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Analysis of the Attitudes of Central European Small- and Medium-Sized Enterprises towards Adaptation to the Low-Carbon Economy and Its Implementation Barriers

Daniela Rybarova, Katarina Remenova, Maria Kmety Bartekova * and Helena Majduchova

Faculty of Business Management, University of Economics in Bratislava, Dolnozemska Cesta 1, 852 35 Bratislava, Slovakia; daniela.rybarova@euba.sk (D.R.); katarina.remenova@euba.sk (K.R.); helena.majduchova@euba.sk (H.M.)

* Correspondence: maria.bartekova@euba.sk; Tel.: +421-910-393-678

Abstract: As developed regions explore avenues to enhance their industries in order to become climate-neutral, numerous studies have identified distinct factors that may hinder the shift towards a low-carbon economy. The objective of our research was to pinpoint key barriers to adaptation to a low-carbon economy among small- and medium-sized enterprises (SMEs) of Central Europe from the viewpoint of the company's structure. The aim was to examine whether attitudes towards barriers to adaptation to a low-carbon economy represent a key factor that prevents the faster and more effective uptake of such adaptations by SMEs. Both the industrial and service sectors were considered. A quantitative data collection method, CATI, was employed. Using our methodology, we applied a non-parametric testing procedure, specifically, the Kruskal–Wallis test, to compare more than two independent samples, together with the Mann–Whitney U test. Through this analysis, it was found that companies regard the uncertainty of return on investment and its payback period as the most serious barrier to adaption to a low-carbon economy. Meanwhile, the lack of cooperation with research institutions and universities is perceived as the least important barrier. Companies are critical of existing regulations for adaptation to the low-carbon economy, which do not provide incentives for companies, though sole traders consider this an insignificant barrier. The shift towards a low-carbon economy is one of the greatest challenges of the 21st century. Understanding the initial motivational variables can significantly contribute to the process of transition towards the use of renewable energy sources by companies, regardless of their size or sector.

Keywords: low-carbon economy; SMEs; competitiveness; renewable energy sources

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1. Introduction

Achieving climate neutrality represents one of the greatest challenges of the 21st century. This challenge, firstly, concerns markets that are considered developed within the global economic ecosystem. It is these markets that represent the carriers of progress. Changes in traditional and customary procedures, not only in industry but also in services, mean unprecedented interventions in almost all company processes. In this context, we examine the attitudes towards and barriers to the transition to low-carbon forms of economy from the perspective of small- and medium-sized enterprises [1], because this segment of enterprises forms the backbone of the national economies of economically advanced countries [2]. Both the industrial and service sectors are considered. A thorough analysis of variables influencing the process of green transition and the utilization of sustainable energy sources is presented. This study improves our understanding of the processes of building and developing a corporate reputation in the turbulent environment of the transforming market.

This article is structured as follows. The thematic introduction is followed by a summary of the current state of knowledge. The methodology is presented together with the procedures used in the third section, followed by the results of the analyses and the discussion. The conclusion then outlines the most important findings and highlights their relevance both in practice and in the context of economics and management sciences, with a focus on energy and the "circular economy" [3,4]. Specifically, we examine the idea of enhancing the availability of essential raw materials for low-carbon technologies by implementing circular economy approaches [5].

2. Analysis of the State of Knowledge

Adaptation to a low-carbon economy requires a fundamental restructuring of human-centric frameworks to operate in greater alignment with the dynamics of natural systems [6]. This paradigm shift necessitates a comprehensive re-evaluation of our strategies for utilizing resources, managing waste, generating energy, and preserving biodiversity. Rather than treating these multifaceted challenges as discrete and independent, adaptation to a low-carbon economy, notably when oriented in a circular fashion [7], highlights the interdependencies of environmental, societal, and economic frameworks. Consequently, it encourages us to devise all-encompassing solutions for these interconnected domains [8].

The literature on the low-carbon economy tends to focus on one or more of the following aspects [9]: (a) the definition of adaptation to the low-carbon economy; (b) the drivers (or facilitators) and the associated barriers to adaptation; and (c) the economic case for adaptation.

