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Comparative Analysis of the Diffusion of Innovations in Wind Energy in European Countries

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ABSTRACT

Objective: The aim of this article is to compare the diffusion processes of innovations in wind energy among selected European countries.
Research Design & Methods: The study used the Bass model, with parameters estimated separately for each country, and then, based on the obtained parameter estimates, a taxonomic analysis of the compared countries was carried out. This enabled the identification of regularities between the obtained indicators of innovation, imitation and market potential. Ward's method, using Euclidean distance, was applied in the cluster analysis, and the contribution of variables to differentiating the resulting groups of countries was assessed using ANOVA.
Findings: The results of the taxonomic analysis enabled the isolation of the diffusion profiles of innovations in wind energy technologies. In particular, it has been proven that innovators are large countries with strong economies, high levels of GDP and a high share of spending on research and development. The imitators of such technologies are primarily countries in Central, Eastern and Southern Europe, where the level of expenditure on research and development is lower than in Western Europe.
Implications/Recommendations: The results presented in the article may support the development of an energy system with a high share of renewable energy sources. Moreover, they

can be helpful in assessing the effectiveness of the actions of individual countries' governments in decarbonising their economies.

Contribution: The research results presented in this article fill the research gap in the field of comparative analysis of innovation diffusion profiles in wind energy in European countries.

Article type: original article.

Keywords: renewable energy, wind energy, Bass model, learning curves, Ward's method.

JEL Classification: Q42, Q55, C38.

1. Introduction

The energy transition aimed at decarbonising economies is one of the most important challenges the world will face in the near future. The urgency of this process arises, on one hand, from adverse climate changes caused by greenhouse gas emissions, and on the other hand, from limited resources of traditional energy raw materials. The need to move away from the use of fossil fuels and replace them with renewable energy sources has long been postulated by governments of many countries, international organisations and associations. This is reflected in international agreements and declarations obliging signatory countries to take specific actions. It is worth recalling here the so-called Paris Agreement concluded by UN member states (Markard, Geels & Raven, 2020) or the European Green Deal, which obliges EU countries to achieve climate neutrality by 2050 (Vela Almeida *et al*., 2023). As part of a package of policy initiatives, the European Commission has developed an EU financing mechanism for the Green Deal to support EU member states in achieving their individual and collective goals in the energy transition (Sikora, 2021). Implementing the assumptions of the Green Deal requires, among other things, intensified innovative activities aimed at developing modern technologies supporting renewable energy sources, increasing their efficiency, availability and reducing the costs of their implementation. An important element of these activities is the development of wind energy. In the EU, in 2022, energy from renewable energy sources accounted for nearly 23% of the total energy consumed, with the share of electricity from wind accounting for approximately 38% of the energy generated from renewable sources. This means that wind is the most significant source of renewable energy in the EU (Eurostat, 2024). There are many indications that this type of energy has significant and still untapped potential. To fully utilise it, innovations and appropriate energy policy are needed, including, for example, legal regulations regarding the location of wind farms, and appropriate public education reducing fears about the construction of wind energy infrastructure (Bin Abu Sofian *et al*., 2024). Technological innovations in this area are multidirectional and include

materials used in the construction of wind turbines, improvements in the design of wind turbine blades and rotors, automation of wind energy control using artificial intelligence solutions (Bin Abu Sofian *et al*., 2024; Machado & Dutkiewicz, 2024). An important challenge for the industry is also the construction of increasingly larger wind turbines, including turbines resistant to extreme weather conditions floating on seas and oceans (Bošnjaković *et al*., 2022).

Wind energy, as a sustainable energy source, is gaining recognition among environmentalists and decision-makers. Nevertheless, like other infrastructure projects, wind farms face challenges related to environmental protection, landscape change and visual impact (Avila, 2018; Dhar *et al*., 2020). Solving these problems is essential for the continued development and wide acceptance of wind energy.

Innovations in wind energy technologies, like other renewable energy sources, undergo diffusion, i.e. spreading throughout the economy. According to Rogers' diffusion model (Rogers, 2003), different groups of people adopt innovations at different rates, and the innovation adoption process includes five stages: knowledge, persuasion, decision, implementation, confirmation. Many studies confirm that diffusion typically follows an S-shaped curve over time, although the pace of this phenomenon and its overall characteristics may differ between the economies of different countries (Söderholm & Klaassen, 2007; Skoczkowski, Bielecki & Wojtyńska, 2019).

This may be due to differences in the market potential of countries, as well as different levels of absorption of new technologies, the availability of locations for this type of investment, and different priorities in the energy policy of individual countries. The diffusion of renewable energy technologies based on wind energy may be influenced by, for example, the availability of winds at appropriate speeds (which is influenced by the topography, length of the sea coastline, barometric conditions), the condition of the existing energy infrastructure, administrative and legal regulations regarding the construction of wind farms, social acceptance for such ventures. Comparative studies on the diffusion of wind technologies are therefore important from the point of view of assessing the effectiveness of actions aimed at creating zero-emission economies in accordance with the guidelines of the European Green Deal. Despite the relatively frequent approach to this issue by researchers, there is a research gap in the literature in this area. There is a lack of research that comprehensively compares the processes of innovation diffusion in wind energy technologies in European countries. However, there are many studies relating to specific countries or regions (Murugesha & Prasanna Kumar, 2012; Zhang *et al*., 2024).

The aim of this article is to compare the diffusion processes of innovations in wind energy among selected European countries. The Bass model was used to achieve this goal. Based on the estimation results of this model, regularities were

determined between the obtained indicators of innovation, imitation and market potential for the studied countries. Additionally, the author conducted a taxonomic analysis of these countries using quantitative characteristics of innovation diffusion processes in wind technologies.

2. Literature Review

Several trends can be identified in the literature on renewable energy research, namely the analysis of technological changes, the study of the diffusion of innovations, the economic and environmental effects of the implementation of renewable energy sources, as well as the psychosocial aspects of innovation in renewable energy technologies (Zhou *et al*., 2020; Omri, Chtourou & Bazin, 2022). The initial research stream employs exogenous and endogenous models. Exogenous models are used to examine, among others, effectiveness of technological solutions, while endogenous models are used to analyse the costs of a standard product within one company (learning curve) or the costs of non-standard products at the global, regional or national level (experience curve) (Horsky & Simon, 1983). When examining the diffusion of renewable energy technologies, one diagnoses technological cycles and innovation saturation levels. Models reflecting S-shaped curves are mainly used here, such as the Bass model, the logistic function, the Gomertz model and others (Meade & Islam, 2006; Zhang *et al*., 2020; Zhou *et al*., 2020). In wind energy research, learning curves and innovation diffusion models are often used, as well as a combination of these tools with the analysis of factors determining or limiting the development of wind turbine technology. There are numerous publications devoted to the Asian wind energy market. Hayashi, Huenteler and Lewis (2018) used learning curves to examine how the accumulation of experience and knowledge of wind farm developers and turbine manufacturers contributed to productivity growth in the Chinese wind energy industry. They showed that the efficiency, turbine size and unit costs in Chinese wind farms depend little on the accumulation of experience and knowledge.

Learning curves were also used by Zhang *et al*. (2024) in a study of the main factors influencing onshore wind energy in China, which made it possible to identify ways to reduce the costs of producing such energy. The diffusion of wind technology also in China was studied by She *et al*. (2019). The authors examined eight wind farm bases in China in terms of innovation diffusion and presented projections for them to increase the use of wind energy by 2030. They showed that a poorly developed energy network is the greatest obstacle to the development of wind energy in regions with large resources and poor developed economy, while subsidies are a key factor in the diffusion of wind energy in developed regions (She *et al*., 2019). The logistic curve was applied in studying the diffusion of wind energy technology in Pakistan and in the forecasting of wind energy consumption by Harijan *et al*. (2011).

Studies also link the diffusion of technological innovations with specific technological parameters of installed wind turbines, such as the height of the rotor hub, wind energy generation capacity and others. Murugesha and Prasanna Kumar (2012) conducted an extensive study of this type in the Indian state of Karnataka. Due to the cointegration of the time series they used, they used vector error correction models. A quantitative analysis of innovation diffusion in the European wind energy sector (for Denmark, Germany, Spain and the UK) was carried out by Söderholm and Klaassen (2007). Using a learning curve model based on dynamic cost reduction, the authors showed, among others, that reductions in investment costs (resulting from, among others, educational activities and public research and development support) were important determinants of the increased dissemination of wind energy. In turn, Dalla Valle and Furlan (2011) used the Generalised Bass Model (GBM), standard Bass model (BM), logistic model, and Gompertz model to analyse the diffusion of wind energy technologies in some European and US markets in connection with the effects of local incentive policies. They also made short-term estimates and forecasts of wind energy life cycles. Dubarić *et al*. (2011) used S-shaped curves in modelling the diffusion of wind energy technology (in terms of power supply technology, rotor form, regulation and pitch adjusting) using panel data. The authors demonstrated that, particularly in regulation technology, there is a strong relationship between the increase in the number of patents and market changes. In the study conducted by Garsous and Worack (2022), barriers to the diffusion of wind energy technologies are examined. The authors argue that some foreign trade instruments that may limit access to markets for key environmental technologies may be used to inhibit the development of wind turbine technologies. The authors further argue that industrial policy should be shaped in such a way that domestic companies specialising in wind turbine technologies can apply their specific potential to new opportunities in global industries.

Hernandez-Negron, Baker and Goldstein (2023) use experience curves as a basis for examining the development of new wind technology for wind turbines located at sea in relation to farms located on land (using mature technology), and hybrid solutions are also examined. By focusing on the levelised cost of electricity obtained from offshore wind energy, the authors show the importance of its connection with onshore wind energy. An intriguing study on the diffusion of innovations in wind energy technologies in European countries using learning curves created on the basis of the Cobb-Douglas model was shown by Grafström and Lindman (2017). Additionally, they used econometric models for panel data, thanks to which they assessed the significance of the impact of various factors on the development of wind energy in Europe. They showed, among others, that the price of steel is an important determinant of the costs of wind energy, and investment costs are an important factor determining the amount of power installed in wind energy.

Thompson (2023) used meta-analysis to prove that renewable energy sources do not replace fossil fuels, but increase energy demand, which results in increased greenhouse gas emissions. According to her, the development of renewable energy, including wind energy, is not possible without billions of dollars in subsidies to support the investment process, it will be insufficient and will not fulfil its fundamental role, i.e., it will not eliminate the use of fossil fuels. A less pessimistic vision of the development of wind energy and its role in improving energy security is presented by Wheatley (2024). She argues that the leading share of renewable energy sources in the energy mixes of individual countries is possible thanks to sustainable technological progress supported by innovation and inter-sectoral and international cooperation. She believes that the transformational potential of these technologies is enormous; thanks to which they will reduce carbon dioxide emissions and improve energy security. Lindman and Söderholm (2012) conducted a comprehensive meta-analysis based on the results of 35 studies that used learning curves. Using the concept of an extended learning curve, they showed, among others, that in the case of wind energy, integrating the effects of public research and development results in lower learning rates than those generated by the so-called single-factor learning curves. A review of the barriers and factors influencing the global imbalance in the diffusion of wind energy in developing countries was performed by Zwarteveen *et al*. (2021). They identified 59 factors influencing the diffusion of wind energy and then grouped them into eight categories, the key of which are: economic, environmental, technical, technological, social, regulatory, political potential, as well as a set of other factors. Lacerda and Van den Bergh (2014) studied the impact of various actions on the diffusion of innovations in wind energy in three large markets: China, Germany and the USA. They demonstrated that policy support for environmental innovations can help create competitive advantages in the wind energy market. Using the examples of China and Germany, they demonstrated a strong relationship between political support and diffusion.

Skoczkowski, Bielecki and Wojtyńska (2019) used logistic curves to describe the diffusion of innovations and based on them, presented forecasts for the development of wind energy until 2100. However, their research was performed for all EU countries jointly, so a detailed comparative analysis between specific countries is not possible here. This article attempts to fill this research gap. Although the issue of diffusion of innovations in wind energy is relatively popular in scientific research, it rarely compares the diffusion of this phenomenon in a larger number of countries. Meanwhile, this type of research is necessary to assess the progress of various countries in the processes of economic decarbonisation. The author of this article met these expectations and compared the diffusion of innovations in wind technologies in 32 European countries. Data for calculations come from the database available under an open licence: Our World in Data (2024). The basis for building models

of the diffusion of innovations in wind technologies were the time series of annual energy production (in TWh) covering the years 1985–2023.

3. Methodology

The Bass model was employed to study the spread of wind energy technology. This model is relatively often used in the analysis of the diffusion of innovations, including those related to wind energy technologies. In analysing the diffusion of this type of technology, Bass's model was used by, among others, She *et al*. (2019) and Dalla Valle and Furlan (2011). It is also worth emphasising that BM is characterised by simplicity, traceability and ease of interpretation of the obtained parameters. The basic form of this model is presented as follows (Bass, 1969, 2004; Guidolin, 2023):

$$\frac{dN(t)}{dt} = \left[p + q\frac{N(t)}{M}\right][M - N(t)], \tag{1}$$

where:

$N(t)$ – total number of users of the innovation in time t,
M – number of potential and current users of the innovation,
p – innovation coefficient,
q – imitation coefficient.

The p parameter indicates the percentage of users who will adopt the innovation. In turn, the component $q\frac{N(t)}{M}$ in formula (1) denotes the percentage share of users of the innovation, scaled by the imitation coefficient q.

Solving the differential equations (1) we obtain the following function:

$$N(t) = M\frac{1 - \exp(-(p+q)t)}{1 + \frac{q}{p}\exp(-(p+q)t)}, \quad t > 0. \tag{2}$$

Its graph is an S-shaped curve, and its derivative showing the immediate process of innovation diffusion can be written as follows:

$$N'(t) = M\frac{p(p+q)\exp(-(p+q)t)}{[p + q\exp(-(p+q)t)]^2}, \quad t > 0. \tag{3}$$

Diffusion models were constructed for each of the analysed countries and then, based on the parameter estimates in the Bass model, the countries were grouped using the Ward method. Ward's method was chosen due to its popularity and effectiveness confirmed in numerous studies (Sokołowski, 1992). Ward's method belongs to hierarchical methods of cluster analysis and uses an approach based on the analysis of variance to estimate the distance between clusters. Its assumption is to minimise the sum of squares of any two clusters that can be formed at individual stages

of the agglomeration procedure. Thanks to this, it is possible to obtain the effect of homogeneity within clusters and heterogeneity between clusters. Ward's method is flexible in data exploration and avoids many problems typical of other hierarchical methods. By using it, one can avoid, for example, the "chain" effect, consisting in the creation of very elongated and uneven clusters. This undesirable effect is typical of many other agglomeration hierarchical methods (e.g., single linkage, average linkage), and does not occur in Ward's method, because it favours groups of similar size, which prevents the formation of clusters resembling a "chain." The grouping of countries using Ward's method was performed in the STATISTICA package.

4. Results and Discussion

The Bass model was estimated for 25 EU and 7 non-EU European countries. The study included only countries with available data on annual energy production from wind turbines for the years 1985–2023. The estimation results of model (1) for European countries are presented in Table 1. The asymptotic standard errors of the parameter estimates are given in parentheses, and the coefficients of determination are given in the last column.

Table 1. Results of Estimation of Parameters p, q and M in the Bass Model

Country	Symbol	Parameters			R^2
		p	q	M	
Austria	AUT	0.0020 (0.0007)	0.2209 (0.0610)	127.5310 (58.4092)	0.9991
Bulgaria	BLR	0.0001 (0.0000)	0.2194 (0.0965)	160.7375 (59.6336)	0.9962
Belgium	BEL	0.0001 (0.0000)	0.3266 (0.1114)	17.7803 (8.3212)	0.9996
Belarus	BGR	0.0012 (0.0003)	0.4830 (0.2106)	21.2182 (8.1902)	0.9988
Czech Republic	CZE	0.0007 (0.0003)	0.7391 (0.1966)	10.6650 (3.4341)	0.9769
Denmark	DNK	0.0032 (0.0007)	0.1268 (0.0569)	544.7865 (233.7134)	0.9842
Estonia	EST	0.0007 (0.0001)	0.7765 (0.4069)	70.7565 (28.1611)	0.9784
Finland	FIN	0.0031 (0.0011)	0.3832 (0.1813)	927.0251 (214.1428)	0.9829
France	FRA	0.0062 (0.0026)	0.3220 (0.1633)	430.7368 (130.9440)	0.9797

Table 1 cnt'd

Country	Symbol	Parameters			R^2
		p	q	M	
Germany	DEU	0.0080 (0.0010)	0.1757 (0.0803)	2963.0164 (1345.2094)	0.9924
Greece	GRC	0.0002 (0.0001)	0.6008 (0.0631)	50.3106 (16.2503)	0.9944
Hungary	HUN	0.0010 (0.0003)	0.7355 (0.2111)	101.9395 (38.0234)	0.9801
Ireland	IRL	0.0043 (0.0007)	0.4746 (0.1011)	22.4051 (4.2122)	0.9760
Italy	ITA	0.0079 (0.0010)	0.2431 (0.1133)	1534.6216 (214.8470)	0.9863
Latvia	LVA	0.0003 (0.0001)	0.6771 (0.1598)	302.6631 (127.4212)	0.9968
Lithuania	LTU	0.0006 (0.0002)	0.6317 (0.1870)	18.5520 (9.3873)	0.9980
Luxembourg	LUX	0.0001 (0.0000)	0.1834 (0.0638)	412.3438 (48.6566)	0.9871
Netherlands	NLD	0.0003 (0.0001)	0.1841 (0.0865)	1224.1204 (561.8713)	0.9843
North Macedonia	MKD	0.0001 (0.0000)	0.4185 (0.1276)	1.8211 (0.4134)	0.9890
Norway	NOR	0.0031 (0.0017)	0.3212 (0.0864)	82.8061 (41.2374)	0.9781
Poland	POL	0.0046 (0.0016)	0.3446 (0.0872)	902.0218 (343.6703)	0.9899
Portugal	PRT	0.0003 (0.0001)	0.2474 (0.0576)	225.4201 (54.5517)	0.9838
Romania	ROU	0.0012 (0.0004)	0.7645 (0.3387)	80.9809 (22.8366)	0.9927
Russia	RUS	0.0001 (0.0000)	0.3168 (0.0716)	1564.2958 (528.7320)	0.9954
Slovakia	SVK	0.0003 (0.0001)	0.6004 (0.2384)	1.9522 (0.7477)	0.9909
Slovenia	SVN	0.0002 (0.0001)	0.1875 (0.0958)	0.0838 (0.0219)	0.9831
Spain	ESP	0.0034 (0.0005)	0.1920 (0.0666)	2199.1364 (888.4511)	0.9900
Sweden	SWE	0.0036 (0.0014)	0.2947 (0.1314)	2380.7366 (630.8952)	0.9837

Table 1 cnt'd

Country	Symbol	Parameters			R^2
		p	q	M	
Switzerland	CHE	0.0002 (0.0001)	0.2705 (0.0995)	192.1953 (77.6469)	0.9772
Ukraine	UKR	0.0001 (0.0000)	0.5480 (0.2066)	161.6696 (31.8489)	0.9936
Great Britain	GBR	0.0058 (0.0032)	0.2868 (0.1259)	3039.7893 (556.2814)	0.9855
Croatia	HRV	0.0004 (0.0001)	0.6316 (0.2248)	27.8272 (6.5116)	0.9856

Source: own study.

To facilitate comparison of the results obtained between countries, the next three figures present 2-dimensional summaries of the values of all pairs of parameters of the BM. This facilitates the identification of countries with similar diffusion of innovations in wind energy and indication of possible regularities between the parameters of the Bass model in different groups of countries. Figure 1 illustrates the values of the p and q parameters for the compared European countries.

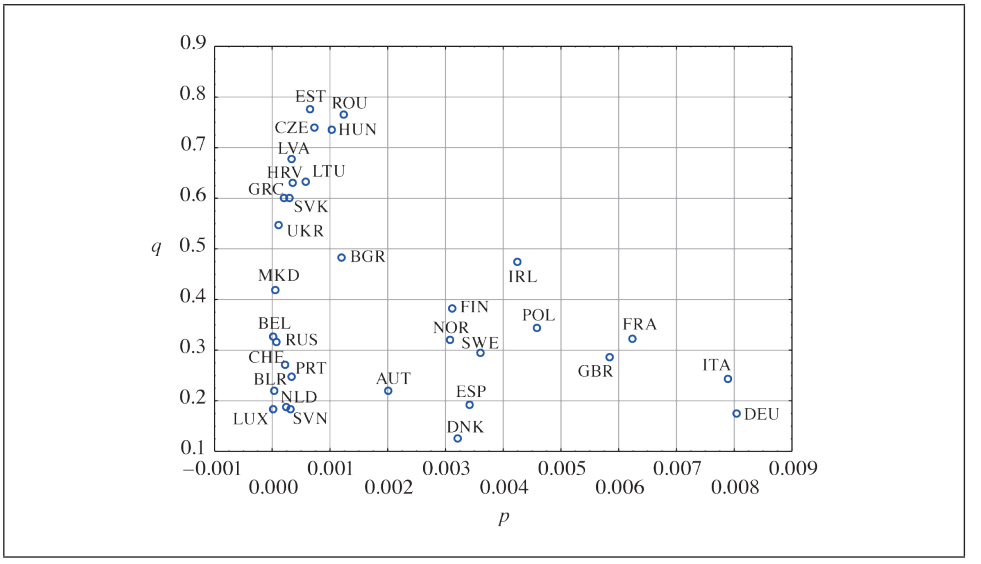

Fig. 1. Summary of the Values of Parameters p and q in the Bass Model Describing the Diffusion of Innovations in Wind Energy in European Countries

Source: own study.

Figure 1 shows that most countries are characterised by a low innovation rate and a low imitation rate. These include Central and Eastern European countries such as Ukraine, Russia, Bulgaria, Belarus, North Macedonia, but also Portugal, Switzerland and Belgium.

Their innovation index does not exceed 0.002, and their imitation index is lower than 0.5. Some of the countries mentioned supply their internal energy sector with nuclear energy (e.g., Russia, Ukraine), which may reduce the need to invest in renewable energy there. Noteworthy is the presence of Switzerland in this group of countries, where well-known wind turbine manufacturers operate. However, in this Alpine country, the key source of renewable energy is water (coming from melting glaciers) and investing in hydroelectric power plants is a priority there.

Another clearly distinguishable group of countries are imitators, characterised by low innovation and high imitation index levels. These include: Lithuania, Latvia, Estonia, Romania, Czech Republic, Hungary, Croatia, and Greece. Therefore, this group mainly includes the countries of Central and Eastern Europe, where expenditure on research and development is clearly lower than in the richer countries of Western Europe.

Countries considered innovators in wind technology with a high innovation index ($p > 0.002$) and a low level of imitation index are: Germany, France, Italy, Spain, Norway, Sweden, but also Poland. It is worth noting that these are mainly Western European countries, generally with a high level of GDP and a high share of research and development expenditure in relation to GDP. Each of them also has access to the sea, which enables the development of offshore wind energy, which is characterised by particularly high efficiency.

Figure 2 presents market potential indicators (M) of European countries and innovation indicators (p).

As shown in Figure 2, among the compared countries, the dominant ones are those with a low market potential index ($M < 1{,}500$) and late adopters of wind technologies ($p < 0.002$). These are mainly Central European countries and the Benelux countries. We also have a group of countries with low market potential but a high innovation rate. They included France, Norway, Ireland, Denmark and Austria. Among the compared countries, Great Britain, Sweden and Spain stand out with a clearly higher market potential ($M > 1{,}500$) and at the same time are pioneers of innovation in wind turbine technologies. Russia has high market potential but low innovation in the field of wind energy technology.

Figure 3 presents market potential indicators (M) of European countries and imitation indicators (q).

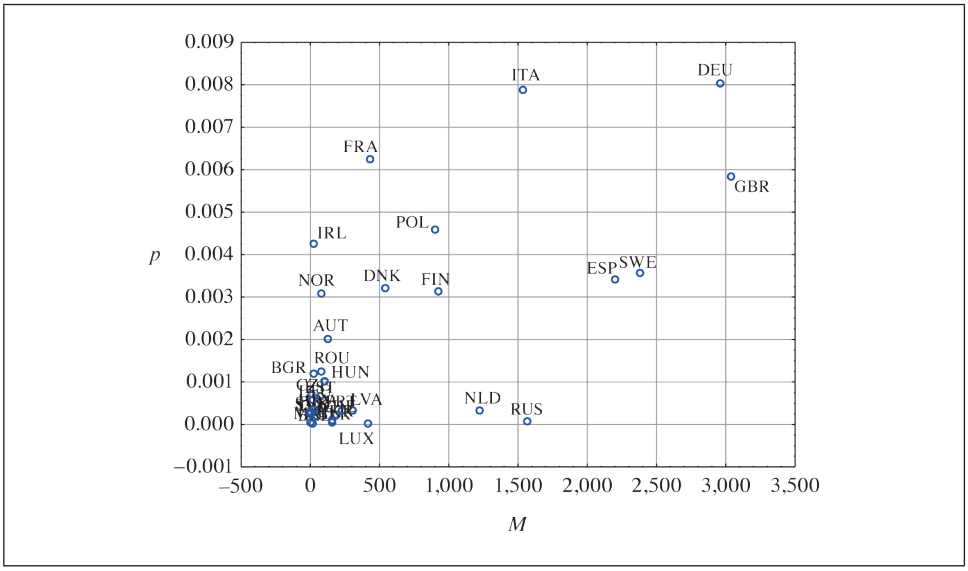

Fig. 2. Summary of the Values of Parameters *M* and *p* in the Bass Model Describing the Diffusion of Innovations in Wind Energy in European Countries

Source: own study.

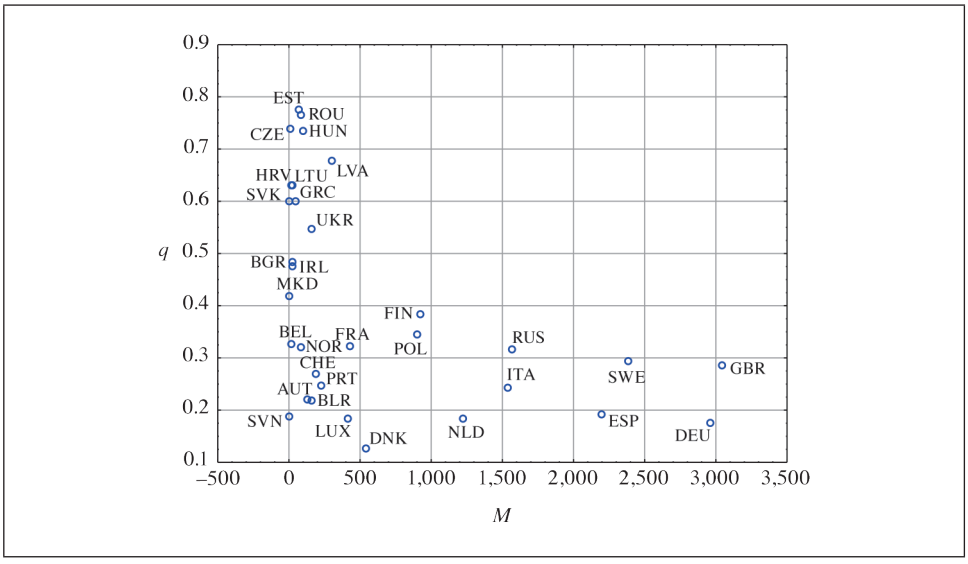

Fig. 3. Summary of the Values of Parameters *M* and *q* in the Bass Model Describing the Diffusion of Innovations in Wind Energy in European Countries

Source: own study.

Based on Figure 3, it can be concluded that the leading imitators of wind energy technology are countries with low market potential, such as Lithuania, Latvia, Estonia, the Czech Republic, Slovakia, Ukraine and Romania. Countries with high market potential ($M > 1{,}500$) are only small imitators of innovations in wind technologies ($q < 0.4$): Great Britain, Spain, Sweden, Germany, Italy, Russia. The dominant group consists of countries with low market potential and a low imitation index, including: the Benelux countries, Slovenia, Denmark, the Netherlands, Switzerland, Ireland, North Macedonia and Poland.

Using the the p, q and M parameters obtained in the Bass model, the compared countries were grouped. For this purpose, the Ward method with Euclidean distance was used, thanks to which clusters of countries with the most similar innovation diffusion profiles in wind energy technologies were identified. The results of this grouping are shown in Figure 4.

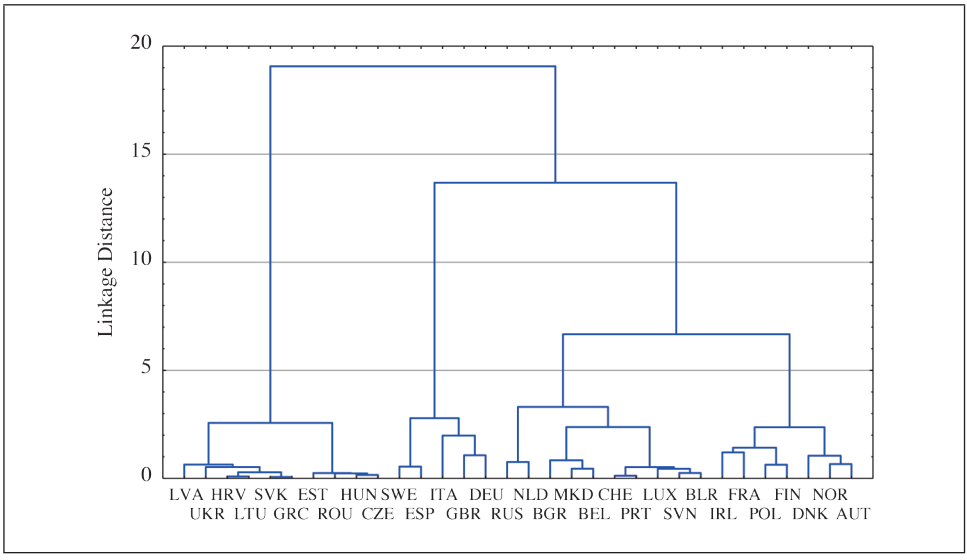

Fig. 4. Results of Grouping European Countries Using the Ward Method According to the Values of Parameters p, q and M Obtained from the Bass Model

Source: own study.

Using the criterion of the first clear increase in agglomeration distance, the dendrogram was cut off at the height of link 5 and as a result, four homogeneous clusters of countries with the following compositions were obtained:

– group one: Austria, Denmark, Finland, France, Ireland, Norway, Poland,

– group two: Czech Republic, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Romania, Slovakia, Ukraine,

– group three: Germany, Spain, Great Britain, Italy, Sweden,

– group four: Belgium, Bulgaria, Belarus, Switzerland, Luxembourg, North Macedonia, the Netherlands, Portugal, Russia, Slovenia.

The first group consists of countries with low market potential that are late adopters. All of the countries in this group, except Austria, have access to the sea, which provides them with favourable conditions for the development of offshore wind energy. Denmark, Norway, France, Finland and Ireland benefit from this in particular. The second group consists of leading imitators with limited market potential. This is a rather heterogeneous group of countries with diverse geographical, climatic, socio-political conditions and different availability of financing sources for wind energy sector development projects. Baltic countries and Balkan countries with a sea coastline have good wind conditions, so they invest more in wind energy development. Inland countries (e.g., Czech Republic, Hungary, Slovakia) have worse wind conditions and greater social resistance to the development of the wind energy sector. The third group comprises countries with significant market potential that are pioneers in the wind energy technology market. All countries in this group are investing in modern wind technologies and developing innovations in the area of building large turbines and offshore farms. Wind energy in this group of countries plays a key role in their energy mix. The fourth group consists of countries with low market potential, low innovation in wind turbines, and low imitation rates. These are countries that are less interested in developing wind energy. These countries, however, are very diverse in terms of wind energy development, as they include technologically advanced leaders such as Belgium, the Netherlands and Portugal, as well as countries less interested in developing wind energy, such as Belarus, Russia, Slovenia and Macedonia. Government support for this sector in group four is also very different, depending on the energy policy pursued by the governments of individual countries.

To determine which parameters significantly contributed to the differentiation of the resulting clusters, a one-way ANOVA was used. The obtained results showed that at the significance level of 0.001, all parameters (p, q, M) significantly differentiate the resulting clusters, and the greatest contribution to the differentiation of country clusters is made by the imitation index (q), for which the value of the F statistic = = 40.8946, and market potential had the smallest contribution (F = 35.6851).

5. Conclusions

Wind energy is undoubtedly a promising renewable energy sector, contributing increasingly to the decarbonisation of the economy in many countries. Modern wind energy employs technology with a beneficial impact on the environment, and its current disadvantages are gradually being eliminated and, most importantly, the costs of obtaining energy from wind are systematically reduced. Increasing the share

of this sector requires substantial investment and appropriate energy policy, which is often not possible without the support of government programmes or support from the EU. Creating a system for synchronisation and coordination of policies and actions towards the transformation of the power system requires detailed analyses in each country. The research results presented in this article address the research gap in comparative analysis of innovation diffusion profiles in wind energy across European countries. The innovators were identified as large countries with strong economies, high GDP, and a significant spending on research and development. The imitators, on the other hand, are primarily countries in Central, Eastern and Southern Europe, where the level of expenditure on research and development is lower than in Western Europe. Although it is challenging to formulate universal recommendations for the energy policy directions of all countries that entered the individual groups based on the obtained results, it seems that countries with low innovation and imitation indicators in many cases have a chance to improve their position in the progress of energy transformation. Typically, these countries should focus on technology transfer (import), simplifying regulations, expanding financial support systems and adapting solutions to local conditions. This can be achieved, among other things, by simplifying investment procedures, ensuring long-term predictability of legal provisions and administrative regulations, importing modern technologies through international cooperation, creating joint consortia with foreign companies and research institutes, expanding the package of incentives for the private sector interested in investing in wind energy. In many cases, modernisation of transmission networks and construction of energy storage facilities will also be indispensable. Increasing social acceptance of wind energy is also crucial, which can be achieved through appropriate ad hoc actions and educational programmes, but also through systemic changes in curricula at school or university level.

The diffusion process of innovations in wind energy technologies in European countries, as presented in this article, is confirmed by other researchers' results (Söderholm & Klaassen, 2007; Dalla Valle & Furlan, 2011; Skoczkowski, Bielecki & Wojtyńska, 2019). However, generally, other authors rarely conduct comprehensive comparative analyses allowing the identification of groups and profiles of countries with similar characteristics of the diffusion of innovations in wind energy. The presented research proposal, based on learning curves, has its limitations. The choice of model in innovation diffusion research is always a controversial issue. Moreover, the adopted method for describing the diffusion of innovations does not consider many factors that may influence the pace and size of this process, such as legal regulations, environmental conditions, price conditions and others. Therefore, future research may also consider endogenous models capable of forecasting wind energy development in individual countries, assuming different energy market development scenarios.

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Conflict of Interest

The author declares no conflict of interest.

References

Avila, S. (2018). Environmental Justice and the Expanding Geography of Wind Power Conflicts. *Sustainability Science*, *13*(3), 599–616. https://doi.org/10.1007/s11625-018-0547-4

Bass, F. M. (1969). A New Product Growth for Model Consumer Durables. *Management Science*, *15*(5), 215–227. https://doi.org/10.1287/mnsc.15.5.215

Bass, F. M. (2004). A New Product Growth for Model Consumer Durables. *Management Science*, *50*(12), 1825–1832. https://doi.org/10.1287/mnsc.1040.0264

Bin Abu Sofian, A. D. A., Lim, H. R., Siti Halimatul Munawaroh, H., Ma, Z., Chew, K. W., & Show, P. L. (2024). Machine Learning and the Renewable Energy Revolution: Exploring Solar and Wind Energy Solutions for a Sustainable Future Including Innovations in Energy Storage. *Sustainable Development*, *32*(4), 3953–3978. https://doi.org/10.1002/sd.2885

Bošnjaković, M., Katinić, M., Santa, R., & Marić, D. (2022). Wind Turbine Technology Trends. *Applied Sciences*, *12*(17), 8653. https://doi.org/10.3390/app12178653

Dalla Valle, A., & Furlan, C. (2011). Forecasting Accuracy of Wind Power Technology Diffusion Models across Countries. *International Journal of Forecasting*, *27*(2), 592–601. https://doi.org/10.1016/j.ijforecast.2010.05.018

Dhar, A., Naeth, M. A., Jennings, P. D., & El-Din, M. G. (2020). Perspectives on Environmental Impacts and a Land Reclamation Strategy for Solar and Wind Energy Systems. *Science of the Total Environment*, *718*, 134602. https://doi.org/10.1016/j.scitotenv.2019.134602

Dubarić, E., Giannoccaro, D., Bengtsson, R., & Ackermann, T. (2011). Patent Data as Indicators of Wind Power Technology Development. *World Patent Information*, *33*(2), 144–149. https://doi.org/10.1016/j.wpi.2010.12.005

Eurostat. (2024). *Renewable Energy Statistics*. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2022 (accessed: 25.07.2024).

Garsous, G., & Worack, S. (2022). Technological Expertise as a Driver of Environmental Technology Diffusion through Trade: Evidence from the Wind Turbine Manufacturing Industry. *Energy Policy*, *162*(C), 112799. https://doi.org/10.1016/j.enpol.2022.112799

Grafström, J., & Lindman, Å. (2017). Invention, Innovation and Diffusion in the European Wind Power Sector. *Technological Forecasting and Social Change*, *114*, 179–191. https://doi.org/10.1016/j.techfore.2016.08.008

Guidolin, M. (2023). *Innovation Diffusion Models: Theory and Practice*. Wiley. https://doi.org/10.1002/9781119756231

Harijan, K., Uqaili, M. A., Memon, K., & Mirza, U. K. (2011). Forecasting the Diffusion of Wind Power in Pakistan. *Energy*, *36*(10), 6068–6073. https://doi.org/10.1016/j.energy.2011.08.009

Hayashi, D., Huenteler, J., & Lewis, J. I. (2018). Gone with the Wind: A Learning Curve Analysis of China's Wind Power Industry. *Energy Policy*, *120*, 38–51. https://doi.org/10.1016/j.enpol.2018.05.012

Hernandez-Negron, C. G., Baker, E., & Goldstein, A. (2023). A Hypothesis for Experience Curves of Related Technologies with an Application to Wind Energy. *Renewable and Sustainable Energy Reviews*, *184*, 113492. https://doi.org/10.1016/j.rser.2023.113492

Horsky, D., & Simon, L. S. (1983). Advertising and the Diffusion of New Products. *Marketing Science*, *2*(1), 1–17. https://doi.org/10.1287/mksc.2.1.1

Lacerda, J. S., & Van den Bergh, J. C. J. M. (2014). International Diffusion of Renewable Energy Innovations: Lessons from the Lead Markets for Wind Power in China, Germany and USA. *Energies*, *7*(12), 8236–8263. https://doi.org/10.3390/en7128236

Lindman, Å., & Söderholm, P. (2012). Wind Power Learning Rates: A Conceptual Review and Meta-analysis. *Energy Economics*, *34*(3), 754–761. https://doi.org/10.1016/j.eneco.2011.05.007

Machado, M. R., & Dutkiewicz, M. (2024). Wind Turbine Vibration Management: An Integrated Analysis of Existing Solutions, Products, and Open-source Developments. *Energy Reports*, *11*, 3756–3791. https://doi.org/10.1016/j.egyr.2024.03.014

Markard, J., Geels, F. W., & Raven, R. (2020). Challenges in the Acceleration of Sustainability Transitions. *Environmental Research Letters*, *15*(8), 081001. https://doi.org/10.1088/1748-9326/ab9468

Meade, N., & Islam, T. (2006). Modelling and Forecasting the Diffusion of Innovation – a 25-year Review. *International Journal of Forecasting*, *22*(3), 519–545. https://doi.org/10.1016/j.ijforecast.2006.01.005

Murugesha, K. M., & Prasanna Kumar, B. (2012). Induced Diffusion of Innovation: A Study on Wind Energy Development in Karnataka. *Journal of Resources, Energy and Development*, *9*(2), 79–88. https://doi.org/10.3233/RED-120096

Omri, E., Chtourou, N., & Bazin, D. (2022). Technological, Economic, Institutional, and Psychosocial Aspects of the Transition to Renewable Energies: A Critical Literature Review of a Multidimensional Process. *Renewable Energy Focus*, *43*, 37–49. https://doi.org/10.1016/j.ref.2022.08.004

Our World in Data. (2024). https://ourworldindata.org/ (accessed: 20.06.2024).

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). Simon & Schuster.

She, Z.-Y., Cao, R., Xie, B.-C., Ma, J. J., & Lan, S. (2019). An Analysis of the Wind Power Development Factors by Generalized Bass Model: A Case Study of China's Eight Bases. *Journal of Cleaner Production*, *231*, 1503–1514. https://doi.org/10.1016/j.jclepro.2019.05.255

Sikora, A. (2021). European Green Deal – Legal and Financial Challenges of the Climate Change. *ERA Forum*, *21*(4), 681–697. https://doi.org/10.1007/s12027-020-00637-3

Skoczkowski, T., Bielecki, S., & Wojtyńska, J. (2019). Long-term Projection of Renewable Energy Technology Difusion. *Energies*, *12*(22), 4261. https://doi.org/10.3390/en12224261

Sokołowski, A. (1992). Empiryczne testy istotności w taksonomii. *Zeszyty Naukowe Akademii Ekonomicznej w Krakowie*, 108.

Söderholm, P., & Klaassen, G. (2007). Wind Power in Europe: A Simultaneous Innovation–Diffusion Model. *Environmental and Resource Economics*, *36*(2), 163–190. https://doi.org/10.1007/s10640-006-9025-z

Thompson, S. (2023). Strategic Analysis of the Renewable Electricity Transition: Power to the World without Carbon Emissions? *Energies*, *16*(17), 6183. https://doi.org/10.3390/en16176183

Vela Almeida, D., Kolinjivadi, V., Ferrando, T., Roy, B., Herrera, H., Vecchione Gonçalves, M., & Van Hecken, G. (2023). The "Greening" of Empire: The European Green Deal as the EU First Agenda. *Political Geography*, *105*, 102925. https://doi.org/10.1016/j.polgeo.2023.102925

Wheatley, M. C. (2024). Advancements in Renewable Energy Technologies: A Decade in Review. *Premier Journal of Science*, *1*, 100013. https://doi.org/10.70389/PJS.100013

Zhang, M., Cong, N., Song, Y., & Xia, Q. (2024). Cost Analysis of Onshore Wind Power in China Based on Learning Curve. *Energy*, *291*(C), 130459. https://doi.org/10.1016/j.energy.2024.130459

Zhang, X., Li, H., Liu, Q., & Tan, X. (2020). A Study on the Technology Diffusion of China's Solar Photovoltaic Based on Bass and Generalized Bass Model. *IOP Conference Series: Earth and Environmental Science*, *571*, 012016. https://doi.org/10.1088/1755-1315/571/1/012016

Zhou, D., Ding, H., Wang, Q., & Su, B. (2020). Literature Review on Renewable Energy Development and China's Roadmap. *Frontiers of Engineering Management*, *8*, 212–222. https://doi.org/10.1007/s42524-020-0146-9

Zwarteveen, W. J., Figueira, C., Zawwar, I., & Angus, A. (2021). Barriers and Drivers of the Global Imbalance of Wind Energy Diffusion: A Meta-analysis from a Wind Power Original Equipment Manufacturer Perspective. *Journal of Cleaner Production*, *290*, 125636. https://doi.org/10.1016/j.jclepro.2020.125636

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Sustainable Luxury: The Essence and Validation of the Measurement Tool

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ABSTRACT

Objective: The purpose of the study was to evaluate the validity and reliability of the proposed research questionnaire for recognising consumer beliefs towards sustainable luxury.
Research Design & Methods: The study employed the diagnostic survey method with the help of computer-assisted web interview, statistical analysis, synthesis, and logical inference.
Findings: The evaluation of the validity and reliability of the authors' survey questionnaire showed that it was an appropriate tool for studying the two indicators adopted, namely: the luxury product perception index and the luxury product buyers' perception index. A detailed evaluation of the questionnaire did not indicate the need for modification, which means that it can be proposed in this version for further in-depth research.
Implications/Recommendations: From a practical perspective, the proposed tool can be used by producers to identify the opinions of different age groups so that a better marketing strategy can be planned.

Contribution: Our study can be considered an original contribution to science when it comes to tools for surveying consumer opinion on luxury products in the context of sustainability requirements.

Article type: original article.

Keywords: luxury, sustainability, consumers, preferences, questionnaire, validation.

JEL Classification: D12, Q01.

1. Introduction

According to the official data, the revenue in the luxury goods market amounts to US$489.37 bn in 2026, and the market is expected to grow annually by 2.69% (Statista Market Insights, 2025). In parallel, it is emphasised that the perception of luxury has significantly changed in recent decades, for example, due to pandemics, economic crises, and climate change (Kunz, May & Schmidt, 2020; Ceron & Monge, 2024). There is also a gradual democratisation of luxury (Plażyk, 2015), which has increased its consumption and thus the share of the luxury market in the creation of national income (KPMG, 2024). It is well known that luxury products are reflective of high quality and exclusivity (Xie & Lou, 2020) or extraordinary design (Dryl, 2022). However, as researchers confirm, for a product to be called "luxury" it is insufficient for it to have superior quality and a particular design; it must also possess a specific symbolic meaning behind the product to be linked to the consumer's perception of luxury (Stanciu & Condrea, 2018). This symbolism is now beginning to be associated with sustainability (Carcano, 2013). Therefore, nowadays, owing to the paradigm of sustainable development, especially among very wealthy people, there is an interest in luxury products but made following this idea (Kim, Park & Septianto, 2022). The attitude of the average consumer towards the phenomenon of luxury products, in light of the requirements of sustainable development, also seems interesting, given the natural aspirations of every human being, wishing to improve their financial situation and life status in the near or distant future (Naaz *et al*., 2024). Taking into account European Union legislation (Directive 2005/29/EC of the European Parliament and of the Council of 11 May 2005), it can be assumed that an average consumer is considered duly (adequately) informed, aware, reasonable, attentive, cautious, critical, observant, and independent, as well as: (sufficiently) educated, suspicious and enlightened (Nowak-Gruca, 2019, pp. 3–16). Making this assumption, we conducted a study on the beliefs of such a consumer, taking into account a luxury product in the context of its sustainability. All the more so because such articles are scarce in the domestic scientific community. There is also a lack of tools to assess these beliefs. The sole studies in Poland

on sustainable luxury products so far have been presented by Dryl (2018a, 2018b), Stępień (2019), and Kemp and Dłużewska (2023), which was confirmed by a review of the repository database of the parent university, by introducing phrases in Polish like "luxury + sustainable development"; "sustainable luxury"; "luxury sustainable product" (on 25 July 2024). The first two papers are theoretical, the third focuses on analysing the perspective of luxury goods salesmen, and the fourth deals with the tourist industry, but is for illustrative purposes only. With the above in mind, a research tool was constructed to identify consumer beliefs towards a sustainable luxury product. The research problem seeks to answer the question: Is the proposed research questionnaire an appropriate tool for recognising consumer beliefs towards a sustainable luxury product? The purpose of the study was to evaluate the validity and reliability of the developed questionnaire. The study employed the diagnostic survey method with the help of computer-assisted web interview (CAWI), statistical analysis using appropriate software, and synthesis and logical inference.

2. Literature Background

The term "luxury" originates from the Latin *luxuria*, where *luxus* means "excess," or "superfluity" (Kiszkiel, 2020, p. 46). There is a consensus among scholars that consumers' associations with luxury products can be described by phrases such as good taste, class, quality, high price, eye-catching, uniqueness, rarity or limited availability, aesthetics, history, pleasure for self, and non-necessity (Kunz, May & Schmidt, 2020). Luxury goods serve not only to satisfy functional needs but also to fulfil the aesthetic and status desires of customers. Their role in society often goes beyond a utilitarian function, becoming a symbol of prestige and success (Pandelaere & Shrum, 2020, pp. 57–74). Luxury brands invest in high--quality materials, workmanship, and customer experience (Batat, 2019, pp. 55–74; Lu, Marjerison & Seufert, 2023), which confirms their value. As Devanathan (2023) points out in presenting the results of the literature review, the characteristics of luxury may broadly be described as 1) brand image (source: born from the history and heritage of the brand), 2) high quality and craftsmanship (source: as luxury is created in a workshop and is handcrafted rather than mass-produced), 3) high price (source: the high cost producing high quality and the restricted supply due to the method of production) and 4) exclusivity and uniqueness (source: the high price is combined with the limited supply and controlled distribution). Dryl and Dryl (2017), on the other hand, describe the features of luxury products this way:

– ostentation, through which a certain position in a reference group is achieved; luxury brands are a symbol of high social status,

– uniqueness, because owning products that other consumers cannot afford helps improve the personal and social image of their buyers; handmade production and unique design and high price reinforce the uniqueness of luxury brands,

– quality, because maintaining the quality of luxury products is a prerequisite for maintaining their luxury image,

– hedonism, as the consumption of luxury goods provides experiences such as pleasure and happiness,

– social values, as consumers identify with the values represented by luxury brands and thus wish to distinguish themselves from buyers of mass goods; by consuming specific luxury brands, customers expect to be identified with prestigious social groups while isolating themselves from lower social classes.

For this reason, a wide variety can be seen among the reasons for acquiring luxury goods. The main motivations for consumers to acquire luxury goods were primarily the desire to stand out in society and to have goods with unique attributes. Nowadays, on the other hand, the desire to be in the highest social group is noted. People belonging to the upper class acquire luxury goods to emphasise their wealth and superiority over others. For such individuals, it is not the quality of the product that is important, but the social status that this product provides them with (Bochańczyk-Kupka, 2014). Therefore, different categories of luxury goods consumers can be distinguished. For example, SRI Consulting Business Intelligence divides consumers into three groups based on their attitudes towards luxury (Solomon, 2022):

– luxury is functional – these customers allocate their money across items with long lifespans and lasting value. They research products thoroughly before making a purchase and choose rationally over-hasty or emotional decisions;

– luxury is a reward – these customers are older than the third group but younger than the first group. They declare, "I've made it," by using opulent items. These customers buy ostentatious luxury goods like expensive cars and residences in gated communities because they want to succeed and show others how successful they are;

– luxury is an indulgence – being the smallest of the three, this group skews slightly more male and includes a younger demographic than the other two. For these customers, the whole point of owning luxury is to indulge in extreme excess. This market is prepared to pay more for products that showcase their uniqueness and draw attention from others. They approach luxury spending more emotionally and are more prone to impulsive purchases than the other two groups.

According to research undertaken by the Netherlands consulting firm Kearney, sustainable products are 75–85% more expensive than conventional products (Gerhardt, Plack & Drost, 2020). Even more so if it involves luxury products with these features. High prices of luxury products cause consumers who cannot afford original products to look for similar but lower-priced substitutes (Song, Suri & Huang, 2023). Hence, there are products on the market, such as the Chanel type, the Dior type, etc. However, the luxury phenomenon has always been accompanied

by another, the counterfeiting of luxury brands. This, in turn, involves illegal activities and the theft of the brand and its logo (Wang *et al*., 2024a).

Thus, as shown, luxury has many facets. All the more the phenomenon of luxury is becoming increasingly linked to the need to provide it following the principles of sustainable development (Athwal *et al*., 2019; Kim, Park & Septianto, 2022). Therefore, any self-respecting brand cannot overlook the need to consider this requirement when shaping the quality of its products. In general, a sustainable product is a product that does not have significant negative impact on environmental and social systems, and this includes not only the use phase, but also the effects of raw materials, the production chain, the supply chain, the use phase, and finally the end of the shelf life, as the development of sustainable products requires consideration of the entire product life cycle. The sustainable product is often evaluated in terms of greenhouse gas emissions, energy efficiency, or environmental pollution (Kammerl *et al*., 2017, pp. 21–32). Given the current situation where wealthy consumers are increasingly worried about environmental and social issues, luxury companies are being pressured to showcase their sustainability initiatives. These businesses need to base their image and brand identity on values that the market and their customers would acknowledge and appreciate. In this regard, sustainable development plans provide an especially good foundation for enhancing the premium brands' and goods' value propositions (Andersen, Åberg & Bujac, 2023). Sustainable luxury is the concept of returning to the essence of luxury based on the tradition of thoughtful purchasing decisions, craftsmanship, the beauty of high-quality materials, and respect for social and environmental concerns. According to the above concept, a consumer of luxury goods is a person who has both the means and the motivation to care about the environment and people, to improve the quality of life for society as a whole (Dryl, 2018a, 2018b). According to Stępień (2019), the emphasis on the promotion and the implementation of this idea is a function of both the interest of the consumer and the importance attached to it by the brand itself. Talukdar and Yu (2020) point out that a sustainable luxury product is considered rare, authentic, and reflective of the desires of consumers who want not only a quality experience but also the satisfaction of having a positive impact on the environment. Kunz, May and Schmidt (2020) indicate that sustainable luxury affects whole supply chains and goes beyond the production of luxury products, making the incorporation of the exploitation of raw materials like gold necessary to fully understand its idiosyncrasy compared to sustainable commodity goods. Sustainability is perceived by consumers as a complementary model to luxury, especially among the wealthy. The researchers add that whenever a brand is perceived as "making luxury" in terms of craftsmanship, rare materials, and anchorage in its origins (local manufacturing, heraldic tradition of protection of soil), luxury is complementary to sustainability, through sustainability in ethos (e.g., eco-brands such as Stella McCartney or Edun

in luxury fashion or Tesla Roadster and Venturi luxury cars), commitment all along the supply chain (Gucci group, Porsche) and/or introduction of eco-collection and eco-lines (BMWi3 electric cars, Vranken-Pommery Pop Earth Champagne, Gucci sunglasses made out of liquid wood produced from sustainably managed forests) (Cervellon & Shammas, 2013). Next, luxury products are typically more reliable and durable, and therefore do not require repair or parts replacements like other products, and thus, do not generate waste. They are also often passed down from generation to generation.

There is also no shortage of voices saying that given the association of luxury consumption with ostentation, overconsumption, overproduction, indulgence, and personal pleasure, the conflicts between luxury and sustainability become evident (Athwal *et al*., 2019). For example, according to Kapferer and Michaut (2015), elements related to ostentation will oppose the fairness or social harmony facets of sustainable development. Luxury values are often coupled with personal pleasure, while sustainable consumption is linked to moderation and ethics.

To be objective it should be pointed out that some luxury brands still violate various aspects of the idea of sustainability. This is particularly true of fashion brands. According to Goodman, Wang and Paton (2021), the supply chains present in such businesses are "long and opaque," with violations happening at different stages of the clothing item's journey from field to shelf – starting from cotton mills to the weaving, dyeing, and finishing stage. In particular, such negative phenomena as excessive water consumption, exploitation of scarce resources, the destruction of rain forests, bulging landfills, toxic chemicals usage, and modern slavery are highlighted (Arrington, 2017). Studies conducted on the subject confirm that the problem is very broad and that the phenomenon itself threatens human health and life (Bhakoo & Meshram, 2021, pp. 268–280) as well as the welfare of animals (Achabou, 2021, pp. 18–36). This is because it also applies to other luxury industries, such as jewellery (Taifa, 2021, pp. 199–228), and the cosmetics industry (Macer, 2023, pp. 575–590), but also to services, such as hospitality (Minor & Heyes, 2022, pp. 425–442).

