. In

a study of Indian pharmaceutical companies by Smriti and Das (2017), VAIC had a significant positive correlation with return on assets (ROA). Zhang et al. (2021) found that VAIC and human capital efficiency (HCE) impact both ROA and return on equity (ROE) in terms of pharmaceutical companies in Vietnam. Chizari et al. (2016) found that VAIC had a significant impact on market performance variables of pharmaceutical companies in the Tehran Stock Exchange, and HCE and capital employed efficiency (CEE) had the greatest impact on the market.

The research hypotheses of this study are as follows:

H1: The countries examined differ statistically significantly in the VAIC ratio components.

H2: Companies differ statistically significantly within a country's ICE and VAIC ratios.

H3: There is a correlation between VAIC and its components and the selected profitability indicators.

H4: Relationships can be determined between value-added intellectual coefficients and companies' profitability ratios in the countries investigated.

This study examines a particular aspect of the pharmaceutical industry's performance in four countries with a very similar historical past that are still economically intertwined. No such comparative study has yet been carried out regarding the countries examined.

2. The concept and measurement of intellectual capital

2.1 The concept of intellectual capital

Intellectual capital is understood as the difference between a company's market value and book value. The book value of the market value is equal to the value of the company's equity. So, the difference between the two values is the "invisible value" recognised by the market, but only a part of it is shown in the balance sheet. Therefore, even though this does not appear in accounting, it can create significant value. The definition and adequate management of intellectual capital are essential because they make it easier to manage. Over the years, many authors have tried to define intellectual capital, and they all agree that it bears great value despite its rather difficult determination.

The following five authors defined intellectual capital in a very similar way. They all identified intellectual capital as an intangible, non-material, or non-financial asset that plays a role at a company in the generation of new value by participating in the production and sale of services or products (Brooking, 1996; Al-Ali, 2003; Kaufmann & Schneider, 2004; Wiederhold, 2014).

According to many authors, intellectual capital consists of three elements:

- human capital,
- relational capital,
- and structural capital (Saint-Onge, 1996; Edvinsson, 1997; Stewart, 1997).

Human capital includes the knowledge, skills, competence, and professional experience of employees. Human capital is "owned" by employees, and they "lend" their knowledge to the company. Structural capital includes the company's innovation capabilities,

organisational structure, culture, and processes. Employees create these elements too, but the company owns them. Even if employees leave a company, these elements remain at the company. Relational capital means the network of contacts with customers and suppliers and their quality. Relational capital includes the company's business relationships with individuals and organisations. This value results from the resources invested in human and organisational knowledge.

In 1978, 80% of companies' assets were tangibles, and only 20% were intangibles. However, this changed entirely by the end of 1998, when companies had 80% intangibles and only 20% tangibles. The reason for this is that knowledge and information have become the driving force of society. As a result, companies have more and more knowledge, and their concepts change as they know more about the world around them (Sullivan & Sullivan, 2000).

Al-Ali (2003) stated that today's companies are using not only bricks but also intangibles to achieve their profits. Therefore, managing these assets is essential for companies' survival and long-term growth. Indeed, Central-Eastern European countries do not attach appropriate importance to this factor. Still, there is an increasing emphasis on its management to produce a clear picture of its intellectual capital and exploit its benefit (Kuzkin et al., 2019).

2.2 Methods for measuring intellectual capital

Why is it important to be aware of the value of a company's intellectual capital? Turner and Jackson-Cox (2002) declared three main reasons. First and foremost, companies should spend a significant amount of money improving their employees' skills and utilising their knowledge and work. This knowledge can also facilitate intellectual capital management. Lastly, this allows companies to monitor performance and improve its efficiency.

There is a need for models that evaluate corporate intellectual capital in intelligent, numerical, and comparable ways. This approach can solve many problems. At the same time, it is essential to keep in mind that intellectual capital's meaning can differ at the organisational and geographical levels (Tovstiga & Tulugurova, 2009; Andreeva et al., 2021).

Sveiby (2001) collected the following methods of measuring intellectual capital, which were categorised into four groups:

1. Based on the ROA ratio: first, the company's average pre-tax profits are calculated for several years. These values are divided by the average values of the tangible assets of the same period. Finally, the results (ROAs) are compared with the industry average and the difference is determined. If the difference is positive, the organisation has strategically important, unique intellectual capital in the industry.
2. Market Capitalisation Methods (MCM): intellectual capital is the difference between market value and book value.
3. Direct Intellectual Capital (DIC) measurement: intellectual capital is broken down into components, and the individual parts are evaluated separately in financial terms.

4. Scorecard type methods (SC): different ratios are determined to describe intellectual property and its change. The characteristic of these models is that assessing financial value is not a primary purpose.

These measurement methods provide different advantages. *Organisational-level financial measurement methods* – ROA and MCM – are primarily used to make fusion and stock market decisions. Furthermore, management can pay more attention by comparing companies within the same sector. Their disadvantages are that they only estimate capital and intellectual capital as a whole, and do not help owners to assess which part of the total capital they should manage. In addition, they may be inaccurate in converting different values into money. The problem with ROA methods is that they are sensitive to interest rates or discount rates. Scorecard methods shift the focus away from the components that compose a company's wealth and its effects.

The most common measurement method is market value and book value difference. However, it has been noticeable over the years that the market value of shares on stock exchanges has been valued higher than their book value. Many things can explain added value, but it has been concluded that intellectual capital could explain a large part of added value.

Market value can be calculated in two ways. First, multiplying the number of ordinary shares by the current exchange rate in listed companies gives market capitalisation value. Another method for unlisted companies is to sum the company's present values of expected future cash flows (Juhász, 2004; Lőre, 2011). However, calculating this value can cause inaccurate results, as the historical cost of tangibles or taxes can significantly affect the book value.

EVA (Economic Value Added) is based on a simple logical concept that has no direct aim of evaluating intellectual capital, but rather of measuring a company's value creation. EVA can be calculated using a relatively simple formula:

$$EVA = (ROIC - WACC) * CE \quad (1)$$

where

ROIC is the return on invested capital,

WACC is the weighted average cost of capital,

and CE is the amount of capital employed.

MVA (Market Value Added) is also derived from the economic profit concept, which is the difference between the company's market value and the capital entrusted to the company by lenders and shareholders. It follows that its intrinsic value is much more than the sum of its equity and debts. If this value is positive, the company can increase its capital; if it is negative, it reduces it.

$$MVA = \text{market value of debt} + \text{market value of equity} - \text{total assets} \quad (2)$$

In another approach, MVA is the sum of the present values of expected future EVA values.

Baruch Lev's model is based on the fact that the company's economic activity is determined by three factors: financial, physical, and intangible assets. Therefore, this method divides the profit realised by the company among the assets which generated it. Namely, this method divides the annual profit among physical, financial, and intangible assets (Daum, 2001).

This method deducts the average profit of tangible and financial assets from normalised profits. The income retained in this way shows the contribution of intangible assets to corporate profits, as illustrated in Figure 1. Intangible capital is determined by calculating the present value of the future income stream generated by intangible assets (Daum, 2001).

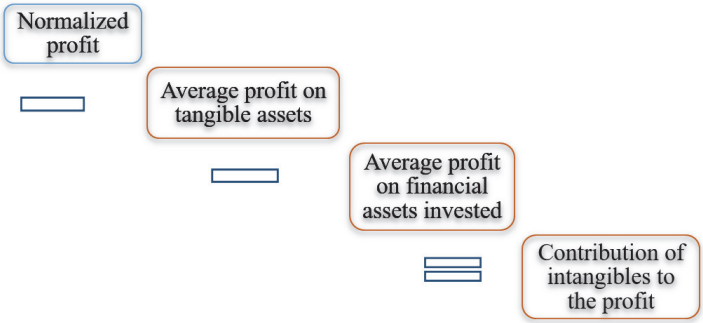

Figure 1: *Determining Baruch Lev's knowledge capital return*
Source: own editing based on Tarnóczi and Fenyves (2010)

Future earnings can be estimated using the average growth rate. For a given year, the normalised profit is equal to the average of the previous year's normalised profit adjusted by the inflation rate and the profit after tax for the current year. The yields were calculated using an estimated expected yield rate. The profit generated by intangible assets is the difference between normalised profit and the profits on tangible and financial assets (Tarnóczi & Fenyves, 2010). This calculation requires the requested yields on tangible and financial assets.

First, the intangibles' contribution is determined by estimating the rate of return on physical and financial assets and deducting them from corporate profits (the product of the expected rates of return of the financial and tangible assets and their actual values). Then, the value of intellectual capital is determined by dividing profit on intangibles by the expected rate of return.

The VAIC method was developed by Alan Pulic, and its purpose is to measure the effectiveness of a company's essential resources. Pulic (2000) stated that traditional accounting focuses on cost control, but, presently, there should be a focus on value creation and management. Indicators measuring conventional business success, such as income, cash flow, profit, and market share, disregard a company's value creation for shareholders and owners.

As value creation is a new condition for success, intellectual resources have become the leading investment area. The value-creating process depends on the efficiency of tangibles and intangibles to no small extent. The quality of customer relationships and the ability to invest in human resources influence the amount of profit. VAIC is an efficiency indicator that measures the efficiency of the company's key assets, considering the requirements of a modern economy.

VAIC is calculated based on the added value associated with intellectual capital. The VAIC indicator has three components: HCE, structural capital efficiency (SCE), and CEE. The detailed calculation of the VAIC ratio is presented in the next chapter.

Considering the research aim and the previous studies assessed during the processing of the literature, the following hypotheses were established:

H1: The countries examined differ statistically significantly in the VAIC ratio components.

H2: Companies differ statistically significantly within a country's ICE and VAIC ratios.

H3: There is a correlation between VAIC and its components and the selected profitability indicators.

H4: Relationships can be determined between value-added intellectual coefficients and companies' profitability ratios in the countries investigated.

3. Data and methodology

3.1 Database for analysis

This research aimed to measure intellectual capital using the VAIC model in selected companies within the Visegrad group (Czech Republic, Hungary, Poland, and Slovakia). Companies were chosen from the pharmaceutical industry, and were selected based on revenues in 2019. Only companies with revenues of more than 1,000,000 Euro were included in the research. Analysis was performed using the public data of 211 companies. The distribution of selected companies is shown in Table 1.

The data used for the analysis were downloaded from the EMIS database (Market Research Database – emis.com) for 2016–2019. The companies' balance sheets and income statements were used for the analysis. The value of VAIC components and the VAIC ratio were calculated for all companies, years, and essential statistical characteristics. These fundamental statistical indicators can help form a broader picture of the countries investigated. The simple (ANOVA) analysis of variance was used to compare the countries. The *t*-test was used to provide a pair-wise comparison. This analysis also examined how VAIC and its components changed over the years studied. Finally, analyses were carried out to determine differences in companies' intellectual capital between countries.

Table 1: The number of companies examined by country

Countries	Number of companies
Czech Republic	33
Hungary	55
Poland	105
Slovakia	17

Source: *compiled by the authors based on their analysis*

The VAIC method facilitates the measure of IC and its components, and is regarded as an objective and transparent method because the data used for the calculations are derived directly from financial statements. Despite some limitations, VAIC can be successfully used for economic analysis. The limitations of the analysis include the fact that a different number of companies operate in the analysed sector in different Visegrad countries, and a significant proportion of the total sample of Slovakian companies (with the smallest sample size) contained outliers, which distorted the values of the regression coefficients. In both business practice and in research, this method can be used to report intellectual capital synthetically and to measure intangible assets.

3.2 Determination of VAIC

Pulic developed the VAIC method to determine the effectiveness of intellectual capital (Svanadze & Kowalewska, 2015). According to Pulic (2004), companies invest in two essential resources in the 21st century: traditional resources (tangible and financial) and intellectual capital. Edvinsson and Malone (1997) divided intellectual capital into human capital and structural capital. According to Jarboe (2007), human capital comprises workers' experiences, skills, and the abilities that workers take with them when they leave the company. Structural capital can include the processes, organisational culture and routines, strategies, information systems, and procedures that operate at a company (Boisot, 2002; Ordonez de Pablos, 2004). Structural capital remains with the company even after workers leave (Jarboe, 2007).

Pulic (2000) describes the VAIC model in 5 steps:

1. Value Added (VA)

Value added is equal to the difference between inputs and outputs. Outputs are sales revenue, while inputs are costs incurred to generate revenue – except for human capital and depreciation expenses. Calculating value added can start from operating profit, and gives the same results if we add employee costs and depreciation/amortisation expenses to operating profit (Fijalkowska, 2014). Value added is generated by working capital, human capital, and structural capital (Pulic, 2000).

2. CEE

This ratio shows how much added value has been invested in unit capital investment, and can be calculated as the ratio of value added to capital employed (CE):

$$CEE = \frac{VA}{CE} \tag{3}$$

3. HCE

This ratio can be used to determine what added value is associated with investing in one unit of human capital. The ratio considers employee costs (EC) as human capital, thus determining the efficiency of human capital.

$$HCE = \frac{VA}{EC} \tag{4}$$

4. SCE

According to Edvinsson (1997), intellectual capital is the sum of human capital and structural capital (SC). Pulic (2000) defined structural capital as the difference between human capital and value added. Human capital and structural capital are complementary; if less human capital is involved in value creation, it is necessary to apply more structural capital. Therefore, the calculation of the SCE ratio reflects this complementary nature:

$$SCE = \frac{SC}{VA} \tag{5}$$

5. VAIC calculation

The final step is to determine VAIC, which summarises the effectiveness of capital employed and intellectual capital (human capital and structural capital):

$$VAIC = CEE + HCE + SCE \tag{6}$$

An advantage of this indicator is that it is additive. A higher value means more efficiency, which shows the added value created by intellectual capital.

3.3 Regression with panel data

In the countries examined, multiannual, cross-sectional (companies), and time-series (years) company data was available. Multicollinearity and heteroscedasticity are the most common problems of cross-sectional data with linear regression analysis. Moreover, autocorrelation can cause time-series data problems (Sheather, 2009). Given the above, it was decided to use the panel regression model. According to Baltagi et al. (2013), the panel model allows controlling individual heterogeneity, utilising more significant variability for more exact estimation, determining effects that cannot be identified from cross-section data, and enhancing measurement precision. Croissant and Millo (2019) remarked that the panel model technique should answer a broad problem from a statistical modelling aspect: unobserved heterogeneity, the supervision of unobserved variables, and possible estimation bias. They used the R statistical system to present panel models. Using panel models is very widespread in social science research, and many examples of using the method can be found in the conference volume edited by Tsounis and Vlachvei (2018).

The panel model was applied to analyse VAIC in several cases to determine the relations between its components and profitability ratios. Tiwari and Vidyarthi (2018) used the fixed-effect panel model to measure the impact of intellectual capital on Indian banks' performance. They used the size and leverage of the banks and the interaction of intellectual capital components as independent variables. ROA and ROE were used to measure bank performance, and 3–3 models were created for both.

Tran and Vo (2018) used the panel model's fixed and random effect methods to analyse the Thai banking sector. They created four models that included value-added intellectual coefficients and components alongside three other banking ratios: credit risk, liquidity, and size.

Nadeem et al. (2017) applied the panel regression model to examine whether ICE affects the performance of companies in BRICS countries.

Using panel regression models, Yao et al. (2019) examined the relationship between intellectual capital and profitability for 111 Pakistani financial institutions in 2007–2018.

ROA, net operating margin (NOM), and assets turnover (ATO) were used as dependent variables. In addition to the indicators used to measure intellectual capital, size, leverage, organisation age, revenue diversifications, operational efficiency, economic growth, and financial crisis were used as independent variables.

Haris et al. (2019) examined the impact of intellectual capital on Pakistani banks' profitability. They also used a panel model to apply corporate governance, bank-specific, industry-specific, and country-specific variables.

The panel model enables the determination of heterogeneity across the distribution of the dataset, and identifies essential relationships among datasets and their determinants that may not be apparent, focusing on average effects. In contrast with the linear regression methods, which use conditional mean restrictions, panel models enable different features of data distributions to be analysed while accounting for possible unobserved heterogeneity (Kato et al., 2012). The panel model can describe the entire conditional distribution of the output variables, be more robust regarding outliers and mis-definition of error distribution, and provide more extensive statistical modelling than the conventional mean-based regression method (Huang et al., 2017).

4. Results and discussion

VAIC was determined for the companies examined in the Visegrad group countries by applying the 5-step model. This calculation was based on the descriptions in section 3.2.

Analysis of variance (ANOVA) was performed to test any statistically significant differences between years. The ANOVA results showed no significant differences among years (Table 3), so the yearly averages can be used for further calculations.

Table 1. *P*-values (%) of ANOVA, analysing the differences among companies by year

Countries	HCE	SCE	ICE	CEE	VAIC
Czech Republic	93.0215	93.6876	85.0632	93.4981	83.3989
Hungary	83.5336	23.9051	79.3534	66.1896	67.1941
Poland	60.1931	77.0384	99.8730	60.3087	63.3837
Slovakia	96.7445	98.4467	89.8196	96.8925	94.9556

Source: *compiled by the authors based on their analysis*

4.1. Analysis of VAIC components by country

Table 2 shows the average VAIC values and their components by country and year for the companies examined in the pharmaceutical industry.

Multivariate analysis of variance (MANOVA) was used to analyse companies by country in the countries studied. The variables in this calculation were HCE, SCE, and CEE. This method used the Pillai test to determine the significance level of differences. The results of this analysis are shown in Table 3, with a significance level of greater than 5%. This value means that the countries do not differ statistically significantly when the three variables are considered together. When the multivariate analysis of variance does not show a statistically significant difference, it makes little sense to analyse variance by variable.

However, it should also be noted that there may still be differences between countries, but these differences cannot be considered statistically significant. The differences between countries for the three indicators (HCE, SCE, CEE) are shown in Table 2 and Figures 2–4.

Table 2. *The average values of VAIC and its components in the examined companies in the pharmaceutical industry by country and year*

Countries	Years	HCE	SCE	ICE	CEE	VAIC
Czech Republic	2017	1.670	0.337	2.008	0.604	2.611
	2018	1.663	0.346	2.009	0.676	2.685
	2019	1.718	0.354	2.073	0.663	2.736
	Yearly averages	1.684	0.346	2.030	0.648	2.677
Hungary	2017	2.155	0.486	2.641	0.508	3.150
	2018	2.048	0.392	2.440	0.555	2.995
	2019	1.986	0.366	2.352	0.497	2.849
	Yearly averages	2.063	0.415	2.478	0.520	2.998
Poland	2017	2.108	0.395	2.503	0.642	3.145
	2018	1.906	0.327	2.233	0.642	2.875
	2019	1.802	0.357	2.159	0.638	2.797
	Yearly averages	1.939	0.360	2.298	0.640	2.939
Slovakia	2017	2.671	0.475	3.146	0.622	3.767
	2018	2.663	0.481	3.143	0.615	3.758
	2019	2.482	0.467	2.948	0.561	3.509
	Yearly averages	2.605	0.474	3.079	0.599	3.678

Source: *compiled by the authors based on their analysis*

Table 3. *The results of MANOVA comparing VAIC components by country*

Factor of MANOVA	*Df*	Pillai-test	Approx. of *F*-test	*Df* of num.	*Df* of denom.	Pr (>*F*)
Country code	1	0.0135	1.8015	3	395	0.1463
Residuals	397					

Source: *compiled by the authors based on their analysis*

Pair-wised comparison was also used to examined whether there was a statistically significant difference between companies in these countries. The results of the pair-wise *t*-test are shown in Table 4. These results are separately evaluated per indicator in the following parts of this chapter.

HCE shows the amount of added value that can be created for a company with one unit of human capital. Since human capital is reflected in employee costs, the average expense of the labour force in the examined sector of a country and its relevant labour code affect the efficiency ratio. Therefore, the higher the cost of employees, the lower this ratio will be. Figure 2 shows the development of the HCE of analysed companies split by years and by country.