The focus of our research is on barriers that hinder widespread adaptation to a low-carbon economy. Both barriers and motivators have been extensively investigated in the literature, with various innovations proposed to aid in adaptation [10]. A particular emphasis has been placed on innovations facilitating the integration of circular economic principles [11–14] in alignment with distinct sectors [15–17], firm sizes [18–20], firm-level degrees of innovativeness [21], the developmental stages of nations [22,23], and geographical considerations [23], often in conjunction. The conclusions concerning the relative significance of barriers and facilitators shaping the low-carbon economy adaptation trajectory are notably contingent upon the scope of an investigation.

The assessment of barriers is also influenced by the temporal window during which a study is conducted [24]. Recognizing that drivers and barriers associated with adaptation to the low-carbon economy are dynamic attributes, necessitating constant vigilance due to their dual role as inhibitors in one context and enablers in another [25], underscores the pivotal role of temporality. However, shifts in the prominence of barriers and catalysts have received limited scholarly attention.

Many obstacles hinder the transition to a low-carbon economy, primarily due to the need for organizational adjustments spanning from alterations in production procedures to shifts in management styles [25]. The literature highlights various categories of hindrances related to the shift toward a low-carbon economy, typically in conjunction with factors that promote adaptation processes. Arranz, Arroyabe, Molina-García, and Fernandez de Arroyabe devised a model [26] that distinguishes between enablers and inhibitors in the adaptation process. Their research reveals that while public funding eases the transition to a low-carbon economy, challenges related to cost, financing, market uncertainty, and inadequate information about technologies impede the adoption of low-carbon solutions. Our study draws attention to the barriers to adaptation, which, unless clearly understood and analyzed with the intention of identifying the most significant obstacles, cannot be effectively mitigated [20]. Many authors have focused on summarizing these barriers in systematic literature reviews. These efforts have provided a comprehensive view of the breadth of factors that can influence EI adoption. The identified barriers are categorized in these studies into different categories, such as financial, structural, operational, attitudinal, and technological barriers [11], or divided [13] into hard (technical and economic) and soft factors (institutional and social). Kirchherr et al. [27] refer to nested barriers, which include cultural, regulatory, market, and technological barriers. Barriers are also divided into financial, institutional, infrastructural, social, and technological categories [12] or grouped into four levels, namely, market and institutional, value chain, organizational, and employment [28]. The purpose of this identification and grouping of individual barriers into coherent categories is to enable their testing, whether in general, in the supply chain [20], or in relation to the transition to a circular economy [13,29].

Although the literature has paid much attention to exploring barriers to the adoption of a low-carbon economy [30], there remain research gaps in regard to specific sectors [27,29] and geographic contexts [19,26]. According to Arranz et al. [26], testing is approached in a distributed manner from multiple perspectives.

3. Materials and Methods

The objective of this research was to identify key barriers to adaptation to a low-carbon economy among Central European enterprises from the perspective of company structure and size and to elucidate whether the explored attitudes to barriers to adaptation represent key factors that prevent a faster and more effective uptake of such adaptations by enterprises in different sectors.

The initial research sample (N = 300) comprised top managers from SMEs in selected sectors: agriculture, forestry, and fishing; manufacturing; water supply, sewerage, waste management and remediation activities, and cleaning; construction; and catering and beverage activities. These individuals occupied senior and top management positions.

3.1. Data Collection Procedure

The survey was designed in compliance with the international quality standards established by WAPOR and ESOMAR and the guidelines of the Slovak Association of Research Agencies (SAVA). A quantitative data collection method, CATI (computer-assisted telephone interview), was employed during 2022 and at the beginning of 2023. To maintain measurement objectivity and minimize any potential influence on the research subjects, data collection was conducted via telephone, with one researcher verbally instructing the participants and asking the research questions.