3. Methodology

The article verifies the validity and reliability of a tool for measuring consumer perceptions of luxury products in the context of sustainability. Such measurement involves answering the question of whether the constructed scale measured the phenomenon it was built to measure and how accurate this measurement is. Validity describes the degree of consistency with which a measurement tool measures what it was constructed to measure (Stanisz, 2007, p. 435). Reliability is a measure of the extent to which a test result reflects the true value of the trait under study and the extent to which it is distorted by errors that have different sources (Brzyski,

Knurowski & Tobiasz-Adamczyk, 2003). The questionnaire comprised metric questions to identify the socio-demographic status of respondents, such as age, gender, education, place of residence, per capita income, and whether they work. The content part consisted of 10 items to analyse the two assumed indicators:

– the luxury product perception index (LPPI), which relates to the perspective of quality (PP1), manufacturing in terms of exploitation of raw materials (PP2), manufacturing that takes into account respect for animal rights (PP3), and human rights (PP4),

– the luxury product buyers' perception index (LPBPI), such as attitudes toward those who own luxury goods and their living situation (PO1 and PO2), a satisfaction of hedonistic needs (PO3 and PO4), a degree of desire for luxury goods (PO5 and PO6),

and two multiple-choice questions PR1 and PR2, which respectively addressed the types of luxury products purchased and the reasons why such products are not purchased (see Table 1).

Table 1. Survey Questionnaire Statements

Statements' Symbols	Statement
PP1	I believe that luxury goods are of higher quality than others
PP2	I believe that the production of many luxury products is combined with the over-exploitation of raw materials
PP3	I believe that the production of many luxury products contradicts respect for animal rights
PP4	I believe that the production of many luxury products conflicts with respect for human rights (e.g., the use of child labour, and poor working conditions)
PO1	I admire people who own expensive houses, cars, and clothes
PO2	I believe that what we own says a lot about how well we are doing in life
PO3	Buying expensive things can give a lot of pleasure
PO4	I would be happy if I could afford to buy more luxury items
PO5	I like having a lot of luxury in my life
PO6	My life would be better if I had certain things that I don't have
PR1	If I buy luxury goods, these are: not applicable (because I don't buy); cosmetics; foodstuffs; household appliances – AGD; home equipment other than household appliances; clothes; footwear; jewellery
PR2	If I do not (never or rarely) buy luxury goods, it is because (you can indicate more than one answer): not applicable (because I buy); I can't afford them because of the high price; I think you can do without them; I believe that you can find similar ones of lower quality; I think it is a manifestation of snobbery

Source: own elaboration.

A five-point Likert scale was used to construct the questionnaire with the following response options (except for questions PR1 and PR2): "definitely no," "no," "undecided," "yes," and "definitely yes" (Edmondson, 2005). According to Nunnally and Bernstein (1994), there should be fewer items in the scale than the sample size. According to Gorusch (1983), the number of respondents for the study to validate the questionnaire, as a minimum, should correspond to the following principle: 50 respondents for a 10-item questionnaire. Bujang *et al*. (2024) suggest that for conducting a study to assess the reliability of a questionnaire, the number of 30 respondents is sufficient. In contrast, Yurdugül (2008, pp. 397–405) assumes that a sample of 30 to 50 is appropriate. And according to Samuels (2017), ideally, the sample should be between 50 and 100. Therefore, bearing in mind that our questionnaire consists of 12 substantive items, we adopted a value of 60 as the minimum sample. Ultimately, 81 people responded to the invitation. The assessment of relevance and reliability was based on a voluntary and anonymous survey conducted from January to March 2024, using the computer-assisted web interview (CAWI) method. The questionnaire was distributed via the Google Forms platform. Anyone willing to participate in the survey was invited. To test the validity of the test, the 10 parts of the scale were subjected to factor analysis, in which the factors were extracted using the principal components method. The validity of the use of factor analysis was demonstrated by Bartlett's test of sphericity, assuming that the correlation matrix of the variables would not be unitary (that is, one with ones on the diagonal and zeros on the other fields), and by the Kaiser-Mayer-Olkin (KMO) factor (Wieczorkowska & Wierzbiński, 2007, p. 322). This coefficient tests the adequacy of the correlation matrix, taking a threshold value of 0.7.

In assessing the relevance, it was assumed that the eigenvalues of the extracted factors would be greater than 1 (Kaiser criterion) and that the variables forming each scale would correlate at least at the level of 0.6 with the first principal component forming the scale, which means a value of factor loadings greater than 0.6. Reliability was tested by analysing the internal consistency of the scales. It was assumed that the scales studied would have a Cronbach's coefficient higher than 0.7 (Nunnally's criterion) (Nunnally, 1976).

The analysis was conducted using the IBM SPSS Statistics package.

4. Results and Discussion

4.1. Characteristics of Respondents

Among the respondents, more than 70% were women, almost 24% were men, and the rest (more than 6%) were non-binary or did not want to comment on their gender. More than 70% of respondents were aged 23–26, 14% were aged 27–37, 7% were over 37, and 9% were aged 18–22. More than half of the respondents held

a bachelor's degree, 27% held a master's degree, 5% held a doctoral degree, and 10% had completed a high school education. The largest proportion of respondents lived in cities with more than 100,000 residents (46%), 41% in cities with up to 100,000 residents, 9% in cities with up to 10,000 residents, and 5% in rural areas. 46% of respondents had a *per capita* household income of PLN 3,000–4,999, and 31% earned less than PLN 3,000. Income in the range of 5 to 10 thousand PLN was declared by 12% of respondents, while above 10 thousand PLN – 11% of respondents. Among the respondents, 89% were employed.

4.2. Verification of the Research Tool

The validity of conducting a factor analysis for the scales in the questionnaire was confirmed by the results of Bartlett's sphericity test and the KMO coefficient value. The test yielded a statistic value of $chi^2 = 554.097$ ($df = 45$, $p < 0.001$), which allows us to accept the hypothesis that the data can be used to perform factor analysis. The KMO value (a measure of sampling adequacy) is 0.826, which is higher than the assumed threshold value (see Table 2).

Table 2. Kaiser-Meyer-Olkin and Bartlett Tests for Variables PO1–PO6 and PP1–PP4

KMO measure of sampling adequacy		0.826
Bartlett's sphericity test	Approximate chi-square	554.097
	df	45
	Relevance	< 0.001

Source: own study.

Table 3. Total Explained Variance for Variables PO1–PO6 and PP1–PP4

Component	Initial Intrinsic Values			Sums of Squares of Loads after Rotation		
	Total	% of variance	% cumulative	Total	% of variance	% cumulative
1	5.403	54.026	54.026	4.386	43.857	43.857
2	1.669	16.690	70.716	2.686	22.859	70.716

Notes: Method of extracting factors – main components.

Source: own study.

As a result of the factor analysis conducted for the scales in questions PP1–PP4 and PO1–PO6, two factors (components) were extracted, which together explained 70.72% of the scale's variation. The value of the extracted factors was 5.403 and 1.669, respectively (see Table 3). The first component included variables referred to as the LPPI and the second component variables were elements of the LPBPI. The variables included in the scale had load values ranging from 0.581 to 0.876

(see Table 4). Cronbach's α coefficient for the standardised items was 0.900, which confirms the reliability of the questionnaire used.

Table 4. Matrix of Components for Variables PO1–PO6 and PP1–PP4

Item	Component	
	1	2
PO4	0.876	0.244
PO6	0.858	0.256
PO2	0.815	0.295
PO1	0.794	0.190
PO5	0.791	–0.106
PO3	0.758	0.301
PP3	0.176	0.818
PP2	0.214	0.817
PP4	0.065	0.813
PP1	0.554	0.581

Notes: Method of extracting factors – main components.

Source: own study.

For the variables included in the luxury product perception index (PP1–PP4), the validity of conducting a factor analysis for the scales in the index was confirmed by the results of Bartlett's sphericity test and the value of the KMO coefficient. The test yielded a statistic value of $chi^2 = 117.097$ ($df = 6$, $p < 0.001$), which allows us to accept the hypothesis that the data can be used to perform factor analysis. The KMO value (a measure of sampling adequacy) is 0.725, which is higher than the assumed threshold value (see Table 5).

Table 5. Kaiser-Meyer-Olkin and Bartlett Tests for Variables PP1–PP4

KMO measure of sampling adequacy		0.725
Bartlett's sphericity test	Approximate chi-square	117.097
	df	6
	Relevance	< 0.001

Source: own study.

As a result of the factor analysis conducted for the scales in questions PP1–PP4, one factor was extracted that explained 64.65% of the scale's variability. The value of the extracted factor was 2.586 (see Table 6). The variables included in the scale had loading values ranging from 0.753 to 0.859 (see Table 7). Cronbach's α coefficient based on standardised items was 0.816.

Table 6. Total Explained Variance for Variables PP1–PP4

Component	Initial Intrinsic Values			Sums of Squares of Loads after Separation	
	Total	% of variance	% cumulative	Total	Cumulative % of variance
1	2.586	64.647	64.647	2.586	64.647

Notes: Method of extracting factors – main components.

Source: own study.

Table 7. Matrix of Components for Variables PP1–PP4

Item	Component 1
PP2	0.859
PP3	0.830
PP4	0.771
PP1	0.753

Notes: Method of extracting factors – main components.

Source: own study.

For the variables included in the luxury shoppers' perception index (PO1–PO6), the validity of conducting a factor analysis for the scales in the index was also confirmed by the results of Bartlett's sphericity test and the value of the KMO coefficient. The test yielded a statistic value of $chi^2 = 354.697$ ($df = 15, p < 0.001$), which allows us to accept the hypothesis that the data can be used to perform factor analysis. The KMO value (a measure of sampling adequacy) is 0.857, which is higher than the assumed threshold value (see Table 8).

Table 8. Kaiser-Meyer-Olkin and Bartlett Tests for Variables PO1–PO6

KMO measure of sampling adequacy		0.857
Bartlett's sphericity test	Approximate chi-square	354.697
	df	15
	Relevance	< 0.001

Source: own study.

As a result of the factor analysis conducted for the scales in questions PO1–PO6, one component was extracted that explained 71.035% of the scale's variability. The value of the extracted factor was 4.262 (see Table 9). The variables included in the scale had loading values ranging from 0.733 to 0.909 (see Table 10). Cronbach's α coefficient based on standardised items was 0.917.

Table 9. Total Explained Variance for Variables PO1–PO6

Component	Initial Intrinsic Values			Sums of Squares of Loads after Separation	
	Total	% of variance	% cumulative	Total	Cumulative % of variance
1	4.262	71.035	71.035	4.262	71.035

Notes: Method of extracting factors – main components.

Source: own study.

Table 10. Matrix of Components for Variables PO1–PO6

Item	Component 1
PO4	0.909
PO6	0.891
PO2	0.865
PO1	0.837
PO3	0.810
PO5	0.733

Notes: Method of extracting factors – main components.

Source: own study.

The distribution of responses to the two open-ended questions, namely PR1 and PR2, are illustrated in Figure 1 and Figure 2, respectively. In both cases, more than one answer could be indicated. Due to the risk of unrepresentative sampling, these results should be treated as causative. Nevertheless, as Apanowicz (2005, p. 43) points out, causative studies, although they deal with a narrower group of the population, are very often used to provide a preliminary overview of a problem (topic, issue), and due to their high cognitive value, these studies are widely used, especially in empirical work. The survey shows that the most frequently purchased luxury goods were clothing (58% of indications). It can be added that right after cars and hotel and spa services, which were not the subject of our study, it is clothing and other accessories that account for the value and structure of the luxury goods market (KPMG, 2024). This was followed by respondents indicating footwear (49% of indications), and cosmetics (31% of indications). One in four people pointed to jewellery products, and slightly fewer to household appliances (24% of indications).

Nearly 14% of respondents did not buy luxury goods. As one can see, this group is relatively small and the respondents, however, aspire to use luxury products in the future. Since the surveyed group had the largest number of representatives of Generation Z, it should be noted that the power of Generation Z is because it is

at the forefront of social and cultural changes. Characteristic of the younger part of society is the search for meaning to define what is most important and moving towards more "purposeful" purchases, emphasising "lived experiences" and concern for the environment. Luxury brands will need to address their needs accordingly in the future (KPMG, 2024). Moreover, as Shin, Eastman and Li (2022) convince, Generation Z's relationships with luxury brands are characterised by "like" rather than "love"; while Generation Z may feel a high level of loyalty towards luxury brands in terms of attitudes and behaviours, they do not necessarily have strong, passionate feelings for them. Nevertheless, the rise of Generation Z consumers has hit the luxury industry, placing new demands on sustainable design for luxury goods (Wang *et al*., 2024b). Consumers will increasingly expect greater transparency, ethical manufacturing practices production, and environmentally friendly processes of creation. Discerning consumers expect authenticity and mission from luxury brands. They support those brands that agree with their values and work for the benefit of society and the environment (KPMG, 2024).

Those who did not buy luxury goods mostly indicated that it was a sign of snobbery (64% of indications). Stępień and Mruk (2017) point out that Poles often take a negative view of the pursuit of luxury, seeing it as a manifestation of snobbery. On the other hand, when they buy such goods, they are often guided by motives, which can be considered snobbish. Similar opinions on luxury products were expressed by consumers in surveys conducted by Newerli-Guz, Rybowska and Sterczyński (2014). Among others, the association of luxury with snobbery was also shown by Schweiger *et al*. (2020, pp. 150–169), and Saruchera and Mthombeni (2023).

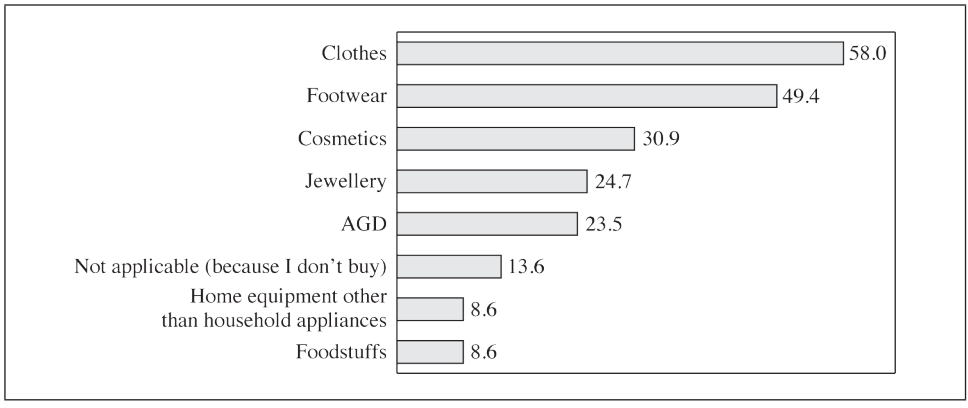

Fig. 1. Responses to PR1: "If I Buy Luxury Goods, These Are…" (% of Indications)
Source: own study.

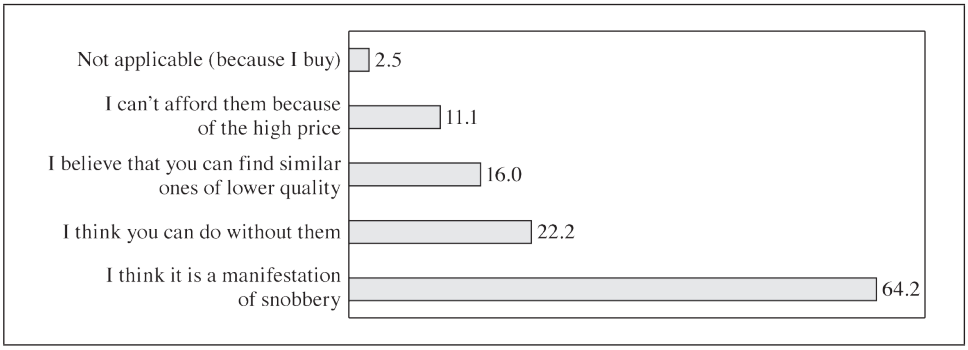

Fig. 2. Responses to PR2: „If I Do Not (Never or Rarely) Buy Luxury Goods, It Is because…" (% of Indications)

Source: own study.

More than one in four said that one can do without luxury (22%), and this is because, as mentioned, luxury products are not necessities (Kunz, May & Schmidt, 2020). 11% do not buy luxury goods because of their high price (Devanathan, 2023), and 16% think that one can find similar products, albeit of lower quality (Song, Suri & Huang, 2023).

5. Conclusions

The evaluation of the validity and reliability of the authors' survey questionnaire showed that it was an appropriate tool for studying the two indicators adopted, namely: the luxury product perception index (LPPI) and the luxury product buyers' perception index (LPBPI). A detailed evaluation of the questionnaire did not indicate the need for modification, which means that it can be proposed in this version for further in-depth research. The evaluation of these indicators showed that they properly measure what they are supposed to measure. The analysis also showed that the test result reflects the true value of the trait under study.

Our study can be considered an original contribution to science when it comes to tools for surveying consumer opinion on luxury products in the context of sustainability requirements.

The motivation to purchase and consume luxury products is different. Therefore, from a practical perspective, the proposed tool can be used by producers to identify the opinions of different age groups so that a better marketing strategy can be planned. All the more so because our research, although it should be treated as causative, has shown that young consumers' interest in luxury products is quite significant.

We are aware of the limitations of the conducted study due to the relatively small group of respondents and the ongoing discussion on its size in this type of research. Therefore, to further verify the validity and reliability of the authors' questionnaire, the research should be continued with a more numerous and diverse sample in terms of the adopted socio-demographic characteristics.

Authors' Contribution

The authors' individual contribution is as follows: Małgorzata Zdzisława Wiśniewska: conceptualisation, methodology, writing – original draft, writing – review and editing, supervision; Eugenia Czernyszewicz: writing – original draft, visualisation, methodology, formal analysis, software; Wiktoria Kosznik: investigation, resources.

Conflict of Interest

The authors declare no conflict of interest.

References

Achabou, M. A. (2021). Is Animal Welfare a Central Issue for Consumers of Luxury Goods? *Natural Resources Forum*, *45*(1), 18–36. https://doi.org/10.1111/1477-8947.12211

Andersen, P. H., Åberg, S., & Bujac, A. (2023). Corporate Sustainable Brand Identity Work and Network Embeddedness: Learnings from Better Place (2007–2013). *Industrial Marketing Management*, *115*, 526–538. https://doi.org/10.1016/j.indmarman.2023.10.014

Apanowicz, J. (2005). *Metodologiczne uwarunkowania pracy naukowej*. Centrum Doradztwa i Informacji Difin.

Arrington, D. W. (2017). Ethical and Sustainable Luxury: The Paradox of Consumerism and Caring. *Fashion, Style & Popular Culture*, *4*(3), 277–285. https://doi.org/10.1386/fspc.4.3.277_1

Athwal, N., Wells, V. K., Carrigan, M., & Henninger, C. E. (2019). Sustainable Luxury Marketing: A Synthesis and Research Agenda. *International Journal of Management Reviews*, *21*(4), 405–426. https://doi.org/10.1111/ijmr.12195

Batat, W. (2019). Customer Experience to Keep up with Changing Consumer and New Luxury Consumption Trends. In: W. Batat, *The New Luxury Experience: Creating the Ultimate Customer Experience* (pp. 55–74). Springer. https://doi.org/10.1007/978-3-030-01671-5_3

Bhakoo, V., & Meshram, K. (2021). Modern Slavery in Supply Chains. In: T. Maak, N. Pless, M. Orlitzky, S. Sandhu (Eds), *The Routledge Companion to Corporate Social Responsibility*. Routledge.

Bochańczyk-Kupka, D. (2014). Luksus i dobra luksusowe. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, 176, 97–108.

Brzyski, P., Knurowski, T., & Tobiasz-Adamczyk, B. (2003). Trafność i rzetelność kwestionariusza oceny ogólnego stanu zdrowia SF-20 w populacji osób w podeszłym wieku. *Przegląd Epidemiologiczny – Epidemological Review*, *57*(4), 693–702.

Bujang, M. A., Omar, E. D., Foo, D. H. P., & Hon, Y. K. (2024). Sample Size Determination for Conducting a Pilot Study to Assess the Reliability of a Questionnaire. *Restorative Dentistry and Endodontics*, *49*(1), e3. https://doi.org/10.5395/rde.2024.49.e3

Carcano, L. (2013). Strategic Management and Sustainability in Luxury Companies: The IWC Case. *The Journal of Corporate Citizenship*, *52*, 36–54. https://doi.org/10.9774/GLEAF.4700.2013.de.00006

Ceron, B. M., & Monge, M. (2024). Luxury Goods and Services in Recession Periods. Time Trends and Persistence Analysis. *Journal of Revenue and Pricing Management*, *23*, 588–595. https://doi.org/10.1057/s41272-023-00469-z

Cervellon, M.-C., & Shammas, L. (2013). The Value of Sustainable Luxury in Mature Markets: A Customer-based Approach. *The Journal of Corporate Citizenship*, *52*, 90–101.

Devanathan, S. (2023). Tracing the Characteristics and Consequences of Luxury through a Review of Literature. *International Journal of Professional Business Review*, *8*(11), e03870. https://doi.org/10.26668/businessreview/2023.v8i11.3870

Directive 2005/29/EC of the European Parliament and of the Council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market and amending Council Directive 84/450/EEC, Directives 97/7/EC, 98/27/EC and 2002/65/EC of the European Parliament and of the Council and Regulation (EC) No 2006/2004 of the European Parliament and of the Council ("Unfair Commercial Practices Directive") (Text with EEA relevance), OJ L 149, 11.6.2005.

Dryl, W. (2018a). Can a Luxury Brand Be Socially Responsible? Luxury Business and Corporate Social Responsibility – Areas of Coexistence. *International Journal of Contemporary Management*, *17*(4), 65–91. https://doi.org/10.4467/24498939IJCM.18.037.10023

Dryl, W. (2018b). Zrównoważony luksus – wyzwanie i szansa dla przedsiębiorstw działających na rynku dóbr luksusowych. *Ekonomika i Organizacja Przedsiębiorstwa*, 8, 24–32.

Dryl, W. (2022). History as a Factor Creating the Value of a Luxury Brand. *Annales Universitatis Mariae Curie-Skłodowska. Sectio H Oeconomia*, *56*(5), 63–80. https://doi.org/10.17951/h.2022.56.5.63-80

Dryl, W., & Dryl, T. (2017). Wartości marki luksusowej i ich znaczenie w procesie kształtowania luksusowego charakteru produktu. *Nowoczesne Systemy Zarządzania*, *12*(1), 169–182. https://doi.org/10.37055/nsz/129459

Edmondson, D. R. (2005). Likert Scales. A History. *CHARM. The Future of Marketing's Past*, *12*, 127–133.

Gerhardt, C., Plack, M., & Drost, N. (2020). *Why Today's Pricing is Sabotaging Sustainability*. Kearney. Retrieved from: https://www.kearney.com/documents/291362523/291369552/Why+todays+pricing+sabotages+sustainability.pdf/38b0b917-886d-3d47-c7b7-74dc6d-89c636?t=1599751848000 (accessed: 18.05.2026).

Goodman, P. S., Wang, V., & Paton, E. (2021). Global Brands Find It Hard to Untangle Themselves from Xinjiang Cotton. *The New York Times*. Retrieved from: https://www.nytimes.com/2021/04/06/business/xinjiang-china-cotton-brands.html (accessed: 12.08.2024).

Gorusch, R. L. (1983). *Factor Analysis* (2nd ed.). Lawrence Erlbaum Associates.

Kammerl, D., Schockenhoff, D., Hollauer, C., Weidmann, D., & Lindemann, U. (2017). A Framework for Sustainable Product Development. In: M. Matsumoto, K. Masui, S. Fukushige, S. Kondoh (Eds), *Sustainability through Innovation in Product Life Cycle Design* (pp. 21–32). Springer. https://doi.org/10.1007/978-981-10-0471-1_2

Kapferer, J.-N., & Michaut, A. (2015). Luxury and Sustainability: A Common Future? The Match Depends on How Consumers Define Luxury. *Luxury Research Journal*, *1*(1), 3–17. https://doi.org/10.1504/LRJ.2015.069828

Kemp, M., & Dłużewska, A. (2023). Defining Luxury and High-end Tourism – Reflections on the Key Issues and Market Trends. *Annales Universitatis Mariae Curie-Skłodowska. Geographia, Geologia, Mineralogia et Petrographia*, *78*, 21–37. https://doi.org/10.17951/b.2023.78.0.21-37

Kim, J., Park, J., & Septianto, F. (2022). The Impact of Socioeconomic Status on Preferences for Sustainable Luxury Brands. *Psychology & Marketing*, *39*(8), 1563–1578. https://doi.org/10.1002/mar.21671

Kiszkiel, Ł. (2020). *Społeczne „piętno" luksusu. Rywalizacja o pozycję w hierarchii społecznej*. Wydawnictwo Uniwersytetu w Białymstoku.

KPMG. (2024). *Rynek dóbr luksusowych w Polsce. Nowe wymiary luksusu*. Retrieved from: https://kpmg.com/pl/pl/home/insights/2024/05/rynek-dobr-luksusowych-w-polsce-nowe-wymiary-luksusu.html (accessed: 14.08.2024).

Kunz, J., May, S., & Schmidt, H. J. (2020). Sustainable Luxury: Current Status and Perspectives for Future Research. *Business Research*, *13*(10), 541–601. https://doi.org/10.1007/s40685-020-00111-3

Lu, S., Marjerison, R. K., & Seufert, J. H. (2023). Experiential Marketing, Customer Engagement, and Brand Loyalty in the Luxury Fashion Industry: Empirical Evidence from China. *Review of Integrative Business and Economics Research*, *12*(2), 58–79.

Macer, D. R. (2023). Ethical Issues from the Use of Animals in the Cosmetics and Fashion Industries. In: E. Valdés, J. A. Lecaros (Eds), *Handbook of Bioethical Decisions. Volume II: Decisions at the Bench* (pp. 575–590). Springer International Publishing.

Minor, K., & Heyes, A. (2022). 50 Shades of the Luxury Hospitality Industry. In: A. S. Kotur, S. K. Dixit (Eds), *The Emerald Handbook of Luxury Management for Hospitality and Tourism*. Emerald Publishing Limited. https://doi.org/10.1108/978-1-83982-900-020211021

Naaz, I., Malik, A., Abdullah, M., Tabash, M. I., & Elsantil, Y. (2024). Role of Key Demographic Factors in Consumer Aspirations and Luxury Brand Preference. *Innovative Marketing*, *20*(2), 254–266. https://doi.org/10.21511/im.20(2).2024.21

Newerli-Guz, J., Rybowska, A., & Sterczyński, R. (2014). Luksusowe usługi kosmetyczne i medycyny estetycznej w opinii konsumentów. *Handel Wewnętrzny*, *4*(351), 251–262.

Nowak-Gruca, A. (2019). Europejski model ochrony konsumenta w kontekście human enhancement. Zarys problemów i wyzwań. In: B. Gnela, E. Sługocka-Krupa, M. Szaraniec, A. Viglianisi Ferraro (Eds), *Prawo konsumenckie w Polsce oraz innych państwach UE. Zagadnienia wybrane*. Wydawnictwo C.H. Beck.

Nunnally, J. C. (1976). *Psychometric Theory*. McGraw-Hill Book Company.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill.

Pandelaere, M., & Shrum, L. J. (2020). Fulfilling Identity Motives through Luxury Consumption. In: F. Morhart, K. Wilcox, S. Czellar (Eds), *Research Handbook on Luxury Branding* (pp. 57–74). Edward Elgar Publishing. https://doi.org/10.4337/9781786436351.00014

Plażyk, K. (2015). Funkcjonowanie rynku dóbr luksusowych w Polsce. *Studia Ekonomiczne*, 231, 80–100.

Samuels, P. (2017). *Advice on Reliability Analysis with Small Samples – Revised Version*. Birmingham City University. Centre for Academic Success. Retrieved from: https://www.open-access.bcu.ac.uk/6077/1/__staff_shares_storage%20500mb_Library_ID112668_Stats%20Advisory_New%20Statistics%20Workshops_17ReliabilityAnalysis_Reliability-SmallSamples3.pdf (accessed: 12.08.2024).

Saruchera, F., & Mthombeni, L. (2023). Antecedents to the Conspicuous Consumption of Luxury Fashion Brands by Middle-income Black South Africans. *Journal of Fashion Marketing and Management: An International Journal*, *27*(6), 944–964. https://doi.org/10.1108/JFMM-06-2022-0126

Schweiger, E., Grewal, D., Roggeveen, A. L., & Beitelspacher, L. S. (2020). Managing the Luxury Shopping Experience: Implications for Retail Channels. In: F. Morhart, K. Wilcox, S. Czellar (Eds), *Research Handbook on Luxury Branding* (pp. 150–169). Edward Elgar Publishing. https://doi.org/10.4337/9781786436351.00020

Shin, H., Eastman, J., & Li, Y. (2022). Is It Love or Just Like? Generation Z's Brand Relationship with Luxury. *Journal of Product & Brand Management*, *31*(3), 394–414. https://doi.org/10.1108/JPBM-08-2020-3049

Solomon, M. (2022). *Targeting the Luxury Consumer*. Retrieved from: https://brandingstrategyinsider.com/targeting-the-luxury-consumer/ (accessed: 12.08.2024).

Song, L., Suri, R., & Huang, Y. (2023). Inferring Quality from Price: The Effect of Stereotype Threat on Price–quality Judgments. *European Journal of Marketing*, *57*(5), 1442–1466. https://doi.org/10.1108/EJM-10-2021-0802

Stanciu, A. C., & Condrea, E. (2018). The Quality of Luxury versus the Luxury of Quality. *"Ovidius" University Annals: Economic Sciences Series*, *18*(1), 260–263.

Stanisz, A. (2007). *Przystępny kurs statystyki z zastosowaniem STATISTICA PL na przykładach z medycyny. Tom 3: Analizy wielowymiarowe*. StatSoft.

Statista Market Insights. (2025). *Luxury Goods – Worldwide*. Retrieved from: https://www.statista.com/outlook/cmo/luxury-goods/worldwide?srsltid=AfmBOor6Z-JamTWBwGSJdq3A3FwDXncPU5-Lcwlx91sJ-EIExje8SYoj#revenue (accessed: 18.05.2026).

Stępień, B. (2019). Zrównoważony rozwój jako nowa kategoria wartości w modzie luksusowej? Wyniki jakościowych badań międzynarodowych sprzedawców. *International Entrepreneurship Review*, *5*(1), 39–56. https://doi.org/10.15678/IER.2019.0501.03

Stępień, B., & Mruk, H. (2017). *Różnice w postrzeganiu luksusu w Polsce i na świecie*. Retrieved from: https://www.ican.pl/b/roznice-w-postrzeganiu-luksusu-w-polsce-i-na-swiecie/P113QvNyZ (accessed: 12.08.2024).

Taifa, I. W. R. (2021). Sustainable Industrialisation for Luxury Products: Manufacturers and Retailers Must Commit to Tackling Modern Slavery in Africa. In: I. Coste-Manière, M. Á. Gardetti (Eds), *Sustainable Luxury and Jewelry. Environmental Footprints and Eco-design of Products and Processes* (pp. 199–228). Springer. https://doi.org/10.1007/978-981-16-2454-4_10

Talukdar, N., & Yu, S. (2020). Do Materialists Care about Sustainable Luxury? *Marketing Intelligence & Planning*, *38*(4), 465–478. https://doi.org/10.1108/MIP-05-2019-0277

Wang, L., Wang, Q., Chan, E. Y., & Keller, L. R. (2024a). Counterfeits Can Benefit Original Products When People Are Caught Using Counterfeits. *Psychology & Marketing*, *41*(5), 977–988. https://doi.org/10.1002/mar.21963

Wang, Z., Liu, J., Qiu, Y., Lin, H., & Xin, Y. (2024b). Luxury Sustainable Design for Gen Z. *International Journal of Mathematics and Systems Science*, *7*(6), 97–101.

Wieczorkowska, G., & Wierzbiński, J. (2007). *Statystyka. Analiza badań społecznych*. Wydawnictwo Naukowe Scholar.

Xie, Q., & Lou, C. (2020). Curating Luxe Experiences Online? Explicating the Mechanisms of Luxury Content Marketing in Cultivating Brand Loyalty. *Journal of Interactive Advertising*, *20*(3), 209–224. https://doi.org/10.1080/15252019.2020.1811177

Yurdugül, H. (2008). Minimum Sample Size for Cronbach's Coefficient Alpha: A Monte Carlo Study. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *35*, 397–405.

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Corporate Bankruptcy Forecasting before and after the COVID-19 Pandemic in Poland

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ABSTRACT

Objective: The main objective of the study is to analyse the impact of the economic crisis caused by the COVID-19 pandemic on the forecasting of corporate bankruptcy in Poland. The analysis verifies the accuracy of models used to make forecasts and examines the determinants of corporate bankruptcy before and after the pandemic.

Research Design & Methods: The study used financial data from 121,000 companies for the 2015–2022 period. Five variable selection methods, eight classification methods and 1,000 different random learning and testing samples were used to perform the study.

Findings: The results indicate different determinants of corporate bankruptcy before and after the outbreak of the COVID-19 pandemic. Models constructed and tested before the pandemic had lower classification accuracy than models constructed and tested after the outbreak.

Implications/Recommendations: The results confirm the need to reconstruct and test models for forecasting corporate bankruptcy during periods of dynamic changes in capital markets, such as those triggered by the COVID-19 pandemic.

Contribution: The considerations presented in the article deepen knowledge of the impact of the economic crisis on the forecasting of corporate bankruptcy in Poland. To date, no research has been conducted with such a wide range of research methodology used in the context of the crisis caused by the COVID-19 pandemic.

Article type: original article.

Keywords: bankruptcy forecasting, crisis, COVID-19, machine learning.

JEL Classification: C38, C53, G33.

1. Introduction

The COVID-19 pandemic affected almost the entire world. According to the WHO, it contributed to more than 775 million illnesses and more than 7 million deaths worldwide (WHO, 2024). In response to its high dynamics, governments in most countries decided to impose numerous restrictions. Their goal was to limit the spread of the disease by limiting human contact. Numerous studies confirm that this goal was achieved, as indicated by a reduction in the number of infected people and deaths during this period (Cho, 2020; Lai *et al*., 2020; Mitze *et al*., 2020; Chernozhukov, Kasahara & Schrimpf, 2021). In addition to the positive impact of lockdowns on human health, the literature also contains many studies emphasising the negative impact of the introduced restrictions. Restrictions on the movement of people, resulting in reduced demand, disruptions in supply chains, and bans on business in many sectors of the economy contributed to the economic crisis. There are studies whose authors present the impact of lockdowns on the health of the entire economy (Coccia, 2020; Kanitkar, 2020; Ke & Hsiao, 2022). There are also a number of studies on the impact of the pandemic and related economic crisis on the financial health of companies. Thus, for example, Gopalakrishnan, Jacob, and Mohapatra (2022) indicate that COVID-19 and related lockdowns contributed to an increase in corporate indebtedness and that the propensity to incur debt depended on the severity of the restrictions imposed in the country. On the other hand, Shen *et al*. (2020) and Makni (2023) argue in their study that the COVID-19 pandemic significantly contributed to a decline in both investment and corporate earnings. Qin *et al*. (2020) indicate that the prevailing global situation caused an increase in the level of cash at the disposal of companies, while Ke (2022) indicates in his analysis that companies experienced an increase in the cost of equity capital during the period under review.

In order to mitigate the negative impact of the economic crisis on the financial health of companies, the governments of many countries decided to intervene by providing financial support to companies. Its absence would result in a drastic

increase in the number of bankruptcies (Gourinchas *et al*., 2020). The literature emphasises that the economic crisis resulting from the pandemic is also associated with dynamic legislative changes, changes in financial reporting rules, or more intensive use of earnings management tools by companies. All this means that the effectiveness of models predicting corporate bankruptcy may change. Research on the impact of the economic crisis on the quality of forecasting models does not allow drawing clear conclusions about the direction of these changes.

Thus, one can find studies whose authors indicate that the economic crisis has no effect on the effectiveness of models predicting corporate bankruptcy. Nam and Jinn (2000), using a logit model and a sample of 142 companies, examined the impact of the Asian crisis on the process of forecasting corporate bankruptcy. The constructed model and the obtained results allowed them to conclude that the economic crisis did not have a direct impact on the probability of bankruptcy. The companies against which bankruptcy was declared had been characterised by poor financial condition long before the crisis. Thus, on this basis, it can be assumed that the currency crisis itself was also the result of the long-term poor financial condition of Korean companies.

At the same time, it is possible to identify in the literature only a few studies, where the results indicate that the accuracy of forecasting models is higher after the outbreak of the economic crisis. Thus, Almamy, Aston and Ngwa (2016), using a discriminant model and a sample of 1,090 companies from the UK, compared the accuracy of forecasts made before, during and after the global financial crisis (2007–2008). The results showed that the accuracy of forecasts made before the crisis was 15.1 to 15.9 percentage points (p.p.) worse than the results obtained during the crisis and 17.1 to 20 p.p. worse than the results obtained after the economic crisis. Similar results were also obtained by Liu *et al*. (2022). Like their predecessors, they also compared the quality of models predicting bankruptcy before and after the onset of the global financial crisis. The objects of the study were companies from seven countries in Western Europe. Seven machine-learning methods and three sampling methods were used. The quality of the models turned out to be higher for those constructed after the outbreak of the crisis than those built during the crisis.

The issue of the impact of the economic crisis on forecasting corporate bankruptcy was also addressed by Papík and Papíková (2023), who studied the COVID-19 pandemic period. They formulated conclusions contrary to the previously presented studies. The study was based on financial data of more than 90,000 companies operating in Slovakia from 2015–2019. Three classification methods were used: CatBoost, LightGBM and XGBoost. When constructing the models, it was decided to distinguish two pre-crisis periods, i.e., before the outbreak of the COVID-19 pandemic (2018–2019) and the crisis period (2020). The obtained results

confirm that the quality of the forecasting models was lower for the economic crisis period. This was particularly evident for forecasts with a one-year horizon.

In the literature, one can find many studies whose authors attempt to forecast the bankruptcy of companies in Poland. Various classification methods are used for this purpose and the constructed models concern both the whole economy and its individual industries (Hadasik, 1998; Korol & Prusak, 2005; Hołda, 2006; Pociecha *et al*., 2014; Herman & Lach, 2024). There are also studies whose authors attempt to identify the main causes of bankruptcies in Poland. In light of the literature and their own research, Hołda and Strojny (2019) indicate that the causes of business bankruptcies in Poland have changed with socio-economic changes. At the beginning of the transformation, the predominant causes were mainly external, resulting from the macroeconomic situation of the country, e.g., market downturn, increasing domestic and foreign competition or a decline in demand. Over the years, however, the situation has changed. The authors point out that the causes of bankruptcy today should be found primarily within the organisation. They indicate as the main reason for bankruptcy the weakness of management, which results, for example, in overinvestment, poor company strategy, inadequate cooperation with the contractor.

The primary purpose of the study was to analyse the impact of the economic crisis caused by the COVID-19 pandemic on the forecasting of corporate bankruptcy in Poland. As indicated above, there are few studies related to the issue at hand and only one of them deals with the crisis caused by the SARS-CoV-2 virus. The conclusions of the described analyses are not unequivocal. In the conducted analysis, the accuracy of models which were used to make predictions constructed and tested both before and after the outbreak of the COVID-19 pandemic was verified. Unlike the studies presented above, the analysis considered and compared the quality of eight machine-learning methods, while the comparison itself was made on the basis of 1,000 random learning and testing samples. The use of such an approach makes the obtained results robust – independent of the methodology and test sample. The second objective of the study is to compare the determinants of company bankruptcy in the periods in question. In contrast to the study by Papík and Papíková (2023) five methods of variable selection were used for this purpose. The results of the study also allowed answering the question of which classification methods – ensemble or individual – proved more effective in predicting the bankruptcy of companies before and after the outbreak of the COVID-19 pandemic. This issue was not addressed in the studies presented earlier.

2. Methodology

Conducting an empirical study required gathering an adequate research sample of enterprises against which the relevant court had issued a decision to declare

corporate bankruptcy (denoted as "bankrupts" in the study) and enterprises operating in the economy in good financial condition (hereinafter denoted as "healthy"). Two data sources were used to obtain information on enterprises that were declared bankrupt during the period under study: The Official Journal of the Court and Economic Monitor and the public portal National Debt Register. In this way, it was possible to draw 1,000 enterprises against which bankruptcy was declared – 500 against which bankruptcy was declared in the 2016–2019 period (before the outbreak of the pandemic) and 500 where the court decision took place in the 2020–2023 period (after the outbreak of the pandemic). After removing observations for which there were data gaps and outliers, the study was left with 946 bankrupt companies. The financial retrieved statements were always for the year preceding the court's decision to declare bankruptcy. In addition, for the purpose of empirical analysis, a database of 120,000 financial statements of companies that efficiently operated in the market during the period under study was collected. Table 1 shows the number of financial statements included in the study from consecutive years of analysis.

Table 1. Number of Bankruptcy and Healthy Companies per Year

Year of Financial Statements	Bankrupts	Healthy
2015	99	2,523
2016	115	6,824
2017	146	24,104
2018	125	26,549
2019	152	10,947
2020	112	16,288
2021	95	19,482
2022	102	13,283

Source: own study.

Table 2, in turn, presents information on the size of assets and sales revenue of the companies in the research sample.

Table 2. Number of Companies Included in the Survey According to the Size of Assets and Sales Revenue

Range (PLN Million)	Size of Assets	Sales Revenue
0–9.99	82,673	77,321
10–19.99	13,075	15,486
20–29.99	8,135	7,298

Table 2 cnt'd

Range (PLN Million)	Size of Assets	Sales Revenue
30–39.99	4,928	4,422
40–49.99	1,777	2,922
50–59.99	1,253	2,143
60–69.99	928	1,513
70–79.99	766	1,081
80–89.99	604	909
90–99.99	490	732
> 100	6,317	7,119

Source: own study.

Assets of 68% of the surveyed companies, while sales revenues of 64% of the entities did not exceed the size of PLN 10 million.

Based on the constructed dataset, the values of 21 financial ratios were calculated representing the basic areas of companies' activities, i.e., profitability, operating efficiency, liquidity and capital structure (Table 3).

Table 3. Financial Ratios Used in the Study

Category	Financial Ratio	Formula
Profitability	Return on assets (ROA) (%)	Net profit/assets
	Return on equity (ROE) (%)	Net profit/total equity
	Return on sales (ROS) (%)	Net profit/net sales
	Operating margin (%)	Operating profit/net sales
	Return on capital employed (%)	EBIT/(assets – current liabilities)
Efficiency	Inventory turnover (days)	Inventories/net sales × 365
	Trade receivable turnover (days)	Receivables/net sales × 365
	Total asset turnover	Net sales/assets
	Trade payables turnover	(Cost + inventory)/trade payables
	Working capital turnover	Net sales/(current assets – current liabilities)
Liquidity	Current ratio	Current assets/current liabilities
	Quick ratio	Current assets – inventories)/short--term liabilities
	Cash ratio	(Working assets – inventories – receivables)/short-term liabilities

Table 3 cnt'd

Category	Financial Ratio	Formula
Capital structure	Debt ratio (%)	Total liabilities/total assets
	Debt to equity ratio (%)	Total liabilities/shareholder's equity
	Cash to total assets (%)	Cash/assets
	Trade receivables to total assets (%)	Trade receivables/assets
	Inventories to total assets (%)	Inventories/assets
	Fixed assets to total assets (%)	Fixed assets/assets
	Current liabilities to total liabilities (%)	Current liabilities/total liabilities
	Equity to assets ratio (%)	Equity/assets

Source: own study.

The following five variable selection methods were used to construct business bankruptcy forecasting models:

– filter-based methods: using entropy (Peng, Long & Ding, 2005), Mann--Whitney statistics (Mann & Whitney, 1947) and the ReliefF algorithm (Kira & Rendell, 1992),

– a method based on model selection (wrappers) – a stepwise "progressive" method (Miller, 1984), which was based on a discriminant function and a criterion for improving classification accuracy,

– a method that is an integral part of the learning algorithm (embedded methods): based on the Gini index.

In the following analysis these methods are labelled as, respectively: "entropy," "Whitney," "relief," "stepwise" and "Gini." Corporate bankruptcy forecasting models were constructed based on eight classification methods. These were: four individual methods, i.e., the *k*-nearest neighbours method (Guo *et al*., 2003), the support vector machines (Cortes & Vapnik, 1995), neural networks (Rumelhart, Hinton & Williams, 1986), logistic regression (Berkson, 1944) and four ensemble methods, i.e. random forests (Breiman, 2001), the bagging algorithm (Breiman, 1996), and two gradient enhancement methods: Extreme Gradient Boosting (Chen & Guestrin, 2016) and Light Gradient-boosting Machine (Ke *et al*., 2019). These methods are denoted hereafter as "KNN," "SVM," "network," "logistic," "forest," "bagging," "XGBoost" and "LightGBM," respectively. Table 4 shows the main assumptions made using the above-mentioned methods. The study did not optimise the values of the parameters listed below as the purpose of the study is not to obtain the best possible forecasting model, but to compare the accuracy of the classification

of models predicting the bankruptcy of companies before and after the outbreak of the COVID-19 pandemic.

In the study itself, each model for predicting corporate bankruptcy, both before and after the pandemic outbreak, was constructed and tested on the basis of a drawn, balanced sample, consisting of 450 bankrupt companies and 450 viable entities. The inclusion of an unbalanced sample often results in a significant deterioration in the obtained classification accuracy, especially for a smaller sample. In the case of an unbalanced sample, it could be necessary to solve this problem, for example, by means of a specific sampling method. However, its choice could, in turn, have a major impact on the results obtained in the study (Veganzones & Séverin, 2018).

Table 4. Assumptions Made for Each Classification Method

Method	Assumptions
KNN	*k* optimised using cross-validation, maximum number of nearest neighbours: 30
SVM	Kernel function: radial
Network	One hidden layer, number of neurons: the average of the number of neurons of the input and output layers
Logistic	Decision threshold: 0.5
Forest	Number of trees: 1,000, number of variables drawn: 5
Bagging	Number of iterations: 1,000
XGBoost	Number of iterations: 1,000, eta: 0.1
LightGBM	Number of iterations: 1,000, eta: 0.1

Source: own study.

The empirical study was conducted using a custom web application with a graphical user interface made in the R environment, to be used in the future for any multidimensional object classification problem.

3. Results and Analysis

At the outset of the study, it was verified whether the surveyed companies differed in terms of their financial health, described by the above-mentioned financial indicators, before and after the outbreak of the COVID-19 pandemic. The financial indicators did not follow a normal distribution. For this reason, the nonparametric Mann-Whitney test was used for comparative analysis. The corresponding results are shown in Tables 5 and 6.

Table 5. Comparative Analysis of Selected Financial Indicators for the Studied Groups before the Pandemic Outbreak

Financial Ratio	Indication	Median		*Z*-statistic	*p* value
		Bankrupts	Healthy		
Return on assets (ROA) (%)	X1	–23.64	4.63	–27.09	0.00
Return on equity (ROE) (%)	X2	23.19	16.68	1.73	0.08
Return on sales (ROS) (%)	X3	–18.00	2.58	–26.29	0.00
Operating margin (%)	X4	–14.56	3.59	–24.91	0.00
Return on capital employed (%)	X5	6.65	15.60	–3.19	0.00
Inventory turnover	X6	14.61	5.55	6.44	0.00
Trade receivable turnover	X7	39.38	38.45	1.58	0.11
Total asset turnover	X8	1.56	1.89	–2.71	0.01
Trade payables turnover	X9	0.00	0.03	–9.37	0.00
Working capital turnover	X10	–1.08	3.76	–16.06	0.00
Current ratio	X11	0.55	1.52	–23.70	0.00
Quick ratio	X12	0.37	1.20	–22.93	0.00
Cash ratio	X13	0.01	0.13	–15.36	0.00
Debt ratio (%)	X14	25.06	0.70	14.70	0.00
Debt to equity ratio (%)	X15	0.00	0.00	–10.69	0.00
Cash to total assets (%)	X16	1.44	5.44	–8.06	0.00
Trade receivables to total assets (%)	X17	18.89	20.12	–0.91	0.36
Inventories to total assets (%)	X18	5.90	2.80	4.57	0.00
Fixed assets to total assets (%)	X19	10.25	6.62	3.38	0.00
Current liabilities to total liabilities (%)	X20	98.46	100.00	–1.95	0.06
Equity to assets ratio (%)	X21	–14.29	41.67	–23.46	0.00

Notes: *Z*-statistic – the value of the test statistic for the *U* Mann-Whitney test.

Source: own compilation based on data from the EMIS professional database.

Table 6. Comparative Analysis of Selected Financial Indicators for Study Groups after the Pandemic Outbreak

Financial Ratio	Indication	Median		*Z*-statistic	*p* value
		Bankrupts	Healthy		
Return on assets (ROA) (%)	X1	–24.11	7.35	–26.90	0.00
Return on equity (ROE) (%)	X2	28.58	21.56	2.85	0.00
Return on sales (ROS) (%)	X3	–22.83	3.79	–25.46	0.00
Operating margin (%)	X4	–18.58	4.79	–23.88	0.00
Return on capital employed (%)	X5	12.64	20.05	–1.96	0.05

Table 6 cnt'd

Financial Ratio	Indication	Median		*Z*-statistic	*p* value
		Bankrupts	Healthy		
Inventory turnover	X6	7.73	5.66	1.52	0.13
Trade receivable turnover	X7	37.00	35.08	2.29	0.02
Total asset turnover	X8	1.14	2.01	–8.01	0.00
Trade payables turnover	X9	0.00	0.00	–10.05	0.00
Working capital turnover	X10	–0.35	4.00	–19.32	0.00
Current ratio	X11	0.46	1.68	–26.52	0.00
Quick ratio	X12	0.31	1.31	–24.94	0.00
Cash ratio	X13	0.00	0.16	–17.75	0.00
Debt ratio (%)	X14	32.26	2.78	16.13	0.00
Debt to equity ratio (%)	X15	–14.72	0.75	–18.13	0.00
Cash to total assets (%)	X16	0.51	6.42	–11.00	0.00
Trade receivables to total assets (%)	X17	17.06	18.78	–1.24	0.21
Inventories to total assets (%)	X18	2.66	2.98	–0.54	0.59
Fixed assets to total assets (%)	X19	6.70	4.90	2.86	0.00
Current liabilities to total liabilities (%)	X20	99.63	99.62	0.58	0.56
Equity to assets ratio (%)	X21	–42.70	45.44	–27.78	0.00

Notes: *Z*-statistic – the value of the test statistic for the *U* Mann-Whitney test.

Source: own compilation based on data from the EMIS professional database.

Based on the results presented in Tables 5–6, it can be concluded that in the period before the outbreak of the pandemic, only for four financial indicators (X2, X7, X17 and X20) the surveyed companies (at a significance level of 0.05) do not differ significantly in terms of financial health. Similarly, after the outbreak of the pandemic, such a situation occurs four times – for indicators X6, X17, X18 and X20. Healthy companies are characterised in most cases by a higher value of profitability indicators and liquidity of operations than bankrupts. In the case of bankrupt entities, one can see a decrease in the value of the aforementioned indicators in the studied periods, while profitability and liquidity for healthy companies increase after the outbreak of the pandemic. Thus, the differences between the medians of the used indicators for healthy and sick companies are in most cases higher after the outbreak of the pandemic than before 2020. This may indicate that the COVID-19 pandemic and the related economic crisis caused the difference between the financial condition in the studied groups of companies to increase significantly, and the financial indicators themselves gained discriminatory power.

In order to construct models for forecasting corporate bankruptcy, the eight classification methods mentioned earlier were used. In the case of individual classifiers: the *k*-nearest neighbours, the support vector machines, neural networks and logistic regression, the variables for the models were selected using filter-based selection methods (entropy, Whitney, relief) and the stepwise method. For ensemble classifiers, i.e., random forests, the bagging algorithm and gradient enhancement methods, the methods integral to the learning algorithm and based on the Gini index were used. In this way, results were obtained for 20 combinations: a classification method – a variable selection method. This procedure is intended to test the robustness of the results of the study to the research methodology used. The construction of a classification model for the period before and after the pandemic outbreak requires the division of the available research sample into a learning sample and a test sample. In all the carried out analyses, it was determined that 1,000 times 450 economically viable (healthy) enterprises and 450 bankrupt enterprises are drawn at random, and then the objects are randomly divided with a ratio of 75:25 into a learning sample and a test sample. For each draw, a learning sample was used to select variables using the methods described earlier. Based on these financial indicators, predictive models were constructed, the quality of which was checked on the basis of test samples. Figure 1 shows the validity of each financial indicator by area of business operation. The validity was assessed based on the average frequency of selection of financial indicators into the model using the four methods of variable selection presented earlier (entropy, Whitney, relief and stepwise). Based on the results, it can be concluded that the models constructed before and after the outbreak of the COVID-19 pandemic differ in the validity of financial indicators that describe different areas of the company's operations. For all the presented methods of variable selection, the importance of profitability indicators decreases after the outbreak of the pandemic. On the other hand, in the case of 3 out of the 4 methods, the importance of indicators included in the groups responsible for operational efficiency and financial structure increases during the studied period. In the case of indicators responsible for liquidity, no clear conclusion can be drawn as to the direction of change.

The next stage of the study compared the average (for 1,000 iterations) classification accuracy obtained for models:

– constructed and tested before the pandemic outbreak (before–before),

– constructed and tested after the pandemic outbreak (after–after),

– constructed before the pandemic outbreak and tested on observations from after the pandemic outbreak (before–after).

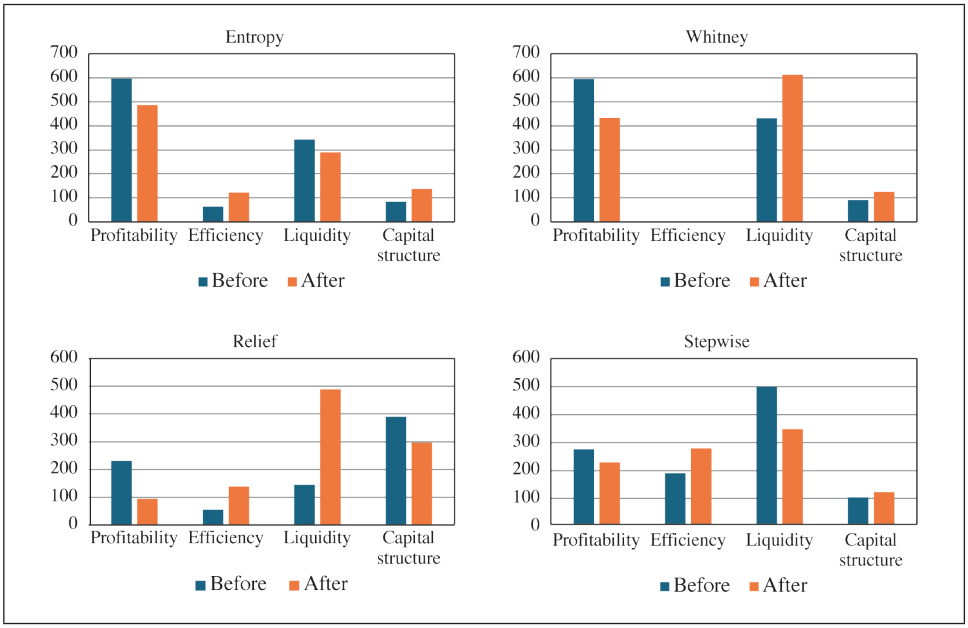

Fig. 1. Mean Frequency of Selection of Financial Indicators Representing Different Areas of Company Operations in Classification Models before and after the COVID-19 Pandemic Outbreak

Source: own compilation based on data from the EMIS professional database.