Table 4. *Yearly averages of VAIC components by countries and p-values (%) of pair-wise t-test comparing country averages*

Statistical indicators	Countries	HCE	SCE	CEE
Mean value of ratio in	Czech Republic	1.684	0.346	0.648
	Hungary	2.063	0.415	0.520
	Poland	1.939	0.360	0.640
	Slovakia	2.605	0.474	0.599
P-values of *t*-test sign. level comparing	The Czech Republic and Hungary	7%	14%	7%
	The Czech Republic and Poland	24%	80%	30%
	The Czech Republic and Slovakia	14%	5%	12%
	Hungary and Poland	63%	31%	55%
	Hungary and Slovakia	38%	36%	37%
	Poland and Slovakia	29%	11%	26%

Source: *compiled by the authors based on their analysis*

Based on Table 2 and Figure 2, it can be concluded that Czech companies performed worst in terms of the HCE indicator, but only in this case can an increase be observed during the three years examined. It can also be stated that, on average, Slovak companies performed best in all three years examined. At the same time, the performance of Slovak companies shows a declining trend. The indicators of the companies of the other three countries approached each other at the end of the period. However, Table 4 shows that a statistically significant difference can only be established between the Czech Republic and Hungary at the 7% significance level with this indicator, which is only acceptable if the significance level requirement is reduced to 10%.

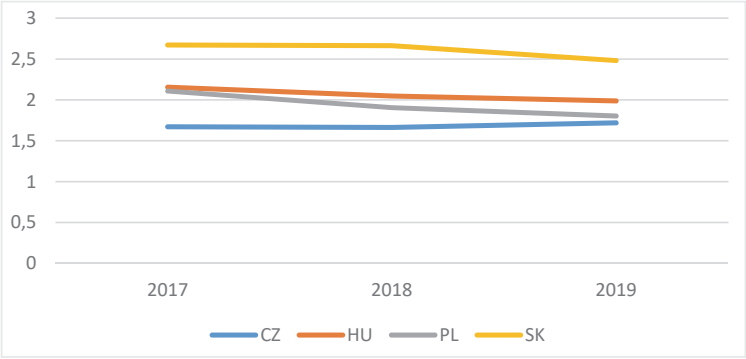

Figure 2. *The average HCE ratio values of the analysed companies*

Source: *compiled by the authors based on their analysis*

The average hourly labour costs in the Visigrad countries in 2020 are shown in Table 5 (The average hourly labour cost in the EU in 2020 was 28.5 EUR). Slovak companies

are likely to outperform the HCE indicator because of the country's relatively high average hourly labour cost. Contrary to this, the Czech Republic has a 5% higher hourly wage cost, yet it is the worst-performing among the four countries. Therefore, it is likely that, besides the costs of labour, its use may also play a role in efficiency.

Table 5. *Average hourly labour cost in countries examined (in EUR)*

Country	Average hourly labour cost	100% = Czech Republic	100% = EU average
Czech Republic	14.1	100%	49%
Slovakia	13.4	95%	47%
Poland	11.0	78%	39%
Hungary	9.9	70%	35%

Source: *compiled by the authors based on https://www.statista.com/statistics/1211601/hourly-labor-cost-in-europe/*

The next component of ICE is SCE. Since structural capital and human capital are complementary (Edvinsson, 1997; Pulic, 2000), the ratio will be in terms of structural capital to value added. Thus, structural capital is the difference between value-added and human capital. The SCE values of the examined companies are presented in Figure 3.

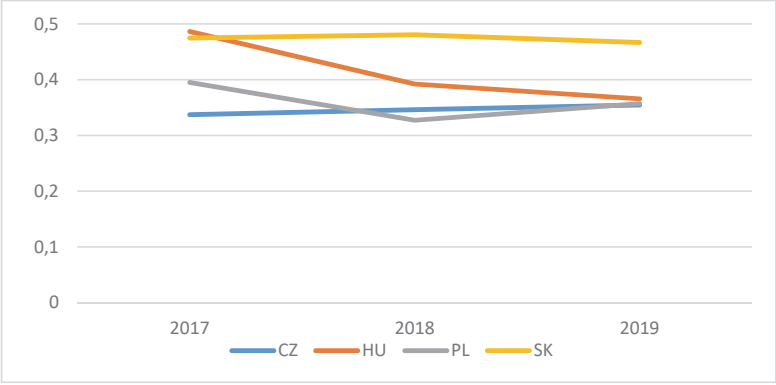

Figure 3. *The average SCE values of the analysed companies*

Source: *compiled by the authors based on their analysis*

According to SCE, Hungarian companies occupied first place in 2017, but a decrease was evident in 2018 and 2019. In the average positions of all three years, Slovak companies occupied first place, followed by Hungarian companies. Polish companies occupied third place, with Czech companies in last. The performance of Hungarian and Polish companies decreased in 2018, and their SCE ratios were almost identical in 2019. Slovak companies' SCE ratio was 30.67% higher than the ratios of the other three countries' companies in 2019. HCE ratios followed the same tendencies, since the Slovakian com-

panies had a 26.28% higher HCE ratio value than second-rank Hungary did in terms of yearly average. Although companies in Hungary had a 44.25% higher SCE in 2017 than the Czech companies, their value was almost the same in 2019.

In the ranking of yearly SCE averages, it can be observed that companies in Slovakia had the highest ratio values, followed by Hungarian companies with a 0.415 value. Polish companies occupied third place, and the lowest SCE was found in Czech companies. As such, the ranking remained the same as HCE ratios.

With pair-wise *t*-test comparisons (Table 4), only companies in the Czech Republic and Slovakia showed a statistically significant difference at the significance level of at least 5%, which is reflected in the average values in Table 4 and in the previously discussed analysis

The CEE ratios are shown in Figure 4. According to Pulic (2004), the CEE ratio shows how physical and financial assets create value added for the company. Czech companies achieved the highest CEE ratio in 2019 compared to other examined countries. Therefore, Czech companies, with a lower CEE ratio, created more value added. Table 2 shows that Polish companies closely followed Czech companies with a difference of only 0.007 units. Slovak companies occupied third place, with Hungarian companies in last. Czech companies had a 24.53% higher CEE ratio than Hungarian companies.

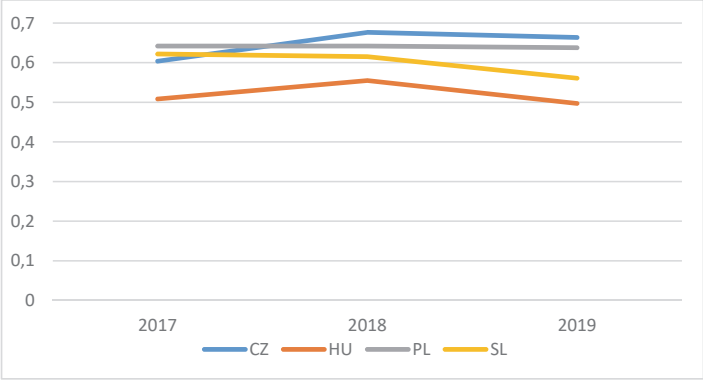

Figure 4. *The average CEE values of the analysed companies*
Source: *compiled by the authors based on their analysis*

Based on Table 4, it can be stated that there was only a statistically significant difference between the Czech Republic and Hungary, but only at a significance level of 7% in the case of CEE. Therefore, there was the same significance level between the CEE of the two countries as there was with HCE, but whereas the latter was in favour of Hungary, the former was in favour of the Czech Republic.

Overall, there were no statistically significant differences between the investigated countries in terms of VAIC components. Consequently, H1 is rejected; i.e., the countries examined did not differ statistically significantly in the components of VAIC.

4.2. Analysis of ICE and VAIC by country

For the ICE and VAIC indicators, the pair-wise comparisons of the countries examined were also performed using the *t*-test, as shown in Table 6. This table shows that there was also no statistically significant difference between the countries according to the two ratios.

ICE is the sum of the HCE and SCE ratios; therefore, the ICE ratio most likely shows the same ranking as the VAIC components. Furthermore, as the companies of the examined countries were ranked in almost the same order in both years, a similar ranking was expected for this ratio. The above is also supported by the values in Tables 2 and 4, as shown in Figure 5.

Even though the Czech companies had the lowest average ICE during the examined period among countries investigated, they had the highest average CEE ratio. In the case of Slovak companies, the opposite trend can be observed: they had the highest ICE ratio, but the lowest CEE ratio. However, by looking into the yearly averages, it can be observed that Slovak companies had a 51.70% higher ICE ratio than Czech companies, who ranked last.

Table 6. *Yearly averages of VAIC and ICE by countries and* **p***-values (%) of pair-wise* **t***-test, comparing country averages*

Statistical indicators	**Countries**	**ICE**	**VAIC**
Mean value of ratio in	Czech Republic	2,030	2,677
	Hungary	2,478	2,998
	Poland	2,298	2,939
	Slovakia	3,079	3,678
P-values of *t*-test sign. level comparing	The Czech Republic and Hungary	25%	20%
	The Czech Republic and Poland	95%	32%
	The Czech Republic and Slovakia	72%	14%
	Hungary and Poland	15%	85%
	Hungary and Slovakia	50%	32%
	Poland and Slovakia	73%	29%

Source: *compiled by the authors based on their analysis*

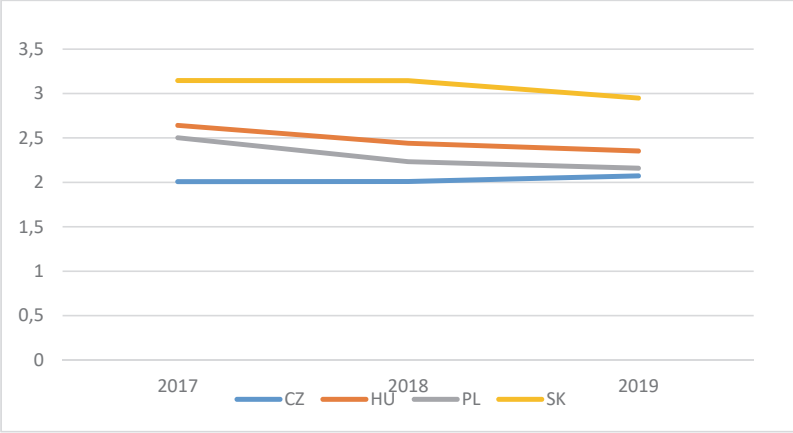

Figure 5. *The average ICE values of the analysed companies*
Source: *compiled by the authors based on their analysis*

The VAIC ratio calculation was the last step in the VAIC analysis. The results of this are provided in Table 2, and the development of values per year is shown in Figure 6. Slovak companies achieved a 22.69% higher VAIC than Hungarian ones, which ranked in second place. Some improvement can be seen with Czech companies, as there were increases in their yearly values. The companies of the other examined countries either had values that decreased or stagnated. The values of all the results were higher than 2.50, but lower than 4.00. In 2017, Slovak companies achieved a 44.28% higher VAIC ratio than the lowest value in that year. Polish and Hungarian companies had almost the same average values considering the VAIC ratios. A higher value added alongside low labour costs and low value of capital employed can provide reason for the high value of the VAIC ratio.

Based on the calculations for ICE and VAIC, H2 was rejected because there was not a statistically significant difference between the countries' ICE and VAIC ratios.

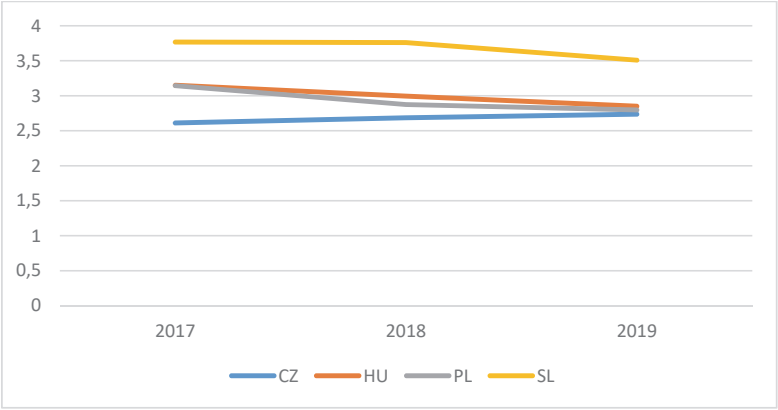

Figure 6. *The average VAIC values of the analysed companies*
Source: *compiled by the authors based on their analysis*

4.3. Correlation analysis on VAIC and its components with profitability ratios

Operating ROS and operating ROA were used for profitability indicators because the countries' performance is more comparable when using these indicators as they do not include differences in debt costs and taxes per country.

First, the correlation coefficients were calculated, measuring the linear relationship between the profitability ratios and the VAIC and its components. The results of the correlation calculation can be seen in Table 7.

Table 7. *Correlation between the profitability ratios and the VAIC and its components*

Profitability ratios	Ratios of Pulic's model				
	HCE	SCE	CEE	ICE	VAIC
ROA	0.5541	0.4110	0.2493	0.5724	0.6239
OROS	0.5047	0.3733	0.0383	0.5212	0.5152
OROA	0.5533	0.4206	0.3206	0.5738	0.6451

OROS – Operating Return on Sales, OROA – Operating Return on Assets
Source: *compiled by the authors based on their analysis*

In terms of HCE, there is a medium, positive, linear relationship with ROA, OROS, and OROA. However, it can also be seen that there is no significant difference in the relationship between HCE and the profitability indicators examined. In the case of SCE, the correlation with profitability ratios was less than 0.5 in all cases. However, a weak, medium, positive correlation with ROA, OROS, and OROA can be observed. The weakest correlation coefficients can be seen in terms of CEE.

By examining ICE, a medium, positive correlation between ICE and ROA, OROS, and OROA can be observed, which is evident as ICE is the sum of HCE and SCE. The last results are the correlation between VAIC and profitability ratios. The correlation between VAIC, ROA, and OROA is a moderate, almost strong, positive correlation. The strongest correlation can be found between profitability indicators and VAIC.

The values in Table 7 show a correlation between VAIC and its components and the selected profitability indicators. Accordingly, H3 is accepted because the correlation coefficients exceed 0.3 in all cases, except CCE. As the standard deviation of the data is generally high for economic data, a value above 0.3 is already considered acceptable.

4.3. Regression analysis of VAIC and its components with profitability ratios

The significance test for correlation coefficients was greater than 5% in 1 case: OROS – CEE (46.02%). In all other cases, the significance level was less than 0.1%.

Because the correlation calculation showed a relationship between profitability indicators and VAIC and its components, a panel regression was performed to determine the extent of the relationship. In panel models, the dependent variables were OROS, OROA, and ROA, and the independent variables were HCE, SCE, and the CEE. These results can be seen in Table 8. Both fixed and random effect panel models were calculated, but the Hausmann test found the random effect model to be higher quality, so it was used in the calculations.

Table 8: *Panel data regression results*

Dep. var.	**Indep. variables**	**Czech Republic**		**Hungary**		**Poland**		**Slovakia**	
		Regr. coeff.	**Sign. level**	**Regr. coeff.**	**Sign. level**	**Regr. coeff.**	**Sign. level**	**Regr. coeff.**	**Sign. level**
Operating ROS	Intercept	–0.0675	-	–0.0639	*	0.0043	-	–0.1358	**
	HCE	0.0721	-	0.0756	***	0.0430	***	0.0087	-
	SCE	0.0730	-	–0.0302	-	0.0403	***	0.4329	***
	CEE	–0.0029	-	0.0373	-	–0.0036	-	0.0511	-
	R^2	0.0496		0.4391		0.5347		0.6597	
	Adj. R^2	0.0165		0.4253		0.5223			
Operating ROA	Intercept	–0.0569	-	–0.0977	***	–0.0545	**	–0.1626	***
	HCE	0.0275	-	0.0444	***	0.0699	***	0.0221	*
	SCE	0.1877	-	0.0397	*	0.0436	**	0.3406	***
	CEE	0.0422	-	0.1829	***	0.0414	*	0.1291	***
	R^2	0.0882		0.5978		0.6833		0.6952	
	Adj. R^2	0.0564		0.5880		0.6748			

Dep. var.	Indep. variables	Czech Republic		Hungary		Poland		Slovakia	
		Regr. coeff.	Sign. level	Regr. coeff.	Sign. level	Regr. coeff.	Sign. level	Regr. coeff.	Sign. level
ROA	Intercept	–0.0586	-	–0.0672	***	–0.0383	*	–0.1532	***
	HCE	0.0204	-	0.0419	***	0.0609	***	0.0172	.
	SCE	0.1736	-	0.0262	-	0.0461	**	0.2950	***
	CEE	0.0352	-	0.1209	***	0.0039	-	0.1142	**
	R^2	0.0734		0.4959		0.5920		0.6515	
	Adj. R^2	0.0411		0.4835		0.5812			

Source: *own editing based on calculated data*

The regression coefficients describe the impact of dependent variables on the independent variables. The signs of regression coefficients show the direction of the effects of the independent variables. There were no significant regression coefficients for the Czech Republic alone in the three panel models. Table 6 also shows that the coefficients of determination (R^2) for the Czech Republic were less than 0.1 for all three models, so the profitability ratios examined cannot be explained by independent variables. For the panel models of the other three countries, there were at least one or two significant regression coefficients per model, and the coefficient of determination also exceeded 0.4 in the worst case. Except for the Czech Republic, the second model shows the best relationships, where the operational ROA is the dependent variable. All explanatory variables and the intercepts were significant, at least at the 5% significance level. In the second model, except for the Czech Republic, the corrected coefficient of determination was acceptable (between 0.5880 and 0.6748), which can be considered suitable for economic data.

Based on the results in Table 6, it can be concluded that a fairly strong relationship can be detected between the operating ROA and the VAIC components, and that the components of the VAIC impact the operating ROA. However, the previous finding is not valid for the Czech Republic, where no relationship could be established between the profitability indicators and the VAIC components. This may be because of the high variance of Czech company data. On the contrary, in the case of Hungary, Poland, and Slovakia, the strongest relationship was found between the operating ROA and VAIC components. For these countries, the coefficient of determination was close to or above 0.6, which is suitable for economic data. Moreover, the coefficient of determination of 0.6 corresponds to a correlation coefficient of 0.7746, which already indicates a close correlation. In this case, the regression coefficients had a statistically significant value, with at least a 5% significance level.

However, the magnitude of these effects varies by country, and each explanatory variable positively impacts operating ROA. Table 6 table also shows that the intercept was negative for all three countries. It can also be stated that, in the case of Hungary, CEE had the greatest impact, while in Slovakia this was exerted by SCE. In Poland, the impact of

the components of VAIC was not significantly different. The regression results also show that the effect of HCE was the largest in Poland and the smallest in Slovakia.

Based on the obtained results, H4 can only be partly accepted because, in the case of the Czech Republic, the effect of VAIC components on profitability indicators cannot be demonstrated.

Conclusion

Intangibles have always been a major challenge for investors, accounting professionals, and corporate evaluators. Accounting systems cannot account for all intangibles, so companies may have some items that are not included in the company's balance sheet. Most accounting systems try to present a company's assets at real value, but the invisibility of these goods can cause difficulties. Most investors want to know why the market and book value gap can create intellectual capital.

This study's primary aim was to examine whether the performance of pharmaceutical companies in the Visegrad countries differs statistically significantly in terms of VAIC. The second aim was to establish whether the components of the VAIC indicator impact the profitability indicators of companies. Pharmaceutical companies were selected because it is likely that intellectual capital may play a significant role in research and development in the case of these companies.

Based on the results and conclusions of this analysis, there are no statistically significant differences among the average values of the companies in the countries investigated. At the same time, there were some differences at the level of VAIC and its components in the analysed countries, but they were not statistically significant. The countries studied used to operate within the framework of the socialist system, after the overthrow of which they switched to a market economy. These countries have undergone significantly similar developments in recent decades. Likely, these similar development paths have not yet led to significant differences between them.