An observational survey was carried out using a questionnaire focused on adaptation to a low-carbon economy among Central European companies. The questionnaire comprised eight substantive questions and three statistical inquiries, yielding responses regarding both nominal and ordinal variables. The respondent commented on each of the 14 barriers in turn, including the following: uncertain market demand (Q08_01); uncertain return on investment or an excessively long payback period for adaptation to the low-carbon economy (Q08_02); a lack of funding within the enterprise (Q08_03); a lack of access to existing subsidies and fiscal incentives (Q08_04); a lack of incentives for low-carbon economic adaptation provided through existing regulations and structures (Q08_05); a lack of external funding (Q08_06); reducing energy consumption is not an innovation priority (Q08_07); technical and technological blockages (e.g., old technical infrastructures) (Q08_08); a lack of skilled personnel and technological capabilities within the enterprise (Q08_09); a market dominated by incumbents (Q08_10); reducing material consumption is not an innovation priority (Q08_11); limited access to external information and knowledge, including a lack of well-developed technical support services (Q08_12); a lack of suitable business partners (Q08_13); and a lack of cooperation with research institutes and universities (Q08_14).

The statements were rated on an ordinal scale to determine the enterprise attributes' significance for a particular barrier, which could be considered as a very serious barrier (1), a somewhat serious barrier (2), not a serious barrier (3), not a serious barrier at all (4), and of no concern at all (5). In the analysis below, we only present the codes of the individual statements.

3.2. Statistical Analysis

Random sampling was conducted as an integral component of our statistical analysis using DATAtab and jamovi 2.3.24 statistical software. The hypotheses were assessed at a significance level of α = 0.05. The fundamental principle governing the application of the test was upheld, ensuring that the theoretical frequencies did not dip below 5 in 80% of cases, with other values adhering to X > 1. We noticed consistent variation in the directions or perspectives of managers based on the legal orientation of an enterprise towards key low-carbon economy adaptation barriers, which were measured on a Likert scale (1–5). For this purpose, we applied non-parametric testing using the Mann–Whitney U test to compare two independent groups [31,32]. The effect size was computed using the following formula [33–35]:

$$r = Z/\sqrt{N} \quad (1)$$

where r represents the effect size, Z refers to the standardized test statistic, and $\sqrt{N}$ is the square root of the number of pairs.

According to the authors of [36], many studies have employed the Kruskal–Wallis test, which extends the Mann–Whitney U test to analyze more than two groups, for behavioral ecology and sociobiology research purposes. This non-parametric test was used to check for differences among several independent groups, because the assumptions required for an analysis of variance were not met. We examined the data to determine whether the rank sums of all the groups were equal.

Numerous authors have emphasized the importance of employing statistical procedures that address type I error control and dependencies between parameters when conducting multiple comparisons between the means or medians of independent samples [37]. The Dwass–Steel–Critchlow–Fligner test is a two-sided, non-parametric approach that safeguards against family-wise error rates. It is commonly applied after detecting significance through the Kruskal–Wallis Test [38]. As the partial eta squared is overwhelmingly cited as a measure of effect size and is commonly reported to augment significance tests in research, we also applied it in our statistical procedure [39,40]. The effect size for the Kruskal–Wallis test was computed as the partial eta squared based on the H-statistic:

$$\text{Partial Eta}^2 = \text{SS(effect)}/(\text{SSeffect} + \text{SSerror}) \quad (2)$$

where the SS (effect) represents the sum of squares for an effect related to a single variable, and SSerror denotes the sum of squares for an error in the ANOVA model. The eta^2 estimate ranges from 0 to 1, serving as an indicator of the proportion of variance in the dependent variable that can be attributed to the independent variable [41]. The interpretation values are as follows: $0.01 \leq 0.06$ (small effect), $0.06 \leq 0.14$ (moderate effect), and ≥ 0.14 (large effect).

Cronbach's alpha (α) was used to confirm the consistency of our questionnaire. We analyzed the reliability of the answers reflecting managers' opinions on low-carbon economy adaptation barriers. At 33 items, the reliability level reached α = 0.75. Comparing the reliability value here with the values reported in other studies indicates an acceptable reliability of the test [42–44].

4. Results and Discussion

This section provides an overview of the results and a discussion, structured according to legal form and sector of the economy.