Tables 7–9 show the average value of global accuracy indices, accuracy for healthy companies, and accuracy for companies declared bankrupt.

Table 7. Average Global Classification Accuracy Obtained for Models Constructed and Tested before and after the Pandemic Outbreak

Classification Method	Variable Selection Method	Before–before (%)	After–after (%)	Before–after (%)	*H*-statistics	Statistically Significant Differences
Forest	Gini	82.7	85.8	84.9	732.8	all of them
Bagging	Gini	81.1	85.1	84.0	1,004.8	all of them
XGBoost	Gini	82.3	84.9	83.2	505.1	all of them
LightGBM	Gini	82.6	85.1	83.3	487.7	all of them
KNN	Entropy	77.6	81.0	79.8	638.1	all of them
SVM	Entropy	79.3	81.3	81.2	302.3	1–2; 1–3
Network	Entropy	79.6	83.5	82.0	852.8	all of them
Logistic	Entropy	79.0	82.1	82.0	585.6	1–2; 1–3
KNN	Whitney	78.0	81.3	80.1	616.7	all of them

Table 7 cnt'd

Classification Method	Variable Selection Method	Before–before (%)	After–after (%)	Before–after (%)	*H*-statistics	Statistically Significant Differences
SVM	Whitney	79.6	81.9	81.4	381.7	all of them
Network	Whitney	79.8	83.9	82.3	930.4	all of them
Logistic	Whitney	79.4	82.7	82.3	655.3	all of them
KNN	RelieF	72.3	72.6	74.8	143.2	all of them
SVM	RelieF	77.1	77.6	79.6	242.8	all of them
Network	RelieF	77.7	78.9	81.1	400.8	all of them
Logistic	RelieF	75.9	76.4	79.9	444.1	all of them
KNN	Stepwise	75.9	78.8	78.6	383.7	1–2; 1–3
SVM	Stepwise	77.5	76.7	80.1	218.0	all of them
Network	Stepwise	79.0	81.3	81.8	408.4	all of them
Logistic	Stepwise	77.7	79.2	80.9	283.5	all of them

Notes: *H*-statistics – the value of the test statistic for the Kruskal-Wallis test.

Source: own compilation based on data from the EMIS professional database.

Table 8. Average Classification Accuracy for Healthy Companies Obtained for Models Constructed and Tested before and after the Pandemic Outbreak

Classification Method	Variable Selection Method	Before–before (%)	After–after (%)	Before–after (%)	*H*-statistics	Statistically Significant Differences
Forest	Gini	82.3	85.0	84.5	279.1	all of them
Bagging	Gini	80.8	83.7	83.4	276.6	1–2; 1–3
XGBoost	Gini	82.2	84.9	83.9	268.4	all of them
LightGBM	Gini	82.4	85.0	84.2	259.5	all of them
KNN	Entropy	77.5	82.4	80.7	624.9	all of them
SVM	Entropy	85.7	86.2	87.8	137.6	all of them
Network	Entropy	79.0	84.1	82.0	448.5	all of them
Logistic	Entropy	83.2	87.5	85.9	336.4	all of them
KNN	Whitney	78.1	82.6	81.2	569.8	all of them
SVM	Whitney	86.2	88.0	88.2	167.3	1–2; 1–3
Network	Whitney	79.2	84.7	82.5	546.6	all of them
Logistic	Whitney	82.7	87.6	85.5	398.6	all of them
KNN	RelieF	73.6	73.1	76.4	147.7	1–3; 2–3
SVM	RelieF	81.4	76.4	84.0	525.8	all of them
Network	RelieF	76.6	79.7	80.0	160.5	1–2; 1–3
Logistic	RelieF	79.5	72.0	82.3	424.5	all of them

Table 8 cnt'd

Classification Method	Variable Selection Method	Before–before (%)	After–after (%)	Before–after (%)	*H*-statistics	Statistically Significant Differences
KNN	Stepwise	75.9	80.2	79.4	424.2	all of them
SVM	Stepwise	80.3	72.1	83.1	293.1	all of them
Network	Stepwise	78.3	81.1	81.7	183.3	all of them
Logistic	Stepwise	78.9	77.8	82.0	93.6	1–3; 2–3

Notes: *H*-statistics – the value of the test statistic for the Kruskal-Wallis test.

Source: own compilation based on data from the EMIS professional database.

Table 9. Average Classification Accuracy for Companies Declared Bankrupt Obtained for Models Constructed and Tested before and after the Pandemic Outbreak

Classification Method	Variable Selection Method	Before–before (%)	After–after (%)	Before–after (%)	*H*-statistics	Statistically Significant Differences
Forest	Gini	83.1	86.6	85.3	449.5	all of them
Bagging	Gini	81.3	86.5	84.5	738.4	all of them
XGBoost	Gini	82.4	84.8	82.4	265.1	1–2; 2–3
LightGBM	Gini	82.7	85.1	82.4	300.2	1–2; 2–3
KNN	Entropy	77.7	79.6	78.9	105.1	all of them
SVM	Entropy	72.9	76.3	74.6	228.6	all of them
Network	Entropy	80.2	83.0	81.9	145.9	all of them
Logistic	Entropy	74.8	76.7	78.1	160.0	all of them
KNN	Whitney	78.0	80.0	79.0	103.5	all of them
SVM	Whitney	73.0	75.9	74.6	179.6	all of them
Network	Whitney	80.5	83.2	82.1	140.2	all of them
Logistic	Whitney	76.1	77.8	79.1	196.1	all of them
KNN	RelieF	70.9	72.0	73.3	77.5	all of them
SVM	RelieF	72.8	78.8	75.2	467.9	all of them
Network	RelieF	78.8	78.2	82.3	163.7	1–3; 2–3
Logistic	RelieF	72.4	80.9	77.5	579.0	all of them
KNN	Stepwise	75.9	77.3	77.9	71.3	1–2; 1–3
SVM	Stepwise	74.7	81.3	77.0	415.9	all of them
Network	Stepwise	79.8	81.5	81.8	62.7	1–2; 1–3
Logistic	Stepwise	76.5	80.5	79.7	221.2	all of them

Notes: *H*-statistics – the value of the test statistic for the Kruskal-Wallis test.

Source: own compilation based on data from the EMIS professional database.

As can be seen in Table 7, for each (except SVM + stepwise) method used, the average global classification accuracy is higher for models constructed and tested after the pandemic outbreak than for models constructed and tested before the COVID-19 pandemic. These differences are always statistically significant. The maximum is as high as 4.1 p.p. Similarly, for models constructed before the pandemic outbreak and tested afterwards, the classification accuracy is always higher than when they were tested before the analysed event.

Analysing separately the accuracy of the classification of efficient enterprises (Table 8) and those declared bankrupt (Table 9), it should be noted that the situation is similar. This time, however, it is clear that the values in question are more differentiated. In the case of enterprises against which bankruptcy was declared, the average difference between the classification accuracy of models built and constructed after the outbreak of the pandemic and those for which construction and testing takes place before this event is 3.1 p.p. In the case of smoothly operating companies, the difference in question is lower and amounts to only 1.5 p.p. On this basis, it can be concluded that the different performance of forecasting models built before and after the outbreak of the pandemic is much more due to the difference in the accuracy of forecasting bankrupt companies.

The analysis of Tables 7–9 also allows us to draw interesting conclusions about the comparison of the classification quality of the used research methods. In the case of the level of average global relevance and the relevance of enterprises against which bankruptcy was declared, the ensemble methods: random forest, XGBoost, LightGBM, and the bagging algorithm consistently occupy the top four places. In the case of the classification of fit enterprises, support vector machines and logistic regression dominate.

4. Discussion

Two main conclusions can be drawn from the study. The first concerns the determinants of corporate bankruptcy in Poland. After the outbreak of the pandemic, profitability indicators lose importance, while financial indicators describing the area of operational efficiency and financial structure of companies gain. The results are similar to those obtained by Papík and Papíková (2023), who also indicated that the economic crisis causes a decline in the importance of profitability indicators and a much greater importance of leverage ratios. The second conclusion concerns the predictive ability of the models. For the most part, models constructed and tested before the pandemic outbreak have worse classification accuracy than those built on the same sample but tested after the pandemic outbreak and those constructed and tested after the pandemic outbreak. The results are analogous to those obtained by Almamy, Aston and Ngwa (2016) and Liu *et al*. (2022). They found that the accuracy of forecasting models is higher after an economic crisis outbreak as well.

The results of the study differ significantly from those obtained by Nam and Jinn (2000) and Papík and Papíková (2023), who indicated that the economic crisis has no effect or a positive effect on the quality of the forecasts made.

Bankruptcy forecasting models are crucial from the perspective of many stakeholders. Correct and early enough detection of companies' financial problems is crucial from the point of view of investors and creditors, who can thus reduce their losses (Srebro *et al*., 2021). As mentioned earlier, among the most frequently cited causes of corporate bankruptcy in Poland in recent years is poor management. An effective forecasting model can be a very helpful tool for enterprise managers. Managers who are alerted to impending problems could intervene well in advance and implement appropriate corrective measures in the enterprise. The results obtained in the study indicate that an effective forecasting model requires that the existence of an economic crisis be taken into account in its construction. As a result, the re-estimated model will be constructed on the basis of a different set of financial indicators and will achieve higher classification accuracy.

The first limitation of the study conducted was the period from which the financial statements of the surveyed companies originated. The horizon of the study was divided into two periods: before the outbreak of the pandemic and the related economic crisis, as well as after the outbreak. It was valuable to investigate what would happen to the models for forecasting corporate bankruptcy after the crisis resulting from the pandemic, how long the observed regularities would be present in the models for forecasting corporate bankruptcy. This is impossible due to the macroeconomic environment of Polish companies, resulting, among other things, from Russia's triggering of a full-scale war in Ukraine. Its effect was, among other consequences, a very high level of inflation and interest rates, which affected all companies severely.

The second limitation of the survey is the drawn research sample. The companies surveyed operated in various, often very different, industries of the economy. It would be worthwhile again, with a more extensive research sample, to conduct a similar survey separately, for individual industries of the economy. Taking into account industry specifics would make the observed relationships very interesting and valuable from the point of view of the survey recipients. The survey, as mentioned in the description of the research sample, focused on small businesses. It would be interesting to perform the analysis exclusively for large companies operating in the market. It seems that larger companies, by their established position in the market, are less exposed to macroeconomic changes. Thus, it would seem interesting to ask whether, in fact, for such entities, the observed correlations regarding bankruptcy forecasting would be repeated.

5. Conclusions

An empirical study was conducted based on a sample of 1,000 enterprises against which bankruptcy was declared in 2016–2023 and 120,000 efficient enterprises. The primary objective of the study was to analyse the impact of the economic crisis caused by the COVID-19 pandemic on the forecasting of corporate bankruptcy in Poland. To achieve it, five variable selection methods, eight classification methods and 1,000 random learning and testing samples were used.

The results of the study allow us to conclude that the determinants of corporate bankruptcy are different in the two studied periods. Taking into account the obtained results, it can be concluded that the accuracy of models for forecasting corporate bankruptcy differs depending on whether they were constructed and tested before or after the outbreak of the pandemic. The greater predictive ability of the models after the pandemic outbreak may be due to the fact that during this period, the difference between the financial condition of companies declared bankrupt and those operating efficiently in the market was greater than it was before the pandemic. Based on the results, it can also be concluded that ensemble methods have higher global accuracy and classification accuracy for bankrupt companies than individual methods. This is observed for both models constructed on data before and after the pandemic outbreak.

Authors' Contribution

The authors' individual contribution is as follows: Sergiusz Herman – conceptualisation, data curation, formal analysis, investigation, validation, visualisation, writing – review and editing; Bartłomiej Lach – conceptualisation, data curation, formal analysis, investigation, validation, visualisation, writing – review and editing.

Conflict of Interest

The authors declare no conflict of interest.

References

Almamy, J., Aston, J., & Ngwa, L. N. (2016). An Evaluation of Altman's Z-score Using Cash Flow Ratio to Predict Corporate Failure Amid the Recent Financial Crisis: Evidence from the UK. *Journal of Corporate Finance*, *36*, 278–285. https://doi.org/10.1016/j.jcorpfin.2015.12.009

Berkson, J. (1944). Application of the Logistic Function to Bio-Assay. *Journal of the American Statistical Association*, *39*(227), 357–365. https://doi.org/10.1080/01621459.1944.10500699

Breiman, L. (1996). Bagging Predictors. *Machine Learning*, *24*, 123–140. https://doi.org/10.1007/BF00058655

Breiman, L. (2001). Random Forests. *Machine Learning*, *45*(1), 5–32. https://doi.org/10.1023/A:1010933404324

Chen, T., & Guestrin, C. (2016). XGBoost: A Scalable Tree Boosting System. KDD '16. In: *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (pp. 785–794). Association for Computing Machinery. https://doi.org/10.1145/2939672.2939785

Chernozhukov, V., Kasahara, H., & Schrimpf, P. (2021). Causal Impact of Masks, Policies, Behavior on Early COVID-19 Pandemic in the U.S. *Journal of Econometrics*, *220*(1), 23–62. https://doi.org/10.1016/j.jeconom.2020.09.003

Cho, S.-W. (Stanley). (2020). Quantifying the Impact of Nonpharmaceutical Interventions during the COVID-19 Outbreak: The Case of Sweden. *Econometrics Journal*, *23*(3), 323–344. https://doi.org/10.1093/ECTJ/UTAA025

Coccia, M. (2020). The Relation between Length of Lockdown, Numbers of Infected People and Deaths of COVID-19, and Economic Growth of Countries: Lessons Learned to Cope with Future Pandemics Similar to COVID-19 and to Constrain the Deterioration of Economic System. *Science of the Total Environment*, *775*, 145801. https://doi.org/10.1016/j.scitotenv.2021.145801

Cortes, C., & Vapnik, V. (1995). Support-vector Networks. *Machine Learning*, *20*, 273–297. https://doi.org/10.1007/BF00994018

Gopalakrishnan, B., Jacob, J., & Mohapatra, S. (2022). COVID-19 Pandemic and Debt Financing by Firms: Unravelling the Channels. *Economic Modelling*, *114*, 105929. https://doi.org/10.1016/j.econmod.2022.105929

Gourinchas, P.-O., Kalemli-Özcan, Ş., Penciakova, V., & Sander, N. (2020). *SME Failures under Large Liquidity Shocks: An Application to the COVID-19 Crisis* (NBER Working Paper No. 27877). National Bureau of Economic Research. Retrieved from: https://www.nber.org/papers/w27877.pdf (accessed: 5.05.2024).

Guo, G., Wang, H., Bell, D., Bi, Y., & Greer, K. (2003). KNN Model-based Approach in Classification. In: R. Meersman, Z. Tari, D. C. Schmidt (Eds), *On The Move to Meaningful Internet Systems 2003: CoopIS, DOA, and ODBASE. OTM 2003. Lecture Notes in Computer Science* (Vol. 2888). Springer. https://doi.org/10.1007/978-3-540-39964-3_62

Hadasik, D. (1998). *Upadłość przedsiębiorstw w Polsce i metody jej prognozowania*. Wydawnictwo Akademii Ekonomicznej w Poznaniu.

Herman, S., & Lach, B. (2024). Czy warto budować modele prognozowania upadłości przedsiębiorstw uwzględniające kryterium przynależności sektorowej? *Wiadomości Statystyczne. The Polish Statistician*, *69*(10), 41–58. https://doi.org/10.59139/ws.2024.10.3

Hołda, A. (2006). *Zasada kontynuacji działalności i prognozowanie upadłości w polskich realiach gospodarczych*. Wydawnictwo Akademii Ekonomicznej w Krakowie.

Hołda, A., & Strojny, K. (2019). Determinants of Entrepreneurs' Bankruptcy in Poland – Systematics and Comparative Analysis of the Opinion of Management and Trustees. *Zeszyty Teoretyczne Rachunkowości*, *101*(157), 9–34. https://doi.org/10.5604/01.3001.0013.0753

Kanitkar, T. (2020). The COVID-19 Lockdown in India: Impacts on the Economy and the Power Sector. *Global Transitions*, *2*, 150–156. https://doi.org/10.1016/j.glt.2020.07.005

Ke, G., Meng, Q., Finley, T., Wang, T., Chen, W., Ma, W., Ye, Q., & Liu, T.-Y. (2019). LightGBM: A Highly Efficient Gradient Boosting Decision Tree. In: *31st Conference on Neural Information Processing Systems* (*NIPS 2017*) (pp. 3149–3157). NIPS.

Ke, X., & Hsiao, C. (2022). Economic Impact of the Most Drastic Lockdown during COVID-19 Pandemic – the Experience of Hubei, China. *Journal of Applied Econometrics*, *37*(1), 187–209. https://doi.org/10.1002/jae.2871

Ke, Y. (2022). The Impact of COVID-19 on Firms' Cost of Equity Capital: Early Evidence from U.S. Public Firms. *Finance Research Letters*, *46*, 102242. https://doi.org/10.1016/j.frl.2021.102242

Kira, K., & Rendell, L. A. (1992). A Practical Approach to Feature Selection. In: D. Sleeman, P. Edwards (Eds), *Machine Learning Proceedings* (pp. 249–256). Morgan Kaufmann. https://doi.org/10.1016/B978-1-55860-247-2.50037-1

Korol, T., & Prusak, B. (2005). *Upadłość przedsiębiorstw a wykorzystanie sztucznej inteligencji*. CeDeWu.

Lai, S., Ruktanonchai, N. W., Zhou, L., Prosper, O., Luo, W., Floyd, J. R., Wesolowski, A., Santillana, M., Zhang, C., Du, X., Yu, H., & Tatem, A. J. (2020). Effect of Non-pharmaceutical Interventions to Contain COVID-19 in China. *Nature*, *585*(7825), 410–413. https://doi.org/10.1038/s41586-020-2293-x

Liu, Y., Zeng, Q., Li, B., Ma, L., & Ordieres-Meré, J. (2022). Anticipating Financial Distress of High-tech Startups in the European Union: A Machine Learning Approach for Imbalanced Samples. *Journal of Forecasting*, *41*(6), 1131–1155. https://doi.org/10.1002/for.2852

Makni, M. S. (2023). Analyzing the Impact of COVID-19 on the Performance of Listed Firms in Saudi Market. *Technological Forecasting and Social Change*, *187*, 122171. https://doi.org/10.1016/j.techfore.2022.122171

Mann, H. B., & Whitney, D. R. (1947). On a Test of Whether One of Two Random Variables Is Stochastically Larger Than the Other. *The Annals of Mathematical Statistics*, *18*(1), 50–60. https://doi.org/10.1214/aoms/1177730491

Miller, A. J. (1984). Selection of Subsets of Regression Variables. *Journal of the Royal Statistical Society. Series A: General*, *147*(3), 389–425. https://doi.org/10.2307/2981576

Mitze, T., Kosfeld, R., Rode, J., & Wälde, K. (2020). Face Masks Considerably Reduce COVID-19 Cases in Germany. *Proceedings of the National Academy of Sciences*, *117*(51), 32293–32301. https://doi.org/10.1073/pnas.2015954117

Nam, J.-H., & Jinn, T. (2000). Bankruptcy Prediction: Evidence from Korean Listed Companies during the IMF Crisis. *Journal of International Financial Management and Accounting*, *11*(3), 178–197. https://doi.org/10.1111/1467-646X.00061

Papík, M., & Papíková, L. (2023). Impacts of Crisis on SME Bankruptcy Prediction Models' Performance. *Expert Systems with Applications*, *214*, 119072. https://doi.org/10.1016/j.eswa.2022.119072

Peng, H., Long, F., & Ding, C. (2005). Feature Selection Based on Mutual Information Criteria of Max-dependency, Max-relevance, and Min-redundancy. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *27*(8), 1226–1238. https://doi.org/10.1109/TPAMI.2005.159

Pociecha, J., Pawełek, B., Baryła, M., & Augustyn, S. (2014). *Statystyczne metody prognozowania bankructwa w zmieniającej się koniunkturze gospodarczej*. Fundacja Uniwersytetu Ekonomicznego w Krakowie.

Qin, X., Huang, G., Shen, H., & Fu, M. (2020). COVID-19 Pandemic and Firm-level Cash Holding – Moderating Effect of Goodwill and Goodwill Impairment. *Emerging Markets Finance and Trade*, *56*(10), 2243–2258. https://doi.org/10.1080/1540496X.2020.1785864

Rumelhart, D., Hinton, G., & Williams, R. (1986). Learning Representations by Back-propagating Errors. *Nature*, *323*, 533–536. https://doi.org/10.1038/323533a0

Shen, H., Fu, M., Pan, H., Yu, Z., & Chen, Y. (2020). The Impact of the COVID-19 Pandemic on Firm Performance. *Emerging Markets Finance and Trade*, *56*(10), 2213–2230. https://doi.org/10.1080/1540496X.2020.1785863

Srebro, B., Mavrenski, B., Bogojević Arsić, V., Knežević, S., Milašinović, M., & Travica, J. (2021). Bankruptcy Risk Prediction in Ensuring the Sustainable Operation of Agriculture Companies. *Sustainability*, *13*(14), 7712. https://doi.org/10.3390/su13147712

Veganzones, D., & Séverin, E. (2018). An Investigation of Bankruptcy Prediction in Imbalanced Datasets. *Decision Support Systems*, *112*, 111–124. https://doi.org/10.1016/j.dss.2018.06.011

WHO. (2024). *Coronavirus Disease* (*COVID-2019*) *Situation Reports*. Retrieved from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports (accessed: 7.06.2024).

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The Split Payment Mechanism and Financial Liquidity of Enterprises in Section F – Construction

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ABSTRACT

Objective: The aim of the study conducted in the article is to examine whether the split payment mechanism (SPM) affects the financial liquidity of enterprises in section F – construction. It was also determined whether adjustments to liquidity ratios should be made for enterprises whose predominant activity is subject to mandatory SPM.

Research Design & Methods: The research was based on a literature review concerning VAT taxation and SPM. An analysis of industry reports was conducted to assess the impact of this mechanism on the financial liquidity of enterprises. Financial analysis tools were utilised to verify whether the implementation of split payment affects the ability of enterprises in section F – construction to settle their liabilities. The study focused on construction sector enterprises subject to mandatory SPM. Calculations were based on financial statements from 2018 and 2022, allowing a comparison of the financial liquidity situation in the construction sector both before and after the introduction of mandatory SPM. Financial ratios calculated for 2022 were

also compared before and after adjustments for restricted funds in bank accounts. Hypotheses were verified using descriptive statistics and inferential statistics tools. Due to deviations from linearity and normal distribution, tools insensitive to these behaviours were used primarily, such as the median to describe the average level, Spearman's rank correlation coefficient to describe dependencies, and the sign tests and Wilcoxon tests to examine the differences in ratio values before and after adjustment. Parametric tools for description and inference were used only as a complement to non-parametric tools.

Findings: The research results show lower values of financial liquidity ratios after adjustment for funds accumulated in the VAT account. The current ratio index values are not significantly different. This means that the introduction of SPM did not significantly affect the ability of enterprises from the construction sector to settle their liabilities on an ongoing and timely basis. Moreover, the ability to allocate funds accumulated in a separate bank account to cover public law liabilities results in a reduction in the number of days needed to repay liabilities.

Implications/Recommendations: It is recommended to adjust classical financial ratios by the value of funds accumulated in the VAT account. Making this type of exclusions contributes to a more precise calculation of individual financial liquidity ratios. This leads to more precise results and an appropriate assessment of the financial situation of the audited company.

Contribution: The research results in a new approach to the construction of financial ratios used to evaluate the company. It also shows the implications of the introduction of SPM on the functioning of enterprises in the construction sector.

Article type: original article.

Keywords: VAT, split payment mechanism, financial liquidity, section F – construction.

JEL Classification: H26, H32, M21, M48.

1. Introduction

The split payment mechanism (hereinafter: SPM) was introduced into Polish economic practice as a response to tax fraud in the area of VAT. Its primary purpose was to limit illegal practices involving disappearing taxpayers (Sarnowski & Selera, 2020). The mechanism became a form of tax risk management within enterprises, introducing safeguards against unwitting participation in carousel fraud schemes.

Initially, SPM operated on a voluntary basis, and later, from 1 November 2019, it became mandatory for 150 groups of goods and services. SPM potentially affects not only budget revenues from VAT by reducing tax fraud, but also the financial liquidity of enterprises. This results from the very essence of the functioning of this mechanism, where the payment is made by the buyer of the goods or services to the supplier's settlement account, while the remaining amount of the receivable, i.e., corresponding to the VAT value, is paid to the VAT account (Kowal, 2019). These funds are, to some extent, "blocked," and the company cannot dispose of them freely, only in the manner specified by the legislator (Nowak-Piechota, 2018).

Thus, by using SPM, suppliers of goods or services cannot disappear during transactions aimed at evading VAT and retain the tax due to the state for their own benefit (Kowal & Lichota, 2020).

Interest in the aspect of financial liquidity when using SPM also resulted from industry reports and analyses (European Commission and Deloitte, 2017; CRIDO, 2018; KPMG, 2019b), and, most notably, from the Deloitte report commissioned by the European Commission (European Commission and Deloitte, 2017).

The aim of this article is to elucidate the essence of the SPM and how it can potentially affect the financial liquidity of enterprises. The study also examines whether adjustments to financial liquidity ratios are needed for enterprises predominantly subject to mandatory SPM. The research was based on a literature review in the field of VAT taxation. The legal and tax regulations of Poland and the EU regarding this solution were analysed. Financial analysis tools were also used to verify whether the split was applied payment affects the ability of enterprises to settle liabilities from section F – construction. Business units that are covered by mandatory SPM were selected for the study. The calculations were made on the basis of financial reports from 2018 and 2022. The financial liquidity situation was compared before the introduction of mandatory SPM and after several years of its implementation. Furthermore, in 2022, the liquidity results were calculated according to traditional formulas provided in the literature and adjusted to take into account the limitation in the use of funds on the VAT sub account. In pursuing the research objectives and verifying the hypotheses set in the study, a statistical evaluation of financial ratios was carried out. This evaluation was carried out using methods of descriptive statistics and statistical inference.

Previous research on financial liquidity, taking into account SPM, was carried out on enterprises from the processing, trade and service industries (Obrzeżgiewicz, 2019), but it was not indicated whether the use of split payment requires adjustment of financial ratios. This article fills a gap in the current scientific literature on this issue. In line with the goals of the study, research hypotheses were formulated:

H1: The split payment mechanism negatively affects the financial liquidity of enterprises in section F.

H2: Classical financial liquidity ratios require adjustment for funds in the VAT account.

2. Theoretical Tax Bases and the Split Payment Mechanism

Tax theories form the foundation of tax system analysis, helping to understand and evaluate the functioning of taxes and tax solutions, their impact on the economy, the behaviour of economic entities, and their activities (Mirrlees *et al*., 2011; Raczkowski, Schneider & Węgrzyn, 2023).

The first and most famous criteria for evaluating tax system were formulated in the 18th century by A. Smith, emphasising certainty, convenience, cost-efficiency, and equity of taxation (see: Olalekan & Oyedokun, 2019). Nowadays, the design of a tax system typically considers several fundamental issues: efficiency, equity, neutrality, and flexibility (Mirrlees *et al*., 2010; OECD, 2014; Commission on Taxation and Welfare Secretariat, 2021). These concepts need to be explained in the context of SPM and its potential impact on the financial liquidity of economic entities.

Economic efficiency is one of the most frequently indicated features of an optimal tax system. When assessing whether a tax system is efficient, it is essential to go beyond just the analysis of fiscal efficiency, which focuses mainly on the performance of the tax system and the quality of individual revenue sources. One must also consider the compliance costs and administrative costs for the taxpayer, which are closely linked to so-called economic tax efficiency. Thus, tax system efficiency should be understood as the resultant of fiscal efficiency and the costs associated with tax collection, which are not always visible and simultaneously easy to determine (Kumor, 2009). The new tax solutions being introduced engage owners and employees in the finance departments in familiarising themselves with the changes in tax regulations. In Poland, tax changes are analysed for an average of 364 hours annually. Additionally, many studies have shown that tax settlement in Poland requires significantly more work than the EU average (Kowalczyk *et al*., 2020).

The literature frequently emphasises that a tax system should be designed to minimally disrupt the economic decisions of entities (Gunnarsson & Eriksson, 2017). The introduction of SPM may affect tax efficiency by reducing VAT fraud, which in turn makes the tax system more transparent and stable (Ćwiąkała-Małys, Karpińska & Piotrowska, 2018). However, additional administrative burdens and limited access to funds in the VAT account may disrupt financial decisions of enterprises and affect their financial liquidity. Therefore, it is important that tax solutions such as SPM are introduced in a way that minimises additional costs and burdens for businesses.

The concept of equity shows how to resolve conflicts between different interests, especially between the interests of the taxpayer and the state. Objective tax equity can be considered in both vertical and horizontal terms (Duclos, 2008). Horizontal equity is closely linked to the principles of equality and universality of taxation (Ooi, 2016; Szołno-Koguc, 2016). It means that entities with similar tax-paying abilities should bear similar tax burdens. Vertical equity, on the other hand, suggests that entities with greater tax-paying abilities should bear relatively higher tax burdens (Elkins, 2006). SPM, by ensuring a fairer and more transparent VAT settlement system, can contribute to increased tax equity. Enterprises that previously avoided paying taxes are compelled to comply with the regulations, which reduces unfair

competition. Conversely, the additional costs and administrative burdens associated with this solution may be more onerous for smaller enterprises, potentially leading to inequality in tax burdens (Kowal, 2019).

The theory of tax neutrality posits that taxes should be neutral in regard to economic decisions, not affecting the allocation of resources or the choices made by economic entities (Princen, 2012). In an ideal tax system, no industry or type of business activity should be "favoured" by tax regulations. Therefore, they should not influence market structure (Hasen, 2012). Of course, the principle of tax system neutrality will never be fully maintained, which is why modern economic theories already discuss relative tax neutrality (Opałka, 2011). SPM can impact tax neutrality by changing how financial resources are managed in companies within a specific sector engaged in certain activities. Limited access to VAT funds for paying current liabilities may force companies to change their liquidity management strategies, which can impact their market position (Kowal, 2019).

According to A. Wagner, the theory of tax flexibility refers to the tax system's ability to meet public expenditure requirements (see: Gomułowicz & Mączyński, 2016). The economist emphasises the importance of the tax system's ability to adapt to changing economic conditions and social needs in his works (see: Owsiak, 2017). SPM aimed at reducing the VAT gap, is an example of such flexibility. By implementing it, the state aims to better monitor invoice payments and counteract tax fraud. On the other hand, the introduced regulations and solutions may limit enterprises' flexibility in managing their finances, negatively affecting their liquidity and ability to adapt to changing economic conditions.

The discussed tax theories provide theoretical frameworks for analysing the impact of SPM on business activities. This solution has the potential to increase the transparency of the tax system, but at the same time, it causes increased administrative burdens and may pose challenges related to financial liquidity management. Therefore, finding a balance between the effectiveness of tax solutions and minimising their negative impact on business activities is crucial (Kowal-Pawul, 2022).

3. The Split Payment Mechanism and the Potential Impact on the Financial Liquidity of Enterprises

The Act of 15 December 2017, amending the VAT Act and certain other acts introduced a new tax law institution into Polish economic practice – the split payment mechanism. This act entered into force on 1 July 2018 and was initially a voluntary solution. However, this was a "seeming voluntariness," as will be explained further in this paper. SPM is one of the tools demonstrating the digitisation of VAT in Poland (Kowal-Pawul & Przekota 2021), but the only one that may significantly threaten the financial liquidity of enterprises (Kijuk, 2018).

The essence of the introduced SPM in Poland is that the payment for purchased goods or services (net value) is made by the buyer to the supplier's settlement account, while the remaining amount of the liability, corresponding to the VAT value, is paid to the VAT account (Fig. 1).

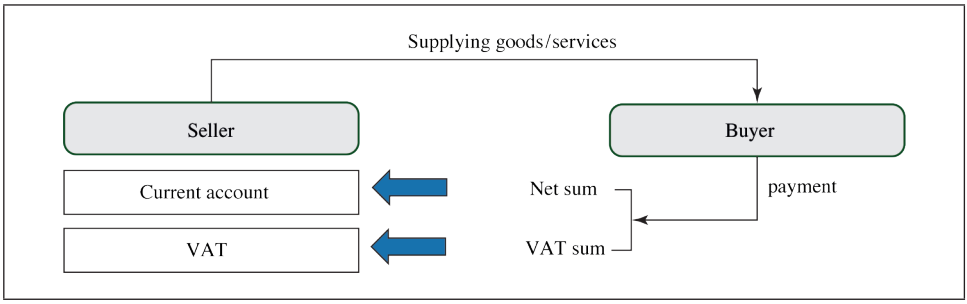

Fig. 1. SPM – Functioning Diagram
Source: own study, based on Kowal (2019).

SPM applies to B2B and B2G transactions conducted electronically. Moreover, SPM became mandatory from 1 November 2019 for fraud-prone goods and services defined in Annex 15 to the Act of 11 March 2004 on goods and services tax (VAT Act). One can also speak of the optional nature of applying the mechanism; however, this statement raises some controversies – because it is the buyer who decides whether to use the split payment institution. The method of payment does not require the payer to inform their contractor. This is known as "apparent voluntariness" for the supplier of goods or services. Furthermore, the seller receiving split payment has their funds frozen in the VAT sub-account, so even if they did not wish to use this solution, they are still "forced" to do so in order to manage the accumulated funds (Weber, 2024).

The voluntary SPM did not play a significant role in reducing tax fraud, so the Polish legislator introduced a mandatory solution for areas particularly vulnerable to VAT-related fraud (e.g., construction services). Such a solution requires the authorisation of the Council at the request of the European Commission. The introduction of mandatory SPM in Poland was made possible by obtaining Council approval in early 2019. The authorisation issued was temporary and valid until 28 February 2022 (PwC, 2019), and it was subsequently extended for another three years (KIS, 2024).

Invoices below 15,000 zloty gross, which pertain to goods and services subject to mandatory SPM, are subject to joint liability of the purchaser, applicable from the first zloty. Liability can be discharged through voluntary payment in accordance with SPM (Podatki.gov.pl, 2024). The purchaser also faces the risk of sanctions

being imposed if, despite being obligated under SPM to settle the invoice accordingly, they settle it in another manner (KPMG, 2019a).

Table 1. Voluntary versus Mandatory Application of SPM

Value of the Invoice		
Up to 15 thousand zloty (or up to the equivalent amount)	Over 15 thousand zloty (or the equivalent amount)	
Voluntary application	Goods or services from Annex 15 of the VAT Act	Other goods or services
	Mandatory application	Voluntary application

Source: own study, based on Andrzejewska (2020).

After the introduction of SPM, Polish entrepreneurs should consider the issue of financial liquidity. For suppliers receiving split payments, there is a risk of accumulating funds in the VAT account (Kopyciańska, 2017). The legislator has provided for the possibility of using these funds not only to pay the VAT amount corresponding to the invoice but also to settle other public-law obligations, such as CIT, PIT, ZUS, excise tax. Until 1 November 2019, it was not possible to pay other public and legal liabilities from the funds in the VAT account, which caused an avalanche of criticism from entrepreneurs and problems with financial liquidity, especially among entities from the SME sector (Kowal, 2019). The taxpayer can apply to the head of the tax office for consent to transfer funds from the VAT account to their settlement account, but the application may be processed within 60 days, exacerbating the issue of frozen funds (Fornalik & Jaworska, 2020).

Although there is no obligation to introduce SPM in the European Union, some countries have also decided to implement such a solution, e.g., Italy or Bulgaria (PwC, 2015; Tratkiewicz, 2017). SPM in individual countries is modified according to their legal specifics and market conditions. Comparing the Polish split payment model to other European solutions, it can be observed that it is more advanced due to:

– ubiquity – used in B2B and B2G transactions,
– automation – in member states, the manual model predominates,
– mandatory nature – it is required for fraud-prone goods and services,
– popularity – in 2020, over 53 million transactions were conducted according to the SPM (Sarnowski & Selera, 2020).

The Polish model differs from others used in EU member states, also because its mandatory application is conditioned not only by the type of goods or services but also by the invoice amount. The solution applied in Poland is much more stringent than the EU standards, especially regarding the freedom to manage funds held in the VAT subaccount (Modzelewski, 2020).

4. Research Method

The study included companies primarily engaged in activities classified under the following groups according to PKD 2007 (PKD, 2024):

– 42.11.Z – construction of roads and highways,
– 42.12.Z – construction of railways and underground railways,
– 42.13.Z – construction of bridges and tunnels.

Companies in this sector are subject to mandatory SPM. Furthermore, companies were selected that, in additional information (a component of financial statements), indicated the value of VAT funds held in a separate account. In total, 76 construction companies were included in the study, and their reports were sourced from the EMIS database.

The years analysed were 2018 and 2022. A comparison was conducted to assess the financial liquidity situation before the introduction of mandatory SPM and after several years of its implementation. The year 2022 represented a period of relative stability, despite the epidemic threat, as the economy was recovering from the pandemic. Earlier years could have distorted the analysis results due to factors such as the COVID-19 pandemic, high inflation, and limited credit availability, potentially misleading the assessment of SPM's impact on financial liquidity.

Additionally, in 2022, results regarding liquidity were compared using traditional formulas cited in the literature and adjusted to account for the restriction on using funds in the VAT subaccount. To evaluate the impact of SPM on the financial liquidity of construction companies, the Current Ratio (CR) was assessed for 2018 and 2022. Subsequently, an evaluation was conducted to determine whether the limitation on using VAT funds affects the Days Payable Outstanding (DPO) ratio. The modification of the ratio formulas considered the value of funds accumulated in the separate bank account and the value of public-law (tax) liabilities that can be covered by these funds. Detailed formulas are provided in Table 2.

Table 2. The Names of the Applied Ratios and Their Classical as Well as Adjusted Formulas

Name of the Ratio	The Construction of a Financial Ratio
CR	$\frac{Current\ assets}{Current\ liabilities}$
CR' (*adjusted CR*)	$\frac{Current\ assets - Cash\ in\ the\ VAT\ account}{Current\ liabilities - Public - law\ liabilities}$
DPO	$\frac{Current\ liabilities}{Total\ revenue} \times 360$
DPO' (*adjusted DPO*)	$\frac{Current\ liabilities - Public - law\ liabilities}{Total\ revenue} \times 360$

Notes: *Current assets* and *current liabilities* were calculated according to the scheme available in a publication by Niemiec and Skoczylas (2024).

Source: own study, based on Niemiec & Skoczylas (2024).

In fulfilling the research objectives and verifying the hypotheses, a statistical assessment of the behaviour of the CR and DPO ratios was conducted. This assessment was performed using methods of descriptive statistics and inferential statistics. In the subsequent points:

1. Descriptive statistics of the distribution of ratio values.
2. The distributions of ratio values were presented along with a normality test of the distribution.
3. The Spearman's rank correlation coefficient was used to examine the interdependence of financial ratio values, as it is insensitive to deviations from normality and the linearity of relationships.
4. Determination of differences in the distributions of ratios before and after adjustment. Given the failure to meet the normality assumption, non-parametric tests – the sign test and the Wilcoxon test – were used as the primary methods for assessing differences in distributions.
5. Descriptive statistics of the differences in ratio values before and after adjustment.

5. Results

The statistical description of the empirical data utilised basic measures of descriptive statistics (Table 3). For each financial ratio, the median was found to be smaller than the mean, indicating the presence of outliers towards higher values and a relatively strong concentration of ratios at lower values in the dataset.

Table 3. Descriptive Statistics for Analysed Financial Ratios

Ratio	Median	Mean	Std. Dev.	Min	Max	Q1	Q3
CR2018	1.76	2.44	1.64	0.55	9.99	1.40	2.84
CR2022	1.97	2.45	1.55	0.89	8.03	1.33	2.84
CR'2022	1.77	2.34	1.50	0.84	7.92	1.32	2.82
DPO2018	64.17	90.28	112.90	19.51	806.42	40.88	99.82
DPO2022	81.32	88.08	61.68	10.89	455.27	44.44	103.40
DPO'2022	67.18	76.37	58.33	7.33	396.80	32.29	95.97

Source: own study, based on the financial statements of companies.

The median values of CR were within the textbook norm range, while the mean values exceeded this norm. Using the norm range for CR as [1.3; 2.0], approximately 40% of enterprises fell within this norm, about 15% were below it, and 45% were above it. Hence, over-liquidity was more common in enterprises than liquidity issues.

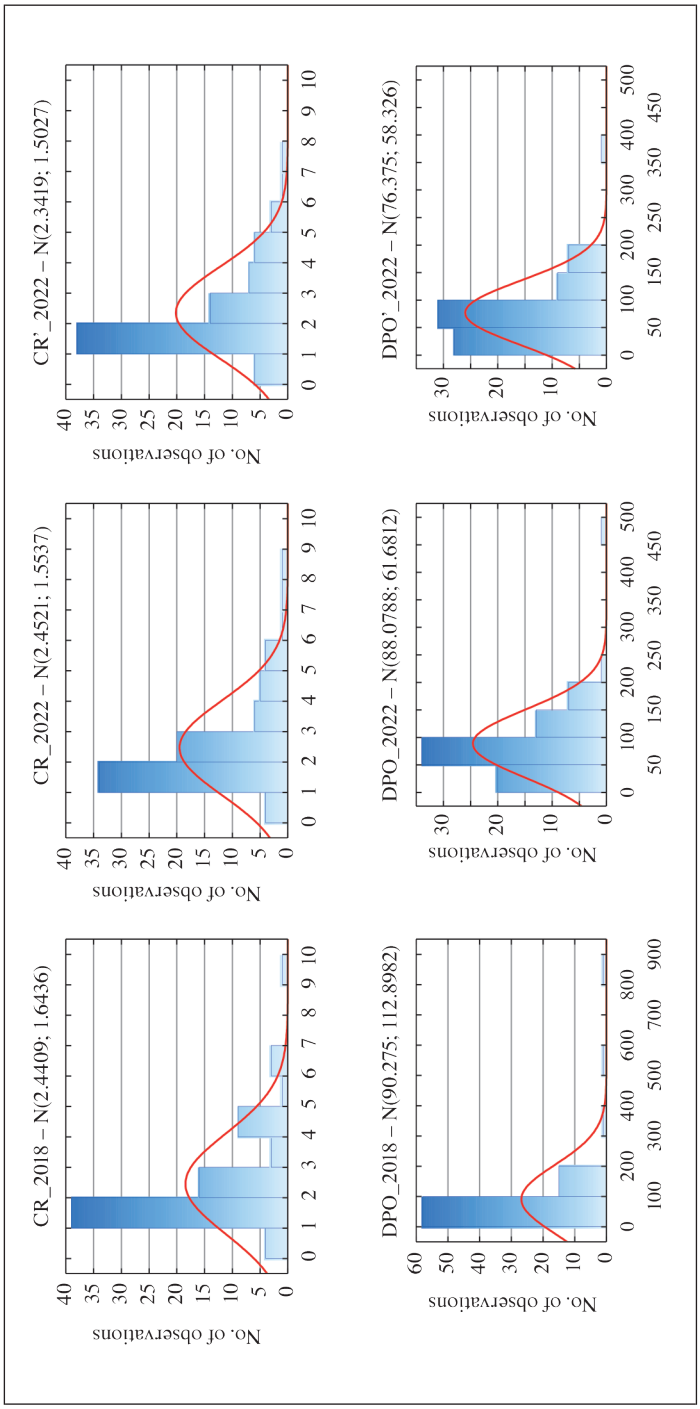

Fig. 2. The Distributions of Analysed Financial Ratios

Source: own study, based on the financial statements of companies.

Based on the presented data, there were no significant changes in liquidity levels between 2022 and 2018; however, this needs confirmation through appropriate statistical tests. Only a slight increase in CR was observed.

Regarding DPO, there was an increase in 2022 compared to 2018, as indicated by higher median, quartile 1, and quartile 3 values in 2022. Although the mean value decreased, this was due to a single outlier case. In 2018, the mean ratio was inflated by an extremely high value recorded for one enterprise, exceeding 800.

The probability distributions of the analysed ratios did not exhibit normal distributions in any case (Fig. 2).

The Kolmogorov-Smirnov and Shapiro-Wilk tests conducted in each case yielded *p*-values less than 0.05, indicating that the hypothesis of normal distribution can be rejected. Therefore, non-parametric sign tests and Wilcoxon signed-rank tests were used as primary tests to assess distribution differences, while parametric *t*-tests were considered supplementary. Spearman's rank correlation coefficient was used to evaluate dependencies, as it is insensitive to asymmetry and extreme observations.

Examining the relationship between the CR and DPO ratios in 2022 compared to their values in 2018 reveals that these are positive correlations. Higher values of the ratios in 2018 generally corresponded to higher values of the ratios in 2022 (Fig. 3).

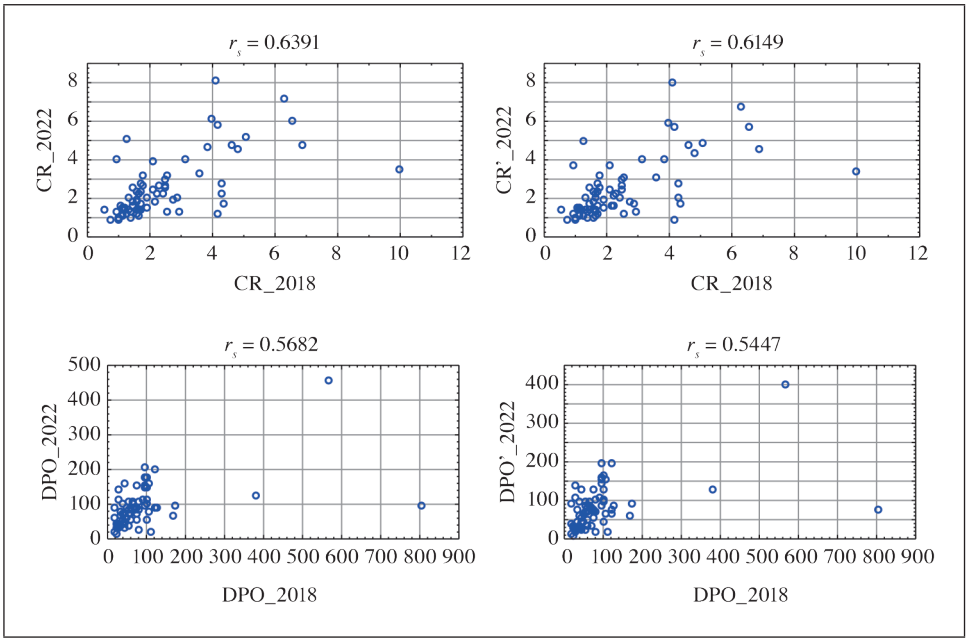

Fig. 3. The Relationships of the Analysed Financial Ratios in 2022 Compared to 2018

Source: own study, based on the financial statements of companies.

The correlations between the CR and DPO ratios coefficients in 2018 and 2022 are moderately strong on average (Spearman's rank correlation coefficient of 0.64 and 0.57, respectively). This is a result of normal economic processes occurring within enterprises, where some improve their financial situation while others experience less favourable conditions. Although the overall direction of the relationship is positive, indicating that companies in better financial health in 2018 tended to remain in better health in 2022, the correlation does not imply causation.

The adjustment of ratios CR and DPO to CR' and DPO' does not fundamentally affect the examined relationships, it only causes a slight decrease in strength.

The influence of the CR value on the DPO value is negative and moderately strong (Fig. 4). In 2018, it was approximately –0.69, while in 2022 it was –0.59. The adjustment of the ratios did not result in a significant change in the correlation coefficient; post-adjustment, it stands at –0.55.

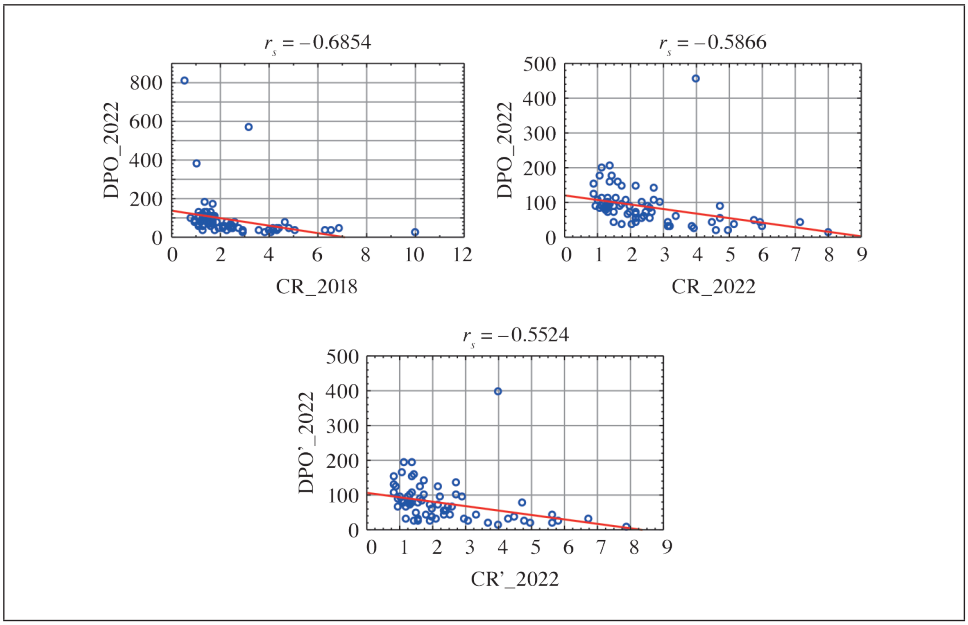

Fig. 4. The Impact of CR on DPO

Source: own study, based on the financial statements of companies.

It is quite important to note here that the adjustment of the ratios, and thus the correlations for the CR' and DPO' ratios, only slightly diminish the strength of the relationship, but the direction remains fully consistent with the original ratios. Therefore, the adjustment of the ratios does not affect the assessment of the

relationships between the ratios, indicating that they measure the same phenomenon after adjustment.

The difference between the distribution of the liquidity ratio (CR) and the distribution of DPO in 2018 compared to analogous ratios in 2022 is statistically insignificant. In each case, Shapiro-Wilk tests conducted in each case yielded a *p*-value less than 0.05, indicating no grounds for rejecting the hypothesis of no significant difference between the ratios. Therefore, there was no significant change in liquidity between 2018 and 2022. This allows for a reliable assessment of the impact of liquidity ratio adjustments.

The most important issue to resolve here is the difference between the distributions of the ratios before adjustment (CR and DPO) and after adjustment (CR' and DPO'). When examining the significance of the difference between CR and CR' ratios as well as DPO and DPO' ratios, non-parametric tests indicate a significant difference ($p < 0.05$, shown in bold in Table 4). This means that adjusting the ratios causes a significant difference in the resulting distribution.

Table 4. Tests of Significance of the Difference in Distributions of Ratios – Significance Levels

CR	CR2018	CR2022	CR'2022
CR2018	–	0.9087	0.5663
CR2022	0.5447	–	**0.0000**
CR'2022	0.6192	**0.0000**	–
DPO	DPO2018	DPO2022	DPO'2022
DPO2018	–	0.0512	0.7308
DPO2022	**0.0440**	–	**0.0000**
DPO'2022	0.6599	**0.0000**	–

Source: own study, based on the financial statements of companies.

Notes: above the diagonal – sign test, below the diagonal – Wilcoxon rank test.

Non-parametric tests measure differences from the perspective of individual enterprises; in this context, it means that the directions of ratio changes after adjustment across all enterprises are directionally consistent and statistically significant. The adjustment of the CR and DPO ratios results in decreases in the values of these ratios (Fig. 5, Table 5).

Post-adjustment, the CR ratio is found to be on average 0.11 lower for the surveyed companies, with a median decrease of 0.06 in this ratio's value. Generally, for the vast majority of companies (75%), the adjustment in liquidity ratios fell within the range of –0.15 to 0, while for 25% of companies, the downward adjustment exceeded 0.15. Despite the decrease in the CR ratio, the adjustment

also led to a reduction in DPO. The average decrease in this ratio was 11.70, with a median decrease of 9.87. Generally, adjusting ratios for funds accumulated in VAT accounts and public-law obligations leads to simultaneous decreases in liquidity ratios (including CR) and decreases in DPO.

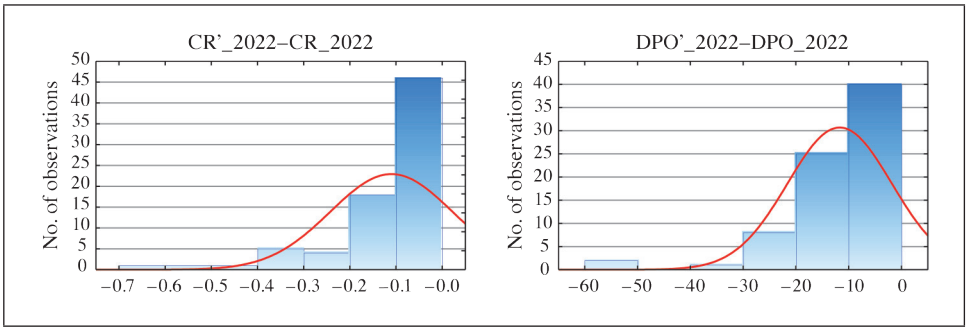

Fig. 5. Distribution of the Difference in Ratio Values after Adjustment

Source: own study, based on the financial statements of companies.

Table 5. Descriptive Statistics of the Adjustment for the CR and DPO Ratios

Variable	Mean	Std. Dev.	Median	Min	Max	Q1	Q3
CR'2022–CR2022	–0.11	0.13	–0.06	–0.65	0.00	–0.15	–0.02
DPO'2022–DPO2022	–11.70	9.88	–9.87	–58.47	0.00	–15.50	–4.98

Source: own study, based on the financial statements of companies.

It is worth noting that the primary advantage of applying corrections to liquidity ratios (including CR) is to adjust their values to a level that corresponds to the actual ability to settle current obligations, even though the difference in the CR ratio values before and after correction was not significant. Another advantage of the correction is to adjust DPO, which in its original form overstates the average time to settle business obligations, which is unfavourable in assessing a company. Generally, applying corrections organises and makes the financial ratios of the enterprise more realistic.

6. Conclusions

The study introduces a new perspective on analysing the financial liquidity of construction companies in the context of the introduction of SPM. As a result of the analysis, it was found that the introduction of SPM did not cause significant changes in the liquidity level between the years examined, which was confirmed by appropriate statistical tests. However, it was noticed that the correction of liquidity ratios, such as CR and DPO, had a significant impact on the distribution of the

values of these ratios. This correction adjusts the values of ratios to the actual ability to settle current liabilities, which is crucial in the financial assessment of enterprises. Moreover, the conducted research confirmed that modifying the ratios does not significantly change their average values, but affects their distributions. The correction of ratios therefore allows for a more reliable assessment of the financial situation of construction companies and their ability to manage liquidity in the long term. Therefore, hypothesis H1 is not fully confirmed, the ratios are not significantly different between 2018 and 2022.