There is usually a medium correlation between the selected profitability indicators and VAIC and its components, which is acceptable for economic data. Because cross-sectional and time-series data are also included in the database, a panel model was selected to determine the extent to which the components of the VAIC indicator could influence the development of the values of the profitability indicators. Relationships can be determined between VAIC components (HCE, SCE, and CEE) and companies' profitability ratios in the case of three countries (Hungary, Poland, and Slovakia). Relationships cannot be determined between VAIC components and profitability ratios in companies in the Czech Republic. It can be stated that, except for the Czech Republic, the components of VAIC impact the development of operating profit.

Based on a study of the literature on the application of VAIC, it can be argued that this indicator is suitable for measuring corporate performance from a specific perspective. Furthermore, this indicator takes a more noteworthy account of intellectual capital's impact, but is not ideal for measuring it.

In the future, it would be useful to extend this analysis toward comparing the results obtained with other performance measures, which different parametric and non-parametric methods can determine. For example, a hierarchical panel model could be used to explore the complex effects of factors. In addition, these investigations could be extended to other countries.

The current research findings can be used in education, can help with further research, and can provide support to various decision-makers.

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ABNORMAL AUDIT FEES AND AUDIT QUALITY: THE INFLUENCE OF FINANCIAL EXPERTISE IN THE AUDIT COMMITTEE

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Abstract. *The Sarbanes-Oxley Act of 2002 had a major influence on the relationship between auditors and clients, and gave audit committees the responsibility for approving and negotiating audit fees. Even if, in theory, abnormal audit fees should be associated with audit quality, there is not yet a consensus in the literature – which is limited and inconclusive – on the statistical significance of their relationship. Therefore, to fill this research gap, this study examines the association between a firm's audit fees with audit quality, while also assessing the impact of audit committee members' financial expertise on that relationship. Specifically, a large time frame is employed for regression analysis in a sample consisting of 3,599 firm-year observations from 2010 to 2018 in the US market. A two-stage approach is used, where the first model estimates audit fees based on the model's residuals according to prior relevant studies, while the second model uses the aforementioned residuals as the main variable of interest in a logistic regression with the appearance of restatements as the dependent variable. The findings conclude that abnormal audit fees have a negative*

impact on audit quality. Furthermore, financial expertise in the audit committees has a positive impact on audit quality. These findings also conclude that there is no significant relationship between the interaction of abnormal audit fees and financial expertise in the audit committees and audit quality. These results are robust, after having been subject to a robustness check of a different audit quality proxy: discretionary accruals. This is consistent with the economic bonding theory and is in line with prior research.

Keywords: *abnormal audit fees, restatements, audit quality, audit committees, financial expertise, discretionary accruals*

JEL Codes*: G34, F33*

1. Introduction

This study examines whether firms with abnormal audit fees and high financial expertise of audit committee members result in higher audit quality. The research question is as follows: "Does financial expertise in the audit committee influence the relationship between abnormal audit fees and audit quality?" A growing body of accounting literature is studying the association between abnormal audit fees and audit quality (Asthana & Boone, 2012; Blankley et al., 2012; Eshleman & Guo, 2014; Kinney & Libby, 2002; Trompeter, 1994; Kinney et al., 2004; Stanley & DeZoort, 2007). There is great interest from researchers in this relationship because, ex-ante, there is no consensus on whether receiving a higher or lower fee from audit clients will improve or decrease the quality of the audit (Eshlemen & Guo, 2004). Concerning the expected level of service provided, higher fees are associated with greater levels of service, and vice versa. Consequently, lower audit effort resulting from abnormally low fees could eventually lead to a restatement. On the other hand, abnormally high fee levels may impair an auditor's independence through economic bonding to the client. This could, similarly, lead to a restatement (Blankley et al., 2012).

A financial restatement provides an explicit response to material errors or misstatements in prior financial statements. For a restatement to appear, the auditor must have failed in detecting and preventing all material errors during a prior audit. This failure can be attributed to impaired auditor independence because the auditor is economically bound to the client (Blankley et al., 2012). Abnormally high audit fees give a reflection of the level of economic bonding between the auditor and the client. Consequently, greater economic bonding reduces audit quality by impairing auditor independence (Asthana & Boone, 2012).

This study contributes to the literature in several ways. According to prior research, there have been studies on audit fees and audit committees (Abbott et al., 2003) – even research on audit committees and restatements as proxies of audit quality (Abbott et al., 2004). Subsequently, there is prior research about the relationship between abnormal audit fees and audit quality (Eshleman & Guo, 2014). However, there is still no consensus, and there has been no research yet performed, on the relationship between abnormal fees, audit quality, and audit committees. Since prior research implies that audit committees' expertise can reduce the likelihood of financial restatement and thereby increase

audit quality, it is relevant to investigate this relationship (Abbott et al., 2004). Additionally, audit committees are responsible for approving and negotiating fees (Sarbanes-Oxley Act, 2002). Accordingly, with the absence of research performed in this area and the conflicting results, this paper will contribute to the academic literature by filling the relevant research gap, as prior research into the relationship between restatements and audit fees is also limited and inconclusive.

The results show that abnormally high audit fees are significantly negatively related to audit quality, as measured by restatement proxies. However, negative abnormal audit fees have an insignificant effect on audit quality. These results imply that abnormally high audit fees are a significant factor in the context of auditor independence due to economic bonding. Contradictorily, abnormally low audit fees do not lead to lower audit effort. Furthermore, there is a significant positive relationship between audit committee expertise and audit quality. The interaction variables, abnormal audit fees, and financial expertise do not show significance. In our final tests for robustness using an alternative audit quality proxy, there is still no support for the research question.

1. Literature review and hypotheses development

Abnormal audit fees occur when there is a difference between actual audit fees paid to auditors for their audit and expected audit fees. The different controls for normal audit fees that reflect the auditor's effort include costs, litigation risk, and normal profits (Simunic, 1980; Choi et al., 2009).

Positive abnormal audit fees (above normal) give a reflection of the degree of economic bonding between the auditor and the client. Consequently, higher economic bonding impairs auditor independence and negatively affects audit quality (Blankley et al., 2012; Eshleman & Guo, 2014). Based on this proposition, prior research has studied the relationship between audit quality and abnormal audit fees. Following Simunic (1980), the auditor's expected fee charged to the client is determined by the units of audit resources expended, the cost per unit of those resources, and the auditor's expected future losses arising from the engagement (e.g., litigation losses, government penalties). The relationship between audit fees and audit quality is not clear, and abnormal audit fees likely have some influence on the probability of an eventual restatement (Kinney et al., 2004; Blankley et al., 2012).

Respectively, there are two views on the linkage between abnormal audit fees and audit quality (Eshleman & Guo, 2014). The first view is that positive abnormal audit fees are a reflection of bribes or economic rents being earned by the auditors (Kinney & Libby, 2002). The second view states that the fees charged represent the amount of effort put into the audit. In the following sections, we will further elaborate on these two views.

Prior research has found that audit quality declines as positive abnormal audit fees increase. Abnormally high fees may impose an incentive on auditors to allow managers to engage in opportunistic audits, and may impair their independence (Kinney & Libby, 2002). This is in accordance with the economic bonding view of Eshleman and Guo (2014), which describes the notion that abnormally high audit fees are an indication

of attempted bribes, economic rents earned by the auditors, or the economic bond of the auditors with the clients. Krauß et al. (2015) researched the relationship between abnormal audit fees and audit quality in a German market setting. They showed a negative association between abnormal audit fees and audit quality, and indicated that the fee premium is a significant indicator of auditors' independence because of the auditor-client relationship. Choi et al. (2010) also examined whether audit quality is associated with abnormal audit fees. Their results show that abnormal audit fees are negatively associated with audit quality. In accordance with these results, Hribarand et al. (2013) examined the relationship between abnormal audit fees and audit quality. Their results show a negative relationship, and provide evidence that abnormal audit fees are strongly informative in predicting restatements, SEC comment letters, and fraud. Furthermore, Gunn et al. (2019) found evidence that, under Big 4 market concentration, audit fees increase while audit quality decreases, indicating a wealth transfer from shareholders to audit firms which are involved in complex audit tasks but offer audits that are of lower quality. In contrast, DeFond et al. (2002) examined the relationship between abnormal audit fees and audit quality but found no significant result. Their explanation advocates the view that market-based institutional incentives, such as reputation loss and litigation costs, stimulate the auditor's independence and overshadow the economic benefits of higher audit fees.

There is also an alternative explanation from a more economic perspective for the audit quality-abnormal audit fee relationship. The statement that audit fees are negatively related to restatements in the subsequent year seems reasonable. Abnormally low fees paid by the client gives rise to great pressure for auditors to complete audits in the available time frame and achieve profitability. Consequently, this pressure can make audit firms over-reliant on the controls of the clients, and can minimize substantive testing by the auditors (Blankley et al., 2012). On the other hand, an effort view suggests that higher audit fees are symptomatic of greater auditor effort and, therefore, higher-quality audits. Higher audit fees are the outcome of audit firms spending more hours on audits, or audit firms charging an above normal fee because of their status. Consequently, low audit fees are the result of less audit work and lower audit quality. This view is recognized as the effort view (Eshleman & Guo, 2014; Blankley et al., 2012; Higgs & Skantz, 2006). Putting more effort into audits is one way an auditor can respond to firms with a heightened risk of earnings management (Francis & Krishnan, 1999). This view is confirmed by the Public Company Accounting Oversight Board (PCAOB). The PCAOB focuses on firms with low audit fees relative to firms in the same industry to decide which audit firm they will review (Eshleman & Guo, 2014). They assume that firms paying (abnormally) low audit fees to the audit firm will receive low-quality audits. Moreover, Bills et al. (2016) found that both audit firms and quality are higher for members of international accounting networks (large audit firms), linking the quality control brought by international accounting networks with their compensation and audit outcome.[1]

[1] Mao et al. (2017) failed to find consistent evidence that audit quality is higher for member audit firms in China's institutional setting. They argued that China's institutional setting demonstrates weaknesses which overcome the higher audit quality offered by international accounting networks.

As discussed earlier, the effect of abnormal audit fees on audit quality is an empirical issue. Literature shows conflicting research on whether abnormal audit fees are an indication of high effort employed by the auditors (effort view) or an indication that the auditors impair their independence (bonding view), thus suggesting that the relationship between auditors' compensation and audit quality is a relevant empirical issue.

Financial restatements occur when a material inaccuracy is found in a prior financial report issued. Prior research has used restatements as a measure of audit quality. The discovery of a material inaccuracy can have major consequences for companies, stakeholders, and auditors. Restatements reduce the reliability of management disclosure (Hennes et al., 2008) and give an indication of the level of management's internal control system and handling of misstatements. Moreover, external auditors are often held responsible for restatements.

Kinney et al. (2004) observed that restatements represent reporting failures by the client and the auditor. Reporting failures of material misstatements are attributable to auditor independence due to the fact that the client pays the auditor. Feldmann et al. (2009) claimed that higher audit fees implicate a higher perceived audit risk and reduced organizational legitimacy. In the end, the client suffers from reporting failures, but the auditors also suffer from reputational damage and legal liability (DeFond et al., 2002). Thus, whether abnormal fees affect audit quality remains an open empirical question, leading to the following hypothesis:

H1: Abnormal audit fees in the current year are systematically associated with the current year's audit quality

The statement that effective audit committees should contain members who possess financial experience is in line with previous research on audit committee expertise. In general, empirical studies argue that audit committees' expertise in various domains (industry expertise, legal expertise, accounting expertise, etc.) enhances audit quality (Alhababsah & Yekini, 2021; Lisic et al., 2019). Knapp (1987) found that auditors that face a complex auditing issue were less likely to communicate this to audit committees that have low expertise. DeZoort (1998) found that audit committee members who possessed earlier experience in the internal control sector made decisions more similar to auditors than those audit committee members without such experience. DeZoort and Salterio (2001) stated that experienced audit committee members had a higher likelihood of understanding and sympathizing with the risks concerning external auditors.

Prior research suggests that audit committees' expertise can reduce the incidence of financial restatement in different ways. First, the existence of audit committees with at least one member with financial expertise increases the likelihood of understanding the internal audit program and its results (Raghunandan et al., 2001). This warrants systems that are in place to increase the effectiveness of internal control in preventing or detecting restatements. Second, financial expertise permits audit committees' members to better understand auditing issues, risks, and the audit procedures proposed to address these issues and risks (DeZoort & Salterio, 2001; Chen & Komal, 2018). Finally, audit commit-

tee members with expertise are more likely to communicate detected material misstatements to the audit committee and correct them (DeZoort & Salterio, 2001). Abbott et al. (2003) found a positive relationship between audit fees and financial expertise in the audit committee. The same conclusion was also reached by Ghafran and O'Sullivan (2019), who argued that audit committees possessing greater levels of financial expertise are related to higher audit fees and consequently higher audit quality. This indicates that audit committees consisting of at least one financial expert are associated with higher audit fees. This implies that audit committees with financial expertise are better able to reduce the occurrence of financial restatements, and are competent in maintaining solid cohesion between abnormally high fees and restatements. Thus, the above findings and arguments lead to the two following hypothesis:

H2: Financial expertise in the audit committee increases audit quality

3 Research method and design

3.1 Data collection and sample selection

To answer the research question and test the hypotheses, in this study the research is built upon analyzing public data from the US. This data was taken from Wharton Research Data Services, the CRSP-Compustat (merged), ISS, and AuditAnalytics databases, and consisted of 3599 firm-year observations from the 2010 to 2018 period. Data from after the economic recession was used to maintain the most consistent dataset. The dataset on restatements was obtained from AuditAnalytics (Non-Reliance Restatements), the data for abnormal audit fee model was obtained from AuditAnalytics, and the financial information was extracted from CRSP-Compustat. The information about the members in audit committees was downloaded from Institutional Shareholder Services (ISS), the board of directors.

A two-stage approach was used. The first model estimated audit fees based on the residuals, following recent prior studies (Blankley et al., 2012; DeFond et al., 2002; Ghosh & Pawlewicz, 2009; Whisenant et al., 2003; Choi et al., 2010). The second model took the residuals from the model in stage one and included them as an independent variable in a logistic regression, with restatements as the dependent variable.

3.2 Multivariate analysis

For the assessment of H1, Abnormal Audit Fee was used as an independent variable. Abnormal audit fee was estimated as the residual from the audit fee model (Esheleman & Guo, 2014; Hoitash et al., 2007; Choi et al., 2010; Gul et al., 2003; Kinney et al., 2004; Krauß et al., 2014; and Blankley et al., 2012). The residual audit fee reflects the abnormal profits from the audit engagement. To the extent that some factors are unobservable, the residual audit fee, ε, measures abnormal audit profitability. This was done in order to capture the relative profitability of the engagement to the specific audit firm (Asthana &

Boone, 2012). The reasoning behind this is that prior research from Reynolds and Francis (2001) showed that audit quality is best measured at the local office level instead of at the national firm level.

Two separate variables from the audit fee were defined to separately examine the relationship of both positive and negative abnormal audit fees with the dependent and moderating variable (Asthana & Boone, 2012; Eshleman & Guo, 2014). If abnormal audit fees >0, then HIGHABNFEE = abnormal audit fees, and 0 otherwise. If abnormal audit fees <0 then LOWABNFEE = abnormal audit fees, and 0 otherwise. The notion of abnormal audit fees was based on the residuals from the audit fee model below (equation 1).

This model estimated audit fees using an audit fee model adapted from prior studies (Ghosh & Pawlewicz, 2009; Choi et al., 2010; Blankley et al., 2012), with an emphasis on controlling for fee determinants associated with firm risk. Based on these studies, we regressed logged audit fees (LAF) on variables controlling for risk, audit effort, and industry. The following model was thus developed:

$$LAF_{i,t} = ß_0 + ß_1LTA_{i,t} + ß_2CR_{i,t} + ß_3CATA_{i,t} + ß_4ARINV_{i,t} + ß_5ROA_{1i},t + ß_6LOSS+ + ß_7FOREIGN + ß_8MERGER + ß_9BUSY_{i,t} + ß_{10}LEV1_{i,t} + ß_{11}INTANG_{i,t} + \quad (1)$$
$$+ ß_{12}SEG_{i,t} + ß_{13}OPINION_{i,t} + ß_{14}MATWEAK_{i,t-(t-1)} + ß_{15\text{-}27}INDCON_{i,t+\varepsilon i,t}$$

Consistent with prior research, several control variables were included (Simunic 1980; Blankley et al., 2012; DeFond et al., 2002; Ghosh & Pawlewicz, 2009; Whisenant et al., 2003; Choi et al., 2010). To control for audit effort, the model included a size proxy variable (LTA), the presence of mergers (MERGER), the number of business segments (SEG), and the issuance of a going concern opinion (OPINION). To control for audit risk, the current ratio (CR), current assets to total assets ratio (CATA), sum of accounts receivable and inventory divided by total assets (ARINVTA), return on assets (ROA1), loss (LOSS), and ratio of intangible assets to total assets (INTANG) were included. Leverage (LEV) was included to measure the long-term financial structure of the firm. If the firm has a calendar year-end (BUSY), the variable equals 1. If the client receives a material weakness opinion in the current year, the variable MATWEAK equals 1.

The dependent variable in this research was Audit Quality. To proxy for audit quality, the financial restatements factor was used. By using restatements as a proxy for audit quality, the demand of Carcello and Nagy (2004) for a more objective and direct measure of audit quality was addressed. Financial restatements are also a significant factor in reducing the confidence of investors in financial reporting and market efficiency (SEC, 2002).

The moderating variable in this research was Audit Committee Quality, which was defined as the percentage of members with financial expertise in the audit committee. The BRC report from 1999 provides specific properties for professional backgrounds that have a high likelihood of an appropriate level of expertise.

3.3 Economic model

A logistic regression model was used to test the hypotheses, since the dependent variable, restatement, is a binary variable. The residuals from the audit fees model in stage one were taken and included as an independent variable. The final restatement model

consisted of 3,599 observations.[2] Consistent with Romanus et al. (2008), Aier et al. (2005), Blankley et al. (2012), Asthana and Boone (2012), Chin and Chi (2009), and Richardson et al. (2002), the restatement model was formed on the basis of prior research. Romanus et al. (2008) investigated the effect of industry expert auditors on restatements. Aier et al. (2005) investigated whether CFO characteristics are associated with restatements. Blankley et al. (2012) examined the relationship between audit fees and restatements in the years following the Sarbanes-Oxley Act of 2002. The following model was thus developed:

$$REST_{i,t} = ß_0 + ß_1 LOWABNFE_{ei,t} + ß_2 HIGHABNFEE_{i,t} + ß_3 \%EXPERT_{i,t} + ß_4 LTA_{i,t} + ß_5 LEV2_{i,t} + ß_6 MTB_{i,t} + ß_7 ROA2_{i,t} + ß_8 MATWEAK_{i,t+\varepsilon i,t} \quad (2)$$

$$REST_{i,t} = ß_0 + ß_1 LOWABNFEE_{i,t} \times ß_2 \%EXPERT_{i,t} + ß_3 LOWABNFEE_{i,t} + ß_4 \%EXPERT_{i,t} + ß_5 LTA_{i,t} + ß_6 LEV2_{i,t} + ß_7 MTB_{i,t} + ß_8 ROA2_{i,t} + ß_9 MATWEAK_{i,t+\varepsilon i,t} \quad (3)$$

$$REST_{i,t} = ß_0 + ß_1 HIGHABNFEE_{i,t} * ß_2 \%EXPERT_{i,t} + ß_3 HIGHABNFEE_{i,t} + + ß_4 \%EXPERT_{i,t} + ß_5 LTA_{i,t} + ß_6 LEV2_{i,t} + ß_7 MTB_{i,t} + ß_8 ROA2_{i,t} + + ß_9 MATWEAK_{i,t+\varepsilon i,t} \quad (4)$$

where:

REST = 1 if the firms announced a restatement in the next two years, 0 otherwise;

LTA = logarithm of end of year total assets;

LEV2 = total debt divided by total assets;

MTB = market-to-book ratio;

ROA2 = return on assets, net income divided by lagged total assets;

MATWEAK = 1 if the client receives a material weakness opinion in the current year or the next year, 0 otherwise;

LOWABNFEE = Equal to abnormal audit fees estimated from Equation (1) if abnormal audit fees are negative, 0 otherwise;

HIGHABNFEE = Equal to abnormal audit fees estimated from Equation (1) if abnormal audit fees are positive, 0 otherwise;

%EXPERT = percentage of experts in the audit committee; and ε = the error term;

Based on previous research, several control variables on the firm- and industry-level were included in the model. The emphasis was on controlling for fee determinants associated with firm risk, audit effort, and industry (Blankley et al., 2012). The first control variable was on the size of the firm, because it was expected that larger firms experience more scrutiny by regulatory agencies and therefore have better internal control systems. Firm size was proxied by lagged total assets (LTA), and a positive relationship was expected between size and the occurrence of restatements (Richardson et al., 2002). Furthermore, leverage (LEV) – which was included to measure the long-term financial structure of the firm – was controlled for. The market-to-book variable (MTB) controls for the market's perception of future growth, and the natureof the market capital leads to the nature of a restatement (Richardson et al., 2002). Lastly, the presence of the opinion of material weakness (MATWEAK) in the current or next year was included (Feldmann et al., 2009).