4.1. Main Barriers Related to the Legal Form of the Enterprise

Enterprises' perspectives on the importance of barriers to adaptation to a low-carbon economy, as well as its actual uptake, may differ for several reasons, such as the size of the enterprise, its legal form, the number of employees, or the sector in which it operates. For these reasons, we focused on identifying key barriers to adaptation to a low-carbon economy among Central European companies. The most common barrier to the accelerated adoption of solutions for a low-carbon economy, from a company's perspective, is an uncertain return on investment or an excessively long payback period for adaptation. This is followed by a 'lack of access to existing subsidies and fiscal incentives' and a 'lack of funding within the enterprise'. First, we were interested in how perceptions of barriers vary between enterprises in terms of their legal form and whether there are statistically significant differences between companies in this respect. To examine these questions, we used the non-parametric Mann–Whitney U test, as the assumptions required for parametric testing were not met.

For this purpose, we conducted a Shapiro–Wilk normality test to determine whether the dataset fulfilled the condition for normally distributed data and the application of a parametric or non-parametric correlation test [45].

The *p*-values for all the tested variables are less than 0.05, indicating statistical significance and, thus, challenging the assumption of normally distributed data. Since the Shapiro–Wilk test confirmed that the conditions for parametric testing were not met (Table 1), we used the non-parametric Mann–Whitney U test to elucidate the differences between two groups of companies distinguished by their legal form. The following hypotheses were tested:

Table 1. Shapiro–Wilk normality test.

	W	***p***
Q08_01	0.899	<0.0001
Q08_02	0.859	<0.0001
Q08_03	0.880	<0.0001
Q08_04	0.872	<0.0001
Q08_05	0.881	<0.0001
Q08_06	0.903	<0.0001
Q08_07	0.925	<0.0001
Q08_08	0.914	<0.0001
Q08_09	0.913	<0.0001
Q08_10	0.903	<0.0001
Q08_11	0.925	<0.0001
Q08_12	0.913	<0.0001
Q08_13	0.933	<0.0001
Q08_14	0.839	<0.0001

Note. A low *p*-value suggests a violation of the assumption of normality.

$H1_0$. *Legal form: There is no statistically significant difference in legal form between enterprises (business companies and sole proprietors) in regard to adaptation barriers.*

$H1_1$. *Legal form: Businesses are more affected by adaptation barriers than sole proprietors.*

The results of Levene's test (Table 2), which is used to assess sphericity and variance homogeneity, affirm the violation of this assumption at $p > 0.05$. Given that both tests confirmed noncompliance with parametric testing conditions, we interpreted the results of the Mann–Whitney U test. The following analysis will help to clarify whether there are differences in attitudes toward adaptation barriers based on the legal form of the enterprise (business companies vs. sole proprietor).

According to the findings of the non-parametric test, we reject the alternative H1 hypothesis and validate the null $H1_0$ hypothesis. There is no statistically significant distinction between the two legal forms of businesses (trade companies and sole proprietors) in regard to the 12 statements about adaptation barriers and their perception as important elements of development.

The statements (Q08_05) and (Q08_09) were confirmed to be significant in relation to the legal form of the enterprise. On average, Group 1 (business companies) received fewer points than Group 2 (sole proprietors) on the ordinal scale for the statement 'Existing regulations and structures do not provide incentives for adaptation to the low-carbon economy'. The mean for Group 2 (mean rank = 191.33, M = 3.9, median = 5) is statistically significantly higher than that for Group 1 (mean rank= 148.13, M = 2.92, *p*-value= 0.0256, median = 2). According to the outcomes of the non-parametric test, we refute the null hypothesis and accept the alternative $H1_1$ hypothesis, because businesses consider the fact that 'existing regulations and structures do not provide incentives for adaptation to the low-carbon economy' as a significantly important barrier for adaptation. The strength of this importance was measured based on effect size (r = 0.288), which showed that, according to Cohen (1988) [46], there was a medium effect in our sample, explaining 28.8% of the variability.

Table 2. Homogeneity of variance test (Levene's).