Although the study results do not allow for definitive confirmation of the hypothesis, their significance in economic practice is substantial. The obtained results are particularly important for economic practice, especially in the context of assessing the creditworthiness and financial condition of construction companies. Adjusting liquidity ratios to the applicable regulations enables more accurate monitoring of the financial situation and better liquidity risk management in the construction sector. They suggest that despite the lack of significant changes in the level of financial liquidity, adjusting the ratios to new regulatory conditions represents a step toward more precise assessments of the financial capacity of construction companies, which may have significant implications for financial decision-making.

Despite the small differences in the level of financial liquidity resulting from the introduction of SPM, it should be considered justified to make adjustments in the calculation of financial ratios by the amount of split payment. Generally, this means that hypothesis H2 is true. There are situations in which failure to make such an adjustment may result in an overstatement of, for example, the current liquidity ratio, which may translate into an incorrect assessment of the overall financial situation of the audited company. The consequences of this can be manifold. From temporary disruptions in repayment of liabilities, even to the insolvency of the company or its bankruptcy. Therefore, adjusting financial liquidity ratios by the amount of funds accumulated in the VAT account will limit the receipt of incorrect results. It may also contribute to a more accurate assessment of the company by its owners, managers, contractors and potential investors.

Authors' Contribution

The authors' individual contribution is as follows: Grzegorz Przekota – methodological concept of the study, analyses and calculations, interpretation of the results, critical revision of the manuscript, supervision of its overall structure; Anna Kowal-Pawul – research concept, literature review, co-authorship of the empirical part of the study, including the concept of adjusted indicators and the interpretation of the results; Rafał Pitera – data collection, calculation of indicators for the analysed enterprises, implementation of adjustments based on the authors' assumptions, contribution to the manuscript editing.

Conflict of Interest

The authors declare no conflict of interest.

References

The Act of 11 March 2004 on goods and services tax (VAT Act) (Journal of Laws 2004 No. 54, item 535) [Ustawa z dnia 11 marca 2004 r. o podatku od towarów i usług (Dz.U. 2004 nr 54, poz. 535)].

The Act of 15 December 2017 amending the VAT Act and certain other acts (Journal of Laws 2018, item 62) [Ustawa z dnia 15 grudnia 2017 r. o zmianie ustawy o podatku od towarów i usług oraz niektórych innych ustaw (Dz.U. 2018, poz. 62)].

Andrzejewska, K. (2020). Mechanizm podzielonej płatności. *Biuletyn Informacyjny dla Służb Ekonomiczno-Finansowych*, 9.

Annex 15 to the Act of 11 March 2004 on goods and services tax (VAT Act) (Journal of Laws 2004 No. 54, item 535) [Aneks nr 15 do Ustawy z dnia 11 marca 2004 r. o podatku od towarów i usług (Dz.U. 2004 nr 54, poz. 535)].

Commission on Taxation and Welfare Secretariat. (2021). *Overview of Economic Principles and Fundamentals of a Tax System*. Retrieved from: https://www.gov.ie/ (accessed: 4.04.2024).

CRIDO. (2018). *Podzielona płatność VAT – jak modelować płynność finansową w firmie*.

Ćwiąkała-Małys, A., Karpińska, M., & Piotrowska, I. (2018). Problemy związane z wdrażaniem mechanizmu podzielonej płatności w praktyce – dyskusja. *Intercathedra*, *4*(37), 335–340. https://doi.org/10.17306/J.INTERCATHEDRA.2018.00041

Duclos, J. Y. (2008). Horizontal and Vertical Equity. In: S. N. Durlauf, L. E. Blume (Eds), *The New Palgrave Dictionary of Economics*. Palgrave Macmillan. https://doi.org/10.1057/978-1-349-95121-5_1961-1

Elkins, D. (2006). Horizontal Equity as a Principle of Tax Theory. *Yale Law & Policy Review*, *24*, 43–90.

European Commission and Deloitte. (2017). *Analysis of the Impact of the Split Payment Mechanism as an Alternative VAT Collection Method – Final Report*. Publications Office of the European Union. https://doi.org/10.2778/195355

Fornalik, J., & Jaworska, M. (2020). *Obowiązkowy split payment*. C.H. Beck.

Gomułowicz, A., & Mączyński, D. (2016). *Podatki i prawo podatkowe*. Wolters Kluwer.

Gunnarsson, A., & Eriksson, M. (2017). *Discussion Paper on Tax Policy and Tax Principles in Sweden, 1902–2016* (FairTax Working Paper Series No. 08).

Hasen, D. (2012). Tax Neutrality and Tax Amenities. *Florida Tax Review*, *12*(1), 1–62.

Kijuk, M. (2018). Mechanizm podzielonej płatności VAT i jego wpływ na płynność przedsiębiorstwa. *Modern Management Review*, *25*(3), 125–139. https://doi.org/10.7862/rz.2018.mmr.29

KIS. (2024). Krajowa Informacja Skarbowa. https://www.kis.gov.pl (accessed: 9.04.2024).

Kopyciańska, K. (2017). Kontrowersje wokół tzw. uszczelniania systemu podatkowego w kontekście ostatnich zmian odnoszących się do podatku od towarów i usług. *Kwartalnik Prawa Podatkowego*, 3, 39–54. https://doi.org/10.18778/1509-877X.03.02

Kowal, A. (2019). Split Payment Mechanism in the Economy of Small and Medium-sized Enterprises. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie*, *4*(44), 39–51. https://doi.org/10.25944/znmwse.2019.04.3951

Kowal, A., & Lichota, W. (2020). Proces cyfryzacji podatku VAT w Polsce. *Studia Prawno-Ekonomiczne*, *115*, 265–282. https://doi.org/10.26485/SPE/2020/115/15

Kowal-Pawul, A. (2022). *Ekonomiczne uwarunkowania i konsekwencje cyfryzacji podatku od towarów i usług w Polsce*. PhD thesis. University of Rzeszów.

Kowal-Pawul, A., & Przekota, G. (2021). Importance of VAT Digitization for Income Disclosure in Section F – Construction – a Case for Poland. *Journal of International Studies*, *14*(4), 67–86. https://doi.org/10.14254/2071-8330.2021/14-4/5

Kowalczyk, J., Samborska, M., Kempa, Ł., Jakubczak, M., & Schwendimann, U. (Eds). (2020). *Tax Compliance in Poland*. Swiss Chamber Poland.

KPMG. (2019a). *Mandatory Split Payment Mechanism from 1st November 2019*. Retrieved from: https://assets.kpmg/content/dam/kpmg/pl/pdf/2019/09/pl-en-tax-alert-KPMG-2019-09-24-mandatory-split-payment-mechanism-from-1-st-november-2019.pdf (accessed: 9.04.2024).

KPMG. (2019b). *Mechanizm podzielonej płatności – kontrowersyjne narzędzie do walki z wyłudzeniami VAT*. Retrieved from: https://kpmg.com/pl/pl/home/insights/2019/12/mechanizm-podzielonej-platnosci-kontrowersyjne-narzedzie-do-walki-z-wyludzeniami-vat.html (accessed: 9.04.2024).

Kumor, E. (2009). Efektywność i sprawiedliwość jako przesłanki budowy racjonalnego systemu opodatkowania dochodów osób fizycznych. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 39, 142–149.

Mirrlees, J., Adam, S., Besley, T., Blundell, R., Bond, S., Chote, R., Gammie, M., Johnson, P., Myles, G., & Poterba, J. (Eds). (2010). *Dimensions of Tax Design: The Mirrlees Review*. Institute for Fiscal Studies. Oxford University Press.

Mirrlees, J., Adam, S., Besley, T., Blundell, R., Bond, S., Chote, R., Gammie, M., Johnson, P., Myles, G., & Poterba, J. (Eds). (2011). *Tax by Design: The Mirrlees Review*. Institute for Fiscal Studies. Oxford University Press.

Modzelewski, W. (2020). *Mechanizm podzielonej płatności w podatku od towarów i usług. Problematyka prawna*. C.H. Beck.

Niemiec, A., & Skoczylas, W. (2024). Wskaźniki finansowe przedsiębiorstw według działów (sektorów) za 2022 r. Sektorowe wskaźniki finansowe. Opracowanie Komisji raportowania i analiz ekonomicznych Rady Naukowej SKwP wspólnie z InfoCredit. *Rachunkowość*, 4, 59–85.

Nowak-Piechota, A. (2018). Mechanizm podzielonej płatności – ocena nowej regulacji. *Kwartalnik Prawa Podatkowego*, 2, 119–132. https://doi.org/10.18778/1509-877X.2018.02.06

Obrzeżgiewicz, D. (2019). Impact of Split Payment on Financial Liquidity of Enterprises. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, *63*(12), 88–99. https://doi.org/10.15611/pn.2019.12.07

OECD. (2014). *Addressing the Tax Challenges of the Digital Economy*. OECD/G20 Base Erosion and Profit Shifting Project.

Olalekan, S., & Oyedokun, G. E. (2019). Relevance of Adam Smith Canons of Taxation to the Modern Tax System. *Journal of Taxation and Economic Development*, *18*(3), 12–34.

Ooi, V. (2016). Redistributive Taxation in the Modern World. *Singapore Law Review*, *34*, 173–218.

Opałka, A. (2011). Neutralność podatkowa – zarys problemu. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia*, 40, 59–69.

Owsiak, S. (2017). *Finanse publiczne. Współczesne ujęcie*. Wydawnictwo Naukowe PWN.

PKD. (2024). *Polska Klasyfikacja Działalności* (*PKD 2007*). Retrieved from: https://stat.gov.pl/Klasyfikacje/doc/pkd_07/pkd_07.htm (accessed: 9.04.2024).

Podatki.gov.pl. (2024). https://www.podatki.gov.pl (accessed: 9.04.2024).

Princen, S. (2012). Determining the Impact of Taxation on Corporate Financial Decision-making. *Reflets et perspectives de la vie économique*, *51*, 161–170. https://doi.org/10.3917/rpve.513.0161

PwC. (2015). *Split payment. Raport PWC*. Retrieved from: https://www.pwc.pl/pl/pdf/split-payment-raport-pwc.pdf (accessed: 4.03.2024).

PwC. (2019). *Obowiązkowy split payment*. Retrieved from: https://www.pwc.pl/pl/pdf/Ta-Mandatory-split-payment-PL.pdf (accessed: 3.03.2024).

Raczkowski, K., Schneider, F., & Węgrzyn, J. (2023). *Tax System Economics*. Wydawnictwo Naukowe PWN.

Sarnowski, J., & Selera, P. (2019). *Reducing the VAT Gap: Lessons from Poland*. Polish Economic Institute.

Sarnowski, J., & Selera, P. (2020). Dwa lata obowiązywania w Polsce mechanizmu podzielonej płatności w VAT – doświadczenia i wnioski. *Doradztwo Podatkowe – Biuletyn Instytutu Studiów Podatkowych*, *10*(290), 4–12. https://doi.org/10.5604/01.3001.0014.4742

Szołno-Koguc, J. (2016). Dylematy sprawiedliwości podatkowej – równość i powszechność opodatkowania a przywileje podatkowe. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, 294, 164–172.

Tratkiewicz, T. (2017). Model podzielonej płatności – remedium na oszustwa w VAT? *Annales Universitatis Mariae Curie-Skłodowska Lublin – Polonia. Sectio H*, *51*(6), 475–484. https://doi.org/10.17951/h.2017.51.6.475

Weber, K. (2024). *Split payment. Co to jest mechanizm podzielonej płatności?* Retrieved from: https://www.ey.com/pl_pl/tax/split-payment-co-to-jest-mechanizm-podzielonej-platnosci (accessed: 9.03.2024).

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On Some Construction of the Design of Experiments for Two Response Variables

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ABSTRACT

Objective: The aim of the article is to propose an alternative approach to constructing a design of experiments that allows for identifying settings of factor levels so that the response variables achieve desired values. The presented method will be used to determine the parameters of the wood pellet production process, which is characterised by two response variables.

Research Design & Methods: This paper presents a proposal for the construction of an experimental design that allows for the inclusion of two outcome variables characterising the production process under study. The method employs an appropriate synthetic variable and considers the desired ranges of variation of the outcome variables. Furthermore, permutation tests were utilised in the analysis of the experimental results.

Findings: A method of constructing an experimental plan was proposed, which allowed unambiguous recommendations to be made for the wood pellet production process under study. The settings of the individual factors for which the quality of the pellets produced and the efficiency of the production line take on values within the specified range were indicated.

Implications/Recommendations: The presented method of constructing the experimental plan, based on the analysis of an appropriately constructed synthetic variable, allowed the wood pellet production process to be designed accordingly.

Contribution: An alternative method of constructing an experimental design has been proposed that allows for the analysis of the influence of factors on the two outcome variables that characterise the production process under study.

Article type: original article.

Keywords: design of experiments, response surface function, response variable, wood pellet production process.

JEL Classification: C99.

1. Introduction

The advanced technological development contributes to the search for new solutions during the production process. In particular, modern manufacturing companies are seeking methods and tools to enhance the technological and economic results of the production process. Among the solutions that address these needs are statistical quality control methods, and in particular, methods of design of experiments (Kończak, 2007).

In the area of designing or improving manufacturing process outcomes, the use of experiment planning methodologies allows for tangible benefits, including a reduction in the time or cost of implementing a manufacturing process (Montgomery, 2020). Typically, experiment planning methods allow the evaluation of the dependence of a single response variable on a fixed number of factors. Contemporary manufacturing processes are complex, and many times the analysis of a single variable characterising the process under study will not be sufficient.

The objective of this article is to propose an alternative method of constructing an experimental plan that allows two response variables to be considered simultaneously in the experiment. The proposed method will be used to improve the results of a real wood pellet production process.

2. Basics of Design of Experiments Methods

In the 1920s, Ronald Aylmer Fisher was the first to propose the use of methods for the design of experiments in agricultural experimentation (Fisher, 1925, 1935). During the following decades, these methods were widely developed and found application not only in the natural sciences, but also in the practice of production enterprises. Nowadays, one sees opportunities for the use of design of experiments methods in the activities of non-manufacturing enterprises or in marketing (Antony *et al*., 2011; Montgomery, 2020).

An experiment consists of n experimental trials. In the experiment, the values of the response variable Y are obtained with fixed values of the factors $X_1, X_2, \ldots, X_m$.

The design of an experiment is the determination of an appropriate arrangement of the levels of the selected factors in the individual experiments, which should be carried out in a randomised manner. The dependence of the response variable Y on the values of the factors $X_1, X_2, \ldots, X_m$ is defined in the form of a statistical model (Wawrzynek, 1993):

$$Y(X_1, X_2, \ldots, X_m) = y(X_1, X_2, \ldots, X_m) + \varepsilon, \tag{1}$$

where $EY(X_1, X_2, \ldots, X_m) = y(X_1, X_2, \ldots, X_m), E(\varepsilon) = 0, V(\varepsilon) = \sigma^2$ and σ^2 is constant. Model (1) can be expressed as a general linear model (Wawrzynek, 2009):

$$Y^T = (Y_1\, Y_2 \ldots Y_m) \tag{2}$$

$$\varepsilon^T = (\varepsilon_1\, \varepsilon_2 \ldots \varepsilon_n) \tag{3}$$

$$\beta^T = (\beta_1\, \beta_2 \ldots \beta_k) \tag{4}$$

$$f^T(x) = \left(f_1(x)\, f_2(x) \ldots f_k(x)\right) \tag{5}$$

$$F = \begin{bmatrix} f_1(x_1) & \cdots & f_k(x_1) \\ \vdots & \ddots & \vdots \\ f_1(x_n) & \cdots & f_k(x_n) \end{bmatrix} \tag{6}$$

where $f_i(x_j) \equiv x_{ij}$, for $i = 1, 2, \ldots, k, j = 1, 2, \ldots, n$. Then the function defined as $y = F\beta$ is referred to as a response surface function. In practical applications, it is typical to consider response surface functions that do not take account for interactions between factors, of the form (Wawrzynek, 2009; Montgomery, 2020):

$$y(x_1, x_2, \ldots, x_m) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \tag{7}$$

or response surface functions that account for factor interactions, given by the formula:

$$y(x_1, x_2, \ldots, x_m) = \beta_0 + \beta_1 x_1 + \cdots + \beta_m x_m + \beta_{12} x_1 x_2 + \cdots + \beta_{m-1m} x_{m-1} x_m. \tag{8}$$

The analysis of experimental results is typically conducted using classical statistical techniques, such as analysis of variance and regression analysis. These methods require the use of parametric tests (Wawrzynek, 1993, 2009; Aczel, 2000; Kończak, 2007; Montgomery, 2009; Myers, Montgomery & Anderson-Cook, 2016). Additionally, the literature considers the use of permutation tests in the significance analysis of response surface function parameters (Złotoś, 2020).

Among the most commonly used experimental designs in practice are full factorial designs of experiments 2^k, which require 2^k experimental trials to be carried out. An important role in practical applications is played by fractional factorial designs of experiments 2^{m-k}, that are constructed based on full factorial designs of experiments and lead to a reduction in the number of experiments by at least half (Dean, Voss & Draguljić, 2017; Rigdon *et al*., 2022; Antony, 2023).

In the usual case, factorial designs of experiments refer to analysing the effect of a fixed number of factors on one response variable. In the case that the production process under study is characterised by two response variables, the analysis of the experimental results will address each variable individually. The recommendations made on the basis of the results obtained may then be inconclusive. In the literature, methods for analysing experimental results with two or more response variables are considered, which are based on graphical methods, take into account response surface functions with relevant parameters or desirability function (Derringer & Suich, 1980; Ryan, 2007; Boateng, 2023). However, the solution proposals considered in the literature do not take into account the nature of the response variables, including their ranges of variation.

3. Construction of Design of Experiment for Two Response Variables

An experiment involving k factors that requires n experimental trials to be performed will be considered. Two response variables, Y_1 and Y_2, are considered in the study, for which the desired ranges of variation have been established as $Y_1^{(z)} = [y_{1d}, y_{1g}]$ and $Y_2^{(z)} = [y_{2d}, y_{2g}]$, respectively. To determine the relationship between the factors considered and the response variables considered together, a synthetic variable must be constructed that takes into account the component variables Y_1 and Y_2.

In the initial stage of the proposed method, for each realisation of the response variable in the individual experimental trials, a function of the form:

$$k(y_{ij}) = \begin{cases} 0, & y_{ij} \in Y_j^{(z)} \\ d\left(y_{ij}, Y_j^{(z)}\right), & y_{ij} \notin Y_j^{(z)} \end{cases} \tag{9}$$

is determined, where $i = 1, 2, \ldots, n$, $j = 1, 2$ and $d\left(y_{ij}, Y_j^{(z)}\right) = \inf\limits_{y \in Y_j^{(z)}} d(y_{ij}, y)$ is a distance of a point y_{ij} from the set $Y_j^{(z)}$. The function (9) characterises the position of the actual values of the component response variables relative to the desired ranges of variation. The values of the function of the form (9) are then normalised according to the formula:

$$z_{ij} = \frac{k(y_{ij})}{\max\limits_i k(y_{ij})}. \tag{10}$$

In the second step of the proposed method, the values of the synthetic response variable are determined according to the following formula:

$$\tilde{y}_i = \delta z_{i1} + (1 - \delta) z_{i2}, \tag{11}$$

where δ is a fixed quantity within the interval (0, 1). The values of δ and $1 - \delta$ correspond to the weights of the individual component response variables Y_1 and Y_2,

and these can be set deliberately, depending on the specifics of the variables analysed. The defined synthetic variable forms the basis for further analysis of the experimental results.

The response surface function, which characterises the dependence of the synthetic response variable $\tilde{Y}$ on the k factors considered in the experiment, is expressed by the following equation:

$$\tilde{y} = \gamma_0 + \gamma_1 x_1 + \gamma_2 x_2 + \ldots + \gamma_k x_k + \tilde{\varepsilon}. \tag{12}$$

The analysis of the experimental results, which involves the evaluation of the significance of the parameters of the response surface function of the form (12), can be carried out using classical methods (Montgomery, 2020) or permutation tests (Złotoś, 2020). It is important to acknowledge that permutation tests can be utilised in circumstances where the assumptions of classical statistical methods are not met or the sample size is limited (Kończak, 2016). The results obtained will then allow for the identification of those factors that have a significant impact on the values of the synthetic response variable.

The individual steps of the presented construction of a design of experiment for two response variables, due to computational complexity, have the potential to result in difficulties in implementing the method in practice. The utilisation of specialised statistical software is then recommended. Of particular note is the R programme (open source software), which facilitates not only the analysis of the results of classical designs of experiment (cf. Lawson, 2015), but also the implementation of permutation tests (cf. Kończak, 2016).

4. The Application of the Proposed Method

Wood pellets are classified as solid biofuels, which are currently the renewable energy source with the largest share of energy production in Poland (GUS, 2023). Wood pellet production technology is a complex process. Proper analysis of the wood pellet production process allows for the production of high-quality pellets in a way that provides economic benefits. The study will consider the wood pellet production process implemented in a certain company in the wood industry.

The objective of this study is to identify the factors that significantly influence the results of the production process of wood pellets produced by a specific company. Additionally, the experimenter's task was to determine the nature of the dependence of pellet quality on the aforementioned factors.

A comprehensive analysis of the various stages of the wood pellet production process was conducted, with a particular focus on identifying the factors that could potentially impact the quality of the final product. Only those factors for which there were no inherent measurement difficulties were included in the study. Four controlled factors were considered in the experiment:

X_1 – moisture content of the raw material (%),
X_2 – moisture content of the raw material after drying (%),
X_3 – drying temperature (°C),
X_4 – feeder speed (rpm).

In order to ascertain the range of variation and levels of the controlled factors, measurements were taken of the values of each factor during the production process. The resulting data is presented in graphical form in Figure 1.

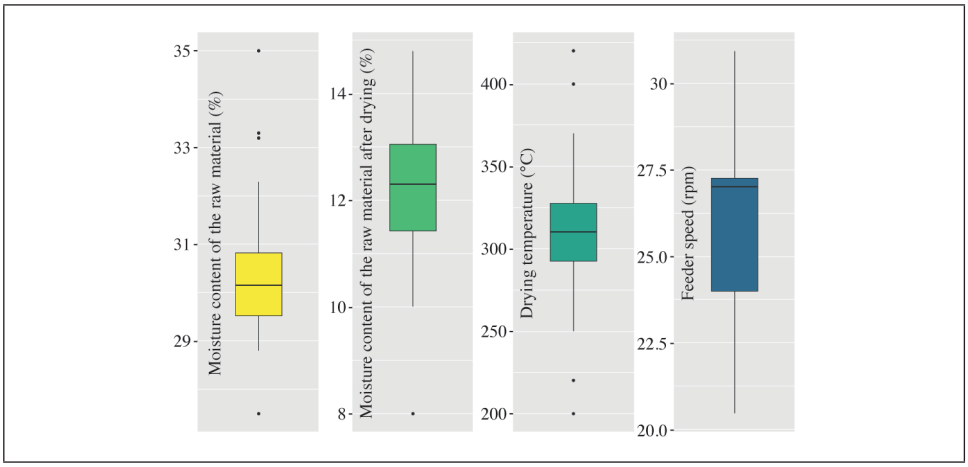

Fig. 1. Measurement Results of Individual Factors
Source: own elaboration.

The specific nature of the production process under study made it impossible to obtain precise values for the individual factor levels. An alternative method of determining factor levels was proposed, which refers to the proposal for imprecisely defined factors presented by Szerszunowicz (2011). Based on the measurements taken, a median value Me_i was determined for each factor $(i \in \{1,2,3,4\})$. It was agreed that each of the factors considered would be taken into account at two levels:

– upper level (denoted by "1") is defined as a value of the factor X_i is greater than Me_i,

– lower level (denoted by "–1"), when the value of the factor X_i is less than or equal to Me_i.

The subsequent step was to identify the response variable that most accurately reflects the pellet-making process. In the study under consideration, two response variables were identified:

Y_1 – bulk density of wood pellets,
Y_2 – production line efficiency.

The value for bulk density of pellets represents the weight of pellets (in kilograms) in a 1 m^3 container. The efficiency of the production line is described by the weight of pellets produced (in kilograms) per hour. The response variables permit an assessment of the quality of the pellets produced and the efficiency of the pellet production process. The bulk density of wood pellets typically ranges from 500 kg/m^3 to 800 kg/m^3, while the efficiency of the production line under consideration takes values from 300 kg/h to 450 kg/h (Kocsis & Csanády, 2019). Based on expert knowledge and accepted standards, ranges of values for the result variables were indicated, which would indicate the proper course of the wood pellet production process. It was assumed that pellets of optimal quality have a bulk density of 680 kg/m^3 to 720 kg/m^3, while the capacity of the production line should be 380 kg/h to 400 kg/h.

The identification of the factors and the response variable enabled the selection of an appropriate experimental design. A full factorial experiment 2^4, which would require the completion of 16 individual experimental trials, was initially considered. The specific characteristics of the pellet production process precluded the possibility of conducting such a large number of experimental trials in a short period of time and under identical conditions. Consequently, it was determined that a fractional factorial design of experiments 2^{4-1} would be employed, with the understanding that individual experiments would be conducted randomly. The experimental design, including the sequence of experiments, is presented in Table 1. The established experimental design allows for a reduction in the number of experimental trials by half. The execution of the experiments is then carried out under as uniform conditions as possible, which allows for a relative reduction in the influence of interfering factors. Furthermore, reducing the number of experiments leads to a reduction in the execution time of the experiment. This reduces the costs associated with the operation of the production line and possible downtime in the production process.

Table 1. Scheme for the Realisation of Fractional Factorial Design Experiments 2^{4-1}

Number of Experimental Trial (Sequence)	X_1	X_2	X_3	X_4
1 (8)	1	1	1	1
2 (3)	1	1	–1	–1
3 (5)	1	–1	1	–1
4 (1)	1	–1	–1	1
5 (6)	–1	1	1	–1
6 (2)	–1	1	–1	1
7 (4)	–1	–1	1	1
8 (7)	–1	–1	–1	–1

Source: own elaboration.

The determination of the levels of factors and response variables and the choice of the experimental design allowed the design of experiments to be carried out in a specific order. The results of the conductive of experiments are presented in Table 2.

Table 2. The Results of Experimental Trials

Number of Experimental Trial (Sequence)	X_1	X_2	X_3	X_4	Y_1	Y_2
1 (8)	1	1	1	1	714	468
2 (3)	1	1	–1	–1	730	362
3 (5)	1	–1	1	–1	696	372
4 (1)	1	–1	–1	1	850	354
5 (6)	–1	1	1	–1	694	318
6 (2)	–1	1	–1	1	512	348
7 (4)	–1	–1	1	1	610	330
8 (7)	–1	–1	–1	–1	802	336

Source: own elaboration.

The aim of the present experiment was to determine the dependence of the response variables on individual factors. Two response variables were included in the study, and therefore two response surface functions were considered of the form:

$$y^{(1)} = \beta_0^{(1)} + \beta_1^{(1)} x_1 + \beta_2^{(1)} x_2 + \beta_3^{(1)} x_3 + \beta_4^{(1)} x_4 + \varepsilon^{(1)}, \tag{13}$$

$$y^{(2)} = \beta_0^{(2)} + \beta_1^{(2)} x_1 + \beta_2^{(2)} x_2 + \beta_3^{(2)} x_3 + \beta_4^{(2)} x_4 + \varepsilon^{(2)}. \tag{14}$$

In order to determine the dependence Y_1 of the response variable on the factors considered, the coefficients of the response surface function of the form (13) were estimated and their significance was verified. Due to the small number of observations, the evaluation of the significance of the parameters of the response surface function was carried out using appropriate permutation tests (Złotoś, 2020). The results of these analyses are presented in Table 3.

For each of the estimated parameters, the value of $\hat{ASL}$ is greater than the established significance level, so there is not enough evidence to reject the null-hypothesis that the factors do not influence the values of the response variable Y_1.

Similar considerations were made for the response variable Y_2. The results of the permutation tests performed to verify the significance of the estimated parameters of the response surface function of the form (14) are presented in Table 4.

Table 3. Results of Testing Significance of Response Surface Function (13)

Parameter $\beta_i^{(1)}$	Parameter Estimator Value $\beta_i^{(1)}$	$\hat{ASL}$ Value
$\beta_0^{(1)}$	701.00	0.5981
$\beta_1^{(1)}$	46.50	0.3179
$\beta_2^{(1)}$	–38.50	0.3833
$\beta_3^{(1)}$	–22.50	0.5917
$\beta_4^{(1)}$	–29.50	0.5202

Source: own elaboration.

Table 4. Results of Testing Significance of Response Surface Function (14)

Parameter $\beta_i^{(2)}$	Parameter Estimator Value $\beta_i^{(2)}$	$\hat{ASL}$ Value
$\beta_0^{(2)}$	356.25	0.5089
$\beta_1^{(2)}$	23.25	0.1976
$\beta_2^{(2)}$	8.25	0.8643
$\beta_3^{(2)}$	15.75	0.4988
$\beta_4^{(2)}$	18.75	0.3631

Source: own elaboration.

As in the case of the response variable Y_1, the results obtained do not allow the identification of factors that have a significant impact on the values of the response variable Y_2. Therefore, the analysis of the experimental results using permutation tests did not allow any recommendations to be made for the setting of the parameters of the wood pellet production process under consideration.

It should be noted that the analysis of the experimental results carried out referred to each of the response variables considered individually. In practice, this may lead to inconclusive results (e.g., a factor has a significant effect on only one of the variables considered). In addition, the study did not take into account the desired ranges of values for the response variables, which were determined at the design stage of the experimental design. This means that methods should be sought to construct a design that allows the analysis of experimental results that take into account more than one response variable at a time. In particular, consideration should be given to response variables whose values are expected to fall within the desired ranges of variability.

The study considered two response variables: bulk density (Y_1) and production line efficiency (Y_2). For these variables, the desired ranges of variation were

determined: $Y_1^{(z)} = [680, 720]$ and $Y_2^{(z)} = [380, 400]$, respectively. According to the proposed method of analysis of the experimental results, for each of the obtained values of the result variables, the values of the function (9) were determined, which for the considered process takes the forms:

$$k(y_{i1}) = \begin{cases} 0, & y_{i1} \in Y_1^{(z)} \\ d(y_{i1}, Y_1^{(z)}), & y_{i1} \notin Y_1^{(z)} \end{cases} \tag{15}$$

and

$$k(y_{i2}) = \begin{cases} 0, & y_{i2} \in Y_2^{(z)} \\ d(y_{i2}, Y_2^{(z)}), & y_{i2} \notin Y_2^{(z)} \end{cases} \tag{16}$$

where $i = 1, 2, \ldots, 8$. The values obtained were then normalised according to formula (10). In addition, the values of the synthetic response variable were determined according to formula (11). Due to the similar importance of the considered response variables, the value of $\delta = 0.5$ was taken. The normalised values of functions (15), (16) and the synthetic response variable for each experiment are shown in Table 5.

Table 5. The Normalised Values of Functions (15) and (16) and Value of Synthetic Response Variable

Number of Experimental Trial (Sequence)	X_1	X_2	X_3	X_4	z_{i1}	z_{i2}	$\tilde{y}_i$
1 (8)	1	1	1	1	0.0000	1.0000	0.5000
2 (3)	1	1	–1	–1	0.0595	0.8235	0.4415
3 (5)	1	–1	1	–1	0.0000	0.1176	0.0588
4 (1)	1	–1	–1	1	0.7738	0.3824	0.5781
5 (6)	–1	1	1	–1	0.0000	0.9118	0.4559
6 (2)	–1	1	–1	1	1.0000	0.4706	0.7353
7 (4)	–1	–1	1	1	0.4167	0.7353	0.5760
8 (7)	–1	–1	–1	–1	0.4881	0.6471	0.5676

Source: own elaboration.

The theoretical values of the synthetic response variable depend on the values of the component variables and are shown in Figure 2. It should be noted that the results of the production process will be of high quality if the values of the synthetic response variable are as small as possible.

A response surface function will be considered that determines the dependence of the synthetic response variable $\tilde{Y}$ on the factors of the form:

$$\tilde{y} = \gamma_0 + \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \tilde{\varepsilon}. \tag{17}$$

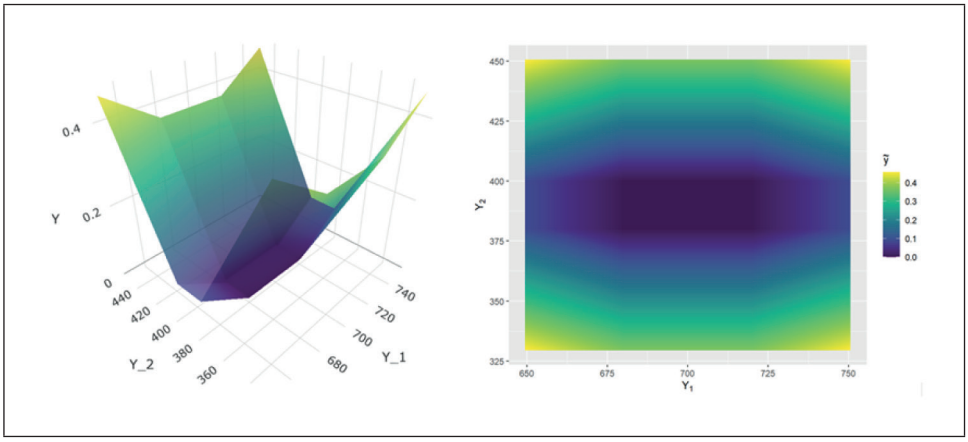

Fig. 2. Theoretical Values of the Synthetic Response Variable
Source: own elaboration.

The analysis of the established response surface function was conducted using permutation tests. The results of the response surface function parameter estimates (17) and an assessment of their significance are presented in Table 6.

Table 6. Results of the Response Surface Function Analysis (17)

Parameter γ_i	Parameter Estimator Value γ_i	$\hat{ASL}$ Value
γ_0	0.4891	0.0154
γ_1	–0.0945	0.0188
γ_2	0.0440	0.4126
γ_3	–0.0915	0.0261
γ_4	0.1082	0.0088

Source: own elaboration.

The resulting $\hat{ASL}$ value estimates are below the established significance level $\alpha = 0.05$ for the parameters $\gamma_0, \gamma_1, \gamma_3, \gamma_4$. This indicates that the values of the synthetic response variable $\tilde{Y}$ are significantly influenced by factors X_1, X_3 and X_4. In order to identify the settings of the factors that will result in the lowest values for the response variable, it is necessary to consider the response surface function, which is given by the following equation:

$$\hat{y} = 0.4891 - 0.0945x_1 - 0.0915x_3 + 0.1082x_4. \tag{18}$$

Consequently, for the factor X_4 at the lower level, the smallest value of the synthetic response variable will be obtained when the factors X_1 and X_3 are set at the

upper levels. The dependence of the value of the response surface function (18) on factor settings X_1 and X_3, for $X_4 = -1$ are shown in Figure 3.

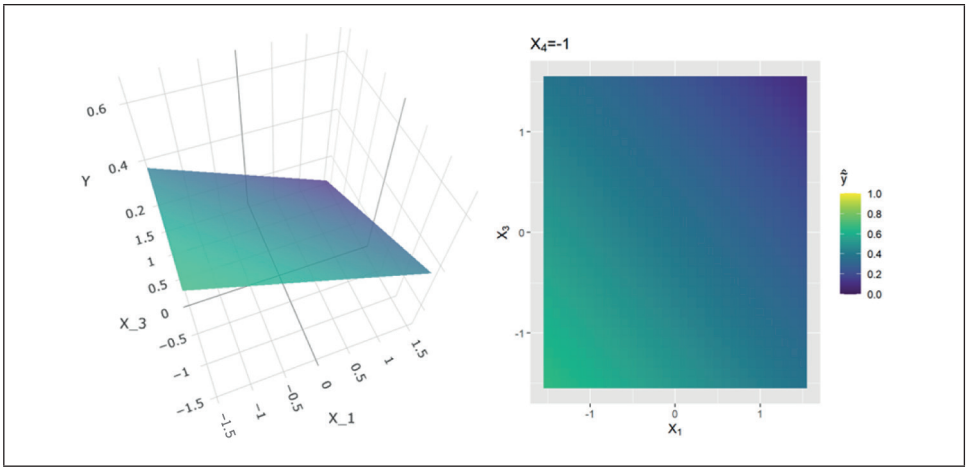

Fig. 3. Response Surface Function Values (18) for $X_4 = -1$
Source: own elaboration.

When a factor X_4 is set at the upper level, the smallest value of the synthetic response variable will be achieved for factors X_1 and X_3 set at the upper levels. The values of the response surface function (18) as a function of factor levels X_1 and X_3 are illustrated in Figure 4. It should be noted that the best of the two factor settings indicated would be to set the factor X_4 at the lower level and the factors X_1 and X_3 at the upper levels.

The results obtained for the wood pellet production process under consideration permit the assertion that the bulk density of pellets and the efficiency of the production line are significantly dependent on the moisture content of the raw material (factor X_1), drying temperature (factor X_3) and on the feeder speed (factor X_4). In addition, it is possible to obtain values for bulk density and production line efficiency that fall within the respective desired value ranges.

In conclusion, a recommendation was made for the production process under consideration, which states that obtaining good quality pellets involves:

– the use for production of raw material with a moisture content above 30.15%,
– setting the drying temperature above 310°C,
– setting the feeder speed to a level less than or equal to 27 rpm.

The above factor settings provide the best opportunity to obtain values for bulk density and production line efficiency at levels corresponding to the desired ranges of variation.

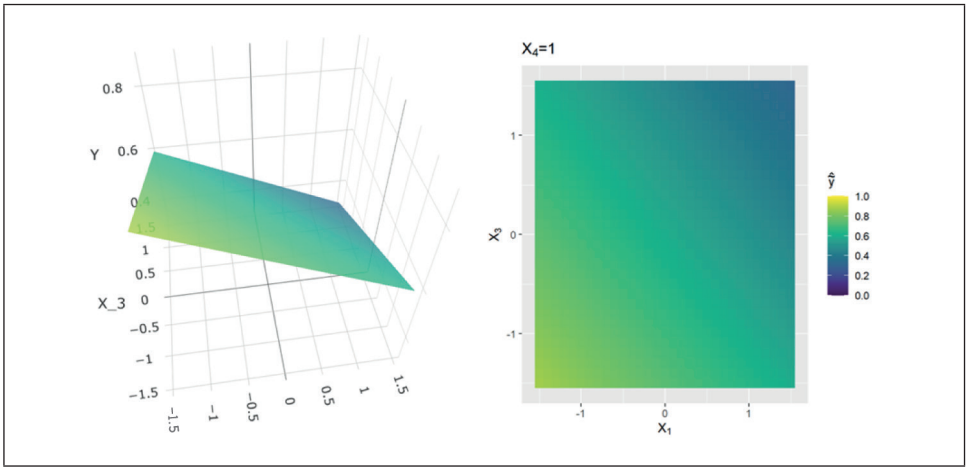

Fig. 4. Response Surface Function Values (18) for Factor $X_4 = 1$
Source: own elaboration.

The presented method has been effectively used to enhance the efficiency of the production line and the quality of the pellets produced. It is noteworthy that the proposed method has the potential for broader implementation in the context of industrial practice. With particular reference to enterprises specialising in the implementation of manufacturing or chemical processes, the results of which are characterised by two response variables. Furthermore, the proposed design of experiment incorporates the desired ranges of values for the outcome variables, thereby enabling the consideration of the specificities resulting from the recommendations for the process under study. The employment of permutation tests in the aforementioned approach renders this method suitable for the analysis of production processes, the course of which prevents the conduct of numerous experimental trials or their replication (which is usually required by classical or factorial designs of experiments).

5. Conclusions

This article presents the author's proposal for the construction of an experimental plan that allows the analysis of the influence of a fixed number of factors simultaneously on two outcome variables. Furthermore, the presented design of the experiment plan takes into account the desired ranges of variation for the values of the individual outcome variables.

The proposed method represents an alternative to the few approaches presented in the existing literature. Typically, these methods rely on individual analysis of each of the outcome variables considered, refer to graphical methods or use a suitably

specified desirability function in their construction (cf. Boateng, 2023). However, the indicated methods do not take into account established ranges of variability for the values of the considered outcome variables, which may lead to inconclusive conclusions for the considered production process. Furthermore, the analysis of experimental results is carried out using parametric methods, the use of which is not always justified.

The proposed method involves determining the value of an appropriately constructed synthetic variable. This permitted the analysis of a single response surface function, which took into account the two outcome variables and their ranges of variation. Moreover, the analysis of the experimental results was conducted using permutation tests. The implementation of the proposed method in the wood pellet production process enabled the formulation of clear technological recommendations to be made for the investigated process.

Conflict of Interest

The author declares no conflict of interest.

References

Aczel, A. D. (2000). *Statystyka w zarządzaniu*. Wydawnictwo Naukowe PWN.

Antony, J. (2023). *Design of Experiments for Engineers and Scientists*. Elsevier.

Antony, J., Coleman, S., Montgomery, D. C., Anderson, M. J., & Silvestrini, R. T. (2011). Design of Experiments for Non-manufacturing Processes: Benefits, Challenges and Some Examples. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *225*(11), 2078–2084. https://doi.org/10.1177/0954405410395857

Boateng, I. D. (2023). Application of Graphical Optimization, Desirability, and Multiple Response Functions in the Extraction of Food Bioactive Compounds. *Food Engineering Reviews*, *15*(2), 309–328. https://doi.org/10.1007/s12393-023-09339-1

Dean, A., Voss, D., & Draguljić, D. (2017). *Design and Analysis of Experiments*. Springer. https://doi.org/10.1007/978-3-319-52250-0

Derringer, G., & Suich, R. (1980). Simultaneous Optimization of Several Response Variables. *Journal of Quality Technology*, *12*(4), 214–219. https://doi.org/10.1080/00224065.1980.11980968

Fisher, R. A. (1925). *Statistical Methods for Research Workers*. Oliver and Boyd.

Fisher, R. A. (1935). *The Design of Experiments*. Oliver and Boyd.

GUS. (2023). *Energia ze źródeł odnawialnych w 2022 roku*.

Kocsis, Z., & Csanády, E. (2019). *Theory and Practice of Wood Pellet Production*. Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-26179-5

Kończak, G. (2007). *Metody statystyczne w sterowaniu jakością produkcji*. Wydawnictwo Akademii Ekonomicznej w Katowicach.

Kończak, G. (2016). *Testy permutacyjne. Teoria i zastosowania*. Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.

Lawson, J. (2015). *Design and Analysis of Experiments with R*. CRC Press.

Montgomery, D. C. (2009). *Introduction to Statistical Quality Control*. John Wiley & Sons.

Montgomery, D. C. (2020). *Design and Analysis of Experiments*. John Wiley & Sons.

Myers, R. H., Montgomery, D. C., & Anderson-Cook, C. M. (2016). *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*. John Wiley & Sons.

Rigdon, S. E., Pan, R., Montgomery, D. C., & Freeman, L. (2022). *Design of Experiments for Reliability Achievement*. John Wiley & Sons.

Ryan, T. P. (2007). *Modern Experimental Design*. John Wiley & Sons. https://doi.org/10.1002/0470074353

Szerszunowicz, M. (2011). Planowanie eksperymentów z uwzględnieniem czynników losowych. In: *Materiały VI Krakowskiej Konferencji Młodych Uczonych* (pp. 1057–1065). Grupa Naukowa Pro Futuro. Fundacja dla AGH.

Wawrzynek, J. (1993). *Statystyczne planowanie eksperymentów w zagadnieniach regresji w warunkach małej próby*. Wydawnictwo Akademii Ekonomicznej we Wrocławiu.

Wawrzynek, J. (2009). *Planowanie eksperymentów zorientowane na doskonalenie jakości produktu*. Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.

Złotoś, M. (2020). On the Use of Permutation Tests in the Significance Testing of Response Surface Function Parameters. *Argumenta Oeconomica Cracoviensia*, 1(22), 21–29. https://doi.org/10.15678/AOC.2020.2202

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Awareness and Perception of Electromobility among Young Consumers: Survey Results

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ABSTRACT

Objective: The purpose of the article is to analyse the knowledge, opinions, and attitudes of young consumers regarding electromobility.

Research Design & Methods: The analysis is based on a computer assisted web interviewing survey conducted among young consumers attending the Krakow University of Economics. The results were analysed using frequency distribution analysis and a chi-squared independence test. We used Cramér's *V* to determine the degrees of association among the variables.

Findings: The study shows that the surveyed group of respondents exhibits a moderate level of knowledge about electromobility and the environmental impact of electric vehicles. According

to the respondents, the most substantial barrier to electromobility is the availability of charging stations and the cost of purchasing electric vehicles.

Implications/Recommendations: The present study addresses part of a research gap found in the literature concerning young consumers' knowledge and opinions about electromobility.

Contribution: The research contributed to new insights about the knowledge, attitudes and opinions of young consumers about electromobility.

Article type: original article.

Keywords: electromobility, sustainable transport, environmental awareness, sustainable development.

JEL Classification: O13, O18, Q42, Q56.

1. Introduction

The growing public interest in electromobility is driven by such factors as excessive greenhouse gas emissions, local pollution (Bjerkan, Nørbech & Nordtømme, 2016), or the struggle for national energy security as the energy market evolves (Niedziółka, 2024, p. 12). Energy security is among the pivotal policy issues in the European Union because the green transition and energy dependency of its member states are critical components of international politics (Nyga-Łukaszewska & Napiórkowski, 2023, p. 209). Electromobility is a road transport system where the driving energy is electricity (Alogdianakis & Dimitriou, 2023). Whether or not electromobility will be achieved hinges on technological challenges and social changes, such as the attitude of the public towards the electrification of private and public transport (Grauers, Sarasini & Karlström, 2013; Degirmenci & Breitner, 2017; Lin & Wu, 2018). Electrification of private and public transport is a vital part of zero-emission transport, whereas sustainable transport and environmental protection are priorities of the transport policy (Zawieska, 2019). The growth in electromobility is motivated by the search for independence from oil, leading to reduced vehicle-derived pollution (Wodnicka & Malinowski, 2023). Nevertheless, many studies and governmental analyses disregard the social aspect, such as consumers' attitudes towards a complete electrification of private transport (Liao, Molin & van Wee, 2017; Lin & Wu, 2018).

Sales of passenger cars (including electric cars) have been growing in the European Union. In 2023, passenger cars sold in the EU by fuel type amounted to petrol at 35.3%, diesel at 13.6%, battery electric vehicles (BEV) at 14.6%, plug-in hybrid electric vehicles at 7.7%, hybrid electric vehicles at 25.8%, and APV other than electric at 3.0%. The same data for Poland show petrol car sales at 41.7%, diesel at 9.9%, BEV at 3.6%, plug-in hybrid electric vehicles at 2.8%, hybrid electric vehicles at 39.4% and APV other than electric at 2.6% (Statista, 2023).

The most important stimuli for electromobility include tax credits, subsidies, preferential rates for owners of electric vehicles, and fee exemptions. The main threats (barriers) to its growth include greater electricity demand, high variability in electric vehicle prices, high initial cost of purchase, potential restrictions on financial support for electric vehicle owners, and stagnation in charging infrastructure development (Bondar *et al*., 2023).

2. Legal Framework for Electromobility Growth in the European Union and Poland

Transition to a low-emission (carbon-neutral) economy is a priority for the European Union. The European Commission intends for Europe to become carbon neutral by 2050 through the decarbonisation effort (Kud, 2019, p. 147). It may prove to be an infeasible goal because four states (Czechia, Hungary, Estonia, and Poland) did not back the idea at a 2019 meeting because of the excessive costs it would cause to their economies. The European Commission, Council of the European Union, and European Parliament agreed on reducing CO_2 emissions from passenger cars and light commercial vehicles on 27 October 2022. The accepted proposal provides for zero-emission road mobility by 2035 (reduction of exhaust gas emissions by 100% compared to 2021) (European Parliament, 2023).

The relevance of electromobility and electric vehicles in Poland grew after the Ministry of Energy published its Plan for Electromobility Development in Poland – Energy for the Future in 2016 (Gov.pl, 2024). The Responsible Development Strategy until 2020, extendable until 2030 (RDS) adopted by Poland is a response to the European Union policy declared in Directive 2014/94/EU (adopted with Resolution No. 8 of the Council of Ministers of 14.02.2017, Official Gazette of the Government of the Republic of Poland item 260). Particular implementing programmes for the strategic goals of the RDS were: Plan for Electromobility Development in Poland. Energy for the Future (adopted 16.03.2017), National Framework for the Policy of Development of Alternative Fuel Infrastructure (adopted 29.03.2017) (European Commission, 2017), Act on electromobility and alternative fuels (adopted 11.01.2018, Polish Journal of Laws of 2020, item 908), and Act establishing the Low-emission Transport Fund (adopted 6.06.2018, Polish Journal of Laws of 2018, item 1356, as amended).

The purpose of the article and the study it reports is to analyse respondents' knowledge, opinions, and attitudes regarding electromobility. The goal was pursued with a structured questionnaire survey. The focus of the analysis was to investigate the knowledge of young consumers and the factors affecting their opinions and attitudes regarding electromobility.

The paper poses the following research hypotheses: (H1) respondents exhibit low levels of knowledge regarding the impact of battery electric vehicles (BEV) on

the environment, and (H2) the respondents believe that the cost of purchase of new electric vehicles and availability of charging stations are the biggest barriers to the development of electromobility.

The next research step is to analyse the decisions resulting from the attitudes of the respondents. The study attempts to answer three main research questions:

Q1: What is the level of knowledge of electromobility among the analysed group of respondents?

Q2: What is the opinion on electromobility among respondents?

Q3: What are respondents' behaviour patterns regarding the use of electric public transport?

3. Literature Review

Our literature study of surveys on electromobility in Poland revealed a diversity of respondent characteristics, survey periods, and research methods (Table 1).

Table 1. Review of Surveys on Electromobility in Poland

Author (Year)	Research Tool, Respondent Profile (Sample Size), Study Period
Gis, Menes & Waśkiewicz (2016)	Original survey questionnaire drafted at INFAS A.G., household representatives (370), 2013–2014
Kud (2019)	Original survey questionnaire, residents of Podkarpackie voivodeship, Poland (522), 2019
Polish Alternative Fuels Association – PAFA (Polskie Stowarzyszenie Paliw Alternatywnych, 2020)	Questionnaire by the PAFA, adult drivers (1,213), 2020
Lewicki *et al*. (2021)	Original survey questionnaire (online CAWI), adult private owners and drivers of ICE vehicles (1,000), 2020
Kowalska-Pyzalska *et al*. (2022)	Telephone survey (CATI) and online CAWI survey, adults who purchased a vehicle in the last 6 months or intended to buy one in the next 12 months (1,002), 2020
Sobiech-Grabka, Stankowska & Jerzak (2022)	Original survey questionnaire (drafted using Survio), adult residents of cities with more than 50 thousand people (198), 2021
Adamczyk *et al*. (2024)	Original survey questionnaire (online), adults (413), 2021–2022

Source: own study, based on literature research.

Gis, Menes, and Waśkiewicz (2016) discussed the problem of private electromobility in the context of car user studies. Having analysed the responses, the authors concluded that it was necessary to disseminate knowledge on the economic aspects of electric vehicle use. Most respondents shared that they were not planning to buy

an electric vehicle in the future, considering their financial capabilities. Apart from the initial cost, the respondents highlighted limited range and high unit operating cost as the main drawbacks. One essential and alarming observation was that the respondents unquestioningly believed that the popularity of electric vehicles affects environmental well-being. Apart from financial reasons, the respondents considered the accessibility of public charging points for electric vehicles as a relevant factor.

In Kud's (2019) research, the author investigated the perception of barriers to electromobility in the context of environmental attitudes of residents of Podkarpackie voivodeship (Poland). The study confirmed the hypothesis that the perception of electromobility depends on the environmental attitude. The respondents considered high vehicle prices, shortage of charging stations, short range, poor information availability, lack of financial incentives, non-existent used vehicle market, and technical problems as the primary barriers for the growth of electromobility.

The *New Mobility Barometer 2019/2020* report by Polish Alternative Fuels Association (Polskie Stowarzyszenie Paliw Alternatywnych, 2020) offers numerous interesting conclusions from its survey. Electric vehicles were popular among men and women to a similar degree. They were most appreciated by young and middle-aged people living in single-family houses. The good reputation of electric vehicles stemmed mostly from lower operating costs and environmental considerations. The study demonstrated an insufficiency of appropriate sources of information about electric vehicles. It was the main cause of the low level of knowledge about electric vehicles, mainly maintenance, operating costs, and use, according to the respondents. Users of electric vehicles believed that their major flaws included price and range.

Lewicki *et al*. (2021) evaluated consumer attitudes towards electromobility. They attempted to identify the primary determinants of electric vehicle purchasing decisions in Poland. Most respondents were not interested in buying an electric vehicle on the five-year horizon if a Polish manufacturer appeared on the market. Most respondents pointed out high prices and lower operating costs compared to internal combustion engine (ICE) vehicles. Nearly half of the respondents answered that the home electric socket was the best charging method, and almost one-third expected a battery replacement service.

An article by Kowalska-Pyzalska *et al*. (2022) presented results of an analysis of consumer preferences regarding alternative-fuel vehicles. The respondents counted safety, price, availability of charging stations, and technical service as critical characteristics of alternative vehicles. Based on their results, the authors called for efforts to support the development of such vehicles. They recommended that manufacturers focus on improving the safety and range of electric vehicles. Governments, on the other hand, should consider higher subsidies and improve charging infrastructure.

Respondents in a survey by Sobiech-Grabka, Stankowska, and Jerzak (2022) considered the price, appearance, segment/class, equipment, and advantages of electric drive as the main determinants for purchasing an electric car. The study identified the need for long-term information campaigns to advertise the benefits of electric vehicles in such areas as performance, technology, or positive environmental impact.

In a study by Adamczyk *et al*. (2024), the respondents expected lower purchase prices, lower charging costs, better charger accessibility, and longer range from the electric vehicle market. The study further emphasised the poor level of knowledge among the Polish public regarding the adverse impact of electric vehicles on the environment.

The literature discussed so far directly pertains to the results of survey-based research on electromobility in Poland. However, the literature review also reveals a growing interest in analysing this issue from alternative perspectives. The challenges of electromobility have been examined in relation to organisational (Lewicki, 2018b), economic (Lewicki, 2018a), technical, infrastructural, and social barriers (Zaniewska-Zielińska, 2018), as well as the lack of coherence between environmental goals and the country's energy policy (Tomaszewski, 2019). Selected determinants of electromobility development, such as pro-environmental trends, operating costs, and technological availability, have been discussed in the study by Janczewski (2017). Motowidlak and Górniak (2022) attempted to identify the most critical factors for the development of electromobility within the context of sustainable mobility systems. The benefits and challenges associated with implementing electric transport in Poland were the focus of Wierzbowski's (2019) analysis. Meanwhile, Hoffmann (2023) highlights the legal and social challenges related to the development of electromobility in Poland.

4. Design and Research Methodology

We investigated the knowledge, attitudes, and opinions concerning electrification with an original survey questionnaire. The survey and the entire research process followed the principles of anonymity and voluntary participation. This way, the respondents were not limited in expressing their opinions. The survey population consisted of first- and second-cycle students at the Krakow University of Economics. The method of collecting surveys was consistent with convenience sampling and is not applicable to all young consumers in Poland as the general population. It was a pilot study conducted from February to September 2023. The layout of the results reflects the questionnaire structure.