[2] Finally, there were 130 observations dropped for merging of the discretionary accruals model. Therefore, the discretionary accruals model consisted of 3,496 observations.

Extreme values of leverage were excluded, namely values higher than one and equal to 0. Moreover, observations with negative equity were deleted to maintain representative market-to-book ratios, and the upper 5 percentiles of the market-to-book ratio were winsorized (Francis et al., 2005). After using a 2-digit sic code, removing the financial firms, and dropping the cases where there were fewer than 20 firms available in an industry-year group, 3,203 observations remained.

3.4 Robustness testing

To corroborate these results, alternative proxies of audit quality were used – namely discretionary accruals. Discretionary accruals are calculated using the modified version of the Jones model (Jones, 1991; Dechow & Dichev, 2002), and are estimated by year and for each industry. Jones (1991) proposed a model that attempts to foresee the effects of changes in a firm's economic circumstances on nondiscretionary accruals. The purpose of the Modified Jones Model is to eliminate the tendency of the Jones Model to measure discretionary accruals with an error when discretion is exercised over revenue recognition.

To measure the effect of abnormal audit fees on discretionary accruals with the moderating effect of audit committee expertise, the following regressions were developed:

$$DACC_{i,t} = ß_0 + ß_1 LOWABNFEE_{i,t} + ß_2 HIGHABNFEE_{i,t} + ß_3 \%EXPERT_{i,t} + \\ + ß_4 LTA_{i,t} + ß_5 LEV2_{i,t} + ß_6 MTB_{i,t} + ß_7 MATWEAK_{i,t} + ß_8 ROA_{i,t} + \\ + ß_9 LOSS_{i,t} + \textit{Industry Fixed Effects} + \varepsilon_{i,t} \quad (5)$$

$$DACC_{i,t} = ß_0 + ß_1 HIGHABNFEE_{i,t} \times ß_2 \%EXPERT_{i,t} + ß_3 HIGHABNFEE_{i,t} + \\ + ß_4 \%EXPERT_{i,t} + ß_5 LTA_{i,t} + ß_6 LEV2_{i,t} + ß_7 MTB_{i,t} + ß_8 MATWEAK_{i,t} + \\ + ß_9 ROA_{i,t} + ß_{10} LOSS_{i,t} + \textit{Industry Fixed Effects} + \varepsilon_{i,t} \quad (6)$$

where:

ADACC = absolute value of discretionary accruals;

LOSS = 1 if the firm incurred a negative net income (loss), 0 otherwise.

The variable LOSS was added to the regression model to control for debt and financial distress (Dechow & Dichev, 2002; Choi et al., 2010). Firms with higher debt ratios have greater incentive to improve earnings to meet specific debt agreements or to avoid bankruptcy (Choi et al., 2010). Therefore, it was expected that the LOSS variable would be positively correlated with discretionary accruals. All variables are described in the Appendix. Financial firms were excluded from analysis, while all variables were winsorized at the 1st and 99th percentiles.

4. Results

4.1 Descriptive statistics

Table 1 represents the descriptive statistics used in the correlation and (logistic) regressions. The descriptive statistics of total members in the audit committees show the total range of options in the sample, namely 1 to 8 members. On average, there were 4 members on the board. The percentage of financial experts in the audit committees

(%EXPERT) shows an array in the descriptive statistics – from the whole committee being financial experts, 1, to no financial experts being present in the audit committee, 0. The mean was above half (57.6%), indicating the whole range of options included in the dataset, which is in line with Davidson et al. (2004) and Romanus et al. (2008). The results of the ABFEE and HIGHABNFEE are in line with prior research on abnormal audit fees (Hoitash et al. 2007; Asthana & Boone, 2012; Blankley et al., 2012; and Krauß et al., 2015). ROA, LEV, Total Assets, and LTA are in line with prior studies (Aier et al., 2005; Hoitash et al., 2007; Asthana & Boone, 2012; Huang et al., 2015; Blankley et al., 2012; Eshleman & Guo, 2014). The mean of the market to book ratio (MBT) is similar to Blankley et al. (2012), but the standard deviation is much smaller than prior research. This ratio depends on how the market and book value compared to each other, and the maximum of the ratio is relatively low. This indicates that the firms are trading high in the market compared to their book values. However, both the mean and standard deviation of MBT from Aier et al. (2005) are comparable. The discretionary accruals (DACC) variable is in line with the results from Gul et al. (2003) and Choi et al. (2010).

By analyzing the rates of occurrence, 117 firms reported a material weakness (MATWEAK), 117 firms incurred a loss (LOSS), and 262 restated their financial statements (REST). Prior research included the restatements in the descriptive statistics instead of a rate of occurrence table, so there is no reference. The descriptive statistics of LOSS are comparable to those of Eshleman and Guo (2014), and the MATWEAK results are the same as from Blankley et al. (2012).

Table 1. *Panel A: descriptive statistics*

Variable	Mean	Min.	Max.	Std. Dev.	N
Total Members	3.8141	1	8	1.0028	3,599
%EXPERT	0.5765	0	1	0.3009	3,599
ABFEE	0.0192	−4.2323	2.2663	0.4243	3,599
HIGHABNFEE	0.1700	0	2.2663	0.2440	3,599
LOWABNFEE	−0.1507	−4.2323	0	0.2630	3,599
LTA	8.0858	4.6602	12.8355	1.4694	3,599
LEV	0.2350	1.60E-07	0.8413	0.1445	3,599
MBT	3.1438	0.1234	11.7445	2.0408	3,599
ROA	0.0564	−0.1726	0.2473	0.0612	3,599
DACC[3]	−0.0059	−0.5323	1.0176	0.2471	3,496

Panel B: rates of occurrence

	0	1	Total
REST	3,337	262	3,599
MATWEAK	3,482	117	3,599
LOSS	2,892	117	3,469

The Pearson correlation matrix for the variables in the restatement regression model is shown in Table 2. The independent variables and control variables have a significant relationship with the dependent variable, as shown in Table 2. The restatement binary variable is significantly positively correlated with HIGHABNFEE and MATWEAK. Second, the restatement binary variable is significantly negatively correlated with %EXPERT, LTA, MBT, and ROA. This shows that there is a linear relationship between the number of restatements and the number of experts in the audit committee, abnormally high fees, the log of total assets, market-to-book ratio, the number of material weaknesses, and return on assets. Table 2 shows that there are no large values of correlation between the independent variables and the control variables. For the moderating variable %EXPERT, there are significant correlations with HIGHABNFEE, LOWABNFEE, LTA, LEV, and MBT. Following Abbott et al. (2003), greater financial expertise of audit committees will lead to enhanced oversight of the management-auditor relationship. The independent variable HIGHABNFEE is significantly correlated with REST, EXPERT, LOWABNFEE, LTA, LEV, MATWEAK, and ROA. The independent variable LOWABNFEE is significantly correlated with EXPERT, HIGHABNFEE, LTA, MBT, MATWEAK, and ROA.

Table 2. *Pearson correlation matrix*

	REST	**%EXPERT**	**HIGHABNFEE**	**LOWABNFEE**	**LTA**	**LEV**	**MBT**	**MATWEAK**	**ROA**
REST	1.0000								
%EXPERT	–0.0279	1.0000							
	0.0942*								
HIGHABNFEE	0.0335	–0.0296	1.0000						
	0.0443**	0.0760*							
LOWABNFEE	0.0006	–0.0425	0.3995	1.0000					
	0.9727	0.0108***	0.0000***						
LTA	–0.0290	0.1181	–0.0803	–0.0241	1.0000				
	0.0824*	0.0000***	0.0000***	0.1485*					
LEV	0.0034	0.0781	–0.0225	–0.0211	0.2412	1.0000			
	0.8372	0.0000***	0.1766*	0.2054	0.0000***				
MBT	–0.0664	0.0416	–0.0188	–0.0318	0.0848	0.1353	1.0000		
	0.0001***	0.0125***	0.2606	0.0564**	0.0000***	0.0000***			
MATWEAK	0.0994	–0.0164	0.0404	–0.0325	–0.0889	0.0070	0.0036	1.0000	
	0.0000***	0.3253	0.0153***	0.0509**	0.0000***	0.6745	0.8269		
ROA	–0.0763	–0.0027	–0.0740	–0.0497	0.0686	–0.2185	0.3604	–0.0742	1.0000
	0.0000***	0.8711	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	

* / ** / *** significant at p-value 0.10/0.05/0.01 respectively

The outcome of multivariate tests on the sample is reported by estimating logistic regression models of restatements regarding the hypotheses and prior research. The coefficients, significance, and explanatory power of the model will be examined using a sample of 3,599 firm-year observations. Logistic regression was used to generate the coefficients and significance levels, and is presented in Table 3 (Blankley et al., 2012; Kinney et al., 2004). For the sake of comparison, regressions are reported with and without the interaction variables to explain Models (2), (3), and (4), with Equations (2), (3), and (4), respectively. The number of observationsin Models (3) and (4) is lower because LOWABNFEE or HIGHABNFEE were excluded.

The multivariate analysis in Table 3 shows a pseudo R^2 of approximately 2.9%, 3.2%, and 3.1%. This shows that the model explains roughly 3% of the variability of all the variability around the mean that the model should explain. Consistent with Blankley et al. (2012), the model's explanatory power is quite low. This can be due to the low amount of restatements in the sample.[3] However, other prior research shows different Pseudo R^2 results. Romanus et al. (2008) developed a model with a Pseudo R^2 of 20%. This can be explained because their research selected firms with restated financial statements and added a control firm without a restatement. In this way, these models give a sample of firms with and without a restatement, which makes it easier to investigate the difference between these firms.

For the restatement regression, 3 of the 5 control variables are significant (at 1 percent level or better). MATWEAK is significantly positive and ROA and MBT are significantly negative (Blankley et al., 2012; Aier et al., 2005; Hoitash et al., 2007). Thus, firms with more material weaknesses, small return on assets, and lower market-to-book ratio are more likely to have more restatements. Referring to prior research, LTA and LEV also appeared significant (Blankley et al., 2012; Asthana & Boone, 2012).

To test H1 and H2, Equation (2) was ran. The first hypothesis states a systematic effect of abnormally low audit fees on audit quality (a negative or positive effect on the incidence of financial restatement) (Equation 2). Table 3 shows the results of the logistic regression model. The coefficient of LOWABNFEE is not significant in all models, showing no support for H1. This indicates that auditors are able to deliver an appropriate level of audit quality even when the audit fee is abnormally low (Krauß et al., 2015).

Furthermore, these results indicate that abnormally low audit fees do not inevitably lead to a decrease in audit effort (Esheleman & Guo, 2014). DeFond et al. (2002) examined the relationship between abnormal audit fees and audit quality, and also found no significant result. Their explanation advocates the view that market-based institutional incentives, such as reputation loss and litigation costs, stimulate the auditor's independence and overshadow the economic benefits of higher audit fees

Factors influencing the relationship between abnormal audit fees and restatements could be due to the measurement of audit quality. Eshleman and Guo (2014); Krauß et al. (2014); Asthana and Boone (2012); Choi et al. (2010); Hoitash et al. (2007); and Gul et al. (2003) used discretionary accruals as a proxy for audit quality, where this research

[3] The total sample amouted to 3,599 observations, where 262 observations had restatements. Hence, 13.7% of the total sample of firms had a restatement.

used restatements. Furthermore, other research examining financial restatements as a proxy for audit quality used a sample of firms with restated financial statements and assessed a control firm for each company (Romanus et al., 2008; Chin & Chi, 2009; Stanley & DeZoort, 2007). The fact that other research found significant outcomes can indicate that the sample is not suited for the restatement model. Moreover, Asthana and Boone (2012) used a different proxy for abnormal audit fees, namely the actual audit fee less the predicted audit fee, with the difference between those fees deflated by the total fee revenue of the audit firm leading the client's audit. Following Esheleman and Guo (2014), there are some concerns that the residual from the audit fee model may simply be picking up random noise.

The second hypothesis argues that the level of financial expertise in audit committees positively influences audit quality (and therefore decreases the number of restatements). Table 3 shows that %EXPERT is significantly negative in Models (2) and (3), and supports H2. This result is in line with prior research and supports the hypothesis that a higher percentage of financial experts in the audit committees is negatively related to the incidence of a restatement (Abbott et al., 2003; DeZoort & Salterio, 2001).

The relationship between the interaction terms and the dependent variable was further tested, and Equation (3) was ran. These findings suggest that the interaction between abnormal audit fees and the level of financial expertise in the audit committee does not affect the incidence of restatements. These results are presented in Models (3) and (4). Moreover, these results suggest that the level of members with financial expertise in the audit committees increases audit quality. Finally, there is no statistically significant evidence that the interaction between abnormal audit fees and financial expertise affects audit quality.

Table 3. *Multivariate analysis: analysis of restatements, abnormally low and high audit fees, and audit committees*

REST	Model 1	P > z	Model 2	P > z	Model 3	P > z
LTA	−0.0242	0.614	−0.0485	0.519	−0.0094	0.880
LEV	0.1293	0.793	−0.3846	0.588	0.6497	0.345
MBT	−0.1151	0.005***	−0.1003	0.099*	−0.1293	0.022***
MATWEAK	1.1985	0.000***	1.2063	0.001***	1.2451	0.000***
ROA	−2.8998	0.013***	−3.4553	0.045**	−2.2802	0.149*
LOWABNFEE	−0.1667	0.486	0.3712	0.625		
HIGHABNFEE	0.3911	0.130*			1.0180	0.140*
%EXPERT	−0.3242	0.140*	−0.7807	0.118*	0.1662	0.719
LOWABNFEE x EXPERT			−1.0426	0.378		
HIGHABNFEE x EXPERT					−1.2611	0.250
Observations	3599		1686		1919	
Pseudo R^2	0.0296		0.0321		0.0310	

* / ** / *** Denote significance at the 0.10/0.05/0.01 levels, respectively

4.3 Robustness test

A robustness check was conducted to determine if these results are sensitive to other specifications of the underlying quality model. To test the robustness of the models, an alternative proxy for audit quality was introduced. Similar studies, with similar variables, used discretionary accruals as a proxy for audit quality (Eshleman & Guo, 2014; Krauß et al., 2014; Asthana & Boone, 2012; Choi et al., 2010; Hoitash et al., 2007; and Gul et al., 2003). As such, the dependent variable audit quality shall be proxied by discretionary accruals.

For the robustness test, the discretionary accruals model from Jones (1991) was used, along with the creation of a new dependent variable – DACC. Consistent with prior literature, a new control variable was also included – LOSS – to control for debt and financial distress. For the sake of comparison, regressions are reported with and without the interaction variables to explain Models (5) and (6), with Equations (5) and (6), respectively.

The discretionary accruals (DACC) and loss (LOSS) variables are included in the descriptive statistics in Table 4. Due to the merge of datasets for the discretionary accrual model, 130 observations were deleted. Furthermore, the above regressions were ran with REST replaced with a continuous variable – DACC. The results for the robustness test using the Jones model are presented in Table 4. The multivariate analysis shown in Table 4 shows an R^2 of 0.5%. This shows that the model explains roughly 0.5% of the variability of all the variability around the mean that the model should explain. This is even lower than the original model using restatements as the dependent variable.

Table 4. *Multivariate analysis: analysis of restatements, abnormally low and high audit fees, and audit committees*

DACC	Model 4	P > z	Model 5	P > z	Model 6	P > z
LTA	–0.0069	0.020**	–0.0070	0.020**	–0.0069	0.020**
LEV	–0.1897	0.552	–0.0194	0.543	–0.0190	0.550
MBT	0.0009	0.681	0.0009	0.675	0.0009	0.684
MATWEAK	0.0207	0.376	0.0212	0.365	0.0205	0.379
ROA	–0.1395	0.176*	–0.1440	0.162*	–0.1397	0.176*
LOSS	0.0105	0.524	0.0101	0.542	0.0105	0.525
LOWABNFEE	0.0016	0.926	–0.0043	0.911		
HIGHABNFEE	0.0097	0.605			0.0081	0.831
%EXPERT	–0.0125	0.371	–0.0102	0.534	–0.0132	0.434
LOWABNFEE x EXPERT			0.0163	0.785		
HIGHABNFEE x EXPERT					0.0039	0.945
Observations	3,469		1630		1873	
R^2	0.0052		0.0051		0.0052	
Adjusted R^2	0.0026		0.0026		0.0026	

* / ** / *** Denote significance at the 0.10/0.05/0.01 levels, respectively

The new measurement brings changes to the variables. Table 4 displays a significant negative relation with firm size (LTA) at the 10% level. This result is in line with the results of Blankley et al. (2012), Romanus et al. (2008), and Kinney et al. (2004), but does not appear in the restatement model. This means that the difference in measurement method and proxy of audit quality affects the results. The control variable ROA is also significantly negative (Blankley et al., 2012; Aier et al., 2005; Gul et al., 2003; Hoitash et al., 2007), but shows a significantly weaker relationship (ß = −0.1395; p = 0.176) as opposed to the restatement model (ß = −2.8998; p = 0.013). The model does not show any other significant results.

5. Conclusion

Prior research provided three reasons to explain how expertise in audit committees reduces the likelihood of a restatement. First, audit committees with higher levels of financial expertise increase the likelihood of understanding the internal audit program (Raghunandan et al., 2001). This ensures corporate responsibility and increases the operationality of internal controls in the detection of a material misstatement. Second, members with financial expertise better understand audit risks, as well as the procedures to respond to and detect risks (DeZoort & Salterio, 2001). Third, audit committee members with financial expertise are more likely to communicate the detected material misstatements to the audit committee (DeZoort & Salterio, 2001).

This study examined whether firms with abnormal audit fees and the presence of members with high financial expertise in audit committees result in higher audit quality. Prior research failed to find consensus on a significant relationship between abnormal audit fees and audit quality (Kinney et al., 2004; Stanley & DeZoort, 2007; Mitra et al., 2009; Choi et al., 2010; Asthana & Boone, 2012; Blankley et al., 2012). Thus, the effect of abnormal audit fees on audit quality is an empirical issue.

Abnormal audit fees were obtained from the audit fee model by extracting the residuals. The final model takes the positive and negative residuals separately from the audit fee model and includes them as an independent variable in the logistic regression and restatements as a proxy for audit quality. To measure financial expertise in the audit committees, a variable of the percentage of members with financial expertise in the audit committee was created. To measure the effects, a sample of 3,599 firm-year observations from the 2010 to 2018 period was used.