Statement	U Statistic	*p*-Value	Effect Size	F Statistic	*p*-Value
"Q08_01"	2455	0.3189	0.1294	2.5113	0.1141
"Q08_02"	2524	0.4140	0.1050	1.6180	0.2044
"Q08_03"	2703	0.7479	0.0417	5.3135	0.0218
"Q08_04"	2187	0.0767	0.2246	1.2637	0.2618
"Q08_05"	2006	0.0256	0.2888	0.0258	0.8726
"Q08_06"	2554	0.4671	0.0945	0.0472	0.8282
"Q08_07"	2504	0.3895	0.1121	1.2930	0.2564
"Q08_08"	2705	0.7546	0.0408	2.7636	0.0975
"Q08_09"	1995	0.0232	0.2927	0.0255	0.8733
"Q08_10"	2683	0.7095	0.0488	0.0267	0.8703
"Q08_11"	2732	0.8109	0.0312	0.3103	0.5779
"Q08_12"	2660	0.6644	0.0567	0.2436	0.6220
"Q08_13"	2391	0.2440	0.1523	3.4761	0.0632
"Q08_14"	2724	0.7797	0.0340	0.0872	0.7680

Note. $H_a\ \mu_{\text{sole proprietor}} \neq \mu_{\text{company}}$.

To evaluate the difference between businesses and sole proprietors for statement Q08_09, the Mann–Whitney U Test was again utilized. The test revealed significant differences in the 'lack of qualified personnel and technological skills within the enterprise' among businesses (mean rank = 148.04, M = 2.57, median = 2) and sole proprietors (mean rank = 192.55, M = 3.35, median = 3), with U = 1979, $p = 0.0232$, and r = 0.2927. In this case, 29.3% of the variability could be explained. Hence, hypothesis $H1_1$ was supported.

Subsequently, the Bayes factor was used in order to quantify the evidence, comparing one statistical model to another. In the case of statement Q08_05 ('Existing regulations and structures do not provide incentives for adaptation to the low-carbon economy'), the Bayes factor_{10} reached BF = 1.40, which means that hypothesis $H1_1$ is 2.72 times more likely than hypothesis $H1_0$, corresponding to a prior probability of 70.7% for $H1_1$ and 29.3% for $H1_0$.

For the statement 'Lack of qualified personnel and technological skills within the enterprise', $BF_{10} = 2.59$. This indicates that hypothesis $H1_1$ is 2.59 times more likely than hypothesis $H1_0$, corresponding to a prior probability of 70.7% for $H1_1$ and 29.3% for $H1_0$. Many entrepreneurs identified this barrier as one that does not affect them.

According to the results, business enterprises consider a 'lack of qualified personnel and technological skills within the enterprise' to be a critical factor in expediting the implementation and advancement of low-carbon economy solutions for the company.

4.2. Main Barriers Related to SMEs in Different Sectors

The substantial body of research on environmental sustainability has predominantly focused on investigating large organizations. This is because these entities have been widely recognized as significant contributors to environmental degradation, and it is their responsibility to seek innovative approaches to minimize pollution [47–49].

Nonetheless, in recent years, numerous studies have addressed the subject of innovation within small and medium enterprises (SMEs) [50–52]. Many of these investigations were conducted at the local level, particularly within European Union countries. Some authors have also pinpointed noticeable data gaps in the lack of sector-specific studies related to adaptation to a low-carbon economy [53,54]. This underscores the need for studies that scrutinize the implementation of low-carbon economy adaptation solutions by companies across various sectors. In 2021, Fernando et al. [55] emphasized that competitiveness is sustained through the development of recycled products, particularly within the automotive and construction industries [56]. This led us to consider two main questions: Is there a differing tendency to generate and implement solutions for adaptation to a low-carbon economy based on employment size among SME companies? If so, does this also differ across industries?

As the Shapiro–Wilk test revealed that the conditions for parametric testing were not met, we opted for the non-parametric Kruskal–Wallis test to analyze the differences between more than two groups of companies categorized according to employment size. The following hypotheses were tested:

$H2_0$. *Employment size: There is no statistically significant difference between the SMEs in low-carbon economy adaptation barriers.*

$H2_1$. *Employment size: Micro enterprises are more affected by low-carbon economy adaptation barriers than medium-sized enterprises.*

To define companies as SMEs, we applied the OECD (2023) [57] categorization, with a further subdivision into micro-enterprises (fewer than 10 employees), small enterprises (10 to 49 employees), and medium-sized enterprises (50 to 249 employees).