The survey utilised an original questionnaire (*Twenty-first Century Consumer Challenges and Threats: Electromobility*). The survey method was CAWI (computer-

-assisted web interviewing). This method was selected because it offers higher potential to reach more respondents. The survey questionnaire was delivered electronically (as a Google form) to respondents who opted in. The questionnaire included 19 questions in four sections:

– section 1: background information,
– section 2: respondents' knowledge of electromobility,
– section 3: respondents' opinion about electromobility,
– section 4: respondents' attitudes towards electromobility.

The results were analysed across three domains: knowledge, opinions, and attitudes, as per the sections of the questionnaire. The background section concerned the respondents' sex, residence, education (technical vs. non-technical), and socio-professional status.

The survey questionnaire contained single- and multiple-answer questions. The results were analysed using frequency distribution analysis and a non-parametric chi-square test. The degree of association among the dependent variables was determined with Cramér's *V*. The analyses were conducted in Statistica 13.1 (StatSoft Polska).

5. Research Results

5.1. General Remarks

The survey resulted in 380 correctly completed questionnaires (100% return rate, $N = 380$). Table 2 presents the sample profile by respondents' sex, residence, education (technical vs non-technical), and socio-professional status.

Table 2. Profile of the Sample ($N = 380$)

Specification		Structure	
		Number	Percentage
Sex	female	221	58.2
	male	159	41.8
Residence	rural area	104	27.4
	town with up to 500,000 residents	101	26.6
	city with over 500,000 residents	175	46.1
Education	year 1	199	52.4
	year 2	79	20.8
	year 3 and over	102	26.8

Table 2 cnt'd

Specification		Structure	
		Number	Percentage
Technical profile	yes	112	29.5
	no	268	70.5
Economic activity status	economically active	227	59.7
	economically inactive	153	40.3
Total		380	100

Source: own study.

Most of the sample were women (58.2%), while men constituted 41.8%. The two dominant groups were residents of cities with over 500,000 people (46.1%) and first--year students (52.4%). Over 70.5% of the respondents were non-technical students. Most of the sample were economically active (59.7%). Figure 1 shows the mobility profile of the respondents.

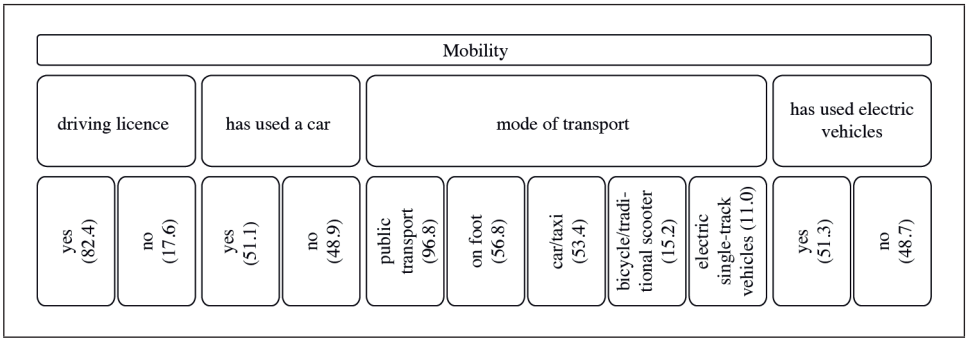

Fig. 1. Respondent Mobility (in %)

Notes: Mode of transport – maximum three answers.

Source: own study.

The vast majority of the respondents had a driving licence when completing the questionnaire (82.4%), but only half of the participants were active car users (51.1%). Most used petrol cars (62.4%). More than half of the respondents confirmed that they had driven an electric vehicle at least once (51.3%). Among them, 68.9% indicated an electric scooter, while 37.9% reported driving an electric car. The main transport mode for the respondents was a bus (79.7%), with a car coming in second (37.9%), demonstrating increased mobility.

5.2. Self-assessment of Knowledge and Awareness of Electromobility

The frequency distribution of answers to the multiple-answer question about the comprehension of the notion of electromobility is presented in Table 3.

Table 3. How Respondents Understand Electromobility

Definitions	Symbol	Total (%)
The notion concerns both technical and operational aspects of electric vehicles, technology, and charging infrastructure	A	60.0
Electromobility concerns social, economic, and legal matters linked to the design, production, purchase, and use of electric vehicles	B	50.3
All issues related to the use and operation of electric vehicles	C	49.7
Electromobility concerns economic matters related to the development of electric and hybrid vehicles	D	30.0
The notion concerns only the technical aspects of electric and hybrid vehicles	E	15.8
All issues related to the use and operation of ICE vehicles	F	6.1

Source: own study.

The respondents correctly interpreted the notion of electromobility. Over half of them (60%) selected answer A. The same applies to B (50.3%) and C (49.7%). Women selected A more often (61.5%) than men (57.9%). Answers C and E were more often selected by men (C: 57.9%, E: 17%) than women (C: 43.9%, E: 14.9%) (Fig. 2).

Residents of rural areas more often chose answer A (63.5%) than people living elsewhere. Residents of cities with over 500,000 people most often chose answers C (55.4%) and E (17.7%). Second-year students most often chose answers A (68.3%) and C (53.2%), while answer E was most common among third-year and older students (21.6%). The type of studies was relevant because students of technical fields selected mostly the right answers, A (62.5%) and C (52.7%). There was not much distinction between economically active and inactive students. Answer A was selected by 58.8% of economically active and 60.8% of economically inactive students. Answer C was selected by 51.6% of active and 48.5% of inactive students. Answer E was selected by 15.7% of economically active and 15.9% of economically inactive students. Variables "having a driving licence" and "having a car" offer some interesting insights. In both cases, people without a driving licence and without a car gave more correct answers. It demonstrates that knowledge of electromobility is not always linked to these characteristics.

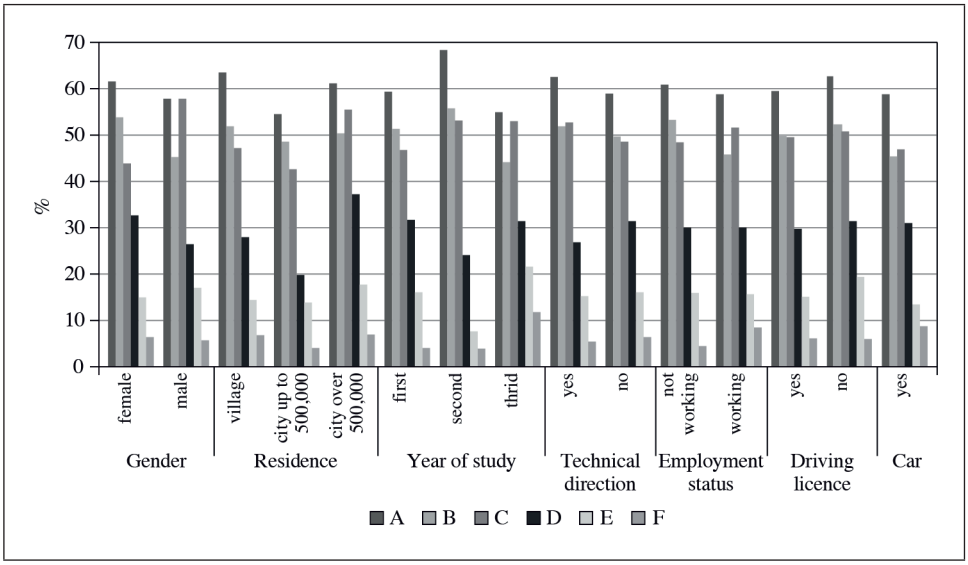

Fig. 2. Understanding of Electromobility by Socio-demographic Characteristics (in %)
Source: own study.

Table 4. Results of Chi-square Independence Test for Knowledge about Electric/Hybrid Vehicles and Socio-demographic Features

Specification	Socio-demographic Characteristics[a]						
	Sex	Residence	Year of study	Education	Economic activity	Driving licence	Car
Chi-square value	9.483	0.081	7.209	10.569	7.079	4.054	8.480
p value	0.002	0.960	0.027	0.001	0.008	0.044	0.004
Cramér's *V*	0.156	–	0.138	0.165	0.135	0.105	0.148

[a] Categories as in Figures 1 and 2.

Source: own study.

The independence test indicated that knowledge of electromobility is independent only of the place of residence (Table 4). The test confirmed the association for the other socio-demographic variables. Values of Cramér's *V*s indicate a moderate association.

5.3. Respondents' Opinions about Electromobility

The frequencies of answers concerning the benefits of and barriers to electromobility development and respondents' opinions in this regard are shown in Figure 3.

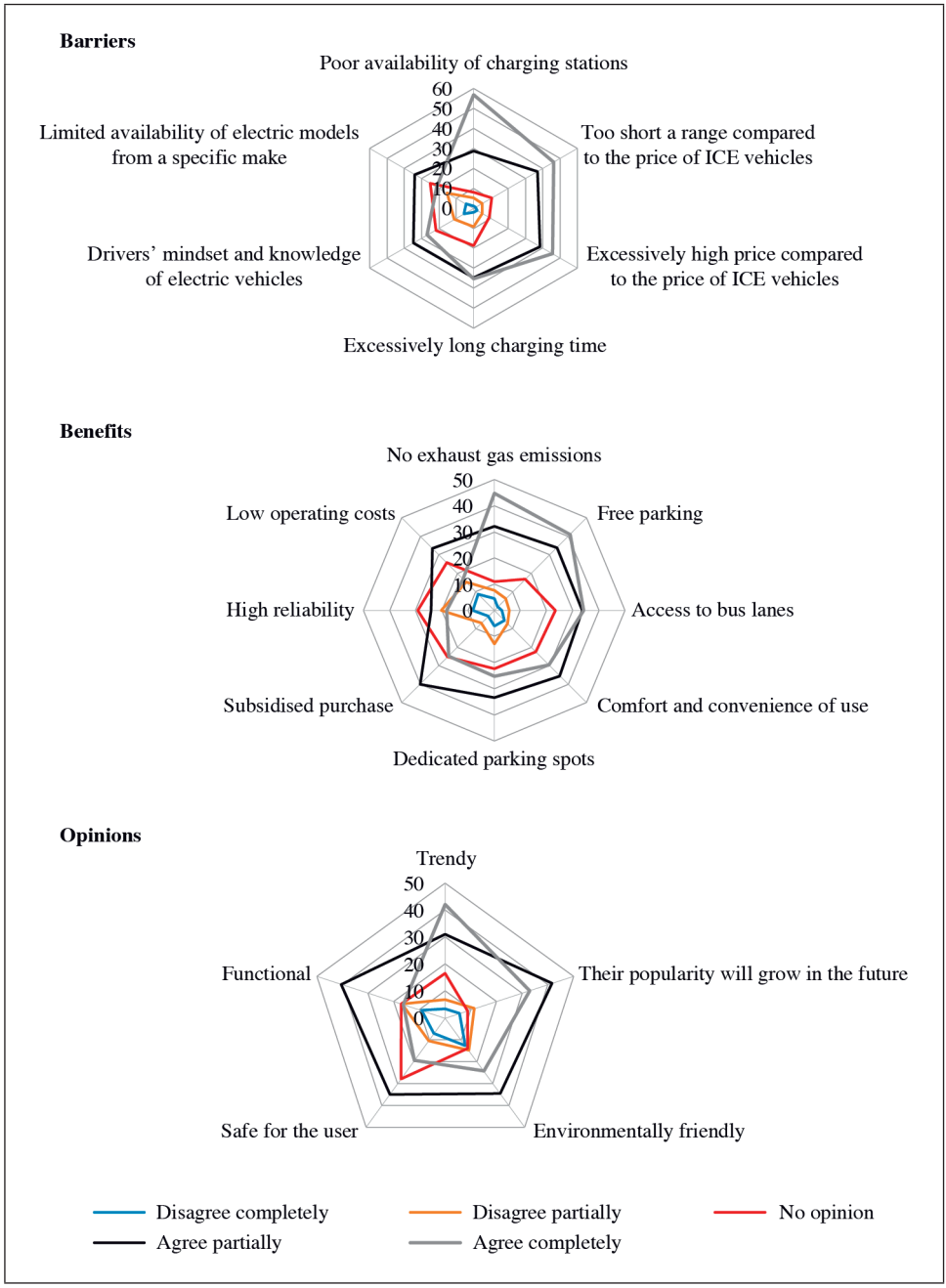

Fig. 3. Respondents' Opinions about Electromobility (in %)

Source: own study.

A group of 42% of the respondents believed that the popularity of electric vehicles was driven by the electromobility fad. One-third of the respondents (33%) agreed that electric vehicles would grow more popular in Poland. Nearly two-thirds agreed (59% "agree completely" and "agree partially") that electric vehicles were environmentally friendly. The respondents agreed that the most significant barrier to electromobility is the insufficient availability of charging stations (56.8%), which is improving but not fast enough considering the demand and volumes of electric cars sold. Short range compared to ICE vehicles was another barrier pointed out by the respondents (46.3%). It is because although the range is increasing, it is insufficient in light of the availability (number) of charging stations.[1] The last major factor detrimental to the growth of electromobility listed by the respondents was excessive prices compared to ICE vehicles (45.5%). Nevertheless, considering answers "agree completely" and "agree partially," one can identify other barriers critical to the growth of electromobility and the popularity of electric vehicles in Poland. These include "excessively long charging," "drivers' mindset and knowledge about electric vehicles," or "limited availability of specific models of cars." Most of the respondents unambiguously listed the three most prominent benefits of electric vehicles: no exhaust gas emissions (44.7%), free parking (41%), and access to bus lanes (34.2%). The respondents explicitly considered these advantages as critical for the development of electromobility in Poland. One can suppose that those participants who were sceptical about these answers exhibit a negative attitude toward the competitive advantage of electric vehicles compared to conventional (ICE) vehicles.

5.4. Respondents' Attitudes towards Electromobility

Respondents' attitudes to purchasing and using electric vehicles are shaped by the administrative environment, financial factors, and their knowledge and opinions. The structured responses to the propositions testing attitudes towards electromobility among respondents are presented in Figure 4. The first observation regarding the attitudes towards factors affecting electric vehicle purchasing decisions is that they unanimously ("agree completely") concerned the availability of charging stations, safety, purchase cost, charging time, and user comfort. Their answers confirm the respondents' accord in the belief that their opinions and attitudes towards purchasing an electric vehicle and developing electromobility in Poland were shaped mostly by the availability of charging stations (64.7% "agree completely" and 25.5% "agree partially").

[1] There were 108,331 electric passenger cars and 6,490 charging points in Poland in March 2024 (PZPM, 2024, data from 1 April 2024).

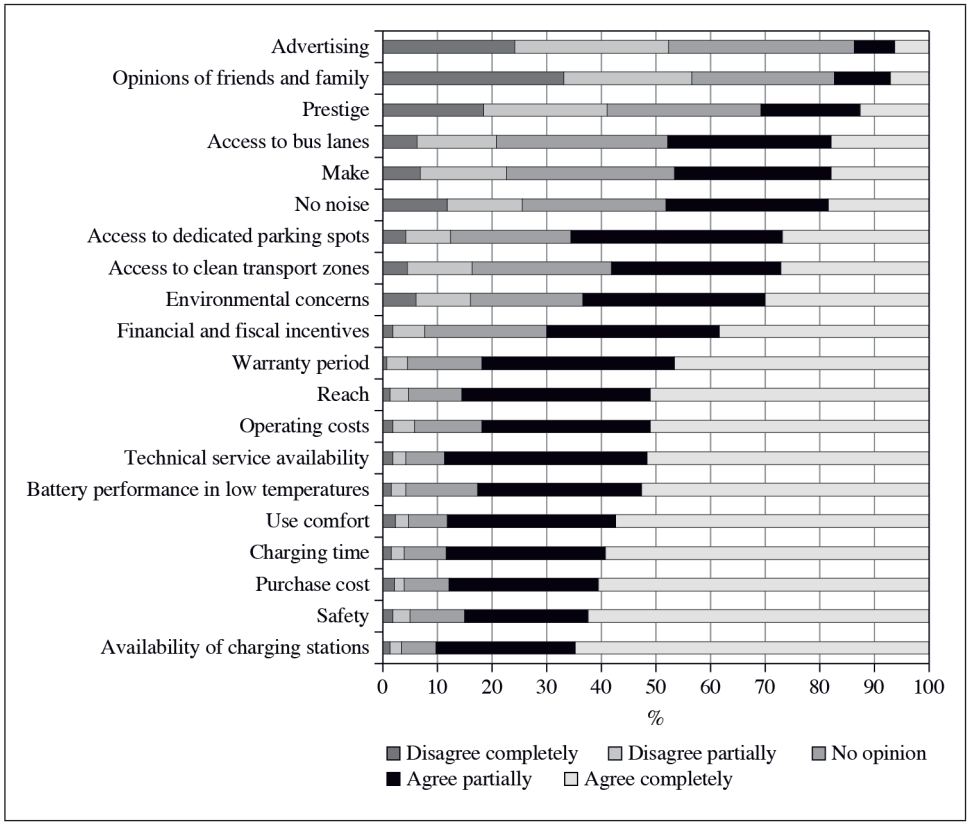

Fig. 4. Respondents' Attitude towards Determinants of Purchasing Decisions Concerning Electric Vehicles (in %)

Source: own study.

More than half of the respondents agreed completely that such factors as the impact of low temperatures on battery performance (52.6%), availability of service points (51.6%), operating costs (51%), and range on a charge (51%) are critical for purchasing decisions. Negative opinions about purchasing decision determinants ("disagree completely" and "disagree partially" in total) concerned advertising (52.4%), opinions of family and friends (56.6%), and prestige related to such vehicles (41%).

Moreover, such factors as operating costs and the impact of low temperatures on battery performance increase the cost of ownership due to relatively short battery life and replacement. The respondents showed interesting attitudes regarding the range of electric cars that would be acceptable to them if they were to buy one (Table 5). The largest group (24.2%) indicated an interval of 501–600 km. A lower

range of 401–500 km was chosen by 21.3% of the respondents, while a mere 13.7% chose 601–700 km. It should be noted that this preference depends on the individual needs of the respondents and the distances they cover.

Table 5. Respondents' Attitude towards Determinants of Purchasing Decisions Concerning Electric Vehicles

Specification		Structure	
		Number	Percentage
Range per charge (km)	101–200	4	1.1
	201–300	27	7.1
	301–400	47	12.4
	401–500	81	21.3
	501–600	92	24.2
	601–700	52	13.7
	701–800	40	10.5
	over 800	37	9.7
Charging method	home charging station	242	63.7
	public charging station	120	31.6
	battery replacement	18	4.7
Total		380	100

Source: own study.

Nearly two-thirds of the respondents (63.67%) preferred a home charging station, while 31.6% indicated public charging stations. Only 4.7% of the respondents believed that the best method of "charging" a car would be to replace the battery, which is beyond any doubt another innovative solution that could convince customers to buy an electric vehicle.

6. Discussion

Climate change drives more rapid efforts to curb pollution. Actions taken by European Union member states clearly define their horizon and identify the private and public transport sectors as needing a thorough transformation. A large part of the EU budget is earmarked for initiatives for electromobility to build new infrastructure, develop transport systems, and upgrade fleets. The implementation of EU laws by the Polish government provides for the same or even stricter emission reductions. In a way, the faulty deployment of electromobility solutions in Poland (especially in public transport) mainly involves subsidies for electric buses and urban infrastructure (such as charging stations). This is because the primary energy

carrier used in electricity generation in Poland is fossil fuels, which drives the need for electromobility and renewable energy sources (Wierzbowski, Filipiak & Lyzwa, 2017).

The present study employs an original survey questionnaire to investigate factors affecting electromobility development according to respondents' beliefs and attitudes. The respondents' relevant knowledge level was verified as well. The data were analysed in terms of answer frequency distribution. Independence hypotheses were also verified for selected variables. The analysis demonstrates that the respondents consider the electrification of public and private transport as a positive and prudent effort.

The present survey is consistent with the conclusions of other researchers (including Gis, Menes & Waśkiewicz, 2016; Kud, 2019; Lewicki *et al*., 2021; Sobiech-Grabka, Stankowska & Jerzak, 2022) that the purchase price of electric vehicles remains too high and offers no competitive advantage over ICE vehicles. Therefore, further efforts to boost electromobility in Poland and the electrification of private transport should focus on the demand side and improving the knowledge and awareness of consumers. It could include purchase incentives. However, they are not a long-lasting solutions and do not improve consumer knowledge.

The respondents consider the charging method a critical determinant of electromobility development. Nearly 64% indicated a home charging station, which is consistent with other studies (Lewicki *et al*., 2021). It may be because respondents living in single-family houses have unrestricted access to self-generated electricity. Nearly 32% of the respondents prefer public charging stations, which is also consistent with other studies (Kud, 2019; Kowalska-Pyzalska *et al*., 2022; Adamczyk *et al*., 2024). The third type of charging method is battery replacement, indicated by nearly 5% of the respondents. This method was reported by Lewicki *et al*. (2021) as preferred by nearly one-third (32%) of the respondents. It shows the need for improved charging methods in terms of procedures and duration. Only 20% of the respondents in the study conducted by Lewicki *et al*. (2021) indicated public charging stations. The reason was insufficient public charging station infrastructure.

Operating costs are another factor affecting electric vehicle purchase decisions among the respondents. The present survey did not back the results of other researchers in this regard because the respondents' perceptions varied. The largest group (33.4%) agreed partially that low operating costs are the primary advantage of electric vehicles and electromobility. In a study by Gis, Menes and Waśkiewicz (2016), the respondents indicated that "electric vehicles offer lower operating costs compared to conventional cars" (7.8%). The authors believed this perception of the financial factor stemmed from unverified intuitions. According to *New Mobility Barometer 2019/2020* by Polish Alternative Fuels Association (Polskie Stowarzyszenie Paliw Alternatywnych, 2020), young and middle-aged people are

the most open to electric vehicles (66.1%). This group considers operating costs an argument for buying an electric vehicle (75.6%) as they perceive them to be low. In a study by Lewicki *et al*. (2021), most respondents (64.0%) indicated that the operating costs of electric vehicles were lower than for ICE vehicles. Other studies corroborate this attitude (Szumska, Jurecki & Pawelczyk, 2019). It may stem from consumer ignorance regarding the high operating costs of electric vehicles, such as battery replacement or repairs.

Another important aspect of electromobility perception among the respondents is its environmental impact. Most believed electromobility to be environmentally friendly and green (nearly 59.0% agreed with this statement completely or partially). The result is consistent with other studies in this field, which also found a positive association between the intent to use electric vehicles in private and public transport and environmental benefits. In a survey by Gis, Menes and Waśkiewicz (2016), 18.1% of the respondents believed that "electric drive systems will help reduce air pollution" and "will help reduce fossil fuel consumption" (17.1%). The authors pointed out that it manifested a naive perception of electric vehicles in the context of their environmental impact. Respondents in a study by Adamczyk *et al*. (2024) indicated that BEVs generated less pollution than ICE vehicles (63.9%). The researchers interpreted these results as an example of poor knowledge of the adverse environmental effects of electric vehicles as compared to ICE vehicles. Sobiech-Grabka, Stankowska and Jerzak (2022) identified a need to disseminate knowledge and information about the advantages of electric vehicles in such domains as their advantageous environmental impact.

Convincing the public to accept the idea is critical for the success of electromobility. Local actions may prove to be the most effective. Considering socio-economics, present and potential users of electric vehicles can be more easily motivated to take desired actions by offering them advantageous conditions for adopting such solutions. For example, Scandinavian countries have numerous benefits for electric car users. They can use bus lanes, register battery electric vehicles and fuel cell electric vehicles for free, park and use motorways for free, and receive tax credits, including a complete VAT credit.

7. Conclusions

The study aims to analyse and assess respondents' knowledge, opinions, and attitudes regarding electromobility. The results contribute to the theoretical analysis of electromobility knowledge and verification of factors affecting the use of electric vehicles in Poland to a certain degree. The respondents were interested in the technical novelty of electric vehicles and the idea of electromobility, which calls for further research in the area and demonstrates the need for accurate information about the knowledge, opinions, and attitudes of the investigated social

group. On the other hand, the study clearly identified the need for electromobility awareness-building among young consumers.

The study confirms developmental barriers to electromobility identified in the literature as the insufficient number of charging stations, excessive prices of electric vehicles, and short range on a charge. The analysis demonstrates that financial aspects remain more important than environmental concerns for the respondents. They also believe that adopting a dense public charger system is among the crucial conditions for electromobility growth in Poland. Moreover, respondents' perception of electromobility and environmental beliefs are associated with their place of residence and financial standing.

Public informational campaigns and education from an early age are vital to consumer electromobility awareness-building in Poland. The primary motivator for the investigated group regarding purchasing an electric vehicle is the financial and economic situation. Developmental barriers indicated by the respondents can be divided into two groups. The first includes short range, poor (insufficient) public charging infrastructure, and high prices. The other encompasses such barriers as excessive charging time, driver mindset and knowledge of electric vehicles, and limited availability of electric models from a specific make.

All the research questions have been answered. The study shows that surveyed group of respondents exhibit sufficient knowledge of electromobility, and their choices are still driven by financial capabilities to a significant extent. The respondents believe that electric cars are "in" and that their popularity will grow. Virtually all of them travel mostly by public transport. More than half also travel on foot and by car or taxi.

The two hypotheses have been confirmed. The level of knowledge of the environmental impact of electric vehicles is moderate among respondents, which means educational effort is needed. Furthermore, the most significant barriers to the development of electromobility in Poland, according to the respondents, are the availability of charging stations and the purchase cost of electric vehicles, as proposed in the other hypothesis.

The present study among young consumers in Poland forms part of a pilot study scheme on a sample of 380 respondents. This fact determines the need for further, in-depth research and analyses, for example, using time-series variation, consumer preferences distribution by age groups, or comparing purchasing trends during the COVID-19 pandemic. Therefore, the present study is far from exhausting the topic. Instead, it illustrates the complexity of the problem and attempts to address a research gap found in the literature concerning consumer attitudes and knowledge of the development of the electric vehicle market in Poland.

Authors' Contribution

The authors' individual contribution is as follows: Chrystian Firlej – research concept, literature review, data collection (survey design, sample, study implementation), material development; Krzysztof Adam Firlej – research concept, data collection (survey design, sample, study implementation), material development; Lidia Luty – research concept, methodology, data and results analysis, material development; Bartłomiej Kabaja – research concept, discussion of results, conclusions, practical implications, and final editing.

Conflict of Interest

The authors declare no conflict of interest.

References

Adamczyk, J., Dzikuć, M., Dylewski, R., & Varese, E. (2024). Assessment of Selected Environmental and Economic Factors for the Development of Electro-mobility in Poland. *Transportation*, *51*, 2199–2223. https://doi.org/10.1007/s11116-023-10402-3

Alogdianakis, F., & Dimitriou, L. (2023). Optimal Mechanism Design of Public Policies for Promoting Electromobility: A Dynamic Programming Formulation. *Transportation Research Interdisciplinary Perspectives*, *19*, 100807. https://doi.org/10.1016/j.trip.2023.100807

Bjerkan, K. Y., Nørbech, T. E., & Nordtømme, M. E. (2016). Incentives for Promoting Battery Electric Vehicle (BEV) Adoption in Norway. *Transportation Research Part D: Transport and Environment*, *43*, 169–180. https://doi.org/10.1016/j.trd.2015.12.002

Bondar, E., Rukszan, S., Jagiełło, H., & Szpilko, D. (2023). Perspektywy rozwoju rynku samochodów osobowych z napędem elektrycznym w Polsce. *Akademia Zarządzania*, *7*(3), 233–271. https://doi.org/10.24427/az-2023-0043

Degirmenci, K., & Breitner, M. H. (2017). Consumer Purchase Intentions for Electric Vehicles: Is Green More Important Than Price and Range? *Transportation Research Part D: Transport and Environment*, *51*(1), 250–260. https://doi.org/10.1016/j.trd.2017.01.001

European Commission. (2017). National Framework for the Policy of Development of Alternative Fuel Infrastructure; Resolution of the Council of Ministers from 29 March 2017.

European Parliament. (2023). *Fit for 55: Zero CO_2 Emissions for New Cars and Vans in 2035*. Retrieved from: https://www.europarl.europa.eu/news/en/press-room/20230210IPR74715/fit-for-55-zero-co2-emissions-for-new-cars-and-vans-in-2035 (accessed: 13.02.2024).

Gis, W., Menes, M., & Waśkiewicz, J. (2016). Przyszłość indywidualnej elektromobilności w Polsce w świetle badań użytkowników samochodów osobowych. *Transport Samochodowy*, *4*, 25–34.

Gov.pl. (2024). *Elektromobilność*. Retrieved from: https://www.gov.pl/web/klimat/elektromobilnosc (accessed: 13.02.2024).

Grauers, A., Sarasini, S., & Karlström, M. (2013). Why Electromobility and What Is It? In: B. Sandén (Ed.), *Systems Perspectives on Electromobility* (pp. 10–21). Chalmers University of Technology.

Hoffmann, T. (2023). Rozwój rynku elektromobilności w Polsce. Dylematy i wyzwania. *Środkowoeuropejskie Studia Polityczne i Medioznawcze*, *1*, 107–129. https://doi.org/10.14746/ssp.2023.1.6

Janczewski, J. (2017). Determinanty rozwoju elektromobilności. Wybrane kwestie. *Zarządzanie Innowacyjne w Gospodarce i Biznesie*, 2(25), 205–219. https://doi.org/10.25312/2391-5129.25/2017_205-219

Kowalska-Pyzalska, A., Michalski, R., Kott, M., Skowrońska-Szmer, A., & Kott, J. (2022). Consumer Preferences towards Alternative Fuel Vehicles. Results from the Conjoint Analysis. *Renewable and Sustainable Energy Reviews*, *155*, 111776. https://doi.org/10.1016/j.rser.2021.111776

Kud, K. (2019). Percepcja barier rozwoju elektromobilności w kontekście postaw ekologicznych mieszkańców województwa podkarpackiego. *Polityka i Społeczeństwo*, *3*(17), 146–159. https://doi.org/10.15584/polispol.2019.3.9

Lewicki, W. (2018a). Ekonomiczne bariery rozwoju rynku elektromobilności w Polsce. *Autobusy – Technika, Eksploatacja, Systemy Transportowe*, *19*(12), 1099–1102. https://doi.org/10.24136/atest.2018.558

Lewicki, W. (2018b). Organizacyjne bariery rozwoju rynku elektromobilności w Polsce. *Autobusy – Technika, Eksploatacja, Systemy Transportowe*, *19*(12), 1103–1106. https://doi.org/10.24136/atest.2018.559

Lewicki, W., Drożdż, W., Wróblewski, P., & Żarna, K. (2021). The Road to Electromobility in Poland: Consumer Attitude Assessment. *European Research Studies Journal*, *24*(1), 28–39. https://doi.org/10.35808/ersj/2026

Liao, F., Molin, E., & van Wee, B. (2017). Consumer Preferences for Electric Vehicles: A Literature Review. *Transport Review*, *37*(3), 252–275. https://doi.org/10.1080/01441647.2016.1230794

Lin, B., & Wu, W. (2018). Why People Want to Buy Electric Vehicle: An Empirical Study in First-tier Cities of China. *Energy Policy*, *112*, 233–241. https://doi.org/10.1016/j.enpol.2017.10.026

Motowidlak, U., & Górniak, J. (2022). Czynniki krytyczne rozwoju elektromobilności z perspektywy zrównoważonych i rezylientnych systemów mobilności. *Studia i Prace Kolegium Zarządzania i Finansów*, 187, 135–149. https://doi.org/10.33119/SIP.2022.187.7

Niedziółka, D. (2024). Opportunities and Threats to Shaping Energy Security in the Conditions of Development and Use of New Technologies. *International Journal of Management and Economics*, *60*(1), 12–21. https://doi.org/10.2478/ijme-2023-0023

Nyga-Łukaszewska, H., & Napiórkowski, T. M. (2023). Energy Security as a Source of International Competitiveness in New EU Member States. *International Journal of Management and Economics*, *59*(3), 209–224. https://doi.org/10.2478/ijme-2023-0015

Polskie Stowarzyszenie Paliw Alternatywnych. (2020). *Barometr nowej mobilności 2019/2020*. Retrieved from: https://pspa.com.pl/wp-content/uploads/2020/11/RAPORT_Barometr_Nowej_Mobilnosci_2020.pdf (accessed: 17.05.2024).

PZPM. (2024). *Licznik elektromobilności*. Retrieved from: https://www.pzpm.org.pl/pl/Elektromobilnosc/Licznik-Elektromobilnosci/Rok-20242/Marzec-2024 (accessed: 1.04.2024).

Sobiech-Grabka, K., Stankowska, A., & Jerzak, K. (2022). Determinants of Electric Cars Purchase Intention in Poland: Personal Attitudes v. Economic Arguments. *Energies*, *15*(9), 3078. https://doi.org/10.3390/en15093078

Statista. (2023). *Passenger Car Sales in Selected European Countries in 2023*. Retrieved from: https://www.statista.com/statistics/500546/share-of-fuel-types-of-passenger-car-fleet-in-europe-by-country/ (accessed: 13.02.2024).

Szumska, E., Jurecki, R., & Pawelczyk, M. (2019). Assessment of Total Costs of Ownership for Midsize Passenger Cars with Conventional and Alternative Drive Trains. *Communications. Scientific Letters of the University of Zilina*, *21*(3), 21–27. https://doi.org/10.26552/com.C.2019.3.21-27

Tomaszewski, K. (2019). Problemy rozwoju elektromobilności w Polsce w kontekście krajowej polityki energetycznej. *Przegląd Politologiczny*, 2, 153–165. https://doi.org/10.14746/pp.2019.24.2.11

Wierzbowski, M., Filipiak, I., & Lyzwa, W. (2017). Polish Energy Policy 2050 – an Instrument to Develop a Diversified and Sustainable Electricity Generation Mix in Coal-based Energy System. *Renewable Sustainable Energy Reviews*, *74*, 51–70. https://doi.org/10.1016/j.rser.2017.02.046

Wierzbowski, P. (2019). Elektryczny transport drogowy jako element systemu wsparcia logistycznego – perspektywa rozwoju elektromobilności w Polsce. *Zeszyty Studenckie „Nasze Studia"*, 9, 38–58. Retrieved from: https://czasopisma.bg.ug.edu.pl/index.php/naszestudia/article/view/3374 (accessed: 1.04.2024).

Wodnicka, M., & Malinowski, M. (2023). Rynek e-mobilności transportu samochodowego Polski i Niemiec. In: Ł. Kozar, M. Matusiak (Eds), *Współczesne wyzwania transportu, spedycji oraz logistyki – wybrane aspekty* (pp. 53–74). Wydawnictwo Uniwersytetu Łódzkiego. https://doi.org/10.18778/8331-350-4.4

Zaniewska-Zielińska, D. (2018). Problemy rozwoju elektromobilności w Polsce. *Europa Regionum*, *35*(2), 63–78. https://doi.org/10.18276/er.2018.35-06

Zawieska, J. (2019). Rozwój rynku elektromobilności w Polsce. In: J. Gajewski, W. Paprocki, J. Pieriegud (Eds), *Elektromobilność w Polsce na tle tendencji europejskich i globalnych* (pp. 9–38). Publikacja Europejskiego Kongresu Finansowego. CeDeWu.

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Monetary Determinants of House Prices in the European Countries

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ABSTRACT

Objective: The aim of this article is to investigate monetary policy effects on the house prices for the panel of 12 Central and Eastern European (CEE-12) countries, 12 small European countries (EU-12) and 5 largest European countries plus the UK (EU-6).
Research Design & Methods: A five-variable Panel Vector Autoregressive (PVAR) model is estimated for quarterly data from 2010Q1 to 2023Q2.
Findings: An increase in the short-term interest rate has a depressing effect on the house prices in the European countries, along with higher inflation and exchange rate depreciation (to less extent). An increase of output over the business cycle brings about a temporary decrease in house prices in both CEE-12 and the EU-12 countries. As intuitively expected, a housing boom is expansionary and inflationary in all European countries, though with a different time profile. There is strong evidence of the interest rate response to house prices in the CEE-12 countries and the EU-12 countries (at longer horizons).
Implications/Recommendations: This paper supports the proposals for using monetary tightening in response to the boom in the housing market. It is especially the case for the CEE

countries where a two-way causality between the short-term interest rates and house prices seems to be particularly strong.

Contribution: This paper contributes to studies of stabilisation properties of monetary policies in the European countries, in the presence of real and nominal effects of housing markets.

Article type: original article.

Keywords: house prices, interest rate, output gap, inflation, PVAR model.

JEL Classification: E31, E47, E52, R31.

1. Introduction

Following a decline in the wake of the 2008–2009 financial crisis, house prices have been on the rise since the middle of last decade in all groups of European countries (Fig. 1). Similarly, a recent downward correction of the house prices can be related to a steep increase in the short-term interest rates. An inverse relationship between the two variables can be explained on theoretical grounds (for example, Martin, Schmitt & Westerhoff, 2022), while being widely supported by empirical studies for both industrial and developing countries. For example, it is the case for Australia (Wadud, Bashar & Ahmed, 2009), Canada (André *et al*., 2022), Germany (Hanck & Prüser, 2020), Norway (Anundsen & Jansen, 2013), the UK (Elbourne, 2008; André *et al*., 2022), and the US (Horvath & Rothman, 2021; Eickmeier & Hofmann, 2010; Jarociński & Smets, 2008). Similar conclusions of a strong link between the short-term interest rate and house prices are obtained for a sample of OECD countries (Sá, Towbin & Wieladek, 2011), 17 industrialised economies (Goodhart & Hofmann, 2008), 20 advanced countries (Iossifov, Čihák & Shanghavi, 2008). Moreover, monetary policy effects on house prices can be much stronger as compared with the output effects (Benati, 2021). As it is obtained on the basis of 31 studies, there is strong interest rate sensitivity of house prices, with the value of regression coefficient at 0.7–0.9 (Ehrenbergerová & Bajzík, 2020). There is evidence of the inverse relationship between interest rate and house prices for the Central and Eastern Europe (CEE) countries as well (Gaspareniene, Venclauskiene & Remeikiene, 2014).

However, a few studies do not support a strong link between the monetary policy stance and house prices (Bernanke, 2010; Shi, Jou & Tripe, 2014; Stahlecker, 2024). The strength of the monetary policy effects on the housing market depends on the level of financial development (Koeniger, Lennartz & Ramelet, 2022), quality of the financial system (Duca, Muellbauer & Murphy, 2021) and/or mortgage markets (Sá, Towbin & Wieladek, 2011), or the level of financial liberalisation (Chen & Lin, 2022). Different supply constraints can affect sensitivity of house prices with respect

to interest rates as well (Miller, Sklarz & Thibodeau, 2005). On the other hand, it cannot be ruled out that the central bank responds to house prices, along with reaction to consumer price inflation and output gap (Finocchiaro & von Heideken, 2009), especially in the countries adopting a policy of inflation targeting (Chen & Lin, 2022). As house prices are likely to have both nominal (inflation) and real (output) effects, it creates an indirect transmission channel for monetary policy as well. For example, a positive link between house prices and macroeconomic developments is found in the abovementioned studies for 17 industrialised countries (Goodhart & Hofmann, 2008), Sweden (Gustafsson, Stockhammar & Österholmb, 2016), and the UK (Elbourne, 2008).

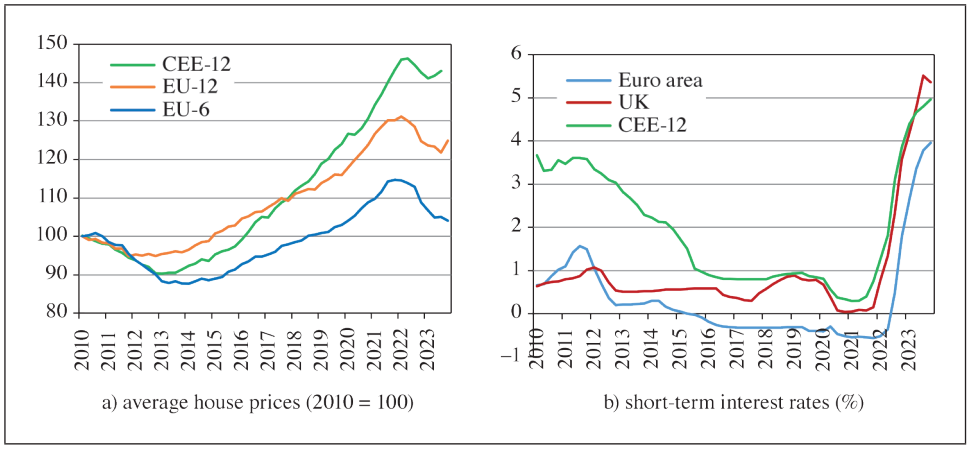

Fig. 1. Real House Prices (a) and Short-term Interest Rates (b) in the European Countries, 2010–2023

Source: own study, based on Federal Reserve Bank of St. Louis (2024), BIS Data Portal (2024).

The aim of this article is to investigate monetary policy effects on the house prices for a panel of 12 CEE countries, 12 small European countries and 5 largest European countries (plus the UK). We try to answer the following questions: Is there any response of house prices to monetary policy shocks? What are real and nominal effects of the house price shocks? Is there causality running from house prices to the short-term interest rate? Although our focus is on the monetary policy effect on house prices, output effects of both macroeconomic variables are worth attention.

The rest of the paper is structured as follows: A brief and selective literature review is presented in section 2. In section 3, data and statistical model are presented. Section 4 provides with a discussion of the empirical findings. Section 5 reports on the robustness checks. Section 6 presents conclusions.

2. Literature Review

Numerous aspects of house price determinants and relevant output effects are surveyed by Duca, Muellbauer and Murphy (2021) and Gaspareniene, Venclauskiene and Remeikiene (2014). First, house price booms have been caused by lower interest rates, besides income, credit standards and housing supply conditions. Second, dynamic effects of the abovementioned fundamental factors can be strengthened by positive news about house prices or extrapolative expectations of future prices. Third, the scope of house price changes is magnified if homes are used as collateral.

As it was summarised earlier by Mishkin (2007), interest rate changes affect the housing market and output through various channels, such as the user cost of capital, expectations of future house prices, supply of new houses, wealth effects in the aggregate demand, balance sheet and credit-channel effects on consumer spending and housing demand. The neoclassical user cost of capital theory implies that a higher short-term interest rate is followed by an increase in long-term interest rates, with a rising user cost of capital contributing to a fall in demand for housing and stagnation of construction activities. However, a higher cost of construction activities works against higher house prices. If housing is a component of wealth, along with stocks and bonds, changes in house prices affect private consumption and thus aggregate demand. The balance sheet and credit channel effects imply that more valuable home equity has a potential of easing of credit constraints on homeowners thus contributing to higher spending and investments, especially if interest rates are low (Tsatsaronis & Zhu, 2004).

An expansionary effect is more likely in countries with high ownership and low property taxes; otherwise higher downpayments or higher property taxes put a constraint on consumption (Duca, Muellbauer & Murphy, 2021). Obviously, the link between house prices and output becomes weaker if higher house prices create an illusion of wealth, with the problem of debt accumulation being underestimated (Gimeno & Martínez-Carrascal, 2010). With house prices on a decline and resulting difficulties in access to credit, the burden of debt service becomes an instrumental factor behind a decrease in aggregate demand and crisis developments. In order to avoid counterproductive macroeconomic instability centred around housing market, stabilisation efforts are useful.

In the context of monetary determinants of house prices, Martin, Schmitt and Westerhoff (2022) have presented a model of the housing market, referencing central bank stabilisation policies via the interest rate:

$$P_t = \frac{E_t[P_{t+1}] + \alpha - (\beta + \lambda V_t[P_{t+1}])\gamma P_{t-1} - (\beta + \lambda V_t[P_{t+1}])(1-\delta)H_{t-1}}{1 + r_0 + \rho\left(\frac{P_{t-1} - P^*}{P^*}\right) + \delta}, \qquad (1)$$

where P_t is the house price level, H_t is the housing stock, P^* is the housing market's fundamental price, r_0 is the central bank's base (target) interest rate, α is a scaling parameter in the relationship between demand and price of housing services, δ is the housing depreciation rate, λ is the risk aversion parameter, $E_t[P_{t+1}]$ and $V_t[P_{t+1}]$ stand for the investors' average future house price expectation and its variance, respectively. Parameters β and γ measure the sensitivity of the rent level with respect to the housing stock and the response of the housing stock to house prices, respectively.

House prices rise in the case of positive and less volatile future house price expectations, stronger demand for houses (α) combined with a lower sensitivity of the rent level with respect to the housing stock (β), less aversion to risk (λ), sluggish response of the housing stock to house prices (γ), and faster depreciation of the housing stock (δ). As expected, a higher supply of houses (with a lag) contributes to lower house prices.

The monetary policy rule of Eq. (1) implies that the central bank responds to the gap between the actual and fundamental house prices, $i_t = r_0 + \rho(P_{t-1} - P^*)/P^*$. If the lagged house price exceeds the equilibrium house price ($P_{t-1} > P^*$), which could be related to demographic and long-term income factors, a positive response from the central bank helps keeping the housing market in order. In the presence of a strong two-way causality between interest rate and house prices, the incidence of destabilising house price fluctuations is minimised. Stabilisation properties of monetary response to house prices are found by André *et al*. (2022) and Gustafsson, Stockhammar and Österholmb (2016). For Norway, it is established that low interest rates contribute to higher housing prices, which in turn lead to a credit expansion (Anundsen & Jansen, 2013).

However, not all studies are so optimistic on the benefits of monetary response to house prices. Accounting for endogenous mortgage defaults, Bekiros, Nilavongse and Uddin (2020) provide theoretical arguments that a monetary reaction to household credit growth can produce price instability, which used to be counterproductive in the long run. In a similar DSGE framework, Baldi (2014) finds that a monetary response to house prices brings about an output slowdown over a business cycle and welfare losses.

Expansionary monetary policy is not the only explanation for the rapid increase in house prices since the 2000s, as capital inflows are important either, at least for the OECD countries (Sá, Towbin & Wieladek, 2011). As argued by Bernanke (2010), significant cross-country differences in the monetary policy effects on house prices can be explained by the fact that capital inflows are associated with monetary tightening, not expansionary monetary policy. If a higher interest rate taps capital inflows, it creates a possibility of the direct proportionality between monetary tightening and house prices.

While most recent DSGE models do not imply a strong link between house prices and output, a promising strand of research includes models with 1) distortions in financial markets (financial frictions) or 2) imperfect learning mechanisms (Williams, 2011). Financial frictions imply that relatively small changes in the short--term interest rate are behind disproportional changes in the value of housing assets (a financial accelerator effect), which in turn are materialised in excess fluctuations of aggregate demand. One of the explanations assume that market decisions are rational, but available information is imperfect thus making to learn through experience (imperfect learning). If the true value of asset prices is not known, it creates ground for excessive instability of output.

While the relationship between short-term interest rates and house prices has been paid enough attention in the literature, indirect effects of consumer prices and exchange rates on the housing market have not been widely explored. Specifically, the relationship between exchange rates and house prices used to be analysed with a focus on the causality running from exchange rates to house prices and not the other way (Yamaka *et al*., 2022). It is found that exchange rate depreciation contributes to higher house prices in South Africa due to demand from non-resident buyers, with counter-cyclical properties as well (Davids, 2020), but no impact is found for Turkey (Sümer & Özorhon, 2020).

There are both theoretical and empirical arguments about positive correlation between house prices and inflation in China (Kuang & Liu, 2015). It is found that housing demand shocks significantly contribute to consumer prices in the US cities (Choi & Jo, 2020), but it is not ruled out that a house price boom is associated with low inflation as well (Bekiros, Nilavongse & Uddin, 2020). Moreover, a decline in inflation is expected in the case of a positive non-fundamental shock to house prices. A negative short-term relationship between house prices and core inflation is confirmed empirically for 15 OECD countries (Rufai, Aor & Salisu, 2025).

3. Data and Statistical Model

All time series spanning from 2010Q1 to 2023Q2 are obtained from the International Monetary Fund (2024), the Bank of International Settlements (BIS Data Portal, 2024) and the Federal Reserve Bank of St. Louis (2024). The following variables are used: the real house price index (2010 = 100), the consumer price index (2016 = 100), the nominal effective exchange rate (index, 2016 = 100), the short-term interest rate (%), the real gross domestic product (index, 2010 = 100). For estimation purposes, we used detrended values of both output and the exchange rate.

Empirical estimates are made for three groups of countries: CEE-12 (Czechia, Hungary, Poland, Romania, Serbia, Bulgaria, Croatia, Slovakia, Slovenia, Estonia, Latvia, Lithuania), EU-12 (Austria, Belgium, Cyprus, Denmark, Finland, Greece,

Ireland, Luxembourg, Norway, Portugal, Sweden, Switzerland), EU-6 (France, Germany, Italy, Netherlands, Spain plus the UK).

For all analysed countries, the ADF test reports the stationarity of the house price rate (in percent), with somewhat weaker evidence for Denmark, Italy, Spain and Switzerland. At the same time, the Supremum Augmented Dickey-Fuller (SADF) test which is based on the estimates the ADF model repeatedly on a forward expanding sample sequence does not indicate presence of the house price bubbles over the 2010Q1–2023Q2 period. Additionally, the absence of a house price bubble is suggested by the estimates of the EGARCH(2,2) model, as there are no signs of an increase in the house price volatility as measured by the conditional standard deviation (all results are available on request).

Our Structural Vector Autoregressive (SVAR) model is as follows (in terms of the contemporaneous innovations):

$$y = u_1 + a_1 e + a_2 \Delta h, \tag{2}$$

$$e = u_2, \tag{3}$$

$$\Delta p = b_1 y + b_2 e + u_3, \tag{4}$$

$$i = c_1 y + c_2 e + c_3 \Delta p + u_4, \tag{5}$$

$$\Delta h = d_1 e + d_2 \Delta p + d_3 i + u_4, \tag{6}$$

where y is the output gap (%), e is the exchange rate misalignment (%), Δp is the consumption price inflation (%), i is the short-term interest rate (%), Δh is the house price growth rate (%).

Endogenous variables of the real house prices, the real output, a general price level (consumer prices or GDP deflator), and the nominal short-term interest rate, as a proxy for the monetary policy stance, are used in the SVAR (VAR) models for a panel of 17 industrialised countries (Goodhart & Hofmann, 2008), 6 European countries (Carstensen, Hülsewig & Wollmershäuser, 2009), the USA, Canada and the UK (Benati, 2021), Australia (Wadud, Bashar & Ahmed, 2009). The effects of the nominal exchange rate are accounted for in the studies for Australia (Wadud, Bashar & Ahmed, 2009) and the UK (Elbourne, 2008), among others. It should be admitted that a relatively short data sample does not allow us to include extra variables in our SVAR model, such as government spending (Wadud, Bashar & Ahmed, 2009), banking reserves in the central bank (Benati, 2021), bank credit to the private sector (Goodhart & Hofmann, 2008), commodity prices (Elbourne, 2008; Benati, 2021), credit growth (Anundsen & Jansen, 2013), the unemployment rate (Gustafsson, Stockhammar & Österholmb, 2016) etc.

It is assumed that the output gap is affected in the current period by exchange rate and house price shocks (Eq. 2). It is consistent with empirical evidence that house price effects are demand-driven and related to expectations of future price

developments. Also, there is literature on the real effects of exchange rate misalignment (for example, Rodrik, 2008; Woodford, 2009; Bergin, 2022). In turn, such misalignments are exogenous in the current period (Eq. 3), with a pass-through to consumer inflation (Eq. 4). Although recent studies report the decline of the exchange rate effects on inflation, for example Ortega and Osbat (2020), changes in the exchange rate dynamics remain an important factor behind inflationary developments. In line with modern New Keynesian models, inflation is related to the output gap either. If house owners prevail in the economy, an increase in the house prices is likely to be inflationary via the wealth effect; otherwise, an inverse relationship between house prices and inflation is suggested. Empirical results are ambiguous (Bjørnland & Jacobsen, 2010; Kuang & Liu, 2015; Christou *et al*., 2018). As it is common in the modelling of central bank response functions, the short-term interest rate is under influence of the output gap, exchange rate and inflation (Eq. 5). There is no immediate response of the interest rate to house prices in the current period.

Finally, dynamics of house prices is dependent on exchange rate, inflation and the interest rate (Eq. 6). A positive reaction to the output gap is likely to occur with a lag, as higher households' income contributes to house prices. However, it is not ruled out that output boom is inflationary, with higher cost of living being a factor behind lower demand for housing. On the other hand, more expensive construction materials could offset a downward pressure on house prices, at least in the short run (Gustafsson, Stockhammar & Österholmb, 2016). If inflation triggers speculative behaviour among potential buyers, it could be a source of upward pressure on house prices either. Exchange rate impact on house prices is not straightforward, being dependent on the relative strength of demand-side and supply-side effects. A higher interest rate is likely to lower house prices.

For countries with a floating exchange rate, the central bank policy rate is used, while the short-term interest rate is used for other countries. Among the controls, the US short-term interest rate (%) and a crisis dummy for the COVID-19 pandemic are used. Based on the average of lag order tests, the PVAR model with four lags is used in estimations for all three groups of countries.

4. Empirical Results

Figure 2 displays the impulse response functions (IRFs) for reaction of house prices to a one standard deviation increase in other endogenous variables over a horizon of 16 quarters. Similar to other studies for the European countries (Anundsen & Jansen, 2013; Gaspareniene, Venclauskiene & Remeikiene, 2014; Hanck & Prüser, 2020; André *et al*., 2022), a one-time positive shock to a short--term interest rate contributes to a decrease in house prices, which is lasting for approximately 8 quarters in the CEE-12 and the EU-12 countries while being more persistent in the EU-6 countries.