This research was conducted on the basis of two hypotheses. Hypothesis 1 claimed that abnormal audit fees are systematically associated with the quality of audits (i.e., they affect the likelihood of a restatement). For the first hypothesis, no statistically significant relation was detected. This indicates that auditors are able to deliver an appropriate level of audit quality even when the audit fee is abnormally low, and are that a lower audit fee does not necessarily indicate lower audit effort.

Hypothesis 2 suggested that financial expertise in audit committees increases audit quality (and therefore decreases the incidence of a restatement). The regression analysis provided supportive evidence for this hypothesis. A higher percentage of financial ex-

perts in the audit committee is negatively related to the incidence of a restatement, and increases the quality of the audit.

Further analysis examined the effect of the interaction of financial expertise with abnormal audit fees on audit quality. These results demonstrated no statistically significant findings for the interaction of variables with restatements.

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Appendix. Descriptions of variables

TA	Total accruals scaled by lagged assets
ASSETS	Beginning balance of total assets
ΔREV	The change in revenues of the firm scaled by lagged assets
ΔREC	The change in receivables of the firm scaled by lagged assets
PPE	The gross property, plant, and equipment of the firm scaled by lagged assets
LAF	The logarithm of audit fees
LTA	The logarithm of the end of year total assets
CR	Current assets divided by current liabilities
CATA	Current assets divided by total assets
ARINVTA	Sum of accounts receivable and inventory divided by total assets
ROA1	Earnings before interest and taxes divided by total assets
LOSS	1 if the firm incurred a negative net income (loss), 0 otherwise
MERGER	1 if the firm reported the impact of a merger or acquisition on net income, 0 otherwise
BUSY	1 if a company's fiscal year is December 31st, 0 otherwise
LEV1	Long-term debt divided by total assets
INTANG	Ratio of intangible asset to total assets
SEG	Logarithm of number of business segments
OPINION	1 if the auditor issues a going concern audit opinion, 0 otherwise
MATWEAK	1 if the client receives a material weakness opinion in the current year or the next year, 0 otherwise
REST	1 if the financial statements were restated, 0 otherwise
LEV2	Total debt divided by total assets
MTB	Market-to-book ratio
ROA2	Return on assets, net income divided by lagged total assets
ABFEE	The residuals from the abnormal audit fee model
LOWABNFEE	Equal to ABFEE if ABFEE is less than 0, 0 otherwise
HIGHABNFEE	Equal to ABFEE if ABFEE is higher than 0, 0 otherwise
%EXPERT	Percentage of members in the audit committee with financial expertise

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ASSESSING THE LEVEL OF HOUSEHOLD FOOD DEMAND PROTECTION BASED ON INCOME

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Abstract. *The goal of this study is to establish the level of food demand protection in Ukrainian households depending on the level of their income, taking into account the impact of other factors and their relationship with the level of food consumption.*

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The survey methodology is based on a sample survey of 8,168 households in Ukraine. This thematic module survey was conducted during a quarterly interview in January 2017 using a special questionnaire. The research was conducted in the context of the following categories of households: place of residence; quantitative composition; number of children; number of adults; availability and number of working persons; on amount of per capita equivalent disposable income; and region.

The results of the study showed that all of the identified factors have a significant impact on the level of food demand protection in Ukrainian households. It was found that the level of food consumption is influenced by, in addition to income, established traditions, the number of adults, status of employment, and the presence of children in the family. At the regional level, specialization and logistics are important factors in food demand protection. In general, a fairly high level of public awareness of the importance of food demand protection was established.

Consideration of the identified factors while forming policy and developing the mechanisms of food demand protection will contribute to the achievement of SDGs 1 and 2.

Keywords: *food security, household, the level of income, analysis.*

JEL Codes: *P25, P46, Q18*

1. Introduction

The key Sustainable Development Goals involve overcoming poverty and ending hunger. Achieving the SDGs involves the fulfilment of all 17 goals, which are considered to be interrelated and complementary. However, for Ukraine as well as for the vast majority of post-socialist (Kotykova & Albeshchenko, 2017) and developing countries, it is impossible to achieve the other SDGs without fulfilling the first and second goals.

A solution to the issue of household food demand protection requires the exploration of various factors.

Kirkpatrick and Tarasuk (2010) raise questions regarding the extent to which neighbourhood-level interventions to improve factors such as food access or social cohesion can mitigate problems of food insecurity that are rooted in resource constraints. Their results reinforce the importance of household-level characteristics, and highlight the need for interventions to address the financial constraints that underlie problems of food insecurity.

An important factor in the level of food demand protection in households is the physical availability of food. This thesis is confirmed, in particular, by the results of the study by Onumah et al. (2020), which indicate that poor households Ghana, which, due to their geographical location, have the opportunity to consume fish, prefer small and cheap pelagic fish. Additionally, it was demonstrated that marital status, religion, occupation, proximity to local market, and city of residence have a positive and significant influence on fish expenditure. Meanwhile, level of income, seasonality of fish, and the interaction of religion and seasonality of fish demonstrated a negative and significant influence.

Satapathy, Nayak, and Mahakud (2020), via sample surveys of households in three states in India, found that the combined substitution and income effects of the food subsidy policy improved the overall welfare of households, presented through the subjective measures of food consumption behaviour, income transfer, and educational achievements. The bargaining effect of the food subsidy programme was reflected in enhanced social status and the empowerment of women. The food security programme seemed to augment the food consumption of the beneficiaries, as observed from the food consumption score.

The results of studies by Oduniyi and Tekana (2020) showed that with more farming experience the probability of household food security decreased. An increase in household size by one member also decreased the probability of a household achieving food security. Similarly, an increase in the age of the head of the household decreased the probability of being food-secure in the study area. These results also revealed that over half of the farming households were food-secure, while the female-headed households were more food-secure, proportionately, compared to male-headed households.

Ma et al. (2016) examined the association of both perceived and geographic neighbourhood food access with food-security status among households with children. The researchers established that caregivers with children who experienced hunger perceived that they had less access to healthy affordable food in their community, even though grocery stores were present. Approaches to improve perceived access to healthy affordable food should be considered as part of the overall approach to improving food security and eliminating child hunger.

In contrast to the results of the research by Ma et al. (2016), Miller (2016) drew another conclusion. In the work "Accessibility of Summer Meals and the Food Insecurity of Low-Income Households with Children", the author investigated whether the geographical accessibility of summer meal program sites (a proxy for program participation) was associated with food insecurity for low-income households. As a result, the author deduced the inference that geographic accessibility was not associated with food insecurity. However, geographic accessibility was associated with a significantly lower probability of very low food security in the full sample, and among households with younger children and those living in less urban areas.

Kirkpatrick and Tarasuk (2003) produced more predictable conclusions. Their research compared food expenditure patterns between low-income households and higher-income households in the Canadian population, and examined the relationship between food expenditure patterns and the presence or absence of housing payments among low-income households. Their outcomes confirmed that among Canadian households, access to milk products and fruits and vegetables may be constrained in the context of low incomes. This study highlights the need for greater attention to be directed towards the affordability of nutritious foods for low-income groups.

A similar conclusion was reached by Korir, Rizov, and Ruto (2020) on the impact of food costs and price elasticity on the level of food security in households in Kenya. The results of their estimation showed positive expenditure elasticities, close to unity, while all compensated and uncompensated own-price elasticities were negative and smaller in

magnitude. This suggests that rising relative food costs have led to the deterioration of the food-security situation in Kenya, and the most severely affected households seem to be those that rely on informal markets and reside in rural areas.

An even greater challenge was faced by low-income households during the coronavirus (COVID-19) pandemic. According to the research results of Kansiime et al. (2021), in two East African countries – Kenya and Uganda – more than two-thirds of respondents experienced income shocks due to the COVID-19 crisis. Results from profit regressions show that income-poor households and those dependent on labour income were more vulnerable to income shock, and had poorer food consumption during the COVID-19 pandemic compared to other categories of respondents. As such, they were more likely to employ food-based coping strategies compared to those pursuing alternative livelihoods, who generally relied on savings.

In countries with a higher income per capita, food security studies are shifting towards another dimension. Such social determinants as education, geography, and time are considered to be important factors. Venn et al. (2018) highlighted that household income seems to be the most important correlate with food expenditure patterns once other socioeconomic status (SES) indicators are controlled for. Time constraints appear to explain some, but not all, of the adjusted SES gradients in food expenditure. Comparing home food consumption categories (processed and unprocessed foods) with foods purchased away from home (takeaway and restaurant foods) shows that wealthier, more highly educated, and less disadvantaged households spend relatively less of their total food budget on processed and unprocessed foods prepared at home, and more on foods purchased away from home at restaurants.

To meet some of the UN's seventeen Sustainable Development Goals by 2030, there is a need for more effective policy to reduce food insecurity in low-income and lower-middle-income countries (LMIC). Measuring progress towards these goals requires reliable indicators of food security in these countries (Russell et al. 2018). Taking into consideration the low purchasing power of Ukrainians (Babych & Kovalenko, 2018), food demand protection should be considered only in the context of overcoming poverty. This study shall establish how significant this impact is, and in what categories of households.

2. Methodology

The sample survey included 8,168 households whose living conditions were surveyed by the government statistics agency in 2016 (TURIL only; State Statistics Service of Ukraine, 2017a). This thematic module survey was conducted during a quarterly interview in January 2017 using a special questionnaire.

The first questionnaire block concerned the household's self-perception of its annual income in terms of sufficiency in order to make savings and meet basic needs, including to provide adequate nutrition.

The second block of questions was designed to determine the levels of disability in individual household groups due to lack of funds (consensus deprivation). To this end, data were obtained on the following:

- frequency of eating hot meals;
- cases of starvation during the last year (separately among adults and children) and the number of days of inability to provide any food;
- the ability of households with children to provide children with fruit, juice, school meals, and treats at least once a week.

In addition, households were asked to indicate their primary intention regarding the direction of channelling additional funds if they were to significantly increase their income.

The survey was conducted by expert interviewers who were employed full-time by territorial bodies of national statistics. The survey materials were processed centrally by the Department of Household Surveys of the State Statistics Service, together with the Department of Household Living Surveys of the Main Directorate of Regional Statistics.

These studies are consistent with:

1. "Methods Used to Assess Household Food Insecurity" (FAO/WFP, 2009):
   - diet diversity and food frequency;
   - a coping strategies index;
   - a household economy rapid appraisal;
   - a food poverty (purchasing power) approach.
2. "Monitoring of Food Security at the Regional Level" (Kotykova, Babych, & Semenchuk, 2019).

3. Results

3.1. The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on place of residence

In Ukraine, there is a significant differentiation of incomes between urban and rural residents, which is reflected in the nutrition indicators of the economic accessibility of these categories. According to the poll in Table 1, residents of small towns are in the worst condition in this regard. This situation is explained by the fact that this group of the population overwhelmingly live in multi-storey houses without their own land plots, but, unlike urban residents, have average salaries as residents of villages. Therefore, rural residents have advantages in the physical availability of food, as most of it is grown individually and sold in local or urban markets. Meanwhile residents of large cities, compared with residents of small cities, have the advantage of affordability of food due to their higher incomes and the level of competition between a large number of food sellers. Residents of small towns are deprived of the benefits experienced by both rural residents and residents of large cities.

Table 1. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on place of residence*

Indicator	All households	including living in			
		in urban areas			in rural areas
		in big cities	in small cities	total	
Number of households, thousand	15033.4	5897.9	4211.5	10109.4	4924.0
Distribution of households by self-assessment of their income over the last year, %:					
• consistently denied themselves basic necessities other than food	44.0	43.1	45.9	44.3	43.3
• failed to provide sufficient nutrition	4.1	3.3	4.1	3.7	5.0
• could not provide children with:					
a) fruit or juice	0.7	0.3	0.7	0.5	1.1
b) food or money for meals at school	0.2	0.0	0.2	0.1	0.4
c) treats at least once a week	0.2	0.3	0.0	0.2	0.3
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	611.9	196.4	171.6	368.0	243.9
Number of the above who reported that:					
• they had the opportunity to eat hot meals, %:					
a) daily	85.6	87.0	83.6	85.5	85.8
b) almost every day	13.5	12.0	15.0	13.4	13.6
c) sometimes	0.9	1.0	1.4	1.1	0.6
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	3.2	0.3	-	0.3	2.9
including starving, %					
a) 1 day	9.1	100.0	-	100.0	-
b) 2–3 days	90.9	-	-	-	100.0
c) 4–5 days	-	-	-	-	-
d) more than 5 days	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	26.1	22.5	30.9	26.0	26.4

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

The situation regarding the provision of food for children is somewhat different: the worst rates were observed in the category of rural residents. The issue here lies in the realm of psychology and the culture of nutrition: rural residents are more appre-

ciative of proteins – i.e., dairy products, meat, and meat products. Therefore, if food is scarce, they will prefer milk over fruit. The issue of "they could not give children food or money for meals at school" should be explained – there are no extended day groups in rural schools, except for the first three years of school in which children are provided lunch free of charge. School normally finishes by 2 pm, so children eat at home where parents can control what and how much the child has to eat, while outside the home the money parents give children for lunch can be (and most often is) used for completely different purposes. That is, it should be understood that the questionnaire response of "could not give children food or money for meals at school" was interpreted in this way by urban residents, but for rural residents, a positive answer to this may have meant something else – for example, "did not give money because they thought it was inappropriate".

Equally, the culture of consumption of sweets in cities and villages is different: this point is of little importance to residents of large cities, as most – especially young – families consider the use of sweets (sweets are classified in Ukraine as "treats") by children to constitute a bad habit, and restrict it in every way. For rural residents, however, eating sweets is traditionally considered an expression of love and care. Thus, for residents of the countryside, this item really means "they could not give the children treats at least once a week" because they could not afford to buy them, whereas for residents of large cities this is because they do not consider it necessary to buy them.

Although this level of food demand protection is not considered critical by households, 22.5% of residents of large cities, 26.4% of rural residents, and 30.9% of residents of small cities reported that with a significant increase in income they would channel additional funds especially towards food.

3.2. The distribution of households based on the self-perception of income and economic expectations for the next 12 months depending on their quantitative composition

The distribution of households depending on their size (Table 2) shows the highest level of food demand protection for households with a population of 3, and the lowest level for households with a population of 1. This result is quite natural, since a three-member household is most often a family of two adults (a working parent and a second parent) and one child. One-person households are most often elderly people whose only income is a pension.

Table 2. *The distribution of households based on the self-perception of income and economic expectations for the next 12 months depending on their quantitative composition*

Indicator	All households	number of people				
		one	two	three	four	five or more
Number of households, thousand	15033.4	2956.0	4855.6	4043.3	2185.2	993.3
Distribution of households by self-assessment of their income over the last year, %:						
• consistently denied themselves basic necessities other than food	44.0	54.9	44.6	37.5	40.4	42.4
• failed to provide sufficient nutrition	4.1	6.2	3.8	2.4	3.8	6.6
• could not provide children with:						
a) fruit or juice	0.7	-	0.1	0.3	1.4	5.3
b) food or money for meals at school	0.2	-	0.0	0.0	0.7	1.2
c) treats at least once a week	0.2	-	0.0	0.2	0.6	0.9
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	611.9	183.8	184.0	96.3	82.2	65.6
Number of the above who reported that:						
• they had the opportunity to eat hot meals, %:						
a) daily	85.6	72.7	87.5	87.8	96.1	100.0
b) almost every day	13.5	24.2	12.5	12.2	3.9	-
c) sometimes	0.9	3.1	-	-	-	-
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	3.2	3.2	-	-	-	-
including starving, %						
a) 1 day	9.1	9.1	-	-	-	-
b) 2–3 days	90.9	90.9	-	-	-	-
c) 4–5 days	-	-	-	-	-	-
d) more than 5 days	-	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	26.1	36.3	29.9	18.9	20.2	19.8

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

The low level of food supply in this category is confirmed by the low rates of the ability to eat hot meals and the number of people who did not eat at all for 1–3 days. In the

category of one-person households, 64.2% of respondents would have spent increased income on medical treatment and 36.3% on food, which exceeds the share of persons who failed to provide a sufficient level of nutrition by almost 6 times. Similarly, in other categories of households the share of respondents who reported that with a significant increase in income they would spend extra money on, above all, food, significantly outweighed the proportion of households who could not provide enough food. In particular: in households of 2 people, almost by 8 times; in households of 3 people, almost by 8 times; in households of 4 people, by 5 times; and in households of 5 people or more, by 3 times. Such results indicate a sufficiently high level of citizens' awareness of the importance of food demand protection.

3.3. The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on number of children

Large discrepancies were observed between groups of households depending on their size in terms of providing children with fruit, food at school, and treats. The best data for these indicators were recorded in households with 5 or more people, and the worst in households with 2 people. As such, a direct correlation was observed between the increase in the values of these indicators and the increase in the number of persons per household. Since the indicators studied are related to child nutrition, it could be assumed that the increase of these indicators is influenced by an increase in the number of children, but this hypothesis has not been confirmed. The worst data for the indicators of providing children with fruit, food at school, and treats were found in the group of households with two children; in the group of households with one or three children, they were insignificant; and in groups of 4 or 5 or more children, there were no such problems at all (Table 3).

Thus, it is logical to assume that it is not the number of children, but the number of adults in the family that affects the level of ability to provide children with fruit, food at school, and treats.

Table 3. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on number of children*

Indicator	All households with children	number of children				
		one	two	three	four	five or more
Number of households, thousand	5744.1	4362.5	1230.2	134.9	10.9	5.6
Distribution of households by self-assessment of their income over the last year, %:						
• consistently denied themselves basic necessities other than food	40.1	39.7	40.3	49.2	44.5	29.8
• failed to provide sufficient nutrition	3.2	2.3	6.1	7.2	-	-
• could not provide children with:						
a) fruit or juice	1.7	0.8	5.1	1.4	-	-
b) food or money for meals at school	0.5	0.2	1.7	0.3	-	-
c) treats at least once a week	0.6	0.4	1.0	0.2	-	-
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	184.6	101.2	73.7	9.7	-	-
Number of the above who reported that:						
• they had the opportunity to eat hot meals, %:						
a) daily	96.7	97.2	95.6	100.0	-	-
b) almost every day	3.3	2.8	4.4	-	-	-
c) sometimes	-	-	-	-	-	-
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	-	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	19.0	18.0	20.4	36.1	36.4	11.1

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

3.4. The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on number of adults

Indeed, the poorest rates of providing children with fruit, food at school, and treats were found in households where the number of adults was 3 or more (Table 4). This category also displayed the smallest share of households that consistently denied themselves basic necessities other than food, and it was in this category that the smallest share of households reported that with a significant increase in income they would spend additional money primarily on food. Recognizing that the responsibility for making nutritional decisions lies with adults and not children, we can state that in this category of

households (those with children and with three or more adults) adults have their own problems and preferences that they pose or are forced to put above the problem of providing food for children. With regard to the first thesis, these are most likely disadvantaged families where one parent (or both) does not work, and instead uses alcohol or drugs.

Table 4. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on number of adults*

Indicator	All households with children	number of adults		
		one	two	three or more
Number of households, thousand.	5744.1	414.3	3404.7	1925.1
Distribution of households by self-assessment of their income over the last year, %:				
• consistently denied themselves basic necessities other than food	40.1	55.0	39.3	38.2
• failed to provide sufficient nutrition	3.2	4.5	1.7	5.6
• could not provide children with:				
a) fruit or juice	1.7	1.4	0.7	3.6
b) food or money for meals at school	0.5	0.3	0.3	1.0
c) treats at least once a week	0.6	0.3	0.4	1.0
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	184.6	18.7	57.3	108.6
Number of the above who reported that:				
• they had the opportunity to eat hot meals, %:				
a) daily	96.7	100.0	89.5	100.0
b) almost every day	3.3	-	10.5	-
c) sometimes	-	-	-	-
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	19.0	24.0	18.7	18.3

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

3.5. The distribution of households whose composition includes children who do not have one or both parents based on self-perception of income, economic expectations for the next 12 months, and number of children

The above thesis is confirmed by the data in Tables 5 and 6. In particular: the share of households that consist of children who do not have one or both parents who consistently denied themselves basic necessities other than food for the category of respondents with

3 children or more was 80.6% (Table 5), and only 46.0% for households with 3 adults or more (Table 6).