The Kruskal–Wallis test (Table 3) showed a statistically significant difference between the three groups in terms of the severity with which the adaptation barriers affect SME companies (Q08_09, Q08_11, and Q08_14).

Table 3. Kruskal–Wallis for employment size of SMEs.

	Kruskal–Wallis			Effect Size	Homogeneity of Variances Test (Levene's)	
	χ^2	df	*p*	ε^2	F	*p*
Q08_01	4.005	2	0.1350	0.01335	8.607	0.0002
Q08_02	0.159	2	0.9237	5.29×10^{-4}	3.956	0.0201
Q08_03	1.539	2	0.4633	0.00513	3.058	0.0484
Q08_04	2.334	2	0.3113	0.00778	0.593	0.5531
Q08_05	3.775	2	0.1514	0.01258	0.526	0.5913
Q08_06	5.581	2	0.0614	0.01860	2.841	0.0600
Q08_07	2.982	2	0.2252	0.00994	2.829	0.0607
Q08_08	3.116	2	0.2105	0.01039	1.543	0.2155
Q08_09	6.041	2	0.0488	0.02014	7.516	0.0707
Q08_10	0.379	2	0.8276	0.00126	1.594	0.2047
Q08_11	5.964	2	0.0500	0.01988	0.943	0.3904
Q08_12	2.554	2	0.2789	0.00851	2.193	0.1134
Q08_13	4.127	2	0.1270	0.01376	3.553	0.0299
Q08_14	7.564	2	0.0228	0.02521	1.592	0.2053

Source: own processing.

Adaptation barrier Q08_09, a 'Lack of qualified personnel and technological skills within the enterprise' ($\chi^2_{(2)}$ = 6.041, p = 0.0488), affects medium-sized enterprises (M = 1.92; mean rank = 118.38) more than micro-enterprises (M = 2.75; mean rank = 157.05) and small enterprises (M = 2.19; mean rank = 130.93).

The next most significant adaptation barrier, as shown in the analysis, is Q08_11, 'Reducing material consumption is not an innovation priority' ($\chi^2_{(2)}$ = 5.964, p = 0.0500), which is more significant for medium-sized enterprises (M = 2.5; mean rank = 98.75) than for micro-enterprises (M = 3.52; mean rank = 155.68) and small enterprises (M = 3.35; mean rank = 141.73). The third important adaptation barrier, Q08_14, a 'Lack of cooperation with research institutes and universities' ($\chi^2_{(2)}$ = 7.564, p = 0.0228), is perceived as a serious issue by medium-sized enterprises (M = 2.75; mean rank = 93.63), micro-enterprises (M = 3.94; mean rank = 155.49), and small enterprises (M = 3.69; mean rank = 143.78).

The effect size for the Kruskal–Wallis test was computed as the partial eta squared based on the H-statistic. This allowed us to interpret the strength of the statistical significance. According to Cohen (1988) [46], an eta coefficient $0.01 \leq 0.06$ refers to a small effect, $0.06 \leq 0.14$ refers to a moderate effect, and ≥ 0.14 refers to a large effect. The low-carbon adaptation barrier that a 'lack of qualified personnel and technological skills within the enterprise' had $\eta^2 = 0.0707$, which represents a moderate effect; the barrier 'reducing material consumption is not an innovation priority' had $\eta^2 = 0.01988$; and a 'lack of cooperation with research institutes and universities' had $\eta^2 = 0.02521$, indicating a small effect.

After obtaining information about the statistically significant differences between the tested variables through the Kruskal–Wallis test, we conducted the non-parametric Dwass–Steel–Critchlow–Fligner (DSCF) test to further investigate the family-wise differences between the associated variables.

The non-parametric DSCF test showed that the pairwise group comparison of micro- and medium-sized enterprises had an adjusted *p*-value of less than 0.05, and thus, based on the available data, it can be assumed that these two groups are significantly different (Table 4).

Table 4. Pairwise comparisons between groups according to company size.