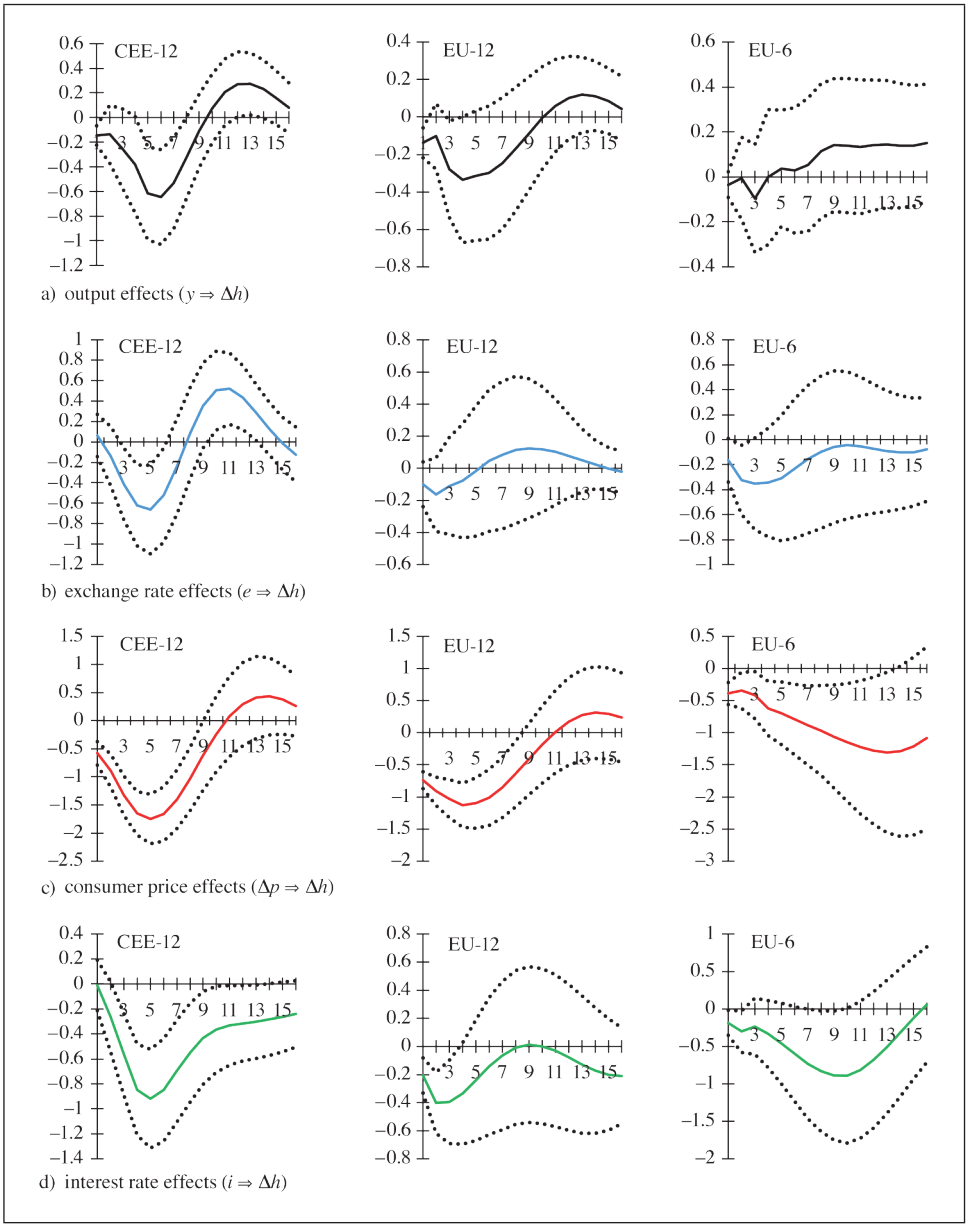

Fig. 2. Impulse Responses of House Prices to One Standard Deviation Innovations in Other Endogenous Variables

Notes: Here and hereafter the point estimates of the impulse response functions are presented in a band with ±2 standard deviations.

Source: own estimations.

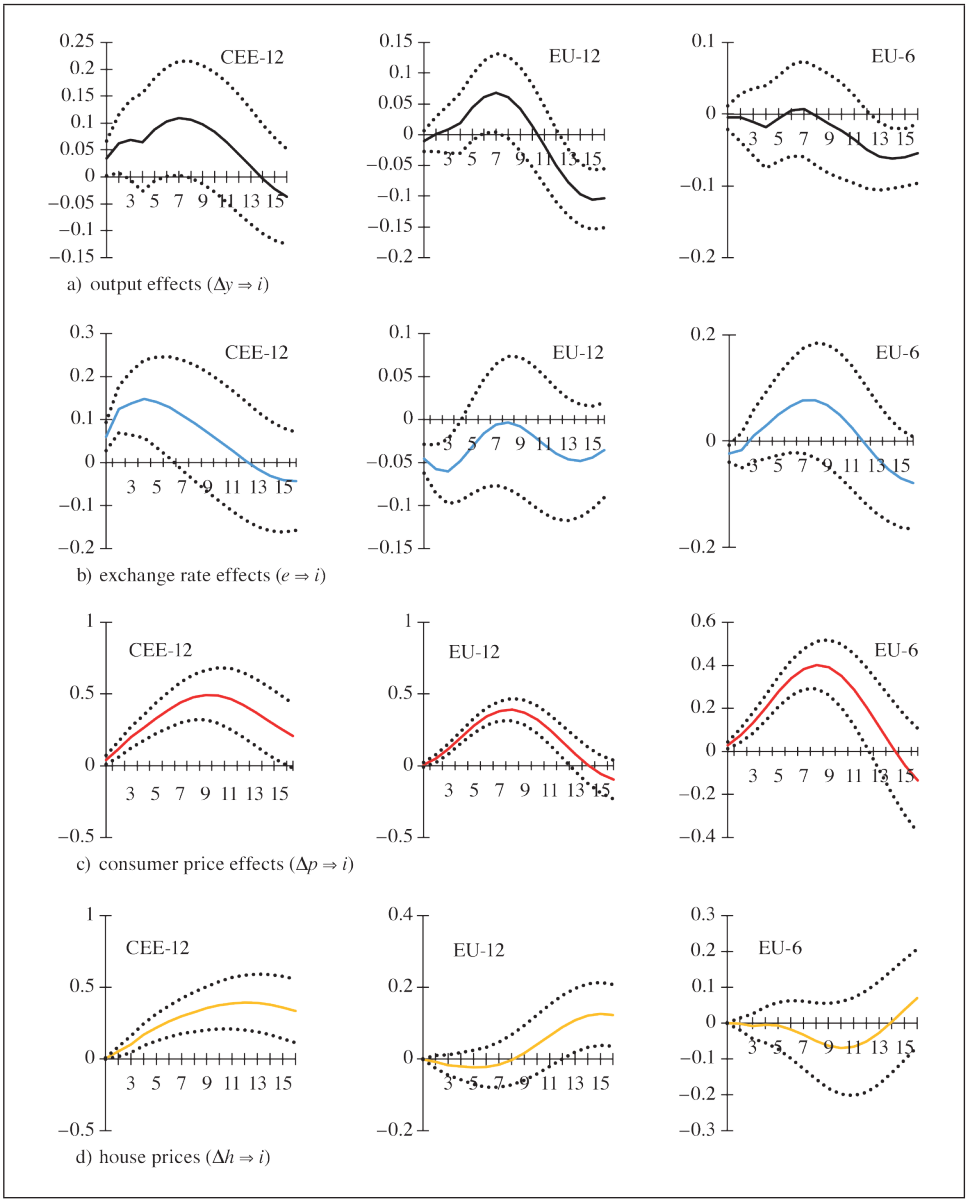

Fig. 3. Impulse Responses of Short-term Interest Rates to One Standard Deviation Innovations in Other Endogenous Variables

Source: own estimations.

Assuming that the central bank effectively controls the short-term interest rate, it means that it is possible to stabilise the housing market in line with theoretical arguments by Martin, Schmitt and Westerhoff (2022). In the absence of a direct link between interest rate and house prices, it makes it less likely that interest rate differentials and resulting capital inflows are behind house price changes, as it is argued by Bernanke (2010).

Among other monetary factors, there is a uniform depressing impact of inflation on house prices in all three groups of countries, which is quite persistent in the EU-6 countries. Such findings can be attributed to a negative wealth effect, as higher consumer prices curb the purchasing power of households. For the CEE-12 countries, a shock to the exchange rate – which indicates undervaluation of the currency – decreases house prices on impact but the effect is reversed with a peak at 10 to 12 quarters since the shock. Such findings can be explained by initial unfavourable supply-side effects, for example, due to higher costs of construction materials, while favourable demand-side effects dominate at longer horizons. Demand for houses by foreigners and returning native migrants is one of the likely factors, as a weaker currency makes local houses less expensive for foreign currency-denominated asset owners. In other European countries exchange rate effects on house prices are weak and short-lived. It is interesting that output effects on house prices are similar to those of exchange rate misalignments in the CEE-12 and the EU-12 countries, with neutrality observed in the EU-6 countries.

Considering a likely two-way causality between house prices and the interest rate, the response of interest rates to house prices is immediate and very strong in the CEE-12 countries (Fig. 3). Similar effect of a house price shock is observed in the EU-12 countries with 12 to 14 quarter lags. No impact is observed for the EU-6 countries. There is no difference across countries in that a consumer price shock is followed by a significant increase in the interest rate. The interest rate response is more persistent for the CEE-12 countries, remaining statistically significant after 16 quarters. As for the reaction to the output gap, it is similar for the CEE-12 and the EU-12 countries on impact but there are differences at longer horizons. A resulting decrease in the interest rate in the EU-12 countries is similar to the impulse response for the EU-6 countries at longer horizons, suggesting efforts to stimulate economic growth. For the EU-12 countries, it contrasts with a previous increase in the interest rate in response to economic boom.

For the CEE-12 countries, the IRF suggests that central banks tend to counter depreciation pressure on local currencies with an interest rate hike, while a decrease in the central bank rate is taking place in order to prevent exchange rate from excessive appreciation (statistical significance is very strong up to 5 quarters after the exchange rate shock). Contrary to the effects for CEE-12 countries, the shock

to the exchange rate is met with a short-lived decrease in the interest rate in the EU-12 countries. It also appears from Figure 3 that the exchange rate depreciation contributes to decrease in the interest rate briefly for about a quarter before it begins to have an opposite effect on the interest rate.

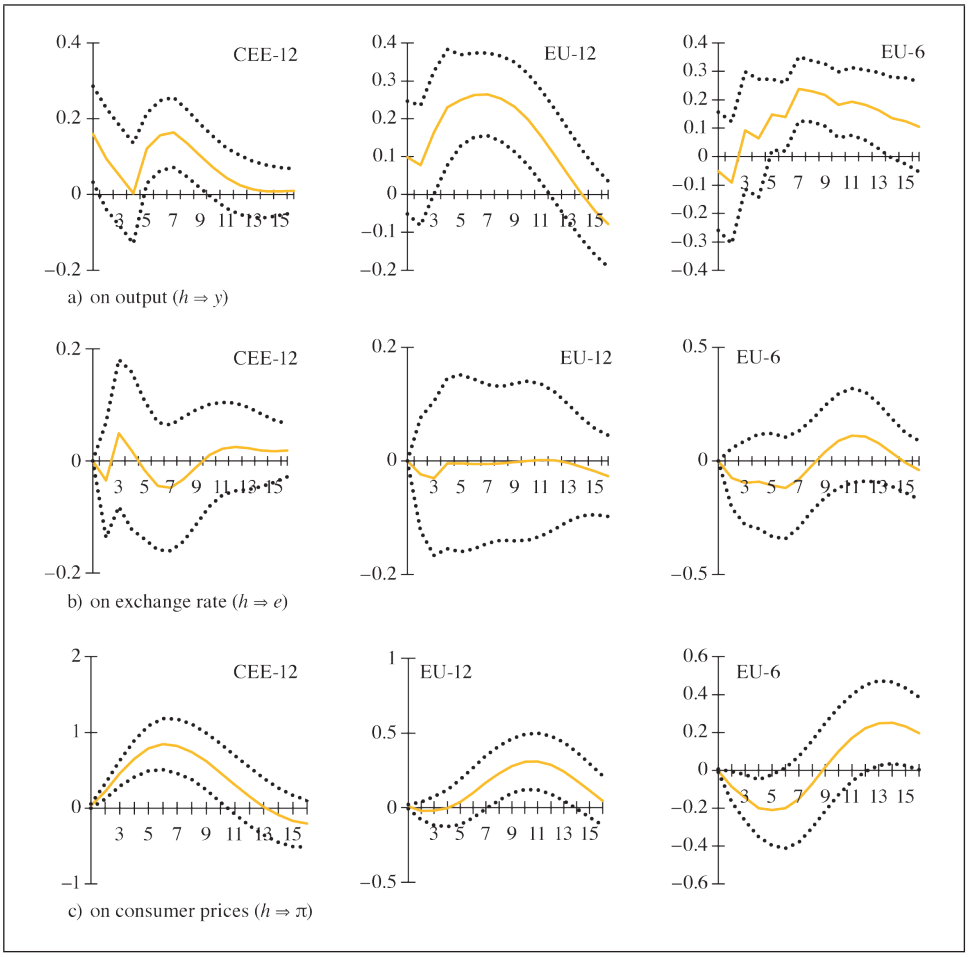

Fig. 4. Impulse Responses to One Standard Deviation Innovation in House Prices
Source: own estimations.

As Figure 4 shows, for any of three groups of countries the response of output to a positive house price shock is expansionary in nature, though with a slightly different time profile. The strongest effect is observed for the EU-12 countries at horizons between 4 and 11 quarters and for the EU-6 countries at horizons between

6 and 16 quarters. As argued by Tsatsaronis and Zhu (2004) and Gimeno and Martínez-Carrascal (2010), the expansionary effect could be due to the easing of credit constraints or presence of illusion of wealth. High house ownership and low property taxes also can play a role.

There is no evidence of any house price effects on exchange rate developments. For the CEE-12 countries, there is a strong causality running from house prices to inflation, with a peak after 6 quarters followed by a gradual decline since then. In the EU-12 countries impulse response for the house price shock exhibits a similar pattern at horizons beyond 6 quarters while there is no effect on impact. In contrast to the other countries, a house price shock results in a statistically significant but short-lived decline in inflation in the EU-6 countries, with a reversal at longer horizons. It is possible to hypothesise that spending on houses divert demand from consumer goods and services thus reducing the inflation rate significantly while the wealth effect starts to dominate at longer horizons. Based on the arguments by Bekiros, Nilavongse and Uddin (2020), a decline in inflation means dominance of non-fundamental shock to house prices.

Additional insights into the transmission mechanism of monetary policy are provided by analysis of the interest rate effects (Fig. 5). Besides direct effects on the house prices, monetary policy can work through its effects on the output gap, exchange rate and inflation. Our findings suggest that a higher interest rate has an immediate dampening effect on inflation rates in the EU-6 countries, with a return to the target in 8 quarters. The same anti-inflationary effect is observed for the EU-12 countries but with the so-called price effect at longer horizons, as there is an increase in the inflation rate. The same acceleration of inflation resulting from an increase in the interest rate is seen in the CEE-12 countries on impact thus magnifying a contractionary impact of monetary tightening on house prices. The relationship is just the opposite for both EU-12 and EU-6 countries, as a decline in inflation provides with support for the housing market, at least in the short run.

As there is a uniform immediate exchange rate appreciation resulting from a higher interest rate, it is an outcome which is favourable for house prices, especially in the CEE-12 countries. In the case of monetary tightening, both favourable indirect inflation and exchange rate effects on house prices are somewhat weakened by a direct contractionary effect on the output gap beyond 12th quarter after the interest rate shock. For the EU-6 countries, a contractionary effect of monetary tightening on the output gap occurs without indirect spillovers on the housing market as house prices are independent of the cyclical fluctuations in output. For two other groups of countries, a slowdown in output (at different horizons) helps to keep house prices lower in the CEE-12 countries, while an opposite outcome is likely in the EU-12 countries.

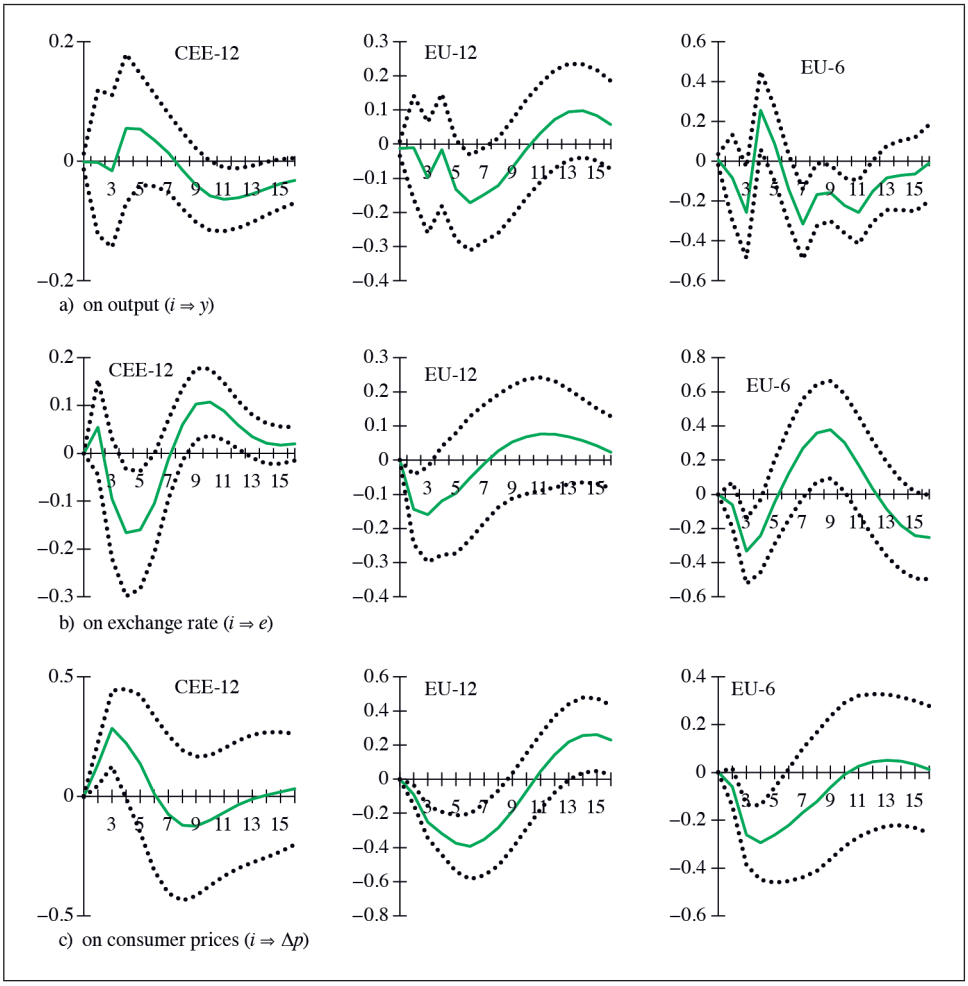

Fig. 5. Impulse Responses to One Standard Deviation Innovation in the Short-term Interest Rate
Source: own estimations.

Despite statistically significant impulse responses, the analysis of the forecast error variance decomposition (FEVD) reveals that the fraction of changes in house prices explained by interest rate shocks is rather small (Table 1). However, house prices are significantly influenced by inflation rates. The effect is strongest in the CEE-12 and EU-6 countries, where the fraction of Δp in the FEVD of Δh gradually increases from 22% to 36% and from 5% to 31%, respectively. The importance of the inflationary shock for house prices is somewhat weaker in the EU-12 countries. Our results support findings by Benati (2021) in that monetary policy effects on house prices outperform monetary effects on output.

Table 2 reports the FEVD results for short-term interest rates. For both EU-12 and EU-6 countries, the dominant source of variance are innovations in inflation which account for more than 60% of FEVD at the end of a 16-quarter horizon. For the CEE-12 countries, the fraction of changes in the interest rate explained by inflation shocks is above 30%, whereas innovation in house prices accounts for as much as 23% of interest rate fluctuations.

Table 1. Forecast Error Variance Decomposition for House Prices

Country Group	Forecast Horizon				Country Group	Forecast Horizon			
	4	8	12	16		4	8	12	16
$y \Rightarrow \Delta h$					$e \Rightarrow \Delta h$				
CEE-12	1	4	4	4	CEE-12	2	3	4	4
EU-12	1	1	1	2	EU-12	0	0	0	0
EU-6	0	0	0	0	EU-6	2	2	1	1
$\Delta p \Rightarrow \Delta h$					$i \Rightarrow \Delta h$				
CEE-12	22	36	36	36	CEE-12	4	9	9	10
EU-12	18	21	20	21	EU-12	2	2	2	2
EU-6	5	11	22	31	EU-6	2	7	11	10

Source: own estimations.

Table 2. Forecast Error Variance Decomposition for the Short-term Interest Rate

Country Group	Forecast Horizon				Country Group	Forecast Horizon			
	4	8	12	16		4	8	12	16
$y \Rightarrow i$					$e \Rightarrow i$				
CEE-12	1	2	1	1	CEE-12	5	4	2	2
EU-12	0	2	1	4	EU-12	3	1	1	2
EU-6	0	0	0	1	EU-6	1	2	2	3
$\Delta p \Rightarrow i$					$\Delta h \Rightarrow i$				
CEE-12	10	24	32	32	CEE-12	3	11	18	23
EU-12	17	61	68	63	EU-12	0	0	1	5
EU-6	22	61	69	66	EU-6	0	0	1	2

Source: own estimations.

Similarly to André *et al*. (2022), Anundsen and Jansen (2013), Gustafsson, Stockhammar and Österholmb (2016), our findings support the stabilisation properties of monetary response to house prices, especially for the CEE-12 and EU-6 countries. However, it seems that indirect effects of monetary policy through inflation are more important in affecting house prices. Among setbacks of a monetary tightening

in response to higher house prices, such effects as output slowdown and the price puzzle, when a higher central bank interest rate is associated with an increase in the price level, are to be mentioned, in line with the arguments by Baldi (2014) or Bekiros, Nilavongse and Uddin (2020).

5. Robustness Checks

Our main results are subject to various robustness checks. First of all, we used deviations from the house price trend as a dependent variable instead of the rate of house price growth. For the CEE-12 countries, the only minor difference is that the inverse relationship between inflation and house prices becomes more persistent over time. For the EU-6 countries, a negative response of house prices to the interest rate disappears at longer horizons, while the causality running from house prices to interest rate becomes slightly positive, more in line with what is obtained for the CEE-12 and EU-12 countries. No changes in the IRFs for house price determinants are found in the EU-12 countries thus further confirming robustness of our results. However, there is a decline in the fraction of house price variance decomposition explained by consumer inflation rates as compared to SVAR model with the rate of house price growth, from 36% to 10% for the CEE-12 countries, from 21% to 8% for the EU-12 countries and from 31% to 8% for the EU-6 countries. Among the house price effects on other endogenous variables, the only significant difference is that the initial anti-inflationary impact of higher house prices in the EU-6 countries disappears completely, with an opposite inflationary effect being observed up to 10 quarters after a positive house price shock. Also, there is weak evidence in favour of an interest rate response to house prices at longer horizons, but against the backdrop of the same marginal fraction of house prices in the variance decomposition of interest rate, as in the case of the SVAR model with the rate of house price growth.

Second, our results stay intact if we drop the exchange rate in the baseline SVAR model thus reducing it to a four-variable model. In general, such an outcome can be attributed to the marginal role of exchange rate misalignments in European economies. At its maximum, the fraction of exchange rate reaches 10% in the variance decomposition of inflation for the CEE-12 countries. However, it is not ruled out that the exchange rate effects are stronger in the context of long-term relationships, especially for the CEE countries (Shevchuk, 2022).

Third, in the SVAR models for EU-12 and EU-6 countries we substituted a short--term interest rate with the so-called shadow interest rate, as provided by the Federal Reserve Bank of Atlanta. As defined by Wu and Xia (2016), the shadow rate is the central bank reference rate when the Zero Lower Bound (ZLB) is not binding, while being negative in the periods when unconventional policy tools are being implemented. It is confirmed that a higher shadow interest rate contributes to a fall in the house prices. Moreover, the inverse relationship between interest rate and house

prices becomes even stronger in both EU-12 and EU-6 countries. A negative effect of inflation on house prices is strengthened for the EU-12 countries, with no changes for the EU-6 countries. For both groups of countries, no changes between SVAR models estimates in that house prices are associated with a positive contribution to output. Inflationary effects of house prices are confirmed for the EU-12 countries, while these ones are lost in the estimates for the EU-6 countries. Similarly estimates from the baseline SVAR model, there is no response of the shadow interest rate to house prices in the the EU-6 countries, while a positive link at longer horizons between house prices and interest rate disappears for the EU-12 countries. As in the baseline SVAR model, a higher shadow interest rate is contractionary on impact, while bringing about a short-lived exchange rate appreciation which is followed by a depreciation above trend. In contrast to the estimates of the baseline SVAR model, an inverse relationship between the shadow interest rate and inflation is observed only at longer horizons for both EU-12 and EU-6 countries.

6. Conclusions

Using panel data estimates of quarterly data for the 2010–2023 period, it is found that house prices are expansionary and inflationary in all countries, though with a different time profile. As expected, house prices decline in response to higher short-term interest rates, with the strongest effect in the CEE-12 and the EU-6 countries. It means that it is possible to stabilise the housing market by a monetary policy reaction, though at the cost of output slowdown. For the CEE-12 countries, there are additional obstacles for stabilisation policies due to presence of the price puzzle. A conventional inverse relationship between interest rates and inflation is found for both EU-12 and EU-6 countries. Among other monetary factors, there is a uniform depressing impact of inflation on house prices in all three groups of countries. A similar negative effect of exchange rate depreciation is short-lived, with a reversal at longer horizons for the CEE-12 countries. An increase in output over the business cycle brings about a decrease in house prices in both CEE-12 and EU-12 countries, with a trough at 5 to 6 quarters.

There is strong evidence of the short-term interest rate response to house prices in the CEE-12 countries, with a similar (albeit weaker) monetary reaction for the EU-12 countries. No response is observed for the CEE-6 countries. On the basis of causality running from consumer prices to the short-term interest rate, it is possible to assume that the monetary reaction function of the central bank favours a response to inflation. As for the monetary response to the output gap, it is observed in the CEE-12 and EU-12 countries, with a reversal at longer horizons suggesting efforts to stimulate economic growth (similar to the EU-6 countries).

Authors' Contribution

The authors' individual contribution is as follows: Viktor Shevchuk – conceptualisation, methodology, validation, writing – review and editing; Roman Kopych – data collection, computing, writing – original draft.

Conflict of Interest

The authors declare no conflict of interest.

References

André, C., Caraiani, P., Călin, A. C., & Gupta, R. (2022). Can Monetary Policy Lean against Housing Bubbles? *Economic Modelling*, *110*, 105801. https://doi.org/10.1016/j.econmod.2022.105801

Anundsen, A. K., & Jansen, E. S. (2013). Self-reinforcing Effects between Housing Prices and Credit. *Journal of Housing Economics*, *22*(3), 192–212. https://doi.org/10.1016/j.jhe.2013.07.001

Baldi, G. (2014). The Economic Effects of a Central Bank Reacting to House Price Inflation. *Journal of Housing Economics*, *26*, 119–125. https://doi.org/10.1016/j.jhe.2014.09.004

Bekiros, S., Nilavongse, R., & Uddin, G. S. (2020). Expectation-driven House Prices and Debt Defaults: The Effectiveness of Monetary and Macroprudential Policies. *Journal of Financial Stability*, *49*, 100760. https://doi.org/10.1016/j.jfs.2020.100760

Benati, L. (2021). Leaning against House Prices: A Structural VAR Investigation. *Journal of Monetary Economics*, *118*(C), 399–412. https://doi.org/10.1016/j.jmoneco.2020.12.002

Bergin, P. R. (2022). Currency Undervaluation and Comparative Advantage. *European Economic Review*, *150*(C), 104316. https://doi.org/10.1016/j.euroecorev.2022.104316

Bernanke, B. S. (2010). *Monetary Policy and the Housing Bubble* (YPFS Documents, 4219). Yale University.

BIS Data Portal. (2024). https://data.bis.org (accessed: 10.11.2024).

Bjørnland, H. C., & Jacobsen, D. H. (2010). The Role of House Prices in the Monetary Policy Transmission Mechanism in Small Open Economies. *Journal of Financial Stability*, *6*(4), 218–229. https://doi.org/10.1016/j.jfs.2010.02.001

Carstensen, K., Hülsewig, O., & Wollmershäuser, T. (2009). *Monetary Policy Transmission and House Prices: European Cross-country Evidence* (CESifo Working Paper No. 2750). Center for Economic Studies and Ifo Institute (CESifo).

Chen, S.-S., & Lin, T.-Y. (2022). Revisiting the Link between House Prices and Monetary Policy. *The B.E. Journal of Macroeconomics*, *22*(2), 481–515. https://doi.org/10.1515/bejm-2021-0099

Choi, C.-Y., & Jo, S. (2020). *How Do Housing Markets Affect Local Consumer Prices? – Evidence from U.S. Cities* (FRBD Globalization Institute Working Paper No. 398). Federal Reserve Bank of Dallas. https://doi.org/10.24149/gwp398

Christou, C., Gupta, R., Nyakabawo, W., & Wohar, M. E. (2018). Do House Prices Hedge Inflation in the US? A Quantile Cointegration Approach. *International Review of Economics and Finance*, *54*, 152–156. https://doi.org/10.1016/j.iref.2017.12.012

Davids, A. (2020). *The Cape of Good Homes: Exchange Rate Depreciations, Foreign Demand and House Prices*. https://doi.org/10.2139/ssrn.3349815

Duca, J. V., Muellbauer, J., & Murphy, A. (2021). What Drives House Price Cycles? International Experience and Policy Issues. *Journal of Economic Literature*, *59*(30), 773–864. https://doi.org/10.1257/jel.20201325

Ehrenbergerová, D., & Bajzík, J. (2020). *The Effect of Monetary Policy on House Prices – How Strong is the Transmission?* (CNB Working Paper Series No. 14/2020). Czech National Bank.

Eickmeier, S., & Hofmann, B. (2010). *Monetary Policy, Housing Booms and Financial (Im)balances* (Discussion Paper No. 07/2010). Deutsche Bundesbank.

Elbourne, A. (2008). The UK Housing Market and the Monetary Policy Transmission Mechanism: An SVAR Approach. *Journal of Housing Economics*, *17*(1), 65–87. https://doi.org/10.1016/j.jhe.2007.09.002

Federal Reserve Bank of St. Louis. (2024). https://www.fred.stlouisfed.org (accessed: 10.11.2024).

Finocchiaro, D., & von Heideken, V. Q. (2009). *Do Central Banks React to House Prices?* (Sveriges Riksbank Working Paper Series No. 217). Sveriges Riksbank.

Gaspareniene, L., Venclauskiene, D., & Remeikiene, R. (2014). Critical Review of Selected Housing Market Models Concerning the Factors That Make Influence on Housing Price Level Formation in the Countries with Transition Economy. *Procedia – Social and Behavioral Sciences*, *110*, 419–427. https://doi.org/10.1016/j.sbspro.2013.12.886

Gimeno, R., & Martínez-Carrascal, C. (2010). The Relationship between House Prices and House Purchase Loans: The Spanish Case. *Journal of Banking & Finance*, *34*(8), 1849–1855. https://doi.org/10.1016/j.jbankfin.2009.12.011

Goodhart, C., & Hofmann, B. (2008). *House Prices, Money, Credit and the Macroeconomy* (Working Paper Series No. 888). European Central Bank.

Gustafsson, P., Stockhammar, P., & Österholmb, P. (2016). Macroeconomic Effects of a Decline in Housing Prices in Sweden. *Journal of Policy Modelling*, *38*(2), 242–255. https://doi.org/10.1016/j.jpolmod.2016.02.011

Hanck, C., & Prüser, J. (2020). House Prices and Interest Rates: Bayesian Evidence from Germany. *Applied Economics*, *52*(28), 3073–3089. https://doi.org/10.1080/00036846.2019.1705242

Horvath, J., & Rothman, P. (2021). Mortgage Spreads, Asset Prices, and Business Cycles in Emerging Countries. *Journal of International Money and Finance*, *115*, 102370. https://doi.org/10.1016/j.jimonfin.2021.102370

International Monetary Fund. (2024). https://data.imf.org/ (accessed: 10.11.2024).

Iossifov, P., Čihák, M., & Shanghavi, A. (2008). *Interest Rate Elasticity of Residential Housing Prices* (IMF Working Paper No. WP/08/247). International Monetary Fund.

Jarociński, M., & Smets, F. R. (2008). House Prices and the Stance of Monetary Policy. *Federal Reserve Bank of St. Louis Review*, *90*(4), 339–366.

Koeniger, W., Lennartz, B., & Ramelet, M.-A. (2022). On the Transmission of Monetary Policy to the Housing Market. *European Economic Review*, *145*, 104107. https://doi.org/10.1016/j.euroecorev.2022.104107

Kuang, W., & Liu, P. (2015). Inflation and House Prices: Theory and Evidence from 35 Major Cities in China. *International Real Estate Review*, *18*(1), 217–240.

Martin, C., Schmitt, N., & Westerhoff, F. (2022). Housing Markets, Expectation Formation and Interest Rates. *Macroeconomic Dynamics*, *26*(2), 491–532. https://doi.org/10.1017/S1365100520000279

Miller, N. G., Sklarz, M., & Thibodeau, T. G. (2005). The Impact of Interest Rates and Employment on Nominal Housing Prices. *International Real Estate Review*, *8*(1), 26–42.

Mishkin, F. S. (2007). *Housing and the Monetary Transmission Mechanism* (NBER Working Paper No. 13518). National Bureau of Economic Research. https://doi.org/10.3386/w13518

Ortega, E., & Osbat, C. (Eds). (2020). *Exchange Rate Pass-through in the Euro Area and EU Countries* (Occasional Paper Series No. 241). European Central Bank.

Rodrik, D. (2008). The Real Exchange Rate and Economic Growth. *Brookings Papers on Economic Activity*, *39*(2), 365–439.

Rufai, A. A., Aor, R. L., & Salisu, A. A. (2025). Testing the Relationship between Housing Prices and Inflation in the OECD Countries. *International Journal of Housing Markets and Analysis*, *18*(5), 1204–1230. https://doi.org/10.1108/IJHMA-02-2024-0020

Sá, F., Towbin, P., & Wieladek, T. (2011). *Low Interest Rates and Housing Booms: The Role of Capital Inflows, Monetary Policy and Financial Innovation* (Globalization and Monetary Policy Institute Working Papers No. 79). Federal Reserve Bank of Dallas.

Shevchuk, V. (2022). Price and Output Effects of Long-term Exchange Rate Changes: Central and Eastern European Countries in 2002–2019. *Entrepreneurial Business and Economics Review*, *10*(3), 37–50. https://doi.org/10.15678/EBER.2022.100303

Shi, S., Jou, J.-B., & Tripe, D. (2014). Can Interest Rates Really Control House Prices? Effectiveness and Implications for Macroprudential Policy. *Journal of Banking & Finance*, *47*(1), 15–28. https://doi.org/10.1016/j.jbankfin.2014.06.012

Stahlecker, S. (2024). Do Housing Prices Decrease When Interest Rates Go up? Housing Prices and Interest Rates: Understanding the Positive Correlation across Five Countries. *Highlights in Business, Economics and Management*, *35*, 332–342. https://doi.org/10.54097/kr380295

Sümer, L., & Özorhon, B. (2020). The Exchange Rate Effect on Housing Price Index and REIT Index Return Rates. *Finansal Araştırmalar ve Çalışmalar Dergisi*, *12*(22), 249–266. https://doi.org/10.14784/marufacd.688468

Tsatsaronis, K., & Zhu, H. (2004). What Drives Housing Price Dynamics: Cross-country Evidence. *BIS Quarterly Review*, March, 65–78.

Wadud, M., Bashar, O., & Ahmed, H. (2009). *An SVAR Analysis of Monetary Policy Dynamics and Housing Market Responses in Australia* (Working Papers. Economics Series No. 2009/22). Deakin University, Department of Economics.

Williams, J. C. (2011). Monetary Policy and Housing Booms. *International Journal of Central Banking*, *7*(1), 345–355.

Woodford, M. (2009). *Is an Undervalued Currency the Key to Economic Growth?* (Discussion Paper No. 0809-13). Columbia University.

Wu, J. C., & Xia, F. D. (2016). Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound. *Journal of Money, Credit, and Banking*, *48*(2–3), 253–291. https://doi.org/10.1111/jmcb.12300

Yamaka, W., Liu, J., Li, M., Maneejuk, P., & Dinh, H. Q. (2022). Analyzing the Causality and Dependence between Exchange Rate and Real Estate Prices in Boom-and-Bust Markets: Quantile Causality and DCC Copula GARCH Approaches. *Axioms*, *11*(3), 113. https://doi.org/10.3390/axioms11030113

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The Impact of the COVID-19 Pandemic on the Value Relevance of Accounting Information: The Case of Polish Listed Banks

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ABSTRACT

Objective: So far, the research focusing on the assessment of the impact of economic crises on value relevance in banks mainly concerned the global financial crisis, while other crises such as the pandemic were not comprehensively analysed in this regard. The aim of the article was to analyse the impact of COVID-19 pandemic, considered an economic crisis, on the value relevance of banks. The value relevance of earnings, book values, and cash flows was taken into consideration in the research.

Research Design & Methods: Value relevance models with share price as an endogenous variable and accounting variables as exogenous ones were estimated. The impact of the COVID-19 pandemic was captured by using variables' interactions. Panel data models with fixed effects were employed. The sample consisted of Polish listed banks. The analysis period was 2017–2024, semi-annual data were used.

Findings: Generally, positive value relevance was found for earnings and deposits, but not for other book values (equity and loans). The impact of COVID-19 pandemic on the value relevance of book values was significantly negative, while it was not significant for earnings. Such results were partially consistent with the hypotheses developed. Value relevance of operating cash flows was not considered due to the multicollinearity issue.

Implications/Recommendations: The paper provides insight into the drivers of banks' market values and their changes during economic crises from the investor's perspective. Such knowledge could be valuable from the perspective of both investors and bank management.
Contribution: The impact of COVID-19 pandemic on the value relevance of earnings and book values in banks has not been analysed yet. Moreover, the semi-annual data was used, while previous research on value relevance in banks was mostly based on annual or quarterly data.

Article type: original article.

Keywords: value relevance, COVID-19, bank, earnings, book values, cash flow.

JEL Classification: G10, G20, M41.

1. Introduction

It is commonly accepted that values included in the financial statements should be reflected in the share prices of listed companies – e.g., such a relationship is the assumption of fundamental analysis. Referring to Ohlson (1995), assuming a clean surplus relation (that occurs when changes in equity are equal to earnings less dividends), not only dividends, capturing the direct cash flows to shareholders, but also both book values (derived from the balance sheet) and earnings are significant drivers of market valuation. However, whether all values from financial statements are significant or only part of them (major/minor), taking into account i.a. that earnings can be decomposed to operating cash flows and accruals (Burke & Wieland, 2017)? This is the general question addressed in value relevance (VR) research.

There are many factors or events that could noticeably affect the relationship between accounting and market values (i.e., value relevance). One might wonder, whether recent economic crises or shocks are among them. Such an issue seems to be significant, as the crisis outbreak noticeably affects financial markets – it often results in a decline in share prices associated with greater market volatility (Izzeldin *et al*., 2023). Taking it into account, the VR of accounting information seems to be significantly affected by the economic crises. Despite the fact that such crises are often perceived as financial ones, they also result from other macroeconomic shocks, such as the pandemic. It is also worth noting that among entities mostly affected by economic crises, there are especially financial institutions.

So far, several studies regarding the impact of the COVID-19 pandemic on VR have already been developed as well as some research concerning the influence of economic crises on VR in banks. However, to the author's best knowledge, there are no studies focused on the impact of the COVID-19 pandemic on VR (of earnings and book values) in banks. Therefore, the purpose of the article was to verify whether the COVID-19 pandemic, considered the most recent economic crisis, significantly affected the value relevance in banks. Such research seems to

be purposeful as it can provide some insight into whether the accounting factors significantly affecting the market value of banks are still valid during economic crisis periods.

The research hypotheses concerned especially earnings and book values in terms of the impact of the COVID-19 pandemic on their VR. To verify them, panel data models were employed. The sample selected for this purpose consisted of Polish listed banks. The period 2017–2024 (using semi-annual data) was taken into account in the research.

Based on the results obtained, a significant negative impact of the COVID-19 pandemic on VR of book values was found, however, such an influence was not significant in the case of earnings. Hence, it seems that investors perceive banks' earnings value relevant even during economic crises, which is not true for book values.

2. Literature Review

2.1. General Remarks

According to the classical view of the company's activity purpose, it is crucial to generate profits. Relating this to the market valuation of companies it could be stated that the better a company performs in terms of earnings, the more expensive are its shares. However, as pointed out within the neoclassical theory, the company should aim to maximise the value for shareholders, i.e. market value of a company itself (Czekaj & Dresler, 2006, p. 14). Hence, still considering earnings a significant driver of a company's value, other market value drivers could also have a noticeable impact on stock prices. According to Ohlson (1995), they are not only dividends (reflecting cash flows to shareholders), but also i.a. book values.

In relation to the stock valuation, value relevance focuses on the relationship between accounting values and market ones. Since accounting values – financial performance measures such as earnings as well as book values capturing equity – are drivers of market equity valuation, the value of a given company might be considered their function. Therefore, the general form of VR models is as follows (Beisland, 2009):

$$MV = f(AV) + \varepsilon, \tag{1}$$

where MV – market value, f – function, AV – accounting values, ε – residuals.

As market values, share prices or returns are usually considered. Among accounting variables, there are categories derived from balance sheet, income statement, and, increasingly, cash flow statement taken into account. According to Beisland (2009), the main areas of VR research concerned: (1) VR of earnings and cash flows, (2) the VR of book values (referring them to the balance sheet), (3) VR and

changes over time and different factors, (4) VR and changes due to the accounting regulations. This work refers to the (3) area, as changes in the VR caused by the occurrence of the COVID-19 pandemic are analysed, but concerning also (1) and (2), as separate VR of earnings, book values, and cash flows were taken into account in the research.

2.2. Value Relevance of Earnings, Book Values and Cash Flows in Banks

It is worth noting that most of the VR research concerns non-financial companies to ensure data comparability (due to the different layout of financial statements of banks and insurance companies in comparison to trade or manufacturing entities). Hence, separate analyses of VR of earnings, book values, and cash flows are made based on the sample of banks only. In Table 1, an extract from some research referring to this subject, included in the Scopus database, is presented.

Table 1. Empirical Research on Value Relevance in Banks

Source	Analysed Countries	Analysed Period	E	BV	CF
Khurana & Kim (2003)	United States of America	1995–1998	x	+	x
Abuzayed, Molyneux & Al-Fayoumi (2009)	Jordan	1993–2004	+	i	x
Dimitropoulos, Asteriou & Koumanakos (2010)	Greece	1995–2004	+	x	+
Agostino, Drago & Silipo (2011)	15 European countries	2000–2006	+	i	x
Anandarajan *et al*. (2011)	38 countries	1993–2004	+	+	x
Carnevale, Mazzuca & Venturini (2012)	12 eurozone countries	2002–2008	+	+	x
Wang, Yu & Ye (2012)	Taiwan	2002–2010	i	+	x
Beltratti, Spear & Szabo (2013)	Several North American and European countries	2007–2009	+	x	x
Drago, Mazzuca & Trinca Colonel (2013)	12 european countries	2005–2008	i	+	x
Siregar, Anandarajan & Hasan (2013)	United States of America	1999–2008	+	+	x
Carnevale & Mazzuca (2014)	14 European countries	2002–2011	+	+	x
Du, Li & Xu (2014)	United States of America	2008–2009	+	x	x
Elnahass, Izzeldin & Abdelsalam (2014)	Middle East and African countries	2006–2011	+	+	x
Jung (2014)	United States of America	2001–2010	+	+	x
Lu & Mande (2014)	United States of America	2009–2010	+	+	x
Mechelli, Cimini & Mazzocchetti (2015)	27 countries	2009–2012	+	+	x
Chiqueto *et al*. (2015)	Brasil	2007–2010	x	+	x
Akeem Adetunji (2016)	Nigeria	2004–2012	i	x	x

Table 1 cnt'd

Source	Analysed Countries	Analysed Period	E	BV	CF
Manganaris, Spathis & Dasilas (2016)	15 European countries	1998–2011	+	+	x
Morris, Kang & Jie (2016)	United States of America	2006–2010	+	x	x
Uwuigbe *et al*. (2016)	Nigeria	2010–2014	+	–	x
Burke & Wieland (2017)	North American countries	2004–2014	x	x	+
Fiechter & Novotny-Farkas (2017)	International bank holding companies	2006–2009	+	+	x
Ahmadi & Bouri (2018)	Tunisia	2010–2015	+	+	x
Ragab & El-Chaarani (2018)	Egypt, Liban	2013–2016	+	i	i
Ben Rejeb Attia, Lassoued & Sassi (2019)	12 Middle East and African countries	1999–2014	i	x	x
Gao, Li & O'Hanlon (2019)	United States of America	2004–2016	+	+	i
Kim & Yoon (2019)	South Korea	2011–2015	+	+	x
Arraiano (2020)	France, Germany, Italy, the Netherlands, Norway, Spain, the United Kingdom	2001–2013	i	+	x
Bose, Saha & Abeysekera (2020)	Bangladesh	2007–2014	x	+	x
Giner, Allini & Zampella (2020)	France, Germany, Italy, Spain, the United Kingdom	2007–2014	+	+	x
Agbodjo, Toumi & Hussainey (2021)	14 Asian and African countries	2010–2018	+	+	x
Bolibok (2021)	Poland	2009–2020	+	+	x
Hameedi *et al*. (2021)	Iraq	2011–2018	+	+	x
Pacheco-Ortiz, Rendón-García & Villada-Medina (2021)	Colombia	2001–2018	+	+	x
Marques, Dalmacio & Rezende (2022)	Brasil	2010–2018	+	+	x
Mgammal & Al-Matari (2022)	Saudi Arabia	2014–2018	+	+	x
Abou-el-Sood (2025)	Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates	2018–2021	x	+	i
Mohammad Jadallah, Salim Haddad & Hussein Al Tarawneh (2023)	Jordan	2010–2018	i	i	i
Menezes da Costa Neto *et al*. (2023)	Brasil	2017–2019	i	i	x
Toumi & Hamrouni (2025)	12 Islamic countries	2012–2019	+	+	x

Notes: E – earnings; BV – book values; CF – cash flows; +/–/i – the positive/negative/insignificant relationship between market values and E, BV, or CF; x – an impact not directly analysed in a given research.

Source: own study, based on literature on the subject.

VR research in banks concerns usually earnings and book values. Referring to Table 1, there seems to be strong evidence that earnings are generally value relevant, similarly in the case of book values. It indicates that investors base their decisions to a significant extent on the accounting data.

The higher the earnings are, the greater is market value of a given bank on average. Such results prove that accruals are properly reflecting the bank's financial situation in the investors' view, and accounting procedures (write-offs etc.) are positively perceived by the market participants. The positive VR of earnings was identified in countries from several continents (Europe, the Americas, Africa, and Asia), moreover, it was found in financial markets at different stages of development (according to the MSCI classification):

– developed markets – United States of America (Du, Li & Xu, 2014; Morris, Kang & Jie, 2016), France, Germany, Italy, Spain, the United Kingdom (Carnevale & Mazzuca, 2014; Giner, Allini & Zampella, 2020),

– emerging markets – Brasil (Marques, Dalmacio & Rezende, 2022), Poland (Bolibok, 2021), South Korea (Kim & Yoon, 2019), Saudi Arabia (Mgammal & Al-Matari, 2022),

– frontier markets – Bangladesh, Pakistan (Toumi & Hamrouni, 2025); Jordan (Abuzayed, Molyneux & Al-Fayoumi, 2009), Tunisia (Ahmadi & Bouri, 2018).

Regarding book values, they seem to be particularly significant in banks due to the relatively low level of equity in financial institutions, in comparison to non-financial entities. VR was empirically confirmed for the book value of equity (e.g., Bose, Saha & Abeysekera, 2020; Pacheco-Ortiz, Rendón-García & Villada-Medina, 2021), as well as loans and deposits (e.g., Khurana & Kim, 2003; Drago, Mazzuca & Trinca Colonel, 2013). In the view of Mechelli, Cimini and Mazzocchetti (2015), regulatory capital is more value relevant than equity – its applicability is not limited to stability maintenance only, but it has also an informative value for investors. Uwuigbe *et al*. (2016) found a significant negative relationship between share prices and book values – this was a unique result in comparison to other research analysed and presented in Table 1. It seems that such an outcome could be at least partially attributed to the market analysed – it was the Nigerian one, which is considered non-developed regarding accessibility, liquidity, and size (MSCI, 2024). This could be referred to Anandarajan *et al*. (2011), who stated that VR was higher for banks operating in: (1) countries with greater requirements regarding financial disclosures, (2) areas, in which the legal environment is more favourable to the banks' owners (shareholders), (3) British-American countries as their regulators require a relatively high level of transparency.

VR of cash flows was analysed recently in significantly less cases compared to the VR earnings and book values. The results regarding cash flows were also mixed

– the positive significant VR of cash flows was identified by Dimitropoulos, Asteriou and Koumanakos (2010) and Burke and Wieland (2017), but inconclusive results were found in other research analysed. Similarly, different results were obtained regarding the comparison of VR between cash flows and earnings. According to Dimitropoulos, Asteriou and Koumanakos (2010), earnings outperformed cash flows in this regard. On the opposite, Ragab and El-Chaarani (2018) found that cash flows were more value relevant than earnings. Such results could indicate that investors do not necessarily focus on banks' cash flows in determining their investment decisions and it is driven i.a. by the differences between individual countries. Moreover, the VR of cash flows varies between banks with different levels of profitability, capital adequacy, and credit risk (Burke & Wieland, 2017). However, more unified results concerned the VR of operating and other cash flows – in the view of Gao, Li and O'Hanlon (2019) and Abou-el-Sood (2025), there were no significant differences between the VR of operating and non-operating cash flows. Hence, it could be assumed that investors take into account only the total cash generated by a bank without valuing the difference between cash flows generated from core business activity from cash generated otherwise. Regarding cash flows, it is worth noting that they could be expressed as earnings less accruals (Burke & Wieland, 2017), which is the approach adopted in this paper.

2.3. The Impact of Crises on Value Relevance

Focusing on the impact of the economic crisis on the VR in banks, the emphasis was put on the global financial crisis, as it was a matter of interest in most of the previous research. The influence of the global financial crisis on the market value of banks was significantly negative according to Chiqueto *et al*. (2015). Similarly, Jung (2014) found a negative impact of the global financial crisis on the VR of earnings and book values. However, a positive impact of the crisis on the VR of unrealised gains/losses on non-agency asset-backed securities was also reported, while insignificant results concerned unrealised gains/losses on other investment securities. On the other hand, Arraiano (2020) found that the VR of book values (equity) increased as a result of the global financial crisis. Moreover, also earnings became more value relevant. However, after the crisis, their impact on market value was negative, while it was insignificant in the pre-crisis period. According to Gao, Li and O'Hanlon (2019), no crucial changes in the VR of earnings and book values were reported, as they were positive and significant in the pre-crisis, crisis, and post-crisis periods. The above-mentioned research proved that there were no unambiguous results regarding the impact of the global financial crisis on the VR in banks. Therefore, it could be supposed that such an impact strongly depends on a given country's specificity, which is supported i.a. by Anandarajan *et al*. (2011).

The next global economic crisis after the financial one was related to the COVID-19 pandemic. Regarding to the banks, it caused i.a.:

– a significant reduction in the performance and stability (Shabir *et al*., 2023),
– an increased banks' contribution to systemic risk (Yan, Jeon & Wu, 2023),
– contagion effects in financial markets (Iwanicz-Drozdowska *et al*., 2021),
– increase in expected credit losses and decline in profitability (Hladika, 2021).

Part of the above-mentioned pandemic's effects concerned also entities other than financial institutions. However, the research focused on the COVID-19 pandemic in non-financial entities led to different conclusions regarding VR – there was found both negative (Aljawaheri *et al*., 2021; Belesis, Kampouris & Karagiorgos, 2022; Liu & Sun, 2022) and positive (Răpan, 2021; Hamid *et al*., 2022; Sahlian *et al*., 2024) impact of COVID-19 pandemic on the value relevance. Regarding the impact of the COVID-19 pandemic on VR in banks, only the analysis by Abou-el-Sood (2025) was identified in the literature on the subject. The influence of COVID-19 pandemic on the VR of cash flows was positive in the author's view, which is the opposite of the results for earnings (according to the research on non-financial entities). The possible explanation for such results is that the investors, during uncertain times, rely on cash flows as they are considered reflecting the businesses' ability to maintain liquidity in the short term. As it is especially crucial for banks, taking into account often liquidity issues and potential "run on banks" during the crisis, it could be more purposeful to focus on cash flows instead of accrual-based earnings (which could be a better predictor of a bank's financial standing in the long term).

3. Research Methodology and Sample

3.1. Research Aim and Hypotheses

Taking into consideration the literature review conducted, the aim of the research was to verify whether the COVID-19 pandemic, considered an economic crisis, significantly affected the value relevance of Polish banks. To examine such impact, research hypotheses were developed. Firstly, basic ones were put to determine whether there is an expected relationship between market value and earnings, book values, and cash flows. They are as follows:

H1: There is a significant, positive value relevance of earnings.
H2: There is a significant, positive value relevance of book values.
H3: There is a significant, positive value relevance of cash flows.

In previous research in the field, similar hypotheses have been confirmed so far i.a. by Carnevale and Mazzuca (2014), Kim and Yoon (2019), Giner, Allini and Zampella (2020) or Bolibok (2021) regarding earnings (H1); Anandarajan *et al*. (2011), Drago, Mazzuca and Trinca Colonel (2013) and Pacheco-Ortiz, Rendón-García and Villada-Medina (2021) regarding book values (H2); Dimitropoulos,

Asteriou and Koumanakos (2010), Burke and Wieland (2017) and Ragab and El-Chaarani (2018) in relation to cash flows (H3).

Further, to verify the specific impact of the COVID-19 pandemic on VR, the following hypotheses were developed:

H4: There was a significant, negative impact of the COVID-19 pandemic on the value relevance of earnings.

H5: There was a significant, negative impact of the COVID-19 pandemic on the value relevance of book values.

H6: There was a significant, positive impact of the COVID-19 pandemic on the value relevance of cash flows.

So far, Belesis, Kampouris and Karagiorgos (2022) and Liu and Sun (2022) confirmed H4, Aljawaheri *et al*. (2021) and Belesis, Kampouris and Karagiorgos (2022) – H5, and Abou-el-Sood (2025) – H6. However, such research focused mainly on non-financial entities.

3.2. Research Sample and Models

The previous empirical research was based on either annual (e.g., Wang, Yu & Ye, 2012; Siregar, Anandarajan & Hasan, 2013; Bolibok, 2021; Menezes da Costa Neto *et al*., 2023) or interim data (e.g., Du, Li & Xu, 2014; Chiqueto *et al*., 2015; Morris, Kang & Jie, 2016). In this research, it was decided to use interim data to ensure a larger number of observations. Semi-annual data was selected, as it could be considered quite reliable due to the semi-annual reviews of interim financial statements by the auditors, which applies i.a. to all Polish listed banks. The analysis period covers the first half of 2017 (1h2017) to the first half of 2024 (1h2024) – accounting information from 1h2017–2h2023 was taken into account, while market data from 2h2017 to 1h2024 were included (shifted one period forward). The COVID-19 pandemic period was defined as 1h2020–2h2021.[1] The sample period was chosen due to data availability, as it was taken from the Orbis BvD Info database.

The sample consisted of accounting and market data of several Polish banks listed on the Warsaw Stock Exchange (WSE) – PKO BP SA, Pekao SA, Santander Bank Polska SA, mBank SA, ING Bank Śląski SA, BNP Paribas SA, Millennium Bank SA, Bank Ochrony Środowiska SA, Alior Bank SA and Citi Handlowy SA. Such entities represent the vast majority of banks listed on the WSE.[2]

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[1] Since 1h2020, COVID-19 had spread across Europe and individual governments carried out the first activities to prevent its expansion. In 1h2022, the World Health Organization announced the end of the pandemic – it occurred after several weeks of lower number of COVID-19 cases.

[2] For instance, as of 20 December 2024, they represented ca. 99.7% (in terms of market value) of WIG-banki index capturing all banks listed on the WSE.