In addition, of the total number of households, the share of those who reported that with a significant increase in income they would spend additional money primarily on food was 48.7% for households with 3 children or more and only 23.7% for households with 3 adults or more.

Table 5. *The distribution of households whose composition includes children who do not have one or both parents based on self-perception of income, economic expectations for the next 12 months, and number of children*

Indicator	Households that include children who do not have one or both parents	number of children		
		one	two	three or more
Number of households, thousand.	1056.7	871.9	162.6	22.2
Distribution of households by self-assessment of their income over the last year, %:				
• consistently denied themselves basic necessities other than food	48.9	48.7	46.0	80.6
• failed to provide sufficient nutrition	3.7	3.6	3.6	7.7
• could not provide children with:				
a) fruit or juice	1.1	0.9	1.8	6.8
b) food or money for meals at school	0.5	0.4	0.6	0.5
c) treats at least once a week	0.5	0.5	0.5	0.5
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	39.1	31.6	5.7	1.8
Number of the above who reported that:				
they had the opportunity to eat hot meals, %:				
daily	92.8	91.1	100.0	100.0
almost every day	7.2	8.9	-	-
sometimes	-	-	-	-
there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	20.3	20.5	15.6	48.7

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

This position is quite obvious – adults, compared to children, can receive income from many sources (salary, pension, scholarship, etc.), while children do not have this

opportunity. Therefore, the overall budget of these families varies greatly, but the nutritional requirements for families with children are higher.

3.6. The distribution of households whose composition includes children who do not have one or both parents based on self-perception of income, economic expectations for the next 12 months, and number of adult persons in their composition

The unexpected result of a household survey of children without one or both parents and with 2 adults in the household (Table 6), with only 34.1% saying they were able to eat hot meals almost every day, is questionable.

At the same time, this was the category of household where the lowest share failed to provide sufficient nutrition (1.9%).

Table 6. *The distribution of households whose composition includes children who do not have one or both parents based on self-perception of income, economic expectations for the next 12 months, and number of adult persons in their composition*

Indicator	Households that include children who do not have one or both parents	number of adults		
		one	two	three or more
Number of households, thousand.	1056.7	307.2	430.8	318.7
Distribution of households by self-assessment of their income over the last year, %:				
• consistently denied themselves basic necessities other than food	48.9	55.5	46.5	46.0
• failed to provide sufficient nutrition	3.7	4.6	1.9	5.3
• could not provide children with:				
a) fruit or juice	1.1	1.8	0.6	1.2
b) food or money for meals at school	0.5	0.3	-	1.2
c) treats at least once a week	0.5	0.5	0.4	0.8
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	39.1	14.0	8.3	16.8
Number of the above who reported that:				
• they had the opportunity to eat hot meals, %:				
a) daily	92.8	100.0	65.9	100.0
b) almost every day	7.2	-	34.1	-
c) sometimes	-	-	-	-
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	20.3	20.2	17.9	23.7

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

3.7. The distribution of households without children based on self-perception of income and economic expectations for the next 12 months depending on household composition

According to the data, the level of food demand protection in households without children is even lower (Figure 1).

However, in households without children, there was significant fluctuation of indicators depending on the number of persons in the household and the availability of working-age and non-working age persons. It is only logical that the level of food demand protection in households that include working-age persons is higher than households where there are non-working age persons present (Table 7).

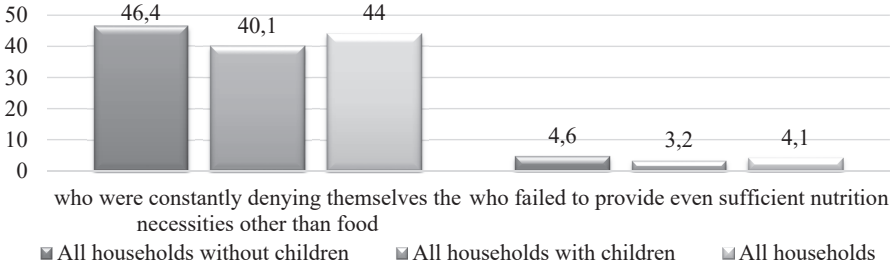

Figure 1. *TThe distribution of households based on self-perception of income and economic expectations for the next 12 months depending on their composition*

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

Table 7. *The distribution of households without children based on self-perception of income and economic expectations for the next 12 months depending on household composition*

Indicator	All households without children	Households with one person		Households with two or more persons		
		of working age	of a non-working age	all of a working age	working and non-working ages	all of a non-working age
Number of households, thousand.	9289.3	1171.2	1784.8	2728.8	1902.0	1702.5
Distribution of households by self-assessment of their income over the last year, %:						
consistently denied themselves basic necessities other than food	46.4	49.4	58.4	36.5	44.6	49.3
failed to provide sufficient nutrition	4.6	5.5	6.7	3.1	5.0	3.8

Indicator	All households without children	Households with one person		Households with two or more persons		
		of working age	of a non-working age	all of a working age	working and non-working ages	all of a non-working age
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	427.3	65.0	118.8	83.8	94.5	65.2
Number of the above who reported that:						
they had the opportunity to eat hot meals, %:						
daily	80.8	54.6	82.6	92.1	77.1	94.3
almost every day	17.9	37.3	17.0	7.9	22.9	5.7
sometimes	1.3	8.1	0.4	-	-	-
there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	3.2	3.2	-	-	-	-
including starving, %						
1 day	9.1	9.1	-	-	-	-
2–3 days	90.9	90.9	-	-	-	-
4–5 days	-	-	-	-	-	-
more than 5 days	-	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	30.6	24.8	43.8	21.0	29.0	37.8

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

It is noteworthy that in households of two or more persons, all indicators of food demand protection far exceed the values of single-person households, even in the category of "all of a non-working age".

This result can be explained by two factors:

1. More efficient allocation of income to fixed costs, which do not depend on the number of household members (rent, utilities, internet, etc.);
2. The mutual support of household members, which has a positive effect on a person's psychological state. As a result, during the survey, single people were more pessimistic about their estimates and projections, and family people, on the contrary, were more optimistic.

3.8. The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on availability and number of working persons in their composition

It is quite obvious that food demand protection rises in households with more workers (Table 8).

Table 8. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on availability and number of working persons in their composition*

Indicator	All households that include working people	number of working people			All households with no working people
		one	two	three or more	
Number of households, thousand.	10627.1	5069.4	4632.5	925.2	4406.3
Distribution of households by self-assessment of their income over the last year, %:					
• consistently denied themselves basic necessities other than food	39.5	46.1	33.7	32.2	54.8
• failed to provide sufficient nutrition	3.0	3.4	2.3	3.9	6.7
• could not provide children with:					
a) fruit or juice	0.8	0.7	0.7	2.2	0.2
b) food or money for meals at school	0.3	0.2	0.1	1.2	0.0
c) treats at least once a week	0.3	0.3	0.3	-	0.1
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	318.4	174.7	107.4	36.3	293.5
Number of the above who reported that:					
• they had the opportunity to eat hot meals, %:					
a) daily	88.5	79.7	98.9	100.0	82.4
b) almost every day	9.9	17.3	1.1	-	17.4
c) sometimes	1.6	3.0	-	-	0.2
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	1.6	1.6	-	-	1.6
including starving, %					
a) 1 day	18.1	18.1	-	-	-
b) 2–3 days	81.9	81.9	-	-	100.0
c) 4–5 days	-	-	-	-	-
d) more than 5 days	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	20.1	23.6	17.4	14.6	40.7

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

It should be noted that households with 3 or more employed persons and households with no working persons, respectively, have the lowest (32.2%) and highest (54.8%) values of the indicator of "consistently denied themselves basic necessities other than food" among all study groups, except for the household category which includes children without one or both parents and 3 or more children (Table 9).

Table 9. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on their composition for the indicator "consistently denied themselves basic necessities other than food"*

Households with 5 or more children	29.8
Households with 3 or more working people	32.2
Households with 2 working people	33.7
Households without children with 2 or more people of working age	36.5
Households with 3 people	37.5
Households with children and 3 or more adults	38.2
Households with children and 2 adults	39.3
Households with 1 child	39.7
Households with 2 children	40.3
Households with 4 people	40.4
Households with 5 people or more	42.4
Households living in large cities	43.1
Households living in rural areas	43.3
Households with 4 children	44.5
Households with 2 people	44.6
Households without children with 2 or more people of both working and non-working ages	44.6
Households living in small towns	45.9
Households that include 2 children without one or both parents	46.0
Households with 3 or more adults that include children who do not have one or both parents	46.0
Households with 1 working person	46.1
Households that have children without one or both parents, with 2 adults	46.5
Households with 1 child who does not have one or both parents	48.7
Households with 3 children	49.2
Households without children with 2 or more persons of non-working age	49.3
Households without children with 1 person of working age	49.4
Households with 1 person	54.9
Households with children and adults	55.0
Households with 1 child and 1 adult where the child does not have one or both parents	55.5
Households without children with 1 person of non-working age	58.4
Households that have children who do not have one or both parents with 3 or more children	80.6

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

3.9. The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on size of per capita equivalent disposable income

According to official data in Ukraine, food costs are 53.6% of total expenditure for urban households and 47.5% for rural households. Of course, under such conditions, the economic availability of food depends directly on the level of income of the population. The data in Table 10 indicates a direct dependence of household food demand on income level. It should be noted that even in the category with the highest income, 1 in 4 households have consistently denied themselves basic necessities other than food.

Table 10. *The distribution of households based on self-perception of income and economic expectations for the next 12 months depending on size of per capita equivalent disposable income*

Indicator	All households	per capita equivalent disposable income per month, dollar										
		< 18.79	18.79-32.88	32.89-46.96	46.97-61.05	61.06-75.14	75.15-89.23	89.24-103.32	103.33-117.41	117.42-131.50	131.51-145.59	> 145.60
Share of households in the group, %	100.0	0.0	0.2	1.5	4.4	10.9	15.2	15.9	13.4	10.2	8.2	20.1
Distribution of households by self-assessment of their income over the last year, %:												
• consistently denied themselves basic necessities other than food	44.0	67.5	65.1	57.8	57.4	59.1	51.3	49.2	46.0	39.5	38.5	25.0
• failed to provide sufficient nutrition	4.1	32.5	32.4	15.7	7.5	5.6	4.3	5.3	4.0	2.6	1.4	2.0
• could not provide children with:												
a) fruit or juice	16.0	100.0	-	56.2	15.7	11.1	14.5	7.0	19.7	2.0	-	33.3
b) food or money for meals at school	4.7	100.0	-	7.3	0.2	6.6	2.0	2.5	4.4	1.0	-	17.7
c) treats at least once a week	5.3	100.0	-	31.7	12.4	4.1	8.4	-	3.1	1.0	-	-
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	611.9	0.2	12.1	35.6	49.2	92.1	97.2	126.9	80.1	40.1	17.4	61.0
Number of the above who reported that:												
• they had the opportunity to eat hot meals, %:												
a) daily	85.6	100.0	44.5	72.3	76.5	72.7	88.8	84.7	96.9	100.0	95.6	97.8
b) almost every day	13.5	-	53.1	26.3	22.5	24.2	9.5	15.3	3.1	-	4.4	2.2
c) sometimes	0.9	-	2.4	1.4	1.0	3.1	1.7	-	-	-	-	-

Indicator	All households	per capita equivalent disposable income per month, dollar										
		< 18.79	18.79-32.88	32.89-46.96	46.97-61.05	61.06-75.14	75.15-89.23	89.24-103.32	103.33-117.41	117.42-131.50	131.51-145.59	> 145.60
• there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	3.2	-	1.6	1.6	-	-	-	-	-	-	-	-
including starving, %												
a) 1 day	9.1	-	18.1	-	-	-	-	-	-	-	-	-
b) 2–3 days	90.9	-	81.9	100.0	-	-	-	-	-	-	-	-
c) 4–5 days	-	-	-	-	-	-	-	-	-	-	-	-
d) more than 5 days	-	-	-	-	-	-	-	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	26.1	100.0	86.3	49.2	35.9	37.5	30.7	25.5	29.1	22.0	20.5	14.9

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

At the same time, roughly 1 in 3 of the poorest households failed to provide sufficient nutrition, and all households in this category, in case of a significant increase in income, would divert additional funds primarily to food.

3.10. The distribution of households based on self-perception of income and economic expectations for the next 12 months by region

Objectively, income levels have a significant impact on food demand. However, this statement is truer of poorer people. In other words, a low level of income definitely leads to the impossibility of sufficient food supply. However, a high level of income does not guarantee food demand protection. This conclusion is confirmed by the data in Annex 1.

In particular, whilst the Zakarpattya region was ranked first among 24 districts in terms of income, 57% (the highest value) of households reported that they were not able to provide sufficient nutrition, 11% could not give food or money to children to buy meals at school, and 52% reported that with a significant increase in income, they would spend the extra money primarily on food.

A similar situation was observed in the Ivano-Frankivsk Region, which ranked in 5th place among the 24 districts by income level. Here, 93% of households reported that they continually denied themselves basic necessities other than food, and 48% said that with a significant increase in income, they would spend the extra money primarily on food.

Alternatively, the Kyiv Region, with an average household income 27% lower than that of Zakarpattya, had the best performance in food demand protection among Ukraine's regions. This situation is explained by the specializations and logistics of each region. For example, very little agricultural production (1.6% and 2.3% of the total volume in the country, respectively) originates from the Zakarpattya and Ivano-Frankivsk regions due to their unique climatic conditions. The logistics of food delivery to these regions, especially to Zakarpattya (a mountainous area), is complex and unprofitable – the territory is large and the number of consumers is small. While the Kyiv region produces 6.1% of the country's agricultural output, it has the best logistical conditions for the delivery and storage of food, and has a high population density – hence a great number of potential consumers. The same is also true for the other major cities and tourist centres of the country, such as the Lviv, Odesa, and Kharkiv regions.

For other regions, specialization and logistics also have a significant impact on the level of food demand protection. The more agricultural products produced by the region and the better the level of logistics and food supply and storage, the better – all else being equal – the food demand protection indicators.

Therefore, in addition to income level, specialization and logistics are important factors at the regional level. However, there are other factors of income level that are important to note. The Luhansk and Sumy Regions have the same household income levels, but agricultural output in the Sumy region (4%) is much higher than in the Luhansk region (1.9%). At the same time, the indicators of food demand protection during the self-assessment of households in the Luhansk Region were much better than in the Sumy Region, which does not align with the previous conclusions. This situation is explained by the fact that the level of perceived satisfaction (in particular – regarding the consumption of food) is very different in these two regions: in the Sumy region it is overstated, and in Luhansk region it is understated. Thus, in the Sumy region, almost 90% of respondents considered themselves to be poor, whereas in Luhansk, less than 70% considered themselves to be poor.

It is fair to point out that if we focus on the self-estimation of households of their income level rather than on actual data, we will observe a close correlation between self-estimated food consumption, self-estimated agricultural output, and self-estimated population poverty. A spectacular example is provided by the Zakarpattya and Ivano-Frankivsk regions, which have the lowest self-estimated household poverty rates and the lowest actual agricultural production and, as a result, the worst self-estimated food demand protection.

4. Discussion

When analysing the quality of the estimates of indicators based on sample survey data, information regarding the magnitude of sampling error is critical in correctly interpreting the results and optimizing the design of the sample. The magnitude of this error determines the limits of confidence intervals in the construction of interval estimates of indicators – i.e., the intervals of possible values of indicators according to the sample

survey. The estimation of an indicator for which the magnitude of the sampling error is significant compared to the value of the estimate itself cannot be used in the analysis of the survey results.

The following indicators are most clearly characterized by the quality of the sample survey data: limit sampling error and relative standard sampling error (or CV coefficient).

Relative standard error is often used as an indicator of the suitability of data for analysis. If RSE ≤ 5%, then the estimate is considered reliable; if 5 % < RSE ≤ 10 %, then the estimate is suitable for quantitative analysis, but its reliability is not high enough; if 10 % < RSE ≤ 25 %, then the estimate is only suitable for qualitative analysis and should be used with caution (but sometimes data is published for which the RSE reaches 30% and even 40%).

Annexes 1 and 2 present the results of calculations of the marginal sampling error for p = 0.95 and the relative standard sampling error for estimating the values of the "number of households whose members consistently denied themselves basic necessities other than food " and "number of households whose members referred to themselves as poor". The assessment of the indicators and the characteristics of their reliability are calculated for the level of Ukraine (in general, in large and small cities, and in rural areas), economic districts, and regions.

The results show that the estimates obtained are accurate for Ukraine: the relative standard error of the sample is 2.34% for the indicator "number of households whose members consistently denied themselves basic necessities other than food" (Annex 2) and 2.12% for the indicator "number of households whose members referred to themselves as poor" (Annex 3).

The sample error margin for the indicator "number of households whose members consistently denied themselves basic necessities other than food" (Annex 2) for the level of Ukraine was 302.76 thousand households – that is, with 95% probability the value of this indicator in the general population is in the range of 6306.83–6912.35 thousand households. The sample error margin for the indicator "number of households whose members referred to themselves as poor" (Annex 3) for the level of Ukraine was 462.44 thousand households – that is, with 95% probability the value of this indicator in the general population is in the range of 10666.11–11590.99 thousand households.

Data on households in large and small towns and in rural areas at the national level were accurate, and the relative standard error of the sample did not exceed 5%. For the indicator "number of households whose members consistently denied themselves basic necessities other than food", the minimum value (3.29%) was for small-town households and the maximum value (4.98%) was for rural households. For the indicator "number of households whose members refer to themselves as poor", the minimum value (2.48%) was for small-town households and the maximum value (4.04%) was for those in large towns.

At the regional level, the accuracy of the estimation for the indicator "number of households whose members consistently denied themselves basic necessities other than food" was not satisfactory: in 16 regions, the relative standard error of sampling exceeded

10% – i.e., the obtained estimates can only be used for qualitative analysis. At the level of economic districts, the estimates were fairly accurate: in the range of 5.65–8.61% – i.e., these estimates are suitable for quantitative analysis.

At the regional level, the accuracy of the indicator "number of households who refer to themselves as poor" was satisfactory, and is suitable for quantitative analysis. The relative standard error of sampling exceeded 10% in only three regions: Volyn, Ivano-Frankivsk, and Kirovohrad.

If the relative standard error of the sample is large enough, it becomes necessary to use the estimates of indicators either by economic area, by large cities, or by Ukraine as a whole (depending on the corresponding values of relative standard error). So, for example, when it is necessary to carry out quantitative calculations, it is better to use the percentage ratios established at the level of Ukraine as a whole (in general, in large and small cities, and in rural areas).

5. Conclusions

A significant differentiation of the population's level of food supply depending upon the distribution of households based on the self-estimation of income and economic expectations for the next 12 months was observed. This depended on: place of residence; quantitative composition; number of children; number of adults; availability and number of working-age persons; amount of per capita equivalent disposable income; region; the presence of children who do not have one or both parents based on number of children; the presence of children who do not have one or both parents based on number of adults; and the presence of children who do not have one or both parents based on household composition.

The obtained results are important for the formulation of food demand protection policies within the framework of SDG1 and SDG2 at the local, regional, and national levels.