		W	*p*
Micro enterprises	Small enterprises	−1.42	0.5763
Micro enterprises	Medium-sized enterprises	−3.70	0.0244
Small enterprises	Medium-sized enterprises	−2.96	0.0907

Source: own processing.

Based on the importance of a company's size and industry in the deployment of solutions for low-carbon economy adaptation, as determined through our literature review, we performed an analysis of the data relating to SMEs in terms of the number of employees and different sectors. The following hypotheses were tested:

$H3_0$. *Industry: No statistically significant distinction exists between sectors in adaptation barriers.*

$H3_1$. *Industry: A specific industry is more affected by adaptation barriers than others are.*

As emerged from the analysis, there is a significant difference between industries with respect to the adaptation barriers (Q08_02, Q08_03, Q08_06), according to the Kruskal–Wallis test (Table 5). The low-carbon economy adaptation barrier Q08_02, 'Uncertain return on investment or too long a payback period for adaptation' ($\chi^2_{(4)} = 9.56$, $p = 0.0485$; IQR = 2; Mode = 1), affects the agriculture, forestry, and fishing industries (M = 1.88) more than the industries of building and construction (M = 2.65); water supply, sewerage, waste management and remediation activities, sanitation, and other small enterprises (M = 2.56); and manufacturing (M = 2.29).

The second most significant barrier is Q08_03, a 'Lack of funding within the enterprise' ($\chi^2_{(4)} = 11.43$, $p = 0.022$; IQR = 2; Mode = 1), which is more significant for agriculture, forestry, and fishing (M = 2.00) than for other industries.

The third most important adaptation barrier, Q08_06, a 'Lack of external funding' ($\chi^2_{(4)} = 12.64$, $p = 0.0132$; IQR = 3; Mode= 5), was perceived as a serious issue in the agriculture, forestry, and fishing industries (M = 2.25) as well as I-56, the food and beverage service activities (restaurants) (M = 2.77).

Table 5. Kruskal–Wallis for industry of SMEs.

	Kruskal–Wallis		Effect Size		Homogeneity of Variances Test (Levene's)	
	χ^2	df	*p*	ε^2	F	*p*
Q08_01	2.94	4	0.5683	0.00979	8.607	0.0002
Q08_02	9.56	4	0.0485	0.03187	3.956	0.2001
Q08_03	11.43	4	0.0222	0.03808	3.058	0.0584
Q08_04	4.38	4	0.3573	0.01459	0.593	0.5531
Q08_05	2.26	4	0.6876	0.00754	0.526	0.5913
Q08_06	12.64	4	0.0132	0.04212	2.841	0.0600
Q08_07	6.93	4	0.1394	0.02311	2.829	0.0607
Q08_08	4.39	4	0.3561	0.01462	1.543	0.2155
Q08_09	4.15	4	0.3856	0.01384	7.516	0.0007
Q08_10	8.04	4	0.0901	0.02680	1.594	0.2047
Q08_11	1.52	4	0.8230	0.00507	0.943	0.3904
Q08_12	4.87	4	0.3005	0.01625	2.193	0.1134
Q08_13	4.26	4	0.3721	0.01420	3.553	0.0299
Q08_14	3.13	4	0.5357	0.01045	1.592	0.2053

Source: own processing.

The effect size for the Kruskal–Wallis test was computed as the partial eta squared, and we were able to interpret the strength of the statistical significance. According to Cohen (1988) [46], an eta coefficient 0.01≤ 0.06 refers to a small effect, 0.06 ≤ 0.14 refers to a moderate effect, and ≥ 0.14 refers to a large effect. The adaptation barrier 'Uncertain return on investment or too long payback period for adaptation' had $\eta^2 = 0.03187$, the barrier concerning a 'Lack of funding within the enterprise' had $\eta^2 = 0.03808$, and a 'Lack of external funding' had $\eta^2 = 0.04212$, all indicating a small effect.

Thus, based on the available data, the null hypothesis was rejected, and we conducted post hoc testing for the Kruskal–Wallis test, where we examined differences in severity according to the size of the SME companies in different industries.