Variables used in the analysis, selected based on the indicators used in the previous research on VR, are presented in Table 2.

Table 2. Description of Variables Used in the Research

Variable	Formula	Sources	Expected Sign
Endogenous variable			
Price	P_t = Share price at the end of a given period	Siregar, Anandarajan & Hasan (2013), Arraiano (2020), Marques, Dalmacio & Rezende (2022)	n/a
Exogenous variables			
Earnings per share	$EPS_t = \frac{\text{Net income}_t}{N_t}$	Abuzayed, Molyneux & Al-Fayoumi (2009), Anandarajan *et al*. (2011), Bolibok (2021)	+
Operating cash flows per share	$CFOPS_t = \frac{\text{Operating cash flows}_t}{N_t}$	Dimitropoulos, Asteriou & Koumanakos (2010), Burke & Wieland (2017), Gao, Li & O'Hanlon (2019)	+
Accruals per share	$ACCPS_t = EPS_t - CFOPS_t$	Burke & Wieland (2017), Ragab & El-Chaarani (2018)	+
Book value per share	$BVPS_t = \frac{\text{Equity}_t}{N_t}$	Chiqueto *et al*. (2015), Mechelli, Cimini & Mazzocchetti (2015), Pacheco-Ortiz, Rendón-García & Villada-Medina (2021)	+
Loans per share	$LPS_t = \frac{\text{Total loans}_t}{N_t}$	Khurana & Kim (2003)	+
Deposits per share	$DEPS_t = \frac{\text{Total deposits}_t}{N_t}$	Khurana & Kim (2003)	–
Binary variable regarding COVID-19 occurrence	$COV = \begin{cases} 1 & \text{for pandemic period} \\ 0 & \text{otherwise} \end{cases}$	Abou-el-Sood (2025)	–

Notes: N – number of shares, n/a – not applicable.

Source: own study, based on literature on the subject.

As total earnings could be divided into operating cash flows and accruals (Burke & Wieland, 2017), EPS, ACCPS, and CFOPS were treated as earning-related variables. Book value-related indicators concerned BVPS, LPS, and DEPS.

From the VR-related perspective, it is essential to focus on the relationships between accounting variables and market values. Hence, a correlation matrix was prepared to provide some initial insight into the relationship between share prices and exogenous variables as well as the correlation between accounting indicators themselves, which is presented in Table 3.

Table 3. Correlation Matrix

Variable	EPS	BVPS	LPS	DEPS	CFOPS	ACCPS	COV	P_t+1
EPS	1.000							
BVPS	**0.385**	1.000						
LPS	**0.273**	**0.941**	1.000					
DEPS	**0.206**	**0.911**	**0.984**	1.000				
CFOPS	0.082	**0.244**	**0.239**	**0.313**	1.000			
ACCPS	0.037	**–0.198**	**–0.207**	**–0.289**	**–0.993**	1.000		
COV	**–0.251**	0.032	0.024	0.040	0.107	–0.138	1.000	
P_t+1	**0.351**	**0.810**	**0.745**	**0.762**	**0.352**	**–0.310**	–0.103	1.000

Notes: Bold values are significant at $p < 0.05$.

Source: own study.

All variables considered exogenous (apart from COV) were significantly (at $p < 0.05$) correlated with future share prices, which is a positive sign regarding their selection for VR models. The strongest linear relationship between share prices and exogenous variables concerned BVPS, LPS, and DEPS, which could potentially indicate the significant positive VR of book values. The correlation between variables concerning earnings and future share prices was noticeably weaker, but still statistically significant. It is worth noting that a very strong linear relationship concerned CFOPS and ACCPS. As it was negative, it might indicate that – in the long term – negative operating cash flows are compensated by positive accruals and inversely, from the total earnings perspective. Despite such a high correlation, it was decided to include both CFOPS and ACCPS in the same model, as the potential multicollinearity issue was verified in the case of each model developed in the empirical research. Taking the above into account, to verify the hypotheses developed based on the literature review, models (balanced panel data with fixed effects) were employed. Their general forms are presented in Table 4.

The use of panel data models was justified by the structure of the data (firm-year observations) and as it is commonly accepted method within the area of VR research (e.g., Carnevale, Mazzuca & Venturini, 2012; Burke & Wieland, 2017; Ben Rejeb Attia, Lassoued & Sassi, 2019; Agbodjo, Toumi & Hussainey, 2021; Toumi & Hamrouni, 2025).

Table 4. General Forms of the Models Estimated

Model	Formula
[1]	$P_{i_{t+1}} = \beta_0 + \sum \beta_i \cdot E_{i_t} + \sum \beta_j \cdot BV_{j_t} + \varepsilon_{i_t}$
[2]	$P_{i_{t+1}} = \beta_0 + \sum \beta_i \cdot E_{i_t} + \sum \beta_j \cdot BV_{j_t} + COV_t + \varepsilon_{i_t}$
[3]	$P_{i_{t+1}} = \beta_0 + \sum \beta_i \cdot E_{i_t} + \sum \beta_j \cdot BV_{j_t} + \sum \beta_i \cdot E_{i_t} \cdot COV_t + \sum \beta_j \cdot BV_{j_t} \cdot COV_t + \varepsilon_{i_t}$

Notes: *E* – earnings-related variables, *BV* – book value-related variables.

Source: own study, based on Ohlson (1995) and Burke & Wieland (2017).

Firstly, models [1] with variables regarding earnings (EPS, ACC, and CFOPS) and book values (BVPS, LPS, DEPS) were built. In the next step [2], a binary variable regarding COVID-19 pandemic was added to the models previously chosen. Finally, interactions between COV and other exogenous variables were included in the models [3].

4. Assessment of the COVID-19 Impact on Value Relevance in Banks – the Results of the Study

Given the specificity of the research proposed, the structure of the variables used is worth knowing. Therefore, descriptive statistics for exogenous variables were estimated. They are presented in Table 5.

Table 5. Descriptive Statistics

Statistic	EPS	CFOPS	ACCPS	BVPS	LPS	DEPS
Mean	1.16	3.96	–2.80	31.12	207.90	256.27
Standard deviation	2.02	16.92	16.88	28.54	197.49	247.06
Variance coefficient	n/a	n/a	n/a	0.92	0.95	0.96
1st quartile	0.17	–1.46	–5.72	8.43	41.35	61.74
Median	0.72	1.67	–1.04	21.23	140.06	170.92
3rd quartile	1.90	6.48	2.17	49.82	357.53	401.65
Minimum	–9.49	–44.23	–107.78	1.03	10.52	12.68
Maximum	8.87	110.43	37.52	104.72	711.41	1,105.65

Notes: n/a – not applicable.

Source: own study.

Variance coefficients for variables based on the balance sheet values (BVPS, LPS, and DEPS) were below one. For earning-related variables (EPS, CFOPS, and

ACCPS), standard deviations were quite high compared to means. However, such a situation is not unexpected as earnings are more volatile than balance sheet values. Over a quarter of CFOPS and a half of ACCPS values were negative, but it was not true for EPS – it seems that negative CFOPS or ACCPS are to some extent compensated, as it was previously supposed based on the correlations between earnings-related variables, which has no direct impact on total earnings. It is also worth noting that means for all exogenous variables were higher than medians (in absolute values), which indicates the existence of significantly higher values of given variables. As during the analysis of descriptive statistics no disturbing results were found, the models [1]–[3] were further developed. The results of their estimation are presented in Table 6.

Table 6. Estimated Models

Variable/Statistic	Model [1.1]	Model [1.2]	Model [1.3]
EPS	11.70 (0.0001)	10.8166 (0.0000)	13.4449 (0.0000)
BVPS	–0.7245 (0.4433)	–	–
LPS	–	0.1986 (0.2949)	–
DEPS	–	–	0.3459 (0.0000)
LSDV R^2	0.8550	0.8556	0.8777
Within R^2	0.1200	0.1235	0.2576
Variable/Statistic	Model [1.4]	Model [1.5]	Model [1.6]
CFOPS	12.0954 (0.0000)	11.1084 (0.0000)	13.3237 (0.0000)
ACCPS	11.3234 (0.0001)	10.3648 (0.0000)	13.0563 (0.0000)
BVPS	–0.7219 (0.4326)	–	–
LPS	–	0.0894 (0.6319)	–
DEPS	–	–	0.3139 (0.0000)
LSDV R^2	0.8637	0.8633	0.8786
Within R^2	0.1725	0.1700	0.2628

Table 6 cnt'd

Variable/Statistic	Model [2.1]	Model [2.2]	Model [2.3]
EPS	9.2526 (0.0047)	9.1274 (0.0008)	11.6734 (0.0000)
BVPS	–0.0779 (0.9381)	–	–
LPS	–	0.2730 (0.1460)	–
DEPS	–	–	0.3647 (0.0000)
COV	–19.7867 (0.0757)	–22.9565 (0.0292)	–25.1613 (0.0082)
LSDV R^2	0.8586	0.8609	0.8843
Within R^2	0.1416	0.1558	0.2976
Variable/Statistic	Model [3.1]	Model [3.2]	Model [3.3]
EPS	0.5726 (0.8919)	4.9409 (0.1257)	8.7250 (0.0027)
BVPS	1.9645 (0.0803)	–	–
LPS	–	0.5021 (0.0098)	–
DEPS	–	–	0.4209 (0.0000)
EPS × COV	7.1271 (0.1784)	3.9835 (0.4257)	0.8337 (0.8507)
BVPS × COV	–1.2406 (0.0000)	–	–
LPS × COV	–	–0.1589 (0.0000)	–
DEPS × COV	–	–	–0.1272 (0.0000)
LSDV R^2	0.8717	0.8726	0.8983
Within R^2	0.2211	0.2265	0.3829

Notes: In parentheses, *p*-values are presented. *, **, *** means respectively: significant at $p < 0.10$, 0.05, 0.01.

Source: own study, using GRETL.

Referring to models [1.1]–[1.3], earnings were value relevant and positively related to the future share prices of banks. However, their breakdown to operating cash flows and accruals (in models [1.4]–[1.6]) did not lead to any valid conclusions due to the econometric issues – a positive sign of ACCPS variable was noted, which

was not in line with the correlation analysis (where a significant, negative relationship was found between accruals and future share prices). Moreover, the potential multicollinearity issue was supported by the result of the Belsley-Kuh-Welsch test that pointed out a moderately strong interdependence of explanatory variables. Hence, in models [2.1]–[3.3], the focus was on total earnings instead of their breakdown into operating cash flows and accruals. Thus, the hypotheses regarding the VR of operating cash flows could not be credibly verified. Among book value-related variables, only deposits out of BVPS, LPS, and DEPS noted a significant VR, which was positive.

The total impact of the COVID-19 pandemic on VR was found to be negative, as indicated in models [2.1]–[2.3], which was in line with the expected results. Following the pandemic situation, investors might not focus on values from past financial statements. Instead, they made investment decisions based on other non-quantified factors. The influence of the COVID-19 pandemic on VR of earnings and book values was, however, differentiated. Some evidence supporting the hypothesis regarding the noticeable impact of the COVID-19 pandemic on VR of book values was identified (equity, loans and deposits), which was not the case for earnings. These results could indicate that during COVID-19 pandemic, entities investing in Polish listed banks focused to a minor extent on main balance sheet categories, while still taking into account banks' earnings.

Summing up, based on the research on the example of Polish listed banks the following conclusions can be drawn:

– earnings are value relevant and positively related to the future share prices (H1 confirmed),

– book values are partially value relevant (deposits are value relevant while equity and loans – not) and positively related to the future share prices (H2 partially confirmed),

– the impact of COVID-19 pandemic on VR of earnings was not significant (H4 rejected),

– the impact of COVID-19 pandemic on VR of book values was significant and negative (H5 confirmed).

– H3 and H6 were not verified due to the multicollinearity issue concerning operating cash flows and accruals.

The results regarding the level of VR of earnings and book values are generally in line with the findings of Agostino, Drago and Silipo (2011), Uwuigbe *et al.* (2016), Ragab and El-Chaarani (2018), or Ben Rejeb Attia, Lassoued and Sassi (2019). However, they are not fully consistent with the results obtained by Khurana and Kim (2003) – regarding VR of deposits, Abuzayed, Molyneux and Al-Fayoumi (2009) – regarding VR of equity, or Mohammad Jadallah, Salim Haddad and Hussein Al Tarawneh (2023) – regarding VR of earnings. The conclusions based on

the assessment of the impact of the COVID-19 pandemic, considered an economic crisis, on VR coincide with the findings of Chiqueto *et al*. (2015), are partially consistent with those of Jung (2014), Aljawaheri *et al*. (2021) and Belesis, Kampouris and Karagiorgos (2022), but contrary to the results reported by Sahlian *et al*. (2024).

5. Summary and Conclusions

Value relevance research focuses on the relationship between accounting and market values. Due to the specificity of financial statements, separate analyses in this regard are made for non-financial entities, insurance companies, banks, etc. So far, regarding banks, the VR of earnings and book values was generally confirmed, but inconsistent results concerning cash flows were identified. However, as economic crises such as the pandemic significantly affect the financial situation of banks, this research focused on the assessment of the impact of COVID-19 pandemic on VR on the example of such entities.

Based on the sample consisting of Polish listed banks, total earnings were found to be value relevant, similarly as in the previous research on the subject. However, mixed results concerned book values – a significant, positive relationship between deposits per share and future share prices was identified, however, it was not true for equity and loans. Such results indicate that investors rely mainly on earnings and deposits when making investment decisions regarding Polish listed banks. It is worth noting that the VR of earnings was not broken down into VR of operating cash flows and accruals due to econometric issues connected with the models developed.

Referring to the empirical results regarding the COVID-19 pandemic's impact on VR, it was not unambiguous. The pandemic only partially significantly affected VR – while a significant negative influence of the pandemic on VR of book values was identified, no statistically significant changes in the VR of earnings were found. Based on these results, it could be stated that, after the crisis outbreak, investors did not rely on book values as much as they had before the crisis periods. However, they consider earnings reflecting the actual business standing even in uncertain times, referring to the stable VR of this category.

The implications resulting from the study could be perceived from the perspective of both investors and bank management, who might be interested in factors that are crucial in the market valuation of a given bank during the economic crises. Based on the results obtained, as earnings remained value relevant even during crisis periods, it could be for instance expected that share prices of banks maintaining relevant levels of profitability will decline to a lower extent compared to other financial entities.

Among the limitations of the study, a relatively small sample could be mentioned. What is more, the research was based on semi-annual data, which might

significantly affect the results obtained. Regarding future research, it seems that it could be worthwhile to analyse the impact of the outbreak of the war in Ukraine on the VR of earnings or book values. Moreover, focusing on more frequent data (i.e., quarters) might be appropriate as well.

Conflict of Interest

The author declares no conflict of interest.

References

Abou-el-Sood, H. (2025). The Impact of COVID-19 Pandemic on the Value Relevance of Cash Flows: Evidence from Banks. *International Journal of Emerging Markets*, *20*(1), 299–315. https://doi.org/10.1108/IJOEM-06-2022-0902

Abuzayed, B., Molyneux, P., & Al-Fayoumi, N. (2009). Market Value, Book Value and Earnings: Is Bank Efficiency a Missing Link? *Managerial Finance*, *35*(2), 156–179. https://doi.org/10.1108/03074350910923491

Agbodjo, S., Toumi, K., & Hussainey, K. (2021). Accounting Standards and Value Relevance of Accounting Information: A Comparative Analysis between Islamic, Conventional and Hybrid Banks. *Journal of Applied Accounting Research*, *22*(1), 168–193. https://doi.org/10.1108/JAAR-05-2020-0090

Agostino, M., Drago, D., & Silipo, D. B. (2011). The Value Relevance of IFRS in the European Banking Industry. *Review of Quantitative Finance and Accounting*, *36*(3), 437–457. https://doi.org/10.1007/s11156-010-0184-1

Ahmadi, A., & Bouri, A. (2018). The Accounting Value Relevance of Earnings and Book Value: Tunisian Banks and Financial Institutions. *International Journal of Law and Management*, *60*(2), 342–354. https://doi.org/10.1108/IJLMA-11-2016-0131

Akeem Adetunji, S. (2016). The Value Relevance of Earnings in the Return–Earnings Relation in the Nigerian Deposit Money Banks. *Cogent Business and Management*, *3*(1), 1210276. https://doi.org/10.1080/23311975.2016.1210276

Aljawaheri, B. A. W., Ojah, H. K., Machi, A. H., & Almagtome, A. H. (2021). COVID-19 Lockdown, Earnings Manipulation and Stock Market Sensitivity: An Empirical Study in Iraq. *Journal of Asian Finance, Economics and Business*, *8*(5), 707–715. https://doi.org/10.13106/jafeb.2021.vol8.no5.0707

Anandarajan, A., Francis, B., Hasan, I., & John, K. (2011). Value Relevance of Banks: Global Evidence. *Review of Quantitative Finance and Accounting*, *36*(1), 33–55. https://doi.org/10.1007/s11156-010-0170-7

Arraiano, I. G. (2020). Is There Value Creation in the Banks Listed in the Dow Jones Sustainability Index Europe? In: B. Díaz Díaz, N. Capaldi, S. O. Idowu, R. Schmidpeter (Eds), *Responsible Business in a Changing World. New Management Approaches for Sustainable Development* (pp. 53–68). Springer. https://doi.org/10.1007/978-3-030-36970-5_4

Beisland, L. A. (2009). A Review of the Value Relevance Literature. *The Open Business Journal*, *2*, 7–27. https://doi.org/10.2174/1874915100902010007

Belesis, N. D., Kampouris, C. G., & Karagiorgos, A. T. (2022). The Effect of COVID-19 on the Value Relevance of European Firms' Financial Statements. *International Journal of Applied Economics, Finance and Accounting*, *14*(1), 91–99. https://doi.org /10.33094/ijaefa.v14i1.661

Beltratti, A., Spear, N., & Szabo, M. D. (2013). The Value Relevance and Timeliness of Write--downs during the Financial Crisis of 2007–2009. *International Journal of Accounting*, *48*(4), 467–494. https://doi.org/10.1016/j.intacc.2013.10.008

Ben Rejeb Attia, M., Lassoued, N., & Sassi, H. (2019). Financial Reporting Timeliness and the Value Relevance of Earnings: Evidence from Banks in the MENA Countries. *International Trade Journal*, *33*(3), 277–301. https://doi.org/10.1080/08853908.2018.1459212

Bolibok, P. (2021). The Impact of Social Responsibility Performance on the Value Relevance of Financial Data in the Banking Sector: Evidence from Poland. *Sustainability*, *13*(21), 12006. https://doi.org/10.3390/su132112006

Bose, S., Saha, A., & Abeysekera, I. (2020). The Value Relevance of Corporate Social Responsibility Expenditure: Evidence from Regulatory Decisions. *Abacus*, *56*(4), 455–494. https://doi.org/10.1111/abac.12207

Burke, Q. L., & Wieland, M. M. (2017). Value Relevance of Banks' Cash Flows from Operations. *Advances in Accounting*, *39*, 60–78. https://doi.org/10.1016/j.adiac.2017.08.002

Carnevale, C., & Mazzuca, M. (2014). Sustainability Report and Bank Valuation: Evidence from European Stock Markets. *Business Ethics*, *23*(1), 69–90. https://doi.org/10.1111/beer.12038

Carnevale, C., Mazzuca, M., & Venturini, S. (2012). Corporate Social Reporting in European Banks: The Effects on a Firm's Market Value. *Corporate Social Responsibility and Environmental Management*, *19*(3), 159–177. https://doi.org/10.1002/csr.262

Chiqueto, F., Silva, R. L. M., Colossal, G., & Carvalho, L. N. G. (2015). Relevance of Fair Value of Brazilian Banks Securities in the Financial Crisis. *International Journal of Emerging Markets*, *10*(4), 684–696. https://doi.org/10.1108/IJoEM-11-2012-0150

Czekaj, J., & Dresler, Z. (2006). *Zarządzanie finansami przedsiębiorstw. Podstawy teorii*. Wydawnictwo Naukowe PWN.

Dimitropoulos, P. E., Asteriou, D., & Koumanakos, E. (2010). The Relevance of Earnings and Cash Flows in a Heavily Regulated Industry: Evidence from the Greek Banking Sector. *Advances in Accounting*, *26*(2), 290–303. https://doi.org/10.1016/j.adiac.2010.08.005

Drago, D., Mazzuca, M., & Trinca Colonel, R. (2013). Do Loans Fair Value Affect Market Value? Evidence from European Banks. *Journal of Financial Regulation and Compliance*, *21*(2), 108–120. https://doi.org/10.1108/13581981311315532

Du, H., Li, S. F., & Xu, R. Z. (2014). Adjustment of Valuation Inputs and Its Effect on Value Relevance of Fair Value Measurement. *Research in Accounting Regulation*, *26*(1), 54–66. https://doi.org/10.1016/j.racreg.2014.02.005

Elnahass, M., Izzeldin, M., & Abdelsalam, O. (2014). Loan Loss Provisions, Bank Valuations and Discretion: A Comparative Study between Conventional and Islamic Banks. *Journal of Economic Behavior and Organization*, *103*, 160–173. https://doi.org/10.1016/j.jebo.2013.08.018

Fiechter, P., & Novotny-Farkas, Z. (2017). The Impact of the Institutional Environment on the Value Relevance of Fair Values. *Review of Accounting Studies*, *22*(1), 392–429. https://doi.org/10.1007/s11142-016-9378-7

Gao, Z., Li, W., & O'Hanlon, J. (2019). The Informativeness of U.S. Banks' Statements of Cash Flows. *Journal of Accounting Literature*, *43*(1), 1–18. https://doi.org/10.1016/j.acclit.2019.03.001

Giner, B., Allini, A., & Zampella, A. (2020). The Value Relevance of Risk Disclosure: An Analysis of the Banking Sector. *Accounting in Europe*, *17*(2), 129–157. https://doi.org/10.1080/17449480.2020.1730921

Hameedi, K. S., Al-Fatlawi, Q. A., Ali, M. N., & Almagtome, A. H. (2021). Financial Performance Reporting, IFRS Implementation, and Accounting Information: Evidence from Iraqi Banking Sector. *Journal of Asian Finance, Economics and Business*, *8*(3), 1083–1094. https://doi.org/10.13106/jafeb.2021.vol8.no3.1083

Hamid, A., Angel Lorita, V., Ria Panggabean, R., & Rusgowanto, F. H. (2022). The Relevancy of Earnings on Post XBRL Adoption for Indonesia Firm Value with Environmental, Social and Governance (ESG) as Moderating Variable. In: *Proceedings of DSDE '22: 2022 the 5th International Conference on Data Storage and Data Engineering* (pp. 97–101). Association for Computing Machinery. https://doi.org/10.1145/3528114.3528130

Hladika, M. (2021). Impact of COVID-19 Pandemic on the Loans Quality, Provisions and Profitability of the Banking Sector. In: J. Janjusevic, T. Taheri, M. Kozina (Eds), *Proceedings of the 69th International Scientific Conference on Economic and Social Development – Sustainability and Post COVID World* (pp. 138–149).

Iwanicz-Drozdowska, M., Rogowicz, K., Kurowski, Ł., & Smaga, P. (2021). Two Decades of Contagion Effect on Stock Markets: Which Events Are More Contagious? *Journal of Financial Stability*, *55*, 100907. https://doi.org/10.1016/j.jfs.2021.100907

Izzeldin, M., Muradoğlu, Y. G., Pappas, V., Petropoulou, A., & Sivaprasad, S. (2023). The Impact of the Russian-Ukrainian War on Global Financial Markets. *International Review of Financial Analysis*, *87*, 102598. https://doi.org/10.1016/j.irfa.2023.102598

Jung, S. (2014). Value Relevance of Unrealised Gains and Losses on Non-agency Securities. *International Journal of Banking, Accounting and Finance*, *5*(4), 418–434. https://doi.org/10.1504/IJBAAF.2014.067024

Khurana, I. K., & Kim, M.-S. (2003). Relative Value Relevance of Historical Cost vs. Fair Value: Evidence from Bank Holding Companies. *Journal of Accounting and Public Policy*, *22*(1), 19–42. https://doi.org/10.1016/S0278-4254(02)00084-4

Kim, H. J., & Yoon, S. S. (2019). Value-relevance of the Regulatory Non-GAAP Adjustments in the Korean Banking Industry. *Asia-Pacific Journal of Accounting and Economics*, *26*(1–2), 160–171. https://doi.org/10.1080/16081625.2019.1546974

Liu, G., & Sun, J. (2022). The Impact of COVID-19 Pandemic on Earnings Management and the Value Relevance of Earnings: US Evidence. *Managerial Auditing Journal*, *37*(7), 850–868. https://doi.org/10.1108/MAJ-05-2021-3149

Lu, H.-Y., & Mande, V. (2014). Factors Influencing Non-compliance with ASU 2010-06 in the Banking Industry. *Managerial Auditing Journal*, *29*(6), 548–574. https://doi.org/10.1108/MAJ-08-2013-0928

Manganaris, P., Spathis, C., & Dasilas, A. (2016). How Institutional Factors and IFRS Affect the Value Relevance of Conservative and Non-conservative Banks. *Journal of Applied Accounting Research*, *17*(2), 211–236. https://doi.org/10.1108/JAAR-09-2014-0094

Marques, M. T., Dalmacio, F. Z., & Rezende, A. J. (2022). IFRS vs Bacen Gaap: Accounting Information's Value Relevance of the Brazilian Financial Institutions. *Brazilian Business Review*, *19*(1). https://doi.org/10.15728/bbr.2022.19.1.1

Mechelli, A., Cimini, R., & Mazzocchetti, F. (2015). Is Regulatory Capital More Value Relevant Than Book Value of Equity? A Cross-country Analysis. *Applied Economics Letters*, *22*(11), 900–903. https://doi.org/10.1080/13504851.2014.985368

Menezes da Costa Neto, A., de Oliveira, A. F., da Silva, A. M. C., & Barbosa, A. (2023). Value Relevance of Financial Risk Disclosures. *Journal of Capital Markets Studies*, *7*(1), 22–37. https://doi.org/10.1108/JCMS-06-2022-0024

Mgammal, M. H., & Al-Matari, E. M. (2022). Sustainability Report Disclosure Moderating Effect on Investment Decision, Financial Accounting Variables and Share Price Relationship: A Case of Saudi Arabia. *Contaduría y Administración*, *67*(3), 210–237. https://doi.org/10.22201/fca.24488410e.2022.3075

Mohammad Jadallah, O., Salim Haddad, F., & Hussein Al Tarawneh, A. (2023). The Value Relevance of Accounting and Financial Information in Stock Returns: The Case of Jordanian Commercial Banks. *Jordan Journal of Business Administration*, *19*(4), 461–472. https://doi.org/10.35516/jjba.v19i4.1427

Morris, R. D., Kang, H., & Jie, J. (2016). The Determinants and Value Relevance of Banks' Discretionary Loan Loss Provisions during the Financial Crisis. *Journal of Contemporary Accounting and Economics*, *12*(2), 176–190. https://doi.org/10.1016/j.jcae.2016.07.001

MSCI. (2024). *MSCI Market Classification*. Retrieved from: https://www.msci.com/our-solutions/indexes/market-classification (accessed: 27.01.2025).

Ohlson, J. A. (1995). Earnings, Book Values, and Dividends in Equity Valuation. *Contemporary Accounting Research*, *11*(2), 661–687. https://doi.org/10.1111/j.1911-3846.1995.tb00461.x

Pacheco-Ortiz, D. M., Rendón-García, J. F., & Villada-Medina, H. D. (2021). The Effect of IFRS Adoption on the Value Relevance of Accounting Information: The Case of Colombian Banks. *Recta*, *22*(2), 77–90. https://doi.org/10.24309/RECTA.2021.22.2.03

Ragab, N. S., & El-Chaarani, H. (2018). The Value-relevance of Operating Cash Flow: Comparative Study of Banks' Listed on the Egyptian and Beirut Stock Exchanges. *Academy of Accounting and Financial Studies Journal*, *22*(3), 1–12.

Răpan, C. M. (2021). Value Relevance of Comprehensive Income and Other Comprehensive Income during Pandemic Outbreak COVID-19: Empirical Evidence from Frankfurt Stock Exchange. In: *Proceedings of the 16th International Conference Accounting and Management Information Systems AMIS 2021* (pp. 101–113). Bucharest University of Economic Studies, Faculty of Accounting and Management Information Systems.

Sahlian, D. N., Popa, A. F., Banţa, V. C., Răpan, C. M., & Chiriac, S. C. V. (2024). The Value Relevance of Financial Performance and ESG Scores during Tumultuous Economic Periods. *Eastern European Economics*, *62*(4), 528–546. https://doi.org/10.1080/00128775.2023.2225500

Shabir, M., Jiang, P., Wang, W., & Işık, Ö. (2023). COVID-19 Pandemic Impact on Banking Sector: A Cross-country Analysis. *Journal of Multinational Financial Management*, *67*, 100784. https://doi.org/10.1016/j.mulfin.2023.100784

Siregar, D., Anandarajan, A., & Hasan, I. (2013). Commercial Banks and Value Relevance of Derivative Disclosures after SFAS 133: Evidence from the USA. *Review of Pacific Basin Financial Markets and Policies*, *16*(1), 1350004. https://doi.org/10.1142/S0219091513500045

Toumi, K., & Hamrouni, A. (2025). Islamic Corporate Governance Quality and Value Relevance of Accounting Information in Islamic Banks. *Journal of Financial Reporting and Accounting*, *23*(6), 2296–2322. https://doi.org/10.1108/JFRA-04-2023-0183

Uwuigbe, O. R., Uwuigbe, U., Jafaru, J., Igbinoba, E. E., & Oladipo, O. A. (2016). Value Relevance of Financial Statements & Share Price: A Study of Listed Banks in Nigeria. *Banks and Bank Systems*, *11*(4), 135–143. https://doi.org/10.21511/bbs.11(4-1).2016.04

Wang, D. H. M., Yu, T. H. K., & Ye, F. R. (2012). The Value Relevance of Brand Equity in the Financial Services Industry: An Empirical Analysis Using Quantile Regression. *Service Business*, *6*(4), 459–471. https://doi.org/10.1007/s11628-012-0156-8

Yan, Y., Jeon, B. N., & Wu, J. (2023). The Impact of the COVID-19 Pandemic on Bank Systemic Risk: Some Cross-country Evidence. *China Finance Review International*, *13*(3), 388–409. https://doi.org/10.1108/CFRI-08-2022-0158

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Intellectual Capital of Game Developers Listed on the Main Market of the Polish Stock Exchange in the Years 2022–2023

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ABSTRACT

Objective: To determine the value of the intellectual capital of joint-stock companies from the gaming sector listed on the Warsaw Stock Exchange Main Market in the years 2022–2023.
Research Design & Methods: The intellectual capital of companies in the gaming sector was calculated using three methods: the difference between market value and book value, economic value added and profit from knowledge capital. Annual financial reports for 2022 and 2023 were used for this purpose. The data were subjected to statistical analysis using methods such as the mean, median, and skewness, Pearson's linear correlation coefficient, and the Shapiro-Wilk normality test.
Findings: The intellectual capital of companies in the gaming sector is highly differential. Three companies have the highest level of intellectual capital, and the value of intellectual capital in other companies in the gaming sector differs significantly from the intellectual capital in these three companies. Such intellectual capital measures as the difference between market value and book value, economic value added and profit from knowledge capital are positively correlated, making them reliable and consistent tools for measuring intellectual capital in the gaming sector.
Implications/Recommendations: The study's findings can benefit both the managers of gaming companies and stock investors, providing insights into the value and trends of intellectual

capital in joint-stock companies within this sector during 2022–2023. The author recommends evaluating intellectual capital using multiple methods and comparing results before managers or investors make decisions.

Contribution: This study is innovative due to the lack of recent research on the intellectual capital of joint-stock companies in the gaming sector.

Article type: original article.

Keywords: intellectual capital, gaming sector, market value, book value, economic value added, knowledge capital earnings.

JEL Classification: M20, M21, M29.

1. Introduction

According to data presented in the report *The Game Industry of Poland – Report 2023*, in 2022 there were 494 game producers and publishers in the Polish computer game industry. The sector employed 15,290 people, and its revenues amounted to EUR 1,286 million. The report also states that more than 530 new games were released during the year (Marszałkowski, Biedermann & Rutkowski, 2023, p. 9). The data indicate great importance of the gaming sector for the economy. In addition, intellectual capital has an impact on business competitiveness (Dyrka, Rogozińska & Soboń, 2023, p. 39), making it a worthwhile area for analysis.

The value of intellectual capital can be calculated using methods such as the difference between market value and book value (MV-BV) – developed by Pulic (2000, pp. 702–714), economic value added (EVA) – developed by Stewart (1991, pp. 118–178), and knowledge capital earnings (KCE) – developed by Gu and Lev (2011, pp. 110–124). The literature review presented in this article indicates the frequent use of these measures of intellectual capital to determine its level and estimate its influence on the companies studied. However, little research has been done on gaming companies.

Taking into account the above, the aim of this article is to determine the value of the intellectual capital of 22 joint-stock companies from the gaming sector listed on the Warsaw Stock Exchange (WSE) Main Market in 2022–2023.

2. Theoretical Background

The MV-BV ratio (also MV/BV) belongs to a group of methods for measuring intellectual capital based on market value (Sopińska, 2008, pp. 130–131). It is also referred to as a measure of a company's saturation with intellectual capital and is an alternative to calculating the value of intellectual capital by subtracting a company's book value from its market value (Urbanek, 2008, p. 106). The research conducted

with the use of indicators based on market value at the Warsaw Stock Exchange has focused on: the level and dynamics of change in intellectual capital of listed companies in 2002–2006 (Sopińska, 2010, pp. 173–178), the measurement of the intellectual capital of banks in 2005–2009 (Śledzik, 2011, pp. 150–151), the relationship with the VAIC indicator based on a study of non-financial companies listed on the WSE, i.e., on the primary and New Connect markets, covering a total of 230 observations (Urbanek & Bohdanowicz, 2012, p. 111), the measurement of intellectual capital in 2007–2012 in WIG20 index companies (Beyer, 2014, p. 14), the value of intellectual capital of companies listed within the WIG30 index in 2009–2012 and the share of intellectual capital in market value (Beyer, 2015, pp. 120–123), the number of companies with intellectual capital in 2012, in terms of sectors – a study conducted on a group of 345 companies (Wasilewska, 2015, pp. 163, 171), the measurement of intellectual capital of selected companies listed on the WSE in 2016 (Bombiak, 2016, p. 115), the relationship with brand value and brand strength based on 56 companies listed on the WSE in the years 2008–2014 (Urbanek, 2016b, p. 345), the relationship with VAIC in joint-stock companies in the food sector in 2011–2014 (Urbanek, 2016a, p. 227), the intellectual capital of companies in the WIG Informatics index (Paździor & Twardowska, 2017, p. 46), the impact of the financial crisis on intellectual capital (the MV/BV and *q*-Tobin ratios were used to measure the intellectual capital) in the food sector (Garncarz & Mierzejewski, 2019, p. 8), and the intellectual capital of game producers (Rydzewski, 2019, p. 141).

The EVA method has been used in studies on correlations with ROA and ROE ratios and financial liquidity ratios: current, quick and increased, based on data from 146 to 201 companies, for the years 1997–2009 (Kacprzyk, Wolski & Bolek, 2012, pp. 284–285), correlations with liquidity ratios based on data from 395 non-financial listed companies for the years 1998–2012 (Wolski & Bolek, 2014, p. 566), the impact on ROA using a sample of 39 companies listed on the Tehran Stock Exchange from 2007 to 2010 (Salehi, Enayati & Javadi, 2014, pp. 267–268), correlations with VAIC in sectors of the Italian economy such as paper production (n = 243), chemicals production (n = 451), basic metals production (n = 406), software and consultancy (n = 782), advertising and market research (n = 525), travel agencies (n = 189) based on data from 2011 (Iazzolino, Laise & Migliano, 2014, pp. 13, 16), the relationship between the economic rate of return and the market rate of return based on data from the largest companies listed on the Warsaw Stock Exchange, classified in the WIG20 index, excluding the financial sector for 2014 (Nowicki, 2016, pp. 141–142), the impact of value added and wage costs on the example of data from two samples of companies from the Czech automotive industry, i.e., 11 manufacturers and 87 suppliers for the period from 2005 to 2012 (Pavelková *et al*., 2018, pp. 82, 92–93), the relationship with VAIC based on data from 91 companies for the

period 2010–2014 listed on the Nigerian Stock Exchange (Anifowose *et al*., 2018, pp. 652–653).

The KCE method has been used in studies on the level of intangible assets of domestic and benchmark banks for the period 2005–2010 (Śledzik, 2012, pp. 77–78), the impact of knowledge capital gains on net worth per share based on a sample of 361 computer industry firms from Taiwan and 1,018 observations of these firms from 2007–2009 (Wang, 2013, pp. 1221), relationships with other measures of intellectual capital (Wasilewska, 2015, pp. 180–182), relationships with price-value ratios, earnings per share, and return on equity based on data from three selected joint-stock companies in the IT sector from 2012–2016 (Bagieńska, 2019, p. 8).

Each method discussed has its own advantages, disadvantages, and limitations. The MV-BV measure, for instance, is only feasible for publicly listed companies. Additionally, market value is subject to considerable fluctuations, meaning the MV-BV value depends only partially on management actions and may not fully represent a company's intellectual capital. Conversely, book value is influenced by a company's adopted accounting policies. To address the challenges of determining market value or its reliability, profit-based methods, such as EVA and KCE, can be employed to measure intellectual capital. EVA serves as both a company valuation tool and a productivity indicator for intellectual capital, while KCE helps calculate the value of intellectual capital. Both measures show significant correlation with a company's market value. However, profit-based methods rely on historical data, which may not accurately capture the current value of intellectual capital. Additionally, their outcomes can be affected by fluctuations in interest rates and capital costs. Given the strengths and weaknesses of each intellectual capital measurement method, none of them should be used in isolation; results should be cross-checked against those of other companies in the sector (Kasiewicz, Rogowski & Kicińska, 2006, pp. 200–215; Wasilewska, 2015, p. 170).

3. Methodology

Intellectual capital in the MV-BV method is calculated by subtracting the difference between the total assets and all liabilities from the product of the share price and the number of shares (Edvinsson & Malone, 2001, p. 18).

The value of intellectual capital using the EVA method was calculated according to the formula (Kijewska, 2016, p. 56):

$$EVA = NOPAT - WACC \cdot IC,$$

where:

NOPAT – net operating profit after tax,
IC – invested capital,
WACC – wage average cost of capital.

Invested capital was calculated as the sum of equity and financial liabilities.

The cost of capital was determined as the weighted average cost of capital (*WACC*) using the formula (Wasilewska, 2011, pp. 556–558):

$$WACC = \frac{E}{E+D} \cdot r_e + \frac{D}{E+D} \cdot r_d \cdot (1-T),$$

where:

WACC – weighted average cost of capital,
E – value of equity capital,
D – value of interest-bearing debt (financial liabilities),
r_e – cost of equity capital,
r_d – cost of interest-bearing external capital,
T – tax rate.

The Capital Asset Pricing Model was used to estimate the cost of equity capital according to the formula (Wasilewska, 2011, p. 558):

$$r_e = r_f + \beta_e \cdot (r_m - r_f),$$

where:

r_e – cost of equity capital,
r_f – rate of return on risk-free investment,
β_e – beta indicator for a given company,
$(r_m - r_f)$ – market risk premium.

The interest rate on ten-year treasury bonds was 6.86% on 25 December 2022 and 5.3% on 31 December 2023 (Investing.com, 2023, 2024). Beta indicators for individual companies were adopted based on data from the Biznesradar.pl portal (Biznesradar.pl, 2023, 2024). The market risk premium, in accordance with the recommendations of the literature on the subject, was assumed to be 5% (Maćkowiak, 2009, p. 59; Wasilewska, 2011, p. 558). The costs of external capital were calculated based on the interest rate as the quotient of selected financial costs and the corresponding financial liabilities (Nowicki, 2016, p. 142).

The KCE method was implemented in the following stages (Bombiak, 2012, p. 240):

1. Calculation of normalised profit based on net profit adjusted by the value of the extraordinary result of the last three years and the forecast for the next three years (the same level of profit as in the current year was assumed) according to the formula:

$$ZPP = \frac{PP_{t-2} + PP_{t-1} + PP_t + 2 \cdot (PP_{t+1} + PP_{t+2} + PP_{t+3})}{9},$$

where:

ZPP – normalised profit,

PP_{vol} – net profit in year t adjusted by the value of the result from extraordinary events.

2. Profit attributable to tangible assets was calculated by multiplying fixed assets by 0.07.

3. The profit attributable to financial assets was calculated by multiplying the company's long-term financial investments by 0.045 (rate of return on financial assets).

4. The profit from knowledge capital was calculated by subtracting the profit attributable to tangible and financial assets from the normalised profit.

5. Knowledge capital (intellectual capital) was calculated by dividing the profit from knowledge capital by 0.105 (rate of return on intellectual capital).

Intellectual capital, calculated using the methods described above, was subjected to statistical analysis using methods such as the mean, median, and skewness, Pearson's linear correlation coefficient, and the Shapiro-Wilk normality test.

4. Results

Table 1 contains data of companies from the gaming sector for 2023, such as market value, net operating profit after tax, and net profit. The market value of the five companies with the highest market value is higher than PLN 1 billion. The company with the highest market value, CD PROJEKT SA, is worth approximately five times more than the second and other most valuable companies, the PLAYWAY SA Capital Group and Huuuge Inc. Moreover, CD PROJEKT SA is worth over 10 times more than the other one-billion-zloty companies listed, i.e. 11bit studios SA and PCF Group SA Capital Group.

Table 1. Data of Companies from the Gaming Sector for 2023, Such as Market Value, Net Operating Profit after Tax, and Net Profit (in PLN)

Company Name	Market Value	NOPAT	Net Profit
CD PROJEKT SA	11,530,935,000	379,922,400	482,137,000
Grupa Kapitałowa PLAYWAY SA	2,112,000,000	128,914,740	127,602,000
Huuuge Inc.	1,912,005,625	299,843,577	330,878,410
11bit studios SA	1,298,574,743	6,149,793	525,609
Grupa Kapitałowa PCF Group SA	1,058,440,981	–70,026,120	–80,889,000
Ten Square Games SA	707,076,841	2,849,457	7,171,333
Grupa Kapitałowa Bloober Team SA	532,705,420	3,889,708	2,471,394
Creepy Jar SA	418,219,672	12,763,999	18,327,451

Table 1 cnt'd

Company Name	Market Value	NOPAT	Net Profit
Grupa Kapitałowa CI Games	384,180,300	25,506,090	14,035,000
Artifex Mundi SA	205,223,250	19,427,341	24,919,038
Games Operators SA	168,827,282	1,012,500	751,000
BoomBit SA	148,261,379	3,180,060	9,141,000
Big Cheese Studio SA	97,172,500	2,255,850	2,375,000
ALL iN! GAMES SA	94,199,039	–4,043,881	–6,526,589
Grupa Kapitałowa Movie Games SA	68,702,624	–7,871,580	–12,013,000
Grupa Kapitałowa Gaming Factory SA	66,969,630	–2,873,880	–3,871,000
DRAGO ENTERTAINMENT SA	62,967,990	1,836,038	1,409,356
Grupa Kapitałowa Ultimate Games SA	52,300,000	2,259,900	–3,827,000
3R Games SA	29,498,773	486,000	613,000
Vivid Games SA	25,505,782	–1,760,462	–2,521,190
Grupa Kapitałowa SIMFABRIC SA	17,375,000	–327,240	–1,544,000
T-Bull SA	5,466,203	–3,406,961	–4,551,900
Mean	954,391,274	36,363,060	41,209,678
Median	158,544,331	2,257,875	1,080,178

Source: own elaboration.

The value of the next seven companies ranges from PLN 148 million to PLN 707 million. The remaining companies are worth less than PLN 100 million. Such a large variation in the value of companies results in an overestimation of the average company value in the sector, which is almost PLN 954 million. However, the middle value is almost PLN 159 million, which better reflects the value of companies in the entire sector. This structure of company values also shows that the largest and most competitive companies have the best position in the sector.

The highest value of operating profit after tax in 2023 was also generated by CD PROJEKT SA, and its value amounted to almost PLN 380 million. In terms of net profit, it was also the highest for CD PROJEKT SA and amounted to PLN 482 million. An interesting case is the PCF Group SA Capital Group, whose market value exceeds PLN 1 billion. In 2023, the net loss from operations amounted to PLN 70 million, and the net loss for the financial year was almost PLN 81 million. Please note that in this case, poor financial results do not immediately result in a loss of company value, which could be related to the existence of intellectual capital there. Among the listed companies, the average value of operating profit after tax in 2023 was PLN 36 million. However, this value is highly overestimated due to extreme values such as the result of CD PROJEKT SA, which is confirmed by the median of

just over PLN 2 million. The same applies to net profit, but the difference between the average and the median is even greater.

The values of intellectual capital measured using the MV-BV method are presented in Table 2.

Table 2. The Values of Intellectual Capital Measured by the MV-BV Method (in PLN)

Company Name	2022	2023	Change
CD PROJEKT SA	11,026,659,240	9,127,445,000	–1,899,214,240
Grupa Kapitałowa PLAYWAY SA	1,542,130,000	1,611,864,000	69,734,000
Huuuge Inc.	492,897,247	1,173,665,834	680,768,587
11bit studios SA	1,173,846,590	1,071,509,710	–102,336,880
Grupa Kapitałowa PCF Group SA	914,059,859	630,560,981	–283,498,878
Grupa Kapitałowa Bloober Team SA	257,748,895	436,834,181	179,085,286
Ten Square Games SA	576,002,843	416,065,907	–159,936,936
Creepy Jar SA	375,583,647	320,529,880	–55,053,767
Grupa Kapitałowa CI Games	315,140,500	223,902,300	–91,238,200
Games Operators SA	27,175,651	151,368,282	124,192,631
Artifex Mundi SA	6,821,552	124,560,849	117,739,297
ALL iN! GAMES SA	106,589,491	112,511,105	5,921,614
Big Cheese Studio SA	164,775,000	76,792,500	–87,982,500
BoomBit SA	85,695,000	74,688,379	–11,006,621
DRAGO ENTERTAINMENT SA	44,207,722	52,026,432	7,818,710
Grupa Kapitałowa Gaming Factory SA	9,652,106	43,376,630	33,724,524
Grupa Kapitałowa Movie Games SA	16,227,266	40,232,624	24,005,358
Grupa Kapitałowa Ultimate Games SA	46,284,200	26,127,000	–20,157,200
Vivid Games SA	23,568,962	20,401,542	–3,167,420
3R Games SA	17,492,667	11,538,773	–5,953,894
T-Bull SA	–2,183,664	–745,123	1,438,541
Grupa Kapitałowa SIMFABRIC SA	–32,500	–1,947,000	–1,914,500
Mean	782,742,831	715,604,990	–67,137,841
Median	96,142,246	118,535,977	22,393,731

Source: own elaboration.

CD PROJEKT SA has the highest level of intellectual capital (over PLN 9 billion). However, its value decreased by PLN 1,899,214,240 compared to the previous year. The intellectual capital of CD PROJEKT SA is almost six times greater than that of the second largest intellectual capital, which belongs to the company PLAYWAY SA Capital Group. In total, only four companies have

intellectual capital worth more than PLN 1 billion. The intellectual capital of the next eight companies ranges from PLN 112 million to PLN 630 million. Another eight companies have intellectual capital of less than PLN 100 million. However, two of the listed companies, i.e. T-Bull SA and SIMFABRIC SA Capital Group, do not have intellectual capital. The average intellectual capital amounted to PLN 716 million and was six times higher than the average value of intellectual capital. This shows that the average value of intellectual capital in the sector is significantly overestimated.

Changes in intellectual capital in the gaming sector, measured using the MV-BV method, indicate that its average value decreased by PLN 67,137,841, while the median increased by PLN 22,393,731. Since the analysis of the above statistics offers no clear results, changes in intellectual capital should be analysed in more detail. The value of intellectual capital increased for 10 companies and decreased for 12. The largest increase was achieved by Huuuge Inc., by PLN 680,768,587, and the largest decrease – by the CD PROJEKT SA, by PLN 1,899,214,240.

The values of intellectual capital measured using the EVA method are presented in Table 3. Huuuge Inc. has the highest level of intellectual capital (PLN 259 million), and its value increased by PLN 209,898,261 compared to the previous year. The intellectual capital of Huuuge Inc. is almost twice as large as that of the second largest intellectual capital listed, which belongs to CD PROJEKT SA. The intellectual capital of the next five companies ranges from PLN 3 million to PLN 93 million. Another three companies have an intellectual capital of less than PLN 1 million. However, the remaining 12 companies do not have intellectual capital because their EVA value is less than zero. The average intellectual capital was PLN 17 million, while the median EVA had a negative value. This shows that the average value of intellectual capital in the sector is significantly overestimated.

Table 3. The Values of Intellectual Capital Measured by the EVA Method (in PLN)

Company Name	2022	2023	Change
Huuuge Inc.	49,489,935	259,388,196	209,898,261
CD PROJEKT SA	72,152,362	146,130,200	73,977,838
Grupa Kapitałowa PLAYWAY SA	87,196,803	93,239,938	6,043,135
Artifex Mundi SA	3,104,011	13,982,629	10,878,618
Grupa Kapitałowa CI Games	–10,750,969	10,230,858	20,981,827
Creepy Jar SA	20,927,361	6,779,468	–14,147,893
BoomBit SA	1,487,870	3,073,624	1,585,754
DRAGO ENTERTAINMENT SA	175,480	802,061	626,581
Big Cheese Studio SA	10,755,373	683,870	–10,071,503
Grupa Kapitałowa Ultimate Games SA	1,811,637	624,088	–1,187,549

Table 3 cnt'd

Company Name	2022	2023	Change
3R Games SA	586,247	–413,916	–1,000,163
Games Operators SA	–577,737	–487,980	89,757
Grupa Kapitałowa Bloober Team SA	–7,412,221	–1,868,806	5,543,415
Grupa Kapitałowa SIMFABRIC SA	–5,660,330	–1,930,966	3,729,364
Vivid Games SA	–122,537	–2,150,352	–2,027,815
ALL iN! GAMES SA	–32,003,255	–3,318,888	28,684,367
T-Bull SA	–7,630,710	–3,831,087	3,799,623
Grupa Kapitałowa Gaming Factory SA	–6,720,314	–5,056,233	1,664,081
11bit studios SA	–2,222,513	–8,074,457	–5,851,944
Grupa Kapitałowa Movie Games SA	–8,113,500	–10,354,020	–2,240,520
Ten Square Games SA	21,223,303	–22,668,044	–43,891,347
Grupa Kapitałowa PCF Group SA	–1,311,626	–105,444,590	–104,132,964
Mean	8,472,030	16,787,981	8,315,951
Median	26,472	–450,948	–477,420

Source: own elaboration.

Changes in intellectual capital, measured by the EVA method, in the gaming sector indicate that its average value increased by PLN 8,315,951, while the median decreased by PLN 477,420. Since the analysis of the above statistics offers no clear results, changes in intellectual capital should be analysed in more detail. The value of intellectual capital increased for 13 companies and decreased for nine. The largest increase was achieved by Huuge Inc. SA, by PLN 209,898,261, and the largest decrease by the PCF SA Capital Group, by PLN 104,132,964.

The values of intellectual capital measured using the KCE method are presented in Table 4.

CD PROJEKT SA has the highest level of intellectual capital (PLN 3.841 billion), and its value increased by PLN 53,923,153 compared to the previous year. Moreover, CD PROJEKT SA, Huuuge Inc. and PLAYWAY SA Capital Group are the only companies with intellectual capital exceeding PLN 1 billion. The intellectual capital of the next five companies ranges from PLN 153 million to PLN 272 million. Six other companies have intellectual capital ranging from PLN 4 to 48 million. However, the remaining eight companies do not have intellectual capital because their intellectual capital value is less than zero. The average intellectual capital of the listed companies was PLN 352 million, while the median was negative. This shows that the average value of intellectual capital in the sector is significantly overestimated.

Table 4. The Values of Intellectual Capital Measured by the KCE Method (in PLN)

Company Name	2022	2023	Change
CD PROJEKT SA	3,787,405,974	3,841,329,127	53,923,153
Huuuge Inc.	505,428,044	2,519,453,998	2,014,025,954
Grupa Kapitałowa PLAYWAY SA	330,343,338	1,050,273,150	719,929,812
BoomBit SA	253,414,534	271,621,989	18,207,455
Ten Square Games SA	746,637,386	239,646,136	–506,991,250
Artifex Mundi SA	109,994,943	207,517,041	97,522,098
Creepy Jar SA	300,442,609	204,329,427	–96,113,182
Grupa Kapitałowa CI Games	110,584,508	152,700,307	42,115,799
Big Cheese Studio SA	136,894,254	48,221,196	–88,673,058
11bit studios SA	217,379,345	39,965,624	–177,413,721
DRAGO ENTERTAINMENT SA	15,836,950	16,805,605	968,655
Grupa Kapitałowa Bloober Team SA	11,686,136	14,326,740	2,640,604
Games Operators SA	27,102,021	11,417,101	–15,684,920
3R Games SA	–721,693	4,423,280	5,144,973
Grupa Kapitałowa SIMFABRIC SA	–15,258,995	–12,375,275	2,883,720
Grupa Kapitałowa Ultimate Games SA	–27,594,164	–31,799,873	–4,205,709
Vivid Games SA	–8,703,162	–33,797,107	–25,093,945
Grupa Kapitałowa Gaming Factory SA	–52,233,862	–39,555,947	12,677,915
T-Bull SA	–87,189,580	–67,389,421	19,800,159
Grupa Kapitałowa Movie Games SA	29,476,747	–83,038,725	–112,515,472
ALL iN! GAMES SA	–284,058,345	–88,222,860	195,835,485
Grupa Kapitałowa PCF Group SA	245,895,873	–519,089,048	–764,984,921
Average	288,761,948	352,125,567	63,363,619
Median	69,735,845	15,566,173	–54,169,672

Source: own elaboration.

Changes in intellectual capital, measured using the KCE method, in the gaming sector indicate that its average value increased by PLN 63,363,619, while the median decreased by PLN 54,169,672. Since the analysis of the above statistics offers no clear results, changes in intellectual capital should be analysed in more detail. The value of intellectual capital increased for 13 companies and decreased for nine. Huuuge Inc. achieved the greatest growth, by PLN 2,014,025,954, and the largest decrease belonged to PCF Group SA Capital Group (PLN 764,984,921).

5. Conclusions

The intellectual capital of gaming sector companies listed on the Main Market was subjected to statistical analysis for the years 2022–2023. Three methods were used to measure intellectual capital: the difference between market value and book value, economic added value, and profit from knowledge capital. The first conclusion that comes to mind after analysing the data is the large diversity of the variables studied.

The next conclusion drawn from the analysis is related to the value of intellectual capital in three companies in the gaming sector, namely: CD PROJEKT SA, PLAYWAY SA Capital Group, and Huuuge Inc. They rank in the top three in terms of the value of intellectual capital calculated using the three methods. CD PROJEKT SA has the highest level of intellectual capital calculated as the difference between market value and book value and the KCE method. This shows the high position of the company in the computer games market and its involvement in the development of intellectual capital. This is also evidenced by the distance that separates it from other companies in terms of intellectual capital, which is several times higher than that of companies in subsequent positions in the ranking. It is also many times higher than in the case of companies with average or low intellectual capital.