These results confirmed the hypothesis, which suggested a decisive impact of income level upon the level of food supply of the vast majority of households. This factor is not always determined directly by the amount of income received, but its impact is clearly traced in specific households which, by their composition, can be classified as socially vulnerable and unprotected. Namely, this includes households: with one person; with children and adults, and that contain children who do not have one or both parents; with one child and with one adult; without children, with one person of non-working age; and with children who do not have one or both parents, with 3 or more children. Therefore, in establishing a food program at the national level, the state has a priority to ensure food access for the following socially vulnerable groups of the population: pensioners; large families; single-parent families with children; and single mothers. This principle is fundamental for the Resolution adopted by the UN General Assembly on 20 December 2018 regarding agriculture development, food security and nutrition:

> *Reaffirming* the right of everyone to have access to safe, sufficient and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger, so as to be able to fully develop and maintain

> their physical and mental capacities, and underlining the need to make special efforts to meet nutritional needs, especially of women, children, older persons, indigenous peoples and persons with disabilities, as well as of those living in vulnerable situations (p. 5).

At the same time, it should be remembered that, all else being equal (number of children, incapacity of households, etc.), the level of food demand protection of rural residents (at an objectively lower level of income compared to urban residents) is not always lower than the level of food demand protection of urban residents. The vast majority of rural residents produce their own food, so household income has a much smaller impact on the quantity and quality of consumed products that they do not need to buy. Revenue has an indirect impact only on the assortment of food. Therefore, policy-making on rural food demand protection should focus on providing access to food production resources, disseminating educational programs on sustainable land-use technologies, and empowering women and youth in rural areas. This approach is fundamental to the aforementioned Resolution of the UN General Assembly (2018):

> *Reiterating* the importance of gender equality and the empowerment of women and girls, as well as the recognition and protection of the rights of smallholders, particularly women, reiterating also the importance, inter alia, of empowering rural women, youth, small-scale farmers, family farmers and livestock farmers, fishers and fish workers as critical agents for enhancing agricultural and rural development and food security and for improving nutrition outcomes, and acknowledging their fundamental contribution to the environmental sustainability and the genetic preservation of agricultural systems and to sustaining productivity on often marginal lands (p. 7).

Studies of this issue have allowed for two determinants of food demand protection at the regional level to be identified: specialization and logistics. The natural climatic conditions and the available natural resources of each region create additional opportunities and advantages or, conversely, limit the development of certain agricultural sectors. However, it is very difficult to influence this factor, and its impact should be minimal within the framework of the Sustainable Development Goals. In terms of logistics, the crucial factors are process management and the technologies used. Today, Ukraine does not face the problem of volume of production, but remains troubled by the possibilities of preserving products. "The share of food consumption and food loss and waste accounted as 61.6% for fruits and vegetables, 72.0% for meat and meat products, and 25.4% for milk. The food loss and waste has significant negative social and economic consequences" (Kotykova & Babych, 2019b). "The sum of economic losses in Ukraine in 2016 amounted to about 991.9 million EUR, which is 2.8% of the budget of Ukraine in 2017, and a 2224.5 million EUR unsatisfied income" (Kotykova and Babych 2019a). Therefore, addressing the issue of food demand protection at the regional level will involve minimizing losses at the stages of food production, processing, and storage. This is encapsulated by the UN General Assembly's Resolution (2018) which states that:

> by 2050, the world urban population is expected to nearly double, making urbanization one of the most transformative trends of the twenty-first century,

underscoring the growing need to take action to fight hunger and malnutrition among the urban poor through promoting the integration of the food security and nutrition needs of urban residents, in particular the urban poor, in urban and territorial planning, to end hunger and malnutrition, promoting the coordination of sustainable food security and agriculture policies across urban, peri-urban and rural areas to facilitate the production, storage, transport and marketing of food to consumers in adequate and affordable ways, to reduce food losses and to prevent and reuse food waste, and promoting the coordination of food policies with energy, water, health, transport and waste and other policies in urban areas to maximize efficiencies and minimize waste (p. 11).

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Annex 1. T*he distribution of households by region according to self-perception of income and economic expectations for the next 12 months*

Indicator	All households	Region																							
		Vinnytsya	Volyn	Dnipropetrovsk	Donetsk	Zhytomyr	Zakarpattya	Zaporizhya	Ivano-Frankivsk	Kyiv	Kirovohrad	Luhansk	Lviv	Mykolayiv	Odesa	Poltava	Rivne	Sumy	Ternopil	Kharkiv	Kherson	Khmelnytskiy	Cherkasy	Chernivtsi	Chernihiv
Per capita equivalent disposable income per month, dollar	210	207	200	206	181	174	288	199	222	211	194	179	254	206	240	187	195	179	197	194	209	181	164	226	180
Number of households whose members refer to themselves as poor, %	74.0	86.5	53.8	76.0	83.6	47.8	99.8	90.5	96.4	93.5	18.7	69.7	53.4	98.4	77.1	62.6	65.5	88.0	86.4	83.3	97.1	54.3	91.5	82.7	66.1
Agricultural production, %	100.0	8.4	2.6	6.0	3.0	3.7	1.6	3.9	2.3	6.1	4.7	1.9	3.6	3.8	4.7	6.8	2.6	4.0	3.3	6.1	4.4	4.9	5.9	1.7	4.1
Share of households in the group, %	100.0	4.2	2.2	9.1	6.2	3.3	2.4	4.8	3.0	4.4	2.8	2.4	5.5	3.0	5.9	4.0	2.5	3.0	2.4	7.4	2.7	3.2	3.5	2.0	2.9
Distribution of households by self-assessment of their income over the last year, %:																									
• consistently denied themselves basic necessities other than food	44.0	77.5	34.6	43.0	47.5	24.9	36.7	53.3	92.6	14.7	19.6	29.8	15.2	53.6	39.5	32.7	49.5	72.6	76.8	49.5	56.8	37.8	42.8	33.3	59.4
• failed to provide sufficient nutrition	4.1	5.8	1.2	2.1	6.4	-	57.4	2.1	3.8	-	-	1.2	0.1	3.4	0.5	0.3	-	12.8	1.9	3.5	14.2	2.9	2.4	0.9	5.0

Indicator	All households	Region																							
		Vinnytsya	Volyn	Dnipropetrovsk	Donetsk	Zhytomyr	Zakarpattya	Zaporizhya	Ivano-Frankivsk	Kyiv	Kirovohrad	Luhansk	Lviv	Mykolayiv	Odesa	Poltava	Rivne	Sumy	Ternopil	Kharkiv	Kherson	Khmelnytskiy	Cherkasy	Chernivtsi	Chernihiv
• could not give children:																									
a) fruit or juice	16.0	22.4	-	27.8	0.5	-	34.7	-	-	-	-	-	-	-	48.9	-	-	7.5	-	-	4.3	-	12.9	-	-
b) food or money for meals at school	4.7	8.6	-	-	0.3	-	11.0	-	2.4	-	-	-	-	-	48.9	-	-	-	-	-	0.9	-	-	-	-
c) treats at least once a week	5.3	2.2		27.8	0.5	-	5.6	-	-	-	-	6.8	-	-	48.9	-	-	5.9	-	-	3.1	-	33.1	-	-
Number of households whose income level during the last year did not allow them to provide even sufficient food, thousand	611.9	37.1	4.1	29.1	59.5	-	203.6	14.7	16.9	-	-	4.4	0.6	15.3	4.5	1.9	-	57.4	6.9	38.5	57.9	13.3	12.4	2.8	21.9
Number of the above who reported that:																									
• they had the opportunity to eat hot meals, %:																									
a) daily	85.6	35.3	35.1	96.6	66.4	-	99.8	68.8	100.0	-	-	70.9	-	81.1	100.0	100.0	-	95.3	68.3	100.0	78.1	48.9	80.6	85.2	95.6
b) almost every day	13.5	59.7	40.1	3.4	32.8	-	-	31.2	-	-	-	22.4	100.0	18.9	-	-	-	4.7	8.6	-	21.9	51.1	19.4	14.8	4.4

Indicator	All households	Region																						
		Vinnytsya	Volyn	Dnipropetrovsk	Donetsk	Zhytomyr	Zakarpattya	Zaporizhya	Ivano-Frankivsk	Kyiv	Kirovohrad	Luhansk	Lviv	Mykolayiv	Odesa	Poltava	Rivne	Sumy	Ternopil	Kharkiv	Kherson	Khmelnytskiy	Cherkasy	Chernivtsi	Chernihiv
c) sometimes	0.9	5.0	24.8	-	0.8	-	0.2	-	-	-	-	6.7	-	-	-	-	-	-	23.1	-	-	-	-	-	-
there had been cases in the last year when one of the household members did not eat at all during the day, thousand.	3.2	-	-	-	-	-	-	1.6	-	-	-	0.3	-	-	-	-	-	1.3	-	-	-	-	-	-	-
including starving, %																									
1 day	9.1	-	-	-	-	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3 days	90.9	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-
4-5 days	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
more than 5 days	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Of the total households, the share of those who reported that, with a significant increase in income, they would primarily spend the extra money on food	26.1	26.3	27.7	25.7	46.4	39.0	51.5	11.9	48.2	13.5	25.3	25.4	22.6	13.4	29.1	17.4	22.3	19.1	21.0	19.3	17.2	21.9	39.3	15.1	22.9

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

Annex 2. *The number of households whose members have consistently denied themselves basic necessities other than food*

Indicator	All households whose members have consistently denied themselves basic necessities other than food	LSE, thousands	RSE, %
Ukraine	6609.59	302.76	2.34
Cities (> 100,000 people)	2542.25	200.94	4.03
Cities (< 100,000 people)	1931.52	124.48	3.29
Countryside	2135.82	208.32	4.98
Region			
Vinnytsa	494.20	55.85	5.77
Volyn	116.76	44.44	19.42
Dnipropetrovsk	586.00	151.94	13.23
Donetsk	443.28	74.54	8.58
Zhytomyr	122.06	31.30	13.08
Zakarpattia	130.43	61.18	23.93
Zaporizhzhia	383.66	59.83	7.96
Ivano-Frankivsk	418.39	92.71	11.31
Kyiv	96.37	34.00	18.00
Kirovograd	82.67	36.04	22.24
Luhansk	105.39	14.71	7.12
Lviv	125.01	40.93	16.70
Mykolayiv	239.44	65.01	13.85
Odesa	351.41	74.29	10.79
Poltava	195.56	55.38	14.45
Rivne	186.18	25.34	6.94
Sumy	326.00	44.18	6.91
Ternopil	274.94	52.33	9.71
Kharkiv	552.89	134.69	12.43
Kherson	230.87	47.71	10.54
Khmelnytskiy	182.07	32.93	9.23
Cherkasy	223.67	56.24	12.83
Chernivtsi	102.38	27.74	13.82
Chernihiv	263.37	47.00	9.11
Economic districts			
East	1074.45	152.15	7.22
Donetsk	548.67	75.98	7.06
Dnipro	1052.33	167.23	8.11
Black Sea	821.72	109.64	6.81
Podilsky	951.21	83.32	4.47
Central	696.63	117.61	8.61
Carpathian	776.21	121.58	7.99
Polissia	688.37	76.29	5.65

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

Annex 3. *The number of households whose members refer to themselves as poor*

Indicator	All households whose members refer to themselves as poor	LSE, thousands	RSE, %
Ukraine	11128.55	462.44	2.12
Cities (> 100,000 people)	4072.09	322.75	4.04
Cities (<100 thousand people)	3245.94	157.51	2.48
Countryside	3810.52	227.20	3.04
Region			
Vinnytsa	551.15	55.85	5.17
Volyn	181.28	44.44	12.51
Dnipropetrovsk	1036.51	151.94	7.48
Donetsk	780.18	74.54	4.87
Zhytomyr	234.57	31.30	6.81
Zakarpattia	354.26	61.18	8.81
Zaporizhzhia	650.56	59.83	4.69
Ivano-Frankivsk	435.33	92.71	10.87
Kyiv	611.86	34.00	2.84
Kirovograd	78.82	36.04	23.33
Luhansk	246.46	14.71	3.04
Lviv	439.22	40.93	4.75
Mykolayiv	439.83	65.01	7.54
Odesa	685.89	74.29	5.53
Poltava	374.93	55.38	7.54
Rivne	246.51	25.34	5.24
Sumy	394.65	44.18	5.71
Ternopil	309.15	52.33	8.64
Kharkiv	930.29	134.69	7.39
Kherson	394.71	47.71	6.17
Khmelnytskiy	261.35	32.93	6.43
Cherkasy	478.01	56.24	6.00
Chernivtsi	254.39	27.74	5.56
Chernihiv	293.18	47.00	8.18
Economic districts			
East	1699.87	197.94	5.94
Donetsk	1026.64	76.08	3.78
Dnipro	1765.89	179.47	5.19
Black Sea	1520.43	139.62	4.69
Podilsky	1121.65	90.27	4.11
Central	1555.33	155.37	5.10
Carpathian	1483.20	165.97	5.71
Polissia	955.54	82.31	4.39

Source: *own data processing of the State Statistics Service of Ukraine (2017b)*

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SOCIAL RESOURCES AND EMOTIONAL EXHAUSTION: THE ROLE OF COMMUNICATION IN PROFESSIONAL RELATIONSHIPS

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Abstract. *Communication is an element that permeates the lives of individuals, from birth to death. Through it, it is possible to create new shared meanings, relationships, and social networks. The importance of the communication process emerges in different contexts, one of which is undoubtedly the work context: several types of research have affirmed that efficient organizational communication produces positive outcomes at the level of workers and organizations, such as increased work commitment, satisfaction, and the reduction of phenomena such as emotional exhaustion and cynicism. Starting from the theoretical*

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framework of the Job Demands-Job Resources model, which divides the characteristics of each work context according to two general categories – namely job demands (representing workers' efforts in performing their job tasks) and job resources (facilitating aspects of work that can provide opportunities for personal growth) – the aim of this research is to explore the role of communication between colleagues and superiors in the relationship between a job resource (increased social resources) and a negative outcome, such as emotional exhaustion, by means of a non-parametric structural equation model (PLS-SEM), in a sample of 479 workers. Reliable structural and measurement models yielded excellent fit indices of the hypothesized latent variables. The results show that, for workers, enhancing social resources by asking for feedback from colleagues and bosses does not protect against the risks of emotional exhaustion, but in fact improves communication. The exclusive use of social resources at work does not have a significant impact on the risk of emotional exhaustion if it is not accompanied by perceived communication appropriate to the circumstances and contexts. Communication, therefore, fully mediates the relationship between increased social resources and emotional exhaustion and stands out as a crucial protective factor.

Keywords: *communication, exhaustion, PLS-SEM, well-being, JD-R model, organizations.*

JEL Codes: *C30; I31; J24; O35.*

Introduction

It is impossible not to communicate: this axiom is the basis of Paul Watzlawick's theory and the Palo Alto School (Watzlawick, Beavin, & Jackson, 1971; Watzlawick & Nardone, 1997), which is of fundamental importance for various areas of the social sciences. Communication is an element that permeates the lives of individuals, from birth to death. As a consequence, from a systemic point of view, it influences all the contexts in which the individual is inserted (Bronfenbrenner, 1979): starting from the microsystem, i.e., the immediate context in which they finds themselves (such as family, friends, and neighbors); passing then through the exosystem, or the set of working or social organisms connected with the subject; before encountering the mesosystem, i.e., the relations between different systems; and finally the macrosystem, consisting of the historical-social or superstructural context (laws, policies, and values). In this sense, therefore, one of the most important contexts, and one in which communication and sociality in general play an important role, is the working environment. In the present times, communication plays a fundamental role not only as a tool used for business purposes, but also and above all as a resource through which to stimulate employee satisfaction in organizations, preventing possible negative outcomes such as emotional exhaustion. Communication is a means to create new shared meanings, relationships, and networks between the actors that constitute the act, as also stated by socio-constructivist theory. Analyzing the relationship implies examining communication, since it is the vehicle of the interactive relationship (Watzlawick, Beavin, & Jackson, 1971; Watzlawick & Nardone, 1997). To communicate means to intentionally transmit something, and this can be done through

various channels such as writing, behavior, or gestures (Bara, 1999). The concept of communication can have numerous definitions; as Anolli (2002) suggests, it can be understood as a social activity, thus constituting a fundamental element of human interaction; as participation, through the cultural sharing of meanings and rules implicit in communicative acts; as a cognitive activity, in that it is the means with which individuals translate what they mentally represent into communicative terms; and finally as an activity connected to action, in that it is intrinsically correlated with the tendency to influence others in the act of reciprocal interaction. From a purely work-related perspective, organizational communication can be considered as a process that enables groups and partners to learn from each other and coordinate their tasks, acting in such a way as to develop and maintain fruitful relationships (Robson, Skarmeas, & Spyropoulou, 2006). Different types of research have shown that effective organizational communication has produced positive outcomes for workers and organizations, such as increased commitment (Newsome & Pillari, 1992), employee satisfaction (De Ridder, 2004), and reduced burnout (Atouba & Lammers, 2020). Emphasizing its role, therefore, becomes an important resource for promoting individual and organizational well-being.

The theoretical framework on which this study is based is the Job Demands-Resources model (Demerouti et al., 2001; Bakker & Demerouti, 2007), hereafter JD-R. JD-R is a theorization used to explain how each work environment has its own characteristics, which can be identified in a general model. This model is more flexible and rigorous than previous models based on job design, as it allows us to illustrate how well-being and efficiency at work can be the precipitates of two types of working conditions, namely job demands and job resources. The interaction between the two components is central to the development of well-being and job performance, but also to burnout behaviors. Specifically, job demands involve professional aspects that produce an effort if they exceed the worker's ability to adapt. This effort can be physical or cognitive (heavy workload, pressure, emotionally challenging interactions with others, high responsibility), and produces physiological and psychological costs (Demerouti et al., 2001). Job demands are not necessarily negative for individuals but may result in obstacles if they require high efforts from workers. Job demands are therefore understood as those physical, psychological, social, and organizational aspects that require substantial physical and psychological effort and are therefore associated with certain costs (Demerouti et al., 2001). The second factor within the JD-R model concerns job resources. These are those physical, psychological, social, or organizational features of work that can be instrumental in achieving objectives, in reducing the physiological and psychological costs associated with job demands, and in improving learning and development capabilities. Examples of work resources are job autonomy, performance feedback, social support, supervision, coaching, and time control. Work resources are intrinsically and extrinsically motivating (Bakker & Demerouti, 2007) as they enable the fulfilment of human needs and the pursuit of growth and autonomy at work.

Underlying the processes described by the model are two psychological mechanisms: work pressure and motivation. The former can quickly result in mechanisms that reduce health processes when work demands lead to exhaustion, lack of energy, and health problems such as burnout (Demerouti et al., 2001; Bakker & Demerouti, 2007). Motiva-

tion increases when work resources are a motivating force and can produce high levels of involvement, low cynicism, and excellent performance. The JD-R model is widely used by researchers and practitioners for many reasons: firstly, it represents a strong paradigm, is flexible, and can be applied to all work environments and easily adapted to specific workplaces. Secondly, the two processes are independent factors leading to organizational and individual outcomes. In particular, job demands drive the weakening of the health element, specifically exhaustion, psychosomatic health disorders, and repetitive strain-related injuries. Job resources, on the other hand, drive motivational processes, predicting work appreciation, motivation, and commitment.

Social resources

The social aspect has always been of great importance in determining a harmonious working environment from the point of view of the worker and the organization itself. Through constant feedback with colleagues or superiors, exchange of opinions, and material or informational support, beneficial effects on work performance can be determined. Social resources, also called social capital, have been studied by several authors, but in general they are defined as "the set of resources, concretely and immediately available, which derive both from the networks in which the subject is inserted and from the position the subject assumes in each network." They are skills and support networks that arise from interpersonal networks, characterized by relationships and cultural and information exchanges (Pittamiglio & Poggi, 2003). Social resources are also of great importance from a labor point of view, as they foster employability (Lo Presti et al., 2019; Ingusci et al., 2020), the management of one's job according to the individual needs of the worker (Ingusci et al., 2020), and both work engagement and job performance (Vermeir et al., 2015; Bhatti, Mat, & Juhari, 2018). Following the theoretical frameworks of the JD-R model (Bakker & Demerouti, 2007) and the Theory of Conservation of Resources, therefore, the social aspect is rightfully part of the resources available to the worker which aim to stem the impact of demands. Social resources can be defined as the social support received, supervision by a boss or colleagues, and everything related to social sharing – in particular networking (Ingusci et al., 2018). Networking plays a key role in people's professional and educational lives (Lo Presti et al., 2019). Developing, maintaining, and increasing relationships can help individuals search for secure employment opportunities, gain access to required information, access useful resources, obtain sponsorship, and receive overall social support. Different studies have highlighted how social capital may be used to improve individual performance in general (Seibert et al., 2017).