The non-parametric Dwass–Steel–Critchlow–Fligner test was used to assess the family-wise error rate protection because significant differences emerged from the Kruskal–Wallis test. The DSCF test showed that the pairwise group comparison of the civil engineering and construction industry with the agriculture, forestry, and fishing industries had an adjusted *p*-value of less than 0.05; thus, these two groups are significantly different from each other (Table 6).

Table 6. Pairwise comparisons between groups representing different industries.

		W	*p*
Civil engineering, construction	Agriculture, forestry, and fishing	−4.159	0.0271

Source: own processing.

5. Conclusions

In this paper, we analyzed the types and levels of barriers that hinder the rapid deployment of adaptations to a low-carbon economy among SME enterprises in Central Europe. We focused on determining whether the attitudes to barriers to low-carbon economy adaptation that we explored represent key factors that prevent the faster and more effective uptake of such adaptions by businesses in different sectors.

During the study, our primary focus revolved around various barriers, including uncertain market demand; uncertain return on investment with extended payback periods for low-carbon economy adaptation; a lack of financial resources within the company; limited access to existing subsidies and fiscal incentives; existing regulations and structures that do not incentivize low-carbon economy adaptation; insufficient external financing; a reduced emphasis on energy consumption as an innovation priority; technical and technological obstacles (e.g., outdated technical infrastructures); a shortage of qualified personnel and technological skills within the enterprise; a market predominantly controlled by incumbents; a lack of emphasis on reducing material consumption as an innovation priority; restricted access to external information and knowledge, including a deficiency in well-developed technical support services; and a scarcity of suitable business partners and collaboration with research institutes and universities. Overall, the results allowed us to determine that the most serious barrier to adaptation to a low-carbon economy, according to enterprises, is an 'uncertain return on investment or too long payback period for adaptation to the low-carbon economy' (M = 2.46). A lack of cooperation with research institutes and universities is considered to be the least serious (M = 3.85), while the 'existing regulations and structures not providing incentives for adaptation to the low-carbon economy' (M-W U = 2004, p-value = 0.0266) is perceived as a critical barrier by businesses but insignificant by sole proprietors.

As emerged from the Mann–Whitney U test, the differences between businesses and sole proprietors with respect to particular adaptation barriers were statistically significant. The most significant problem for businesses in introducing low-carbon economy adaptations is the fact that existing regulations and structures do not provide incentives for adaptation. Another significant factor limiting adaptation to a low-carbon economy in a company is a lack of skilled personnel and technological capabilities.

We also investigated the sectoral specificity of adaptation barriers. We found that adaptation barriers differ substantially across industries. We should stress that the sector most affected by low-carbon economy adaptation barriers is the agriculture, forestry, and fishing industries, with the following posing serious obstacles in the adaptation process: an 'uncertain return on investment or too long payback period for adaptation to the low-carbon economy; a 'lack of funding within the enterprise'; and a 'lack of external funding'.

By understanding the basic variables and change determinants, it is possible to effectively direct corporate resources towards increasing competitiveness [58]. Moreover, given the accelerated pace of innovation in the post-COVID world [59], failure to adopt a proactive approach in adapting to inevitable changes will threaten the survival of companies in the market. The findings of this study contribute to the advancement of knowledge not only in economics and management but also in interdisciplinary sciences.

Limitations of the Study

A limitation of this study is that we focused on adaptation barriers in Central European enterprises alone, i.e., only the views and experiences of enterprises in this legislative sphere were presented.

Adaptation to a low-carbon economy is a very broad topic, especially in terms of the external factors that either accelerate or hinder the implementation of, and present barriers to, adaptation. Since our findings confirm that SMEs pay little attention to low-carbon economy adaptation barriers, we suggest that policymakers promote financial mobilization for the purpose of boosting low-carbon economy adaptation across industries.

Another future research direction should be technology foresight life cycle assessment (LCA) in order to understand the directions that Central European SMEs are taking in the transition towards a low-carbon economy, as indicated in a study by Spreafico et al. [60].

Patent analysis could help researchers to answer this question.

The state should also create a certain set of conditions through legislative measures. In future research, we will focus on the financial support provided by the EU and the state for adaptation to a low-carbon economy in Central European SME enterprises, in accordance with the new EU strategy for promoting adaptation, as mentioned in the introduction.

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