Please note that not all companies in the gaming sector possess intellectual capital. According to the MV-BV method, there are two companies in the ranking possessing intellectual capital. When measured using the EVA method, intellectual capital was found in 12 companies, and when the KCE method was used, eight companies. Such a large number of companies lacking intellectual capital can be attributed to the deterioration of the profitability of gaming companies. As shown in the data in Table 1, eight companies in the analysed sector recorded a net loss. In turn, in the case of the EVA method, the large number of companies with a negative result of economic value added could have been influenced by the high cost of capital.

As part of the statistical analysis, a Shapiro-Wilk test for the normality of the distribution of variables was conducted. It revealed that when using all three valuation methods, the value of intellectual capital was not normally distributed. In turn, the skewness coefficients calculated for individual methods reach positive values, indicating a right-skewed distribution. In the case of the MV-BV and KCE methods, the skewness is above 4, which is high and results in the arithmetic mean being significantly overestimated. In the case of the EVA method, the skewness of the distribution is lower, amounting to approximately 2.

The high variability of the analysed variables, the skewness of the distribution manifested by large differences between the mean and the median, and only two analysed periods are factors that make it difficult to draw general conclusions

regarding the level and changes in the level of intellectual capital of companies in the Polish gaming sector.

Finally, it should be noted that the study of Pearson's linear correlation between the level of intellectual capital measured using the MV-BV, EVA, and KCE methods for 2023 confirmed a statistically significant positive correlation (at $p < 0.05$). It was 0.87 between intellectual capital measured using MV-BV and EVA methods, 0.89 between intellectual capital measured using MV-BV and KCE methods, and 0.90 between intellectual capital measured using EVA and KCE methods. This shows the consistency of the study results and the high practicality of the intellectual capital measurement methods.

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Conflict of Interest

The author declares no conflict of interest.

References

Anifowose, M., Abdul Rashid, H. M., Annuar, H. A., & Ibrahim, H. (2018). Intellectual Capital Efficiency and Corporate Book Value: Evidence from Nigerian Economy. *Journal of Intellectual Capital*, *19*(3), 644–668. https://doi.org/10.1108/JIC-09-2016-0091

Bagieńska, A. (2019). Evaluation of the Possibilities of Using the Knowledge Capital Earnings Method (KCETM) for Depicting Intellectual Capital in the Annual Reports of Polish Companies. *Financial Internet Quarterly „e-Finanse"*, *15*(4), 1–11. https://doi.org/10.2478/fiqf-2019-0023

Beyer, K. (2014). Pomiar kapitału intelektualnego wskaźnikiem MV/BV. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania*, *1*(38), 9–19.

Beyer, K. (2015). Wartość kapitału intelektualnego spółek notowanych na WIG 30. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania*, *1*(39), 115–126. https://doi.org/10.18276/sip.2015.39/1-10

Biznesradar.pl. (2023). https://www.biznesradar.pl/skaner-akcji/ (accessed: 25.08.2023).

Biznesradar.pl. (2024). https://www.biznesradar.pl/skaner-akcji/ (accessed: 5.05.2024).

Bombiak, E. (2012). Wycena kapitału intelektualnego na przykładzie Wawel S.A. – studium przypadku. *Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Seria: Administracja i Zarządzanie*, *22*(95), 229–244.

Bombiak, E. (2016). Kapitał intelektualny jako specyficzny zasób współczesnych organizacji. *Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Seria: Administracja i Zarządzanie*, *36*(109), 105–119.

Dyrka, S., Rogozińska, J., & Soboń, D. (2023). Human Capital as a Factor in Building the Competitive Advantage of Modern Companies. *Zeszyty Naukowe Akademii Górnośląskiej*, *6*, 32–44. https://doi.org/10.53259/2023.6.04

Edvinsson, L., & Malone, M. S. (2001). *Kapitał intelektualny*. Wydawnictwo Naukowe PWN.

Garncarz, J., & Mierzejewski, M. (2019). The Impact of Crises on the Intellectual Capital of Companies in the Food Sector. *Financial Internet Quarterly „e-Finanse"*, *15*(3), 1–9. https://doi.org/10.2478/fiqf-2019-0015

Gu, F., & Lev, B. (2011). Intangible Assets: Measurement, Drivers, and Usefulness. In: G. Schiuma (Ed.), *Managing Knowledge Assets and Business Value Creation in Organizations: Measures and Dynamics* (pp. 110–124). IGI Global. https://doi.org/10.4018/978-1-60960-071-6.ch007

Iazzolino, G., Laise, D., & Migliano, G. (2014). Measuring Value Creation: VAIC and EVA. *Measuring Business Excellence*, *18*(1), 8–21. https://doi.org/10.1108/MBE-10-2013-0052

Investing.com. (2023). https://pl.investing.com/rates-bonds/poland-10-year-bond-yield (accessed: 25.08.2023).

Investing.com. (2024). https://pl.investing.com/rates-bonds/poland-10-year-bond-yield (accessed: 5.05.2024).

Kacprzyk, M., Wolski, R., & Bolek, M. (2012). Analiza wpływu wskaźników płynności i rentowności na kształtowanie się ekonomicznej wartości dodanej na przykładzie spółek notowanych na GPW w Warszawie. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 271, 279–288.

Kasiewicz, S., Rogowski, W., & Kicińska, M. (2006). *Kapitał intelektualny. Spojrzenie z perspektywy interesariuszy*. Oficyna Ekonomiczna.

Kijewska, A. (2016). Causal Analysis of Determinants Influencing the Economic Value Added (EVA) – a Case of Polish Entity. *Journal of Economics and Management*, *26*(4), 52–70. https://doi.org/10.22367/jem.2016.26.03

Maćkowiak, E. (2009). *Ekonomiczna wartość dodana. Miernik oceny kondycji finansowej i wartości przedsiębiorstwa*. PWE.

Marszałkowski, J., Biedermann, S., & Rutkowski, E. (2023). *The Game Industry of Poland – Report 2023*. Polish Agency for Enterprise Development. Retrieved from: https://en.parp.gov.pl/storage/publications/pdf/The_Game_Industry_Poland_2023_12_07.pdf (accessed: 7.05.2024).

Nowicki, D. (2016). Ekonomiczna wartość dodana w największych spółkach notowanych na Giełdzie Papierów Wartościowych w Warszawie. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, 282, 137–146.

Pavelková, D., Homolka, L., Knápková, A., Kolman, K., & Pham, H. (2018). EVA and Key Performance Indicators: The Case of Automotive Sector in PreCrisis, Crisis and Post-crisis Periods. *Economics and Sociology*, *11*(3), 78–95. https://doi.org/10.14254/2071-789X.2018/11-3/5

Paździor, A., & Twardowska, S. (2017). Wpływ czynników niematerialnych na wartość przedsiębiorstwa na przykładzie spółek publicznych z indeksu WIG-Informatyka. *Zeszyty Naukowe Politechniki Częstochowskiej. Zarządzanie*, 26, 39–50. https://doi.org/10.17512/znpcz.2017.2.04

Pulic, A. (2000). VAIC™ – an Accounting Tool for IC Management. *International Journal of Technology Management*, *20*(5–8), 702–714. https://doi.org/10.1504/IJTM.2000.002891

Rydzewski, R. (2019). Market-to-Book Ratio and Creative Industries – Example of Polish Video Games Developers. *Economics and Culture*, *16*(1), 137–147. https://doi.org/10.2478/jec-2019-0015

Salehi, M., Enayati, G., & Javadi, P. (2014). The Relationship between Intellectual Capital with Economic Value Added and Financial Performance. *Iranian Journal of Management Studies*, *7*(2), 259–283. https://doi.org/10.22059/ijms.2014.36618

Sopińska, A. (2008). *Wiedza jako strategiczny zasób przedsiębiorstwa*. Oficyna Wydawnicza, Szkoła Główna Handlowa w Warszawie.

Sopińska, A. (2010). *Wiedza jako strategiczny zasób przedsiębiorstwa. Analiza i pomiar kapitału intelektualnego przedsiębiorstwa*. Oficyna Wydawnicza, Szkoła Główna Handlowa w Warszawie.

Stewart, G. B. (1991). *The Quest for Value. The EVATM Management Guide*. HarperCollins.

Śledzik, K. (2011). *Kapitał intelektualny a wartość rynkowa banków giełdowych*. Fundacja Rozwoju Uniwersytetu Gdańskiego.

Śledzik, K. (2012). Wykorzystanie wskaźnika KCE™ do wyceny poziomu zasobów niematerialnych banków krajowych i banków porównawczych za okres 2005–2010. *Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 689. Finanse, Rynki Finansowe, Ubezpieczenia*, 50, 71–82.

Urbanek, G. (2008). *Wycena aktywów niematerialnych przedsiębiorstwa*. PWE.

Urbanek, G. (2016a). The Links between the Intellectual Capital Efficiency Ratio (ICER) and the Performance of Polish Listed Companies from the Food Industry Sector. *Electronic Journal of Knowledge Management*, *14*(4), 220–230.

Urbanek, G. (2016b). Marka a wartość przedsiębiorstwa na przykładzie polskich spółek giełdowych. *Finanse, Rynki Finansowe, Ubezpieczenia*, *1*(79), 339–348. https://doi.org/10.18276/frfu.2016.79-26

Urbanek, G., & Bohdanowicz, L. (2012). Intelektualna wartość dodana, rentowność spółek oraz ich wycena rynkowa: Wyniki badań spółek notowanych na GPW w Warszawie. *Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 689. Finanse, Rynki Finansowe, Ubezpieczenia*, *50*, 107–114.

Wang, M.-C. (2013). Value Relevance on Intellectual Capital Valuation Methods: The Role of Corporate Governance. *Quality & Quantity*, *47*, 1213–1223. https://doi.org/10.1007/s11135-012-9724-1

Wasilewska, M. (2011). Wycena kapitału intelektualnego metodą Calculated Intangible Value (CIV) dla wybranych przedsiębiorstw polskiego sektora telekomunikacyjnego w latach 2006–2010. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 182, 554–563.

Wasilewska, M. (2015). *Wycena i raportowanie kapitału intelektualnego w spółkach giełdowych*. PhD thesis. Wydział Zarządzania, Informatyki i Finansów, Uniwersytet Ekonomiczny we Wrocławiu. https://doi.org/10.48812/uew.wir-hq9a-cm59

Wolski, R., & Bolek, M. (2014). Wpływ zarządzania płynnością na poziom wartości dodanej przedsiębiorstwa na przykładzie spółek notowanych na GPW w Warszawie. *Zeszyty Naukowe Uniwersytetu Szczecińskiego, nr 803. Finanse, Rynki Finansowe, Ubezpieczenia*, 66, 559–572.

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Perceptions of the Polish Customer on Socially or Ecologically Labelled Food Products: Findings of the Research

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ABSTRACT

Objective: The article aims to identify the characteristics that consumers attribute to food products labelled with eco-labels or social labels.

Research Design & Methods: A critical literature analysis and a survey using a proprietary research tool were conducted. Data from 801 respondents was collected using PAPI, CAWI, and CATI techniques. Pearson's χ^2 test and the data mining technique of association analysis were used to analyse the data.

Findings: Consumers' perceptions of food products with eco-labels or social labels, differentiated by gender, age, education, and occupational status, were determined. Determinants of trust in products with eco-labels or social labels, and consumers' willingness to pay a higher price for such products were indicated.

Implications/Recommendations: The research findings have practical value and may enable businesses to more effectively influence consumer purchasing behaviours by designing marketing communications that appeal to the characteristics of food products with eco-labels or social labels. Companies may implement the recommendations outlined in the article to contribute to increasing sales volume and profitability.

Contribution: Research findings contribute to the current debate on the perception of food products labelled with eco-labels or social labels. They indicate the determinants of consumer trust in products with eco-labels or social labels and tendencies to pay a higher price for them. They also serve as guidelines for employees of businesses responsible for creating marketing communications regarding products with environmental or social designations.

Article type: original article.

Keywords: eco-label, social label, association analysis, consumer purchasing behaviour, food industry.

JEL Classification: M14, M31, L66.

1. Introduction

Ecolabelling and social labelling involve providing additional (non-legally required) information on labels regarding specific social or environmental responsibility principles, considering the entire product lifecycle (often including the supply chain). Ecolabelling may pertain to ecological protection principles, sourcing raw materials and semi-finished products used in the production process, and the potential for reusing packaging materials after food consumption. Social labelling, on the other hand, can convey information such as the absence of child labour, fair wages for workers, and safe and hygienic working conditions without compulsory overtime work during the production process of a particular product. Social labelling can also symbolise a company's commitment to raising awareness of social issues and attempting to mitigate them. Both eco-labels and social labels aim to distinguish products from others available on the market and provide consumers with information about the product, reducing information asymmetry between producers and consumers (Murali, Lim & Petruzzi, 2019).

An example of an eco-label is the EU Ecolabel (awarded based on a product's life cycle assessment); Euroleaf (mandatory on packaged organic products produced within the EU that meet established community standards); the Green Dot (indicating that the producer contributes to the recycling and recovery of packaging, often through a licensed scheme); Ekoland label (designating organic and environmentally friendly food products that ensure sustainable and eco-conscious production practices).

Among social labels, notable examples include *Mamo, tato, wolę wodę!* (Mom, dad, I prefer water!), which promotes healthy dietary habits with an emphasis on the role of water in children's daily diets; *W ciąży nie piję alkoholu* (I don't drink alcohol while pregnant) and *Alkohol. Tylko dla pełnoletnich* (Alcohol for adults only), both of which draw attention to the risks of alcohol consumption by pregnant women or minors, often placed on beer packaging; *Podziel się posiłkiem* (Share

your meal), which promotes the fight against child hunger by encouraging food donations to organisations and institutions involved in child nutrition programmes.

The FairTrade label is also worth mentioning, as it addresses both ecological and social criteria, ensuring that products are produced under fair working conditions and with environmental care (Zadek, Lingayah & Forstater, 1998).

Consumers are showing interest in environmental protection issues. They are concerned about how human activities contribute to the natural environment's ongoing degradation. Consumers also indirectly influence how the economy affects the natural environment (Zhang, 2022). Firstly, they expect businesses to operate in a manner that minimises their negative environmental impact. Secondly, consumers know that their purchasing decisions partially determine how companies operate and produce their goods (Tao *et al*., 2023). When deciding which product to buy, consumers consider whether companies take pro-environmental actions (Chmielewski *et al*., 2023a) and choose products labelled with environmental symbols.

Consumers are also becoming increasingly aware of social issues and that companies can take socially responsible actions to address them. Although this is not the primary goal of business activities, consumers expect them to take such actions (Kiliańska & Pajęcki, 2023). When purchasing food products, they consider whether they come from companies implementing pro-social initiatives (Vicente-Molina, Fernández-Sáinz & Izagirre-Olaizola, 2013).

According to research (Michaud & Llerena, 2011), consumers who are informed about product characteristics are more inclined to purchase them. Placing environmental or social labels on products encourages consumers to make sustainable purchasing decisions. As a result, some companies strive to facilitate consumers' access to information about their environmental and social actions by incorporating appropriate labelling on their products (Lin *et al*., 2015).

Unfortunately, some companies place misleading and false claims about the environmental impact of food products, deceiving customers; these actions are known as greenwashing. To combat this issue, the European Parliament adopted the Green Claims Directive (Directive (EU) 2024/825 of the European Parliament and of the Council of 28 February 2024), which addresses environmental claims. The Green Claims Directive serves as a tool to effectively limit the use of unjustified eco-labels on products available to EU consumers.

Although research literature (Nikolaou & Tsalis, 2018) addresses the topic of consumer perception of products with environmental or social labels, scholars tend to focus more on environmental labels. Chmielewski *et al*. (2023b) emphasise that studies regarding products with social labels are scarce. Issues related to social labelling and the perception of products labelled with them are not adequately recognised. This constitutes a clear research gap that encourages exploration of

the topic. The identified research gap guided the direction of the study, providing the basis for designing and conducting primary research, the results of which are discussed in the article. The article aims to determine the perception of food products with eco-labels or social labels.

The paper comprises both theoretical and empirical parts. The theoretical section critically analyses the literature concerning eco-labels and social labels, serving as the foundation for designing the primary research. Subsequently, the research methodology and its main findings are presented. The article concludes with a synthetic discussion of the conclusions, indicating the research's implications and limitations.

2. Literature Review

According to numerous studies (De Canio, Martinelli & Endrighi, 2021; Riskos *et al*., 2021; Rossi & Rivetti, 2023), information displayed on packaging can positively influence consumers' perceptions of product attributes and thereby shape their purchasing behaviours. Ecological certifications related to sustainable development placed on products lead to more favourable consumer perceptions (Prell *et al*., 2020). Brécard (2014) demonstrated that consumers prefer to buy products with eco-labels because they signal higher product quality. A similar conclusion was reached by Łuczka-Bakuła (2011). Organic food is perceived as healthier (Schuldt & Hannahan, 2013), leading to a higher propensity for purchase (Dang *et al*., 2021). Other studies (Woś *et al*., 2022) conducted among Polish consumers confirm that organic products are perceived as healthier and free from harmful substances (Soroka & Wojciechowska-Solis, 2019).

According to Bryła (2016), the perception of products with eco-labels as tastier and healthier is the most important motivation for Polish consumers to purchase organic food. Czudec, Miś, and Zając (2022) add that high quality and concern for the natural environment also strongly motivate consumers to purchase such food. When buying organic products, consumers feel that they contribute to environmental preservation (Hong & Guo, 2019; Sharma, 2021). Some studies (Cooley, 2021, p. 42) confirm a strong relationship between purchasing intentions and environmentally friendly production. However, conclusions from other research (Donato & D'Aniello, 2021) provide insight that consumers buy products with eco-labels primarily because they perceive them as healthier and safer, with environmental benefits being less of a priority for consumers.

Dangi, Gupta, and Narula (2020) analysed 91 studies conducted between 2001 and 2020, and found that ecolabelling on products leads consumers to perceive them as trustworthy, increasing their willingness to purchase. Trust in eco-labels positively influences consumer purchasing behaviour (Taufique, Vocino & Polonsky, 2017). However, it should be noted that according to the results of other studies, consumers' knowledge about eco-labels and their trust in them varies (Sonntag

et al., 2023), among other factors, depending on the country (Rejman *et al*., 2023). Consumers' trust in organic products contributes to accepting their higher prices (Perrini *et al*., 2010).

Various researchers (Hong & Guo, 2019; Sharma, 2021) argue that consumers are willing to pay higher prices for eco-label products. Other studies (Nielsen, 2015) additionally show that the willingness to pay a higher price for products with eco--label decreases with consumers' age. According to a study conducted among Poles, as many as 70% of them are willing to purchase environmentally friendly products, even if they cost more (http://ec.europa.eu/public_opinion/archives/ebs/ebs_365_pres_en.pdf, accessed: 12.10.2023). Consumers' willingness to pay a higher price for an ecological product has also been of interest to Tilikidou (2007). The conclusions from her research indicate that consumers often choose an ecological product if its price does not significantly differ from the prices of alternative products.

Research from 2019 (Forum Odpowiedzialnego Biznesu, 2020) shows that 70% of consumers expect businesses to address social issues and contribute to local communities' development. 56% avoid purchasing products from entities that hurt society or the environment. Consumers with a prominent level of altruism are more willing to buy products that provide benefits to themselves and indirectly to others (Barbarossa & de Pelsmacker, 2016). They are willing to pay more for products with a social mission to contribute to the well-being of others (Teng, Wu & Liu, 2015).

Research (Hiscox & Smyth, 2011) conducted in New York demonstrates that when products (such as towels or candles) feature a social label indicating compliance with labour standards, demand for them increases. Furthermore, consumers stated they would pay up to 20% more for a labelled product than one without a social label. An experiment (Hiscox & Smyth, 2011) examining consumers' willingness to pay a higher price for clothing items showed that approximately 25% of consumers were willing to pay a higher price for a product with a social label.

Consumers who have a positive attitude towards environmentally friendly products or products with a social mission are more likely to purchase pro-environmental products (Vu *et al*., 2022) or products that have a positive impact on society (Hojnik, Ruzzier & Manolova, 2020; Nguyen *et al*., 2020).

3. Materials and Methods

Based on the theoretical part of the synthetic literature review presented in the article, research gaps were identified regarding insufficient recognition of how food products with eco-labels or social labels. Additionally, there is insufficient exploration of the relationship between attributes of products with eco-labels or social labels. Therefore, five research hypotheses were formulated:

H1: Food products with an eco-label are more likely to evoke consumer trust than products with a social label.

H2: Socio-demographic characteristics of consumers influence the perception of food products with an eco-label and social label.

H3: Trust in food products with an eco-label stems from customers' belief that they are of high quality and healthier than products without an eco-label.

H4: Trust in food products with a social label stems from customers' belief that their purchase allows them to participate in critical decision-making.

H5: Consumers' willingness to pay a higher price for food products with an eco-label is higher than for products with a social label.

A primary study was designed and conducted to achieve the set goal and verify the research hypotheses. This study used a diagnostic survey method, utilising a custom questionnaire. Participants were asked to indicate their agreement or disagreement on a dichotomous scale with six statements related to food products with eco-labels or social labels (Table 1). These statements were developed based on a literature review on the subject.

Table 1. Legend of Symbols Corresponding to Statements Included in the Study

Symbol	Statement
Decision-making	Buying products with such a label allows for participation in critical decision--making
Trust	Products with such a label inspire my trust
Environment	This label indicates a lesser negative impact of the product on the environment than others lacking such a label
Healthier	Products with this label are healthier than products without it
Quality	Products with this label are characterised by higher quality than products without it
Price	I will pay a higher price for a product with this label than for a product without it

Source: own elaboration.

A purposive sampling method was used to select units for the research sample, and two control characteristics were determined: gender and year of birth. Data from respondents were collected using PAPI, CAWI, and CATI techniques between December 2019 and February 2020, as well as November 2020 and March 2021 (the break was due to the outbreak of the COVID-19 pandemic). After formal checks, the data cleaning and coding process was conducted. Data from 801 respondents (residents of the Świętokrzyskie voivodeship) were included in the analysis (Table 2). The study involved 52% women and 48% men. The majority of respondents were aged 55 and over (40%) and had completed secondary education (43%) or higher education (42%). The most significant portion of respondents were employed (62%).

Table 2. Structure of the Research Sample (Total $N = 801$)

Specification	*N*	%
Gender		
Woman	415	52
Man	386	48
Socio-occupational status		
Business owner	64	8
Employee	427	54
Student	57	7
Retiree/Pensioner	177	22
Unemployed	76	9
Age		
18–34	214	27
35–54	264	33
55 and older	323	40
Education		
Primary	38	5
Vocational	82	10
Secondary	345	43
Higher	336	42

Source: own elaboration.

The data obtained from consumers were subjected to frequency analysis, cross-tabulation, and statistical testing. All calculations were performed using Statistica 13.3 software and the interactive programming environment YupiterLab. To determine the statistical significance of the diversity of the variables studied, Pearson's chi-square test (χ^2) was utilised, with a significance level (α) set at 0.05. The strength of the relationship between variables was assessed using the Phi-Yule (ϕ) coefficient and Cramer's *V*. Data mining techniques such as association analysis were employed to examine the characteristics attributed to products labelled with eco-labels or social labels by consumers. This allowed for the exploratory discovery of relationships between variables and the detection of rules and associations guiding the dataset. The relationships between the data were described using association rules in the form of "if-then" statements and three quality measures of the rule. Support determines the percentage of consumer responses in which the rule's antecedent and consequent occurred relative to the total number of respondents. Confidence indicates the conditional probability of choosing the consequent if the antecedent is chosen. Lift represents the probability of choosing one response given

the choice of another response. If this measure exceeds 1, the responses are complementary to each other.

4. Results

4.1. Perception of Food Products with Eco-labels or Social Labels by Consumers

The distribution of responses from the entire consumer base is presented in Table 3. According to consumers, purchasing food products with an eco-label and those with a social label allows for co-decision-making on essential matters – approximately 75% of consumers agreed with this statement. A more significant proportion of consumers acknowledged that they trust products with an eco-label (78%) more than those with a social label (70%), confirming research hypothesis H1. Consumers were significantly more likely to agree with statements indicating that food products with an eco-label have a lesser negative impact on the natural environment (80%), are healthier (74%), and are of higher quality (71%) compared to goods without an eco-label than with similar statements referring to food products with a social label. The corresponding percentages of responses for products with a social label were 61%, 54%, and 57%, respectively.

Table 3. Perception of Food Products with Eco-labels or Social Labels – Distribution of Responses (in %)

Specification			Product with a Social Label	Product with an Eco-label
Statement	Decision-making	I agree	75	74
		I disagree	25	26
	Trust	I agree	70	78
		I disagree	30	22
	Environment	I agree	61	80
		I disagree	39	20
	Healthier	I agree	54	74
		I disagree	46	26
	Quality	I agree	57	71
		I disagree	43	29

Source: own elaboration.

To verify whether the socio-demographic characteristics of consumers differentiate the way they perceive food products with eco-labels or social labels, Pearson's χ^2 tests were conducted. Based on the data provided in Table 4, it can be concluded

that gender is statistically significantly associated with the perception of products with a social label in the context of two statements: purchasing food products allows participation in important decisions ($\chi^2 = 12.52$, $p = 0.001$); products inspire trust ($\chi^2 = 10.37$, $p = 0.001$). The relationship between the analysed variables is weak. Gender also exhibits a weak, though statistically significant, association with the statement that food products labelled with an eco-label are of higher quality than products without such labelling ($\chi^2 = 6.37$, $p = 0.012$). In the case of all three statements mentioned above, women tended to agree with them more often.

The research findings regarding the perception of food products with eco-labels are consistent with those of studies conducted by Brécard (2014), Łuczka-Bakuła (2011), Schuldt and Hannahan (2013), and Woś *et al*. (2022). According to a study (Chekima *et al*., 2016), gender matters in purchasing decisions regarding eco-labelled products. Women are more likely to buy such products.

To explore the relationship between consumers' gender and their perception of food products with eco-labels or social labels, statistical analyses were conducted (see Table 4).

Table 4. The Relationship between the Perception of Food Products with Eco-labels or Social Labels and Consumer Gender

Specification		Women		Men		χ^2	p	ϕ
		I agree (%)	I disagree (%)	I agree (%)	I disagree (%)			
Social label	Decision-making	80	20	70	30	**12.52**	**0.001**	0.125
	Trust	75	25	65	35	**10.37**	**0.001**	0.114
	Environment	59	41	63	37	1.47	0.225	0.043
	Healthier	53	47	55	45	0.11	0.740	0.012
	Quality	60	40	54	46	3.30	0.069	0.064
Eco-label	Decision-making	75	25	73	27	0.60	0.440	0.027
	Trust	80	20	76	24	1.72	0.189	0.046
	Environment	79	21	80	20	0.07	0.786	0.009
	Healthier	76	24	71	29	2.48	0.115	0.056
	Quality	74	26	66	34	**6.37**	**0.012**	0.089

Notes: Bolded test statistics and *p*-values indicate statistically significant relationships between the analysed variables.

Source: own elaboration.

Table 5 presents the results of Pearson's χ^2 tests for the relationship between age and consumers' agreement with specific statements. The test results did not confirm statistically significant relationships. This indicates that regardless of age,

consumers perceive food products with eco-labels or social labels similarly. It is worth noting that for the statement "products with an eco-label inspire trust," the *p*-value is 0.052, indicating a statistical trend. It can be observed that consumers aged 35–54 declared less frequently than others that products with an eco-label inspire their trust.

Table 5. The Relationship between the Perception of Food Products with Eco-labels or Social Labels and the Age of Consumers

Specification		Age						χ^2	*p*	*V*
		18–34		35–54		55 and older				
		I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)			
Social label	Decision-making	78	22	72	28	76	24	1.96	0.376	0.494
	Trust	73	27	67	33	72	28	2.86	0.239	0.598
	Environment	61	39	61	39	62	38	0.07	0.964	0.009
	Healthier	52	48	54	46	55	45	0.40	0.819	0.022
	Quality	59	41	57	43	56	44	0.36	0.836	0.021
Eco-label	Decision-making	73	27	70	30	77	23	3.42	0.180	0.065
	Trust	79	21	73	27	81	19	5.90	0.052	0.086
	Environment	78	22	78	22	82	18	2.45	0.293	0.055
	Healthier	69	31	74	26	77	23	3.87	0.145	0.069
	Quality	67	33	71	29	73	27	2.19	0.333	0.052

Source: own elaboration.

No statistically significant relationships were identified between consumers' education level and their perception of food products with eco-labels or social labels. This means that regardless of their level of education, products with special labelling are perceived similarly. A *p*-value on the borderline of statistical tendency was obtained for two statements: food products with a social label are healthier than products without it ($p = 0.060$), and food products with an eco-label are healthier than products without it ($p = 0.508$). This indicates that although the relationship is not statistically significant, the agreement among consumers with different education levels regarding these statements is most diverse. Consumers with a higher level of education were the least likely to agree that food products with a social label are healthier than alternatives (49%, compared to an average of 60% for other groups).

Table 6. Relationship between the Perception of Food Products with Eco-labels or Social Labels and the Education Level of Consumers

Specification		Education								χ^2	p	V
		Primary		Vocational		Secondary		Higher				
		I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)			
Social label	Decision--making	66	34	72	28	77	23	76	24	2.68	0.443	0.058
	Trust	55	45	71	29	72	28	70	30	4.70	0.194	0.078
	Environment	50	50	67	33	63	37	59	41	4.69	0.196	0.765
	Healthier	61	39	62	38	57	43	49	51	7.39	0.060	0.096
	Quality	53	47	67	33	59	41	53	47	6.23	0.101	0.088
Eco-label	Decision--making	61	39	76	24	73	27	76	24	4.26	0.235	0.072
	Trust	71	29	78	22	81	19	75	25	4.49	0.213	0.075
	Environment	82	18	78	22	80	20	79	21	0.35	0.949	0.021
	Healthier	71	29	78	22	75	25	71	29	2.33	0.508	0.539
	Quality	71	29	77	23	69	31	70	30	1.85	0.605	0.048

Source: own elaboration.

Table 7. Relationship between the Perception of Food Products with Eco-labels or Social Labels and the Socio-occupational Status of Consumers

Specification		Decision-making		Trust		Environment		Healthier		Quality	
		I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)	I agree (%)	I disagree (%)
Social label											
Socio-occupational status	Business owner	80	20	73	27	63	27	61	39	58	42
	Employee	75	25	67	33	60	40	52	48	56	44
	Student	65	35	70	30	63	27	54	46	47	53
	Retiree/ pensioner	75	25	73	27	58	42	51	49	57	43
	Unemployed	82	18	79	21	72	28	68	32	72	28
χ^2		5.631		5.918		5.436		9.139		**9.776**	
p		0.228		0.213		0.253		0.058		**0.044**	
V		0.084		0.085		0.081		0.106		0.110	
Eco-label											
Socio-occupational status	Business owner	77	23	77	23	84	16	70	30	75	25
	Employee	72	28	75	25	80	20	74	26	67	33
	Student	68	32	74	26	68	32	67	33	63	37
	Retiree/ pensioner	82	18	84	16	78	22	73	27	76	24
	Unemployed	66	34	83	17	88	12	84	16	79	21
χ^2		**10.275**		6.654		9.019		6.237		9.239	
p		**0.036**		0.155		0.061		0.182		0.055	
V		0.113		0.091		0.106		0.088		0.107	

Notes: Bolded test statistics and *p*-values indicate statistically significant relationships between the analysed variables.

Source: own elaboration.

However, food products with an eco-label are perceived as healthier, especially by consumers with vocational education (78%, compared to an average of 72% for other groups). Such a conclusion is consistent with Chan's (1999) findings, which confirm that people with higher education are more likely than others to perceive products with an eco-label as healthier.

No statistically significant relationship was identified between education level and the perception of food products with eco-labels or social labels (see Table 6). However, it is worth noting that consumers with vocational education (78%) slightly more often than other respondents (an average of 72%) agreed that food products with an eco-label are healthier than products without labelling.

Occupational status significantly differentiates consumers' responses regarding one statement: food products with a social label are of higher quality than products without labelling (see Table 7). Students were least likely to agree with this statement (47%), while the unemployed were most likely to agree (72%). Statistical testing revealed a weak association between consumers' occupational status and whether they believe food products with an eco-label allow them to participate in critical decision-making. The unemployed (66%) and students (68%) were least likely to agree with this statement, while retirees/pensioners were most likely to agree with it (82%). There were no statistically significant differences in consumer responses regarding other statements.

Based on the above analyses, we can partially confirm research hypothesis H2. Gender and socio-professional status influence the perception of food products with eco-labels or social labels. However, age and education do not show such an influence.

The findings on the perception of eco-labelled food products are consistent with those of Brécard (2014), Łuczka-Bakuła (2011), Schuldt and Hannahan (2013), and Bernard, Bertrandias and Elgaaied-Gambier (2015). Studies (Rodríguez-Bermúdez *et al*., 2020; Woś *et al*., 2022) have also found that organic foods – including those with an eco-label – are perceived to be healthier and of high quality.

According to the studies (Prothero, 1990; Chekima *et al*., 2016), gender matters in purchasing decisions regarding products with an eco-label – women are more likely to buy such products. This conclusion is consistent with the results of the study described in this article. However, it is worth noting that other studies (Mehraj *et al*., 2023) show that gender does not differentiate purchasing behaviour regarding eco-labelled products.

A study by Mehraj *et al*. (2023) found that education influences the propensity to buy eco-labelled products. Another study (Chekima *et al*., 2016) also showed that people with higher education are more likely to buy products with an eco-label. Additionally, Chan's (1999) research confirms that people with higher education are more likely than others to perceive products with an eco-label as healthier. The findings described in this article did not confirm such a relationship.

4.2. Consumer Trust in Food Products with Eco-labels or Social Labels

Association analysis was conducted to gather information about the co-selection of individual responses, which can help examine the relationships between them. Association rules were evaluated, selecting those with high-quality measures. Subsequently, the rules were grouped to verify the research hypotheses. Table 8 presents selected association rules regarding consumer trust in food products with eco-labels or social labels. According to rule 1, 91% of consumers who declare trust in food products with a social label also express trust in food products with an eco-label. Rule 2 concerns the same elements as rule 1, but the antecedent and consequent were reversed. The confidence for rule 2 was lower than for rule 1, reaching 0.820. This allows us to conclude that among consumers who trust food products labelled with eco-labels or social labels, a more oversized proportion trusts food products with an eco-label – providing additional confirmation of hypothesis H1.

Table 8. Form of Association Rules along with Measures of Their Quality – Consumer Trust

No.	Antecedent	Successor	Quality Measures of the Rule
1	Food products with a social label inspire my trust	Food products with an eco-label inspire my trust	Confidence: 0.906 Support: 0.638 Lift: 1.165
2	Food products with an eco-label inspire my trust	Food products with a social label inspire my trust	Confidence: 0.820 Support: 0.638 Lift: 1.165
3	Food products with an eco-label are of higher quality; food products with an eco-label are healthier than products without such a label	Food products with an eco-label inspire my trust	Confidence: 0.867 Support: 0.537 Lift: 1.115
4	Purchasing food products with a social label allows me to participate in critical decision-making	Food products with a social label inspire my trust	Confidence: 0.847 Support: 0.638 Lift: 1.204

Source: own elaboration.

Rules 3 and 4 allowed us to identify the characteristics of food products with eco-labels or social labels that contribute to building consumer trust towards food products with a social or eco-label. Based on the analysis results, it can be concluded that food products with an eco-label inspire trust because consumers perceive them as being of high quality and healthier than food products without an eco-label. This is confirmed by the high support (0.537) and confidence (0.867) measures of associative rule 3. 64% of consumers simultaneously declared that purchasing food products with a social label allows them to participate in critical decision-making

processes and that food products with this label inspire trust. Almost 85% of consumers who agreed that buying food products with a social label allows them to influence critical issues also agreed that these products inspire their trust (rule 4). The analysis results confirm hypotheses H3 and H4.

4.3. Willingness to Pay a Higher Price for Food Products with Eco-labels or Social Labels

Some association rules pertained to consumers' willingness to pay a higher price for food products with eco-labels or social labels (Table 9). Rule 1 demonstrates that the percent of responses indicating consumers' willingness to pay a higher price for food products with eco-label and social labels is 44%. Additionally, 90% of consumers who declared they would incur a higher cost for purchasing product with eco-label also admitted their willingness to pay a higher price for a food product with a social label. The confidence measure of rule 2 is lower than that of rule 1. The low lift quality measure for rules 1 and 2 does not suggest a strong relationship between the elements of these rules. This indicates that consumers more frequently declared readiness to incur a higher purchasing cost for food products with an eco-label than a social one, confirming hypothesis H5.

Table 9. Form of Association Rules along with Measures of Their Quality – Willingness to Pay a Higher Price

No.	Antecedent	Successor	Quality Measures of the Rule
1	I will pay a higher price for a food product with a social label	I will pay a higher price for a food product with an eco-label	Confidence: 0.899 Support: 0.435 Lift: 1.045
2	I will pay a higher price for a food product with an eco-label	I will pay a higher price for a food product with a social label	Confidence: 0.685 Support: 0.435 Lift: 1.045
3	I will pay a higher price for a food product with an eco-label	Food products with an eco-label are healthier	Confidence: 0.843 Support: 0.534 Lift: 1.244
4	I will pay a higher price for a food product with an eco-label	Food products with an eco-label are of higher quality; food products with an eco-label have a low negative impact on the natural environment	Confidence: 0.804 Support: 0.503 Lift: 1.268

Source: own elaboration.

Association analysis revealed what influences consumers' willingness to pay a higher price for a food product with an eco-label. Rule 3 confirms that consumers

are willing to incur a higher purchasing cost for a food product with an eco-label because they perceive it as healthier. Over half of the respondents agreed that food products labelled with an eco-label are healthier and they are willing to pay a higher price. Remarkably, 84% of consumers who declared their willingness to pay a higher price for goods with an eco-label also acknowledged perceiving them as healthier than products without such a label. The high value of the lift for rule 3 allows us to conclude that these responses are complementary to each other.

Rule 4 demonstrates that over 80% of respondents declare such willingness because they believe that such food products signify higher quality and simultaneously have a lesser negative impact on the natural environment than products without an eco-label. The increase in the rule confirms that the elements of this rule are complementary.

Previous research (Hiscox & Smyth, 2011; Nielsen, 2015; Teng, Wu & Liu, 2015; Hong & Guo, 2019; Sharma, 2021), show that customers are willing to pay a higher price for a product with eco-labels or social labels.

A study by Biswas (2016) identified factors influencing customers' willingness to pay a higher price for organic products. The results of the analysis lead to the conclusion that price, availability and quality have the greatest impact on customers' willingness to pay for organic products. Another study (Kirmani & Khan, 2018) aimed at identifying important determinants of customers' willingness to pay a higher price for organic products showed that such a characteristic is the willingness to care about the environment. The results of the research presented in this article are in line with the conclusions of the studies of the aforementioned authors and confirm that customers are willing to pay a higher price for products with an eco-label because they believe they have higher quality and less negative impact on the environment than products without the label.

Biswas (2016) proved that consumers' willingness to pay will increase with their trust in these products. Other authors (Britwum, Bernard & Albrecht, 2021) have also proven that customers who trust organic food products are willing to pay a higher price for them. However, this was not confirmed in the research described in this article.

5. Conclusions

Food products with an eco-label are primarily perceived as having a more negligible, negative environmental impact, healthier than products without an eco-label, and inspiring trust. Food products with a social label are often perceived as goods that allow consumers to participate in decision-making on prominent issues through their purchase and inspire trust. Food products with an eco-label are more trusted by consumers than products with a social label.

It has been shown that trust in food products with an eco-label stems from the perception of them as high-quality and healthier than products without an ecological designation. In the case of food products with a social label, the determinant of trust is primarily the ability to participate in important matters by purchasing such a product. Companies should focus on these mentioned features in their communications about food products with an eco-label and a social label. This will reinforce consumers' belief that these labelled products possess trustworthy qualities. Additionally, such communications can more effectively shape consumer purchasing behaviour. This increases the chances of attracting new consumers, retaining existing ones, and increasing company sales volume and profits.

The analysis did not show a relationship between the perception of food products with eco-labels or social labels and the age and education of consumers. However, it was demonstrated that gender and socio-economic status slightly differentiate the way consumers perceive these products. Companies may consider conducting an informational campaign (in collaboration with schools or NGOs) about their environmental and social initiatives to encourage consumers to buy their products. The campaign should include pictograms and short textual information about these initiatives on the products.

A more significant proportion of consumers accept a higher price for eco-label food products than a social label. Therefore, companies should adjust their pricing policy for products with these labels differently. Companies should reinforce consumers' belief that labelled food products contribute to solving environmental and social problems to strengthen their willingness to pay a higher price.

Although the study was limited to a few characteristics of food products with eco-labels or social labels, it provides valuable insights for companies. The study can be seen as a pilot study, especially regarding the perception of food products with a social label. The author intends to expand the study to other characteristics of products labelled with eco-labels or social labels. Allowing consumers to respond on a scale other than dichotomous (agree/disagree) would be beneficial. Qualitative research may also be worth considering, giving consumers more freedom in expressing how they perceive food products with eco-labels or social labels.

Conflict of Interest

The author declares no conflict of interest.

References

Barbarossa, C., & de Pelsmacker, P. (2016). Positive and Negative Antecedents of Purchasing Eco-friendly Products: A Comparison between Green and Non-green Consumers. *Journal of Business Ethics*, *134*(2), 229–247. https://doi.org/10.1007/s10551-014-2425-z

Bernard, Y., Bertrandias, L., & Elgaaied-Gambier, L. (2015). Shoppers' Grocery Choices in the Presence of Generalized Eco-labelling. *International Journal of Retail & Distribution Management*, *43*(4–5), 448–468. https://doi.org/10.1108/IJRDM-12-2013-0218

Biswas, A. (2016). A Study of Consumers' Willingness to Pay for Green Products. *Journal of Advanced Management Science*, *4*(3), 211–215. https://doi.org/10.12720/joams.4.3.211-215

Brécard, D. (2014). Consumer Confusion over the Profusion of Eco-labels: Lessons from a Double Differentiation Model. *Resource and Energy Economics*, *37*(C), 64–84. https://doi.org/10.1016/j.reseneeco.2013.10.002

Britwum, K., Bernard, J. C., & Albrecht, S. E. (2021). Does Importance Influence Confidence in Organic Food Attributes? *Food Quality and Preference*, *87*, 104056. https://doi.org/10.1016/j.foodqual.2020.104056

Bryła, P. (2016). Organic Food Consumption in Poland: Motives and Barriers. *Appetite*, *105*, 737–746. https://doi.org/10.1016/j.appet.2016.07.012

Chan, K. (1999). Market Segmentation of Green Consumers in Hong Kong. *Journal of International Consumer Marketing*, *12*(2), 7–24. https://doi.org/10.1300/J046v12n02_02

Chekima, B., Wafa, S. A. W. S. K., Igau, O. A., Chekima, S., & Sondoh, S. L. (2016). Examining Green Consumerism Motivational Drivers: Does Premium Price and Demographics Matter to Green Purchasing? *Journal of Cleaner Production*, *112*(4), 3436–3450. https://doi.org/10.1016/j.jclepro.2015.09.102

Chmielewski, M., Malinowska, E., Płoska, R., & Próchniak, J. (2023a). Sustainable Student Consumer – Myth or Reality? *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 1(999), 47–64. https://doi.org/10.15678/ZNUEK.2023.0999.0103

Chmielewski, M., Malinowska, E., Płoska, R., & Szymańska-Brałkowska, M. (2023b). Aspekty zrównoważonego rozwoju w oznakowaniu produktów spożywczych. *Problemy Jakości*, 4, 13–23. https://doi.org/10.15199/46.2023.4.2

Cooley, S. L. (2021). *Impact of Corporate Social Responsibility and Sustainability Practices on Brand Trust and Purchase Intention in the Wine Practices on Brand Trust and Purchase Intention in the Wine Industry*. Dissertation. George Fox University. Retrieved from: https://digitalcommons.georgefox.edu/cgi/viewcontent.cgi?article=1043&context=dbadmin (accessed: 26.04.2024).

Czudec, A., Miś, T., & Zając, D. (2022). Supporting Local Economic Development as a Motive for Purchasing Organic Food. *Economics and Environment*, *81*(2), 291–312. https://doi.org/10.34659/eis.2022.81.2.444

Dang, V. T., Wang, J., Nguyen, H. V., Nguyen, Q. H., & Nguyen, N. (2021). A Moderated Mediation Study of Consumer Extrinsic Motivation and CSR Beliefs towards Organic Drinking Products in an Emerging Economy. *British Food Journal*, *124*(4), 1103–1123. https://doi.org/10.1108/BFJ-12-2020-1096

Dangi, N., Gupta, S. K., & Narula, S. A. (2020). Consumer Buying Behaviour and Purchase Intention of Organic Food: A Conceptual Framework. *Management of Environmental Quality: An International Journal*, *31*(6), 1515–1530. https://doi.org/10.1108/MEQ-01-2020-0014

De Canio, F., Martinelli, E., & Endrighi, E. (2021). Enhancing Consumers' Pro-environmental Purchase Intentions: The Moderating Role of Environmental Concern. *International Journal of Retail & Distribution Management*, *49*(9), 1312–1329. https://doi.org/10.1108/IJRDM-08-2020-0301

Donato, C., & D'Aniello, A. (2021). Tell Me More and Make Me Feel Proud: The Role of Eco-labels and Informational Cues on Consumers' Food Perceptions. *British Food Journal*, *124*(4), 1365–1382. https://doi.org/10.1108/BFJ-04-2021-0416

Directive (EU) 2024/825 of the European Parliament and of the Council of 28 February 2024 amending Directives 2005/29/EC and 2011/83/EU as regards empowering consumers for the green transition through better protection against unfair practices and through better information.

Forum Odpowiedzialnego Biznesu. (2020). *Raport z 4. edycji badania „CSR w praktyce – 21 barometr Francusko-Polskiej Izby Gospodarczej*". Retrieved from: https://odpowiedzialny22biznes.pl/aktualno%C5%9Bci/raport-z-4-edycji-badania-csr-w-praktyce-barometr-23francusko-polskiej-izby-gospodarczej/ (accessed: 24.04.2024).

Hiscox, M. J., & Smyth, N. F. B. (2011). Is There Consumer Demand for Improved Labor Standards? Evidence from Field Experiments in Social Labeling. *SSRN Electronic Journal*, 1–41. https://doi.org/10.2139/ssrn.1820642

Hojnik, J., Ruzzier, M., & Manolova, T. S. (2020). Sustainable Development: Predictors of Green Consumerism in Slovenia. *Corporate Social Responsibility and Environmental Management*, *27*(4), 1695–1708. https://doi.org/10.1002/csr.1917

Hong, Z., & Guo, X. (2019). Green Product Supply Chain Contracts Considering Environmental Responsibilities. *Omega*, *83*, 155–166. https://doi.org/10.1016/j.omega.2018.02.010

Kiliańska, K., & Pajęcki, M. (2023). Oczekiwania społeczne wobec podejmowania inicjatyw społecznie odpowiedzialnych przez przedsiębiorstwa branży spożywczej. *Zeszyty Naukowe Akademii Górnośląskiej*, 6, 68–78. https://doi.org/10.53259/2023.6.07

Kirmani, M. D., & Khan, M. N. (2018). Decoding Willingness of Indian Consumers to Pay a Premium on Green Products. *South Asian Journal of Business Studies*, *7*(1), 73–90. https://doi.org/10.1108/SAJBS-11-2016-0091

Lin, H., Zeng, S., Ma, H., & Chen, H. (2015). Does Commitment to Environmental Self-regulation Matter? *Management Decision*, *53*(5), 932–956. https://doi.org/10.1108/MD-07-2014-0441

Łuczka-Bakuła, W. (2011). Decyzje zakupu na rynku żywności a świadomość i zachowania proekologiczne konsumentów. *Handel Wewnętrzny*, 3, 52–59.

Mehraj, D., Qureshi, I. H., Singh, G., Nazir, N. A., Basheer, S., & Nissa, V. (2023). Green Marketing Practices and Green Consumer Behavior: Demographic Differences among Young Consumers. *Business Strategy and Development*, *6*(4), 571–585. https://doi.org/10.1002/bsd2.263

Michaud, C., & Llerena, D. (2011). Green Consumer Behaviour: An Experimental Analysis of Willingness to Pay for Remanufactured Products. *Business Strategy and the Environment*, *20*(6), 408–420. https://doi.org/10.1002/bse.703

Murali, K., Lim, M. K., & Petruzzi, N. C. (2019). The Effects of Ecolabels and Environmental Regulation on Green Product Development. *Manufacturing and Service Operations Management*, *21*(3), 519–535. https://doi.org/10.1287/msom.2017.0703

Nguyen, P.-M., Vo, N. D., Nguyen, N. P., & Choo, Y. (2020). Corporate Social Responsibilities of Food Processing Companies in Vietnam from Consumer Perspective. *Sustainability*, *12*(1), 71. https://doi.org/10.3390/su12010071

Nielsen. (2015). *Consumers Willingness-to-Pay a Premium for Sustainable Food Attributes in Europe in 2014*. Retrieved from: https://www.statista.com/statistics/384975/consumers-willingness-to-pay-a-premium-for--sustainable--food-attributes-europe/ (accessed: 12.02.2024).

Nikolaou, I. E., & Tsalis, T. (2018). A Framework to Evaluate Eco- and Social-labels for Designing a Sustainability Consumption Label to Measure Strong Sustainability Impact of Firms/Products. *Journal of Cleaner Production*, *182*, 105–113. https://doi.org/10.1016/j.jclepro.2018.02.042

Perrini, F., Castaldo, S., Misani, N., & Tencati, A. (2010). The Impact of Corporate Social Responsibility Associations on Trust in Organic Products Marketed by Mainstream Retailers: A Study of Italian Consumers. *Business Strategy and the Environment*, *19*(8), 512–526. https://doi.org/10.1002/bse.660

Prell, M., Zanini, M. T., Caldieraro, F., & Migueles, C. (2020). Sustainability Certifications and Product Preference. *Marketing Intelligence & Planning*, *38*(7), 893–906. https://doi.org/10.1108/MIP-12-2019-0616

Prothero, A. (1990). Green Consumerism and the Societal Marketing Concept – Marketing Strategies for the 1990s. *Journal of Marketing Management*, *6*(2), 87–103. https://doi.org/10.1080/0267257x.1990.9964119

Rejman, K., Kaczorowska, J., Halicka, E., & Prandota, A. (2023). How Do Consumers Living in European Capital Cities Perceive Foods with Sustainability Certificates? *Foods*, *12*(23), 4215. https://doi.org/10.3390/foods12234215

Riskos, K., Dekoulou, P., Mylonas, N., & Tsourvakas, G. (2021). Ecolabels and the Attitude–Behavior Relationship towards Green Product Purchase: A Multiple Mediation Model. *Sustainability*, *13*(12), 6867. https://doi.org/10.3390/su13126867

Rodríguez-Bermúdez, R., Miranda, M., Orjales, I., Ginzo-Villamayor, M. J., Al-Soufi, W., & López-Alonso, M. (2020). Consumers' Perception of and Attitudes towards Organic Food in Galicia (Northern Spain). *International Journal of Consumer Studies*, *44*(3), 206–219. https://doi.org/10.1111/ijcs.12557

Rossi, C., & Rivetti, F. (2023). Young Consumers' Purchase Behaviour of Sustainably--labelled Food Products. What Is the Role of Scepticism? *Food Quality and Preference*, *105*, 104772. https://doi.org/10.1016/j.foodqual.2022.104772

Schuldt, J. P., & Hannahan, M. (2013). When Good Deeds Leave a Bad Taste. Negative Inferences from Ethical Food Chains. *Appetite*, *62*, 76–83. https://doi.org/10.1016/j.appet.2012.11.004

Sharma, A. P. (2021). Consumers' Purchase Behaviour and Green Marketing: A Synthesis, Review and Agenda. *International Journal of Consumer Studies*, *45*(6), 1217–1238. https://doi.org/10.1111/ijcs.12722

Sonntag, W. I., Lemken, D., Spiller, A., & Schulze, M. (2023). Welcome to the (Label) Jungle? Analyzing How Consumers Deal with Intra-sustainability Label Trade-offs on Food. *Food Quality and Preference*, *104*, 104746. https://doi.org/10.1016/j.foodqual.2022.104746

Soroka, A., & Wojciechowska-Solis, J. (2019). Consumer Motivation to Buy Organic Food Depends on Lifestyle. *Foods*, *8*(11), 581. https://doi.org/10.3390/foods8110581

Tao, F., Zhou, Y., Bian, J., & Lai, K. K. (2023). Optimal Channel Structure for a Green Supply Chain with Consumer Green-awareness Demand. *Annals of Operations Research*, *324*, 601–628. https://doi.org/10.1007/s10479-022-04665-9

Taufique, K. M. R., Vocino, A., & Polonsky, M. J. (2017). The Influence of Eco-label Knowledge and Trust on Pro-environmental Consumer Behaviour in an Emerging Market. *Journal of Strategic Marketing*, *25*(7), 511–529. https://doi.org/10.1080/0965254X.2016.1240219

Teng, Y.-M., Wu, K.-S., & Liu, H.-H. (2015). Integrating Altruism and the Theory of Planned Behavior to Predict Patronage Intention of a Green Hotel. *Journal of Hospitality & Tourism Research*, *39*(3), 299–315. https://doi.org/10.1177/1096348012471383

Tilikidou, I. (2007). The Effects of Knowledge and Attitudes upon Greeks' Pro-environmental Purchasing Behaviour. *Corporate Social Responsibility and Environmental Management*, *14*(3), 121–134. https://doi.org/10.1002/csr.123

Vicente-Molina, M. A., Fernández-Sáinz, A., & Izagirre-Olaizola, J. (2013). Environmental Knowledge and Other Variables Affecting Pro-environmental Behaviour: Comparison of University Students from Emerging and Advanced Countries. *Journal of Cleaner Production*, *61*, 130–138. https://doi.org/10.1016/j.jclepro.2013.05.015

Vu, D. M., Ha, N. T., Ngo, T. V. N., Pham, H. T., & Duong, C. D. (2022). Environmental Corporate Social Responsibility Initiatives and Green Purchase Intention: An Application of the Extended Theory of Planned Behavior. *Social Responsibility Journal*, *18*(8), 1627–1645. https://doi.org/10.1108/SRJ-06-2021-0220

Woś, K., Dobrowolski, H., Gajewska, D., & Rembiałkowska, E. (2022). Organic Food Consumption and Perception among Polish Mothers of Children under 6 Years Old. *International Journal of Environmental Research and Public Health*, *19*(22), 15196. https://doi.org/10.3390/ijerph192215196

Zadek, S., Lingayah, S., & Forstater, M. (1998). *Social Labels: Tools for Ethical Trade. Final Report*. New Economics Foundation. Retrieved from: https://hiyamaya.files.wordpress.com/2009/12/social_labels.pdf (accessed: 14.11.2024).

Zhang, N. (2022). How Does CSR of Food Company Affect Customer Loyalty in the Context of COVID-19: A Moderated Mediation Model. *International Journal of Corporate Social Responsibility*, *7*, 1. https://doi.org/10.1186/s40991-021-00068-4

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