Organizational communication

Interpersonal communication is defined as a social process in which those involved have a mutual influence. Its impact derives from the communicative competence that everyone can develop, i.e., the ability an individual has to communicate in an "effective and socially appropriate" way. Interpersonal communication can be direct or indirect, but

what is of paramount importance in organizations is, above all, the quality of interpersonal communication. In the organizational context, having good communication skills facilitates groups to make more innovative and creative decisions, and, often, individuals who possess good communication skills are more likely to advance in their careers than individuals who have not developed such skills (Wibowo, 2017). Good organizational interpersonal communication involves leaders providing clear directions and information to employees. From this follows work performance that can be carried out by means of the information that has been provided. For these reasons, organizational communication should not be especially harsh, and can facilitate the overcoming of problems that may be generated in work contexts. The present literature on organizational communication (Widyanti, 2020; Zito et al., 2021; Prasetyo et al., 2021) allows us to define the construct as the set of workers' perceptions regarding the sharing of information, ideas, and both professional and non-professional emotions within work teams. Organizational communication may concern sharing between team members internally or between team members and a leader. Some research has confirmed that people with high communication competence may also be more likely to maintain a healthy psychological state through effective communication with their supervisor and colleagues (Gochhayat, Giri, & Suar, 2017; Haroon & Malik, 2018; Prasetyo et al., 2021; Widyanti, Zito et al., 2021).

Other types of research have shown that good internal communication that facilitates the exchange of information, ideas, opinions, thoughts, and emotions can have a positive influence on employee productivity, innovation, and motivation, and drives employees towards initiating change processes that are beneficial to the organization (Gochhayat, Giri, & Suar, 2017; Widyanti, 2020; Haroon & Malik, 2018; Zito et al., 2021).

However, this study considers organizational communication by framing it within the theoretical model of JD-R, a comprehensive model that includes two processes: a positive motivational process and a negative health impairment (stress, burnout) process. This model provides a common code among members of the organization that can facilitate communication at work and organizational well-being, and, furthermore, it offers itself as a vehicle for understanding the underlying psychological dynamics in terms of stress and motivational processes (Shirom, 1989).

Job demands and job resources investigate two different types of processes, specifically health impairment and motivational processes. Several studies have shown the presence of this dual pathway: job demands are generally related to exhaustion, burnout, and possible depressive tendencies; job resources, on the other hand, are associated with job involvement and commitment.

Emotional exhaustion and burnout

Among the various theorizations of burnout, that of Maslach, Schaufeli, and Leiter (2001) is the most important. The authors developed a multidimensional theory of burnout, which is conceptualized as a construct consisting of three components: emotional exhaustion, disaffection (or cynicism), and reduced personal efficacy. Over the years, there have been several discussions regarding the content and validity of this conceptu-

alization (Shirom, 1989; Demerouti et al., 2001; Maslach, Schaufeli, & Leiter, 2001). In the original conceptualization, Maslach (1982) defined burnout as a psychological stress syndrome that characterized the helping professions (nurses, physicians, psychologists, law enforcement, teachers). Maslach (1982), Maslach, Schaufeli, and Leiter (2001), and Maslach and Leiter (2016) defined three dimensions of burnout: *emotional exhaustion*, *depersonalization*, and *reduced professional accomplishment*. Emotional exhaustion is the main manifestation of burnout, referred to as the feeling of having used up all the psychophysical energy needed to cope with job demands. Depersonalization is the interpersonal component of burnout: it refers to the emotional and cognitive detachment that occurs in the relationship with users/patients through a dehumanized and cynical perception of them. According to Borgogni and Consiglio (2005), depersonalization is a defense mode that the worker puts in place to protect themselves from the overwhelming emotions caused by the relationship with the user. Reduced professional accomplishment is a negative evaluation of one's own work performance and ability to cope with work demands.

Initially, the dimensions of burnout were conceived in sequential terms: relational and work demands trigger emotional exhaustion. The worker, to protect themselves, adopts a cynical view of users, detaching themselves cognitively and emotionally from them. Finally, due to their inability to cope with the work demands and the relationship with the users, the worker would experience a sense of work inadequacy and reduced professional fulfilment (Cordes & Dougherty, 1993).

When the burnout concept was extended to other occupational settings, a new conceptualization of the construct was needed, which had difficulty adapting to other occupations. Maslach, Schaufeli, and Leiter (2001), therefore, reformulated the three dimensions of burnout, or *exhaustion*, *cynicism*, and *reduced personal* efficacy. As regards exhaustion, there was less emphasis on emotions, and it did not necessarily refer to relationships with clients. Characteristic symptoms of exhaustion include a lack of psychophysical energy, feeling tired at the mere thought of going to work, feeling frustrated at work, and a lack of energy to devote to family and other non-work activities. Work disaffection or cynicism indicates a general attitude of indifference and negative detachment towards one's work. Finally, reduced personal efficacy refers to the decrease in the general sense of efficacy. This manifests itself through negative emotions and thoughts regarding one's goals or ability to succeed in work and life, a significant decrease in self-esteem, and the feeling that one's work is meaningless.

The dimensions that constitute burnout are, even today, a matter of debate – even if some researchers have stated that the dimension of exhaustion is sufficient to measure it (Maslach, 1982; Shirom, 1989).

Aims and hypotheses

Starting from the proposed theoretical review, the aim of this work is to investigate, from the perspective of the relationship between job resources and negative work outcomes, the role of perceived communication quality. Specifically, the aim is to explore the impact that social resources have on health impairment processes, in what terms they can

protect against emotional exhaustion, and how the quality of communication between co-workers and bosses can mediate the relationship between social resources and burnout, reinforcing this protective effect.

Therefore, the starting hypotheses are:

H_1: Increasing social resources will negatively influence emotional exhaustion.

H_2: Increasing social resources will positively affect perceived communication quality.

H_3: The quality of perceived communication will negatively impact on emotional exhaustion.

These research hypotheses were tested by means of non-parametric structural equation models (PLS-SEM – Figure 1).

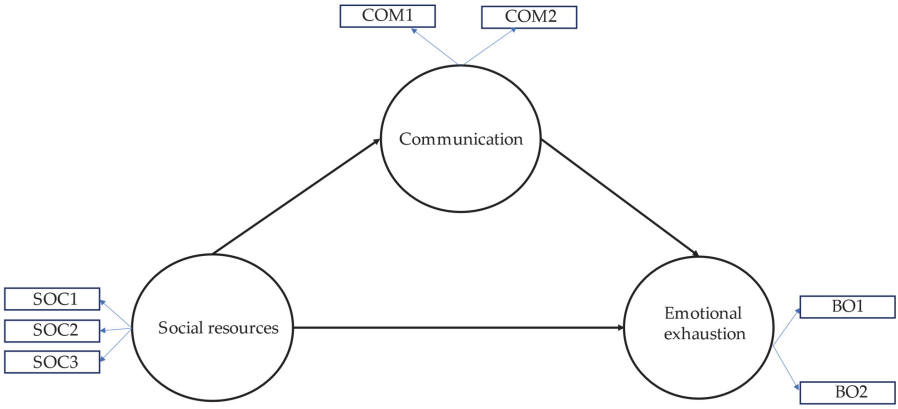

Figure 1. *The assumed PLS-SEM model*

Data analysis

The survey was carried out by analyzing data from an anonymous quantitative questionnaire in which were administered validated scales in the literature to detect:

1. The level of resource-seeking and social support through the proactive job crafting strategy (Ingusci et al., 2018). The latent constructs were measured by 3 items. An example item is as follows: "*I ask my colleagues in the groups I belong to if they are satisfied with the work they have done*."
2. The quality of communication with colleagues and superiors (surveyed through 2 single items created ad hoc), measured through 2 items. An example item is as follows: "*Overall, how satisfied do you feel with the communication at work with your colleagues*?"
3. The level of perceived emotional exhaustion (Maslach, 1982; Maslach, Schaufeli, & Leiter, 2001; Maslach & Leiter, 2016), measured through 2 items. An example item is as follows: "*I feel that every hour of work is tiring for me*."

The questionnaire was completed by 479 individuals from public and private organizations. All participants gave their prior consent to take part in the research, and of course

had the possibility to withdraw from completing the questionnaire at any time. The subjects were also assured that the data would be processed in aggregate form and without any possibility of tracing private and personal information. After appropriate descriptive analyses using R Studio and Jamovi, observations with missing values (9.6% of the total) were eliminated, bringing the dataset to a total of 433 observations. The theoretical hypotheses were investigated using a non-parametric Structural Equation Model or PLS-SEM, through SMART-PLS software (Ringle, Wende, & Becker, 2015), due to the sample size of the study. As Hair et al. (2017) and Hair et al. (2021) suggested, PLS-SEM is, in fact, a robust method aimed at providing good estimates in case of a small sample and no distributional assumptions on the collected data. Furthermore, PLS-SEM's rule of thumb to detect minimum sample size is to dispose of twenty to thirty times the maximum number of arrows pointing at a construct, or independent variables. Our study sample fully met these criteria. The mean age of the sample was 38 years, ranging from a minimum of 20 to a maximum of 67 years. From a gender point of view, the largest proportion of subjects was female (58.5%), while 41.5% were male. The prevailing educational qualifications of the sample were High School Diploma (29.6%) and bachelor's degree (28.4%). Further, 48.2% of subjects were single, while 45.9% were in a relationship/married; 39.0% of the sample had at least one child, while 61.0% had no children. Finally, 67.0% of individuals worked for a private company, while 33% had a job in a public organization (Table 1).

Table 1. *Descriptive analyses of the sample*

	Frequency	Percentage
Gender		
Female	280	58.5%
Male	199	41.5%
Educational level		
Secondary school diploma	40	8.4%
High school diploma	142	29.6%
Bachelor's degree	75	15.7%
Master's degree	136	28.4%
Postgraduate degree	86	18.0%
Marital status		
Single	231	48.2%
In a relationship/married	220	45.9%
Separated/divorced	24	5.0%
Widower/widow	4	0.8%
Children		
Child	187	39.0%
No child	292	61.0%
Sending organizations		
Private	321	67.0%
Public	158	33.0%

Results

From a methodological point of view, the three latent constructs hypothesized – namely social resources, communication, and emotional exhaustion – all possessed excellent reliability indices, measured through Cronbach's alpha, McDonald's omega, Dillon-Goldstein's rho, and Average Variance Extracted. These results are shown in Table 2.

Table 2. *Reliability measures for latent variables*

	Cronbach's α	McDonald's ω	Rho	AVE
Social resources	0.87	0.90	0.90	0.78
Communication	0.82	0.82	0.82	0.84
Emotional exhaustion	0.82	0.83	0.83	0.84

The measurement model allows the proposed indicators to be identified, from a reflective perspective (Cheah et al., 2019), as good proxies for the composite constructs through loadings, all of which were greater than 0.70 and significant (Table 3). At the same time, all AVEs were larger than the 0.50 cut-off. All estimates were validated through 5,000 bootstrap re-samplings. Furthermore, we assessed and confirmed discriminant validity through cross-loadings.

Table 3. *Loadings of the structural model and cross-loadings*

	Social resources	Communication	Emotional exhaustion
SOC1	**0.92 (.000)**	0.22	−0.03
SOC2	**0.89 (.000)**	0.23	−0.08
SOC3	**0.84 (.000)**	0.15	−0.03
COM1	0.23	**0.92 (.000)**	−0.27
COM2	0.18	**0.91 (.000)**	−0.28
BURNOUT1	−0.01	−0.25	**0.91 (.000)**
BURNOUT2	−0.09	−0.30	**0.93 (.000)**

As highlighted in Table 3, the strongest loading of each indicator was with its latent variable. From the results concerning the structural model, it emerged that, within the sample analyzed, the effect of increasing social resources on emotional exhaustion was almost null ($\beta_1 = 0.011$, ns, CI: [−0.089; 0.109]), while the quality of perceived communication, both with superiors and colleagues, had a significant and negative impact with emotional exhaustion ($\beta_2 = -0.302$, $p < 0.000$, CI: [−0.392; −0.216) and a positive impact with increasing social resources ($\beta_3 = 0.227$, $p < 0.000$, CI: [0.141; 0.314). According to Nitzl, Roldan, & Cepeda (2016), this mediation is only indirect, as the effect of social

resources on emotional exhaustion is completely absorbed by communication, which could be considered a protective factor in this relationship (Figure 2).

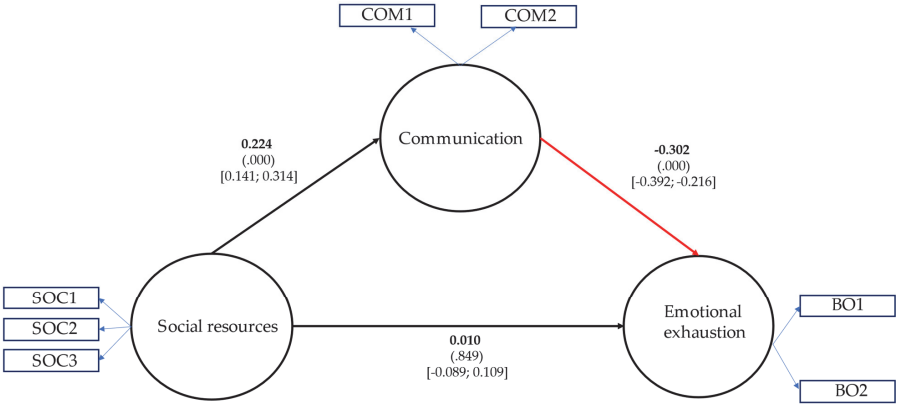

Figure 2. *The structural model hypothesized*

We furthermore tested whether the hypothesized model differed based on gender (Table 4) or type of organization (Table 5). For this reason, we performed a multigroup analysis (Hair et al., 2017; Hair et al., 2021).

Table 4. *Multigroup analysis on gender*

	Path Coefficients Female	Path Coefficients Male	*p*-value Female	*p*-value Male	Differences Female–Male	*p*-value differences
COM → BO	−0.334	−0.272	0.000	0.000	−0.062	0.492
SOC → BO	−0.026	0.049	0.687	0.556	−0.075	0.475
SOC → COM	0.222	0.239	0.000	0.000	−0.017	0.840

Table 5. *Multigroup analysis on type of organization*

	Path Coefficients Private	Path Coefficients Public	*p*-value Private	*p*-value Public	Differences Private–Public	*p*-value differences
COM → BO	−0.283	−0.355	0.000	0,000	0.073	0.429
SOC → BO	0.034	−0.055	0.594	0.582	0.090	0.438
SOC → COM	0.255	0.181	0.000	0.024	0.074	0.414

These results show non-significant differences between the coefficients. The significances remained the same regardless of the categorization variable (gender or type of organization), whereby communication assumed the mediating role in both models. In more detail, the relationship between social resources and communication was stronger

in males and private organizations, while the relationship between communication and emotional exhaustion was stronger in females and public organizations. Nevertheless, as mentioned above, these coefficients were not statistically significant differences.

Discussion and conclusions

These results essentially show that for employees, enhancing social resources by asking for feedback from colleagues and bosses does not in itself protect against the risk of emotional exhaustion, but in fact improves communication. In other words, the mere use of social resources at work does not have a significant impact on the risk of emotional exhaustion if it is not accompanied by perceived communication appropriate to the circumstances and contexts. This intervening variable ultimately makes the relationship useful in avoiding stressful situations that may lead to emotional exhaustion. Consequently, it is possible to state that communication fully mediates the relationship between increased social resources and emotional exhaustion, marking itself out as a fundamentally important protective factor. In this regard, this research was also conducted by differentiating the sample into workers in public and private organizations. From these analyses, it emerged that there is no significant difference between the two different types of companies, so that communication assumes the role of mediator regardless of the organization's origin. Ultimately, therefore, it emerged from these analyses that the predominant role in reducing the impact of emotional exhaustion belongs to the quality of perceived communication with colleagues and superiors. The aspect of seeking social resources does not seem to have a direct effect on emotional exhaustion, but in turn positively influences communication.

This result is in line with those found in different work contexts, especially for care professions, such as social workers (Cho & Song, 2017) and intensive care unit nurses (Vermeir et al., 2018), but also for university students (Chadwick et al., 2016) and IT professionals (Atouba & Lammers, 2020). According to these studies, in fact, positive communication between a supervisor and a worker allows the establishment of a supportive climate, in which the individual's perception of importance is made salient. This condition allows the professional to increase the levels of job satisfaction (Ng et al., 2006, Seibert et al., 2017), possibly decreasing burnout (Houkes et al., 2003) and turnover intentions (Newsome & Pillari, 1992; Houkes et al., 2003; Ng et al., 2006). The theoretical conceptualization of the JD-R model (Demerouti et al., 2001; Bakker & Demerouti, 2007) considers effective communication not only as a working condition that reduces perceived stress, but also as a coping tool to withstand stress in a fruitful way, becoming in effect a resource to cope with demands. The quality of communication with superiors and colleagues is an element that can foster worker participation, influencing the degree of control over the work environment. The research and theoretical framework reported, therefore, agree in defining communication as a resource to implement the quality of organizations from a healthy organizational point of view, i.e., those contexts in which culture, climate, and good practices can create an environment that promotes employee health and organizational safety and effectiveness (Lowe, 2010).

Limitations and practical implications

The study has, of course, limitations which must be considered before generalizing the results. Firstly, the size of the sample. Although non-parametric structural equation models (PLS-SEM) do not assume the existence of criteria based on a minimum number of observations, future studies could increase the number of participants or use more robust modelling methods. Secondly, the convenience sample used does not allow causal relationships to be inferred. In addition, the measures used in the study were self-reported measures, thus subject to biases such as social desirability. Future studies could use more objective measures to consider variables such as the level of absenteeism. In addition, the cross-sectional nature of this study undermines the generalizability of the results. Further research could consider longitudinal research designs. Finally, the number of indicators for latent variables could be increased to capture different nuances inherent in the latent concept.

Despite these limitations, the practical implications for the organization and management of companies are obvious. Emotional exhaustion is one of the psychosocial risks that most often results in absenteeism, presenteeism, or consequences that can damage the productivity of organizations and at the same time individual well-being (Gemmano et al., 2020). There has been much discussion about the types of interventions that could be put in place to reduce the risk of emotional exhaustion in employees (primary, secondary, and tertiary). An interesting application could be, furthermore, to adopt linguistic analysis techniques, such as sentiment analysis, to explore emotional exhaustion in-depth (Corallo et al., 2020; Tavazoee et al., 2020) and to propose specific intervention on it (Boyd, Pasca, & Conroy-Beam, 2019; Cardazzone et al., 2021). This study shows that improved communication with colleagues and superiors has an important and negative effect on the risk of emotional exhaustion, in contrast to seeking social feedback. This aspect is crucial because implementing interventions that are aimed at fostering a frank and qualitatively adequate communication exchange could influence health and quality of organizational life. Communication, therefore, could be considered, following the JD-R model, as a resource able to cushion the impact of work demands and the process of weakening health that could result. The protective impact of communication at the work level could also, therefore, lead to a reflection on the policies to be implemented in order to promote well-being at the individual, group, and organizational levels. Acting on individual workers to promote their well-being has a significant impact on productivity.